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National Greenhouse Gas Inventory Document of JAPAN

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Ministry of the Environment, Japan
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Foreword

On the basis of Articles 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC) and Article 13 of the Paris Agreement, all Parties to the Convention and the Paris Agreement are required to submit national inventories of greenhouse gas emissions and removals. Therefore, Japan's inventory on emissions and removals of greenhouse gases and precursors are reported in this National Inventory Document, in accordance with the *Modalities, Procedures and Guidelines for the Transparency Framework for Action and Support Referred to in Article 13 of the Paris Agreement* (Decision 18/CMA.1 Annex).

This Document presents Japan's national inventory arrangements, the estimation methods of greenhouse gas emissions and removals from sources and sinks, and the trends in emissions and removals for greenhouse gases (carbon dioxide [CO_2], methane [CH_4], nitrous oxide [N_2O], hydrofluorocarbons [HFCs], perfluorocarbons [PFCs], sulfur hexafluoride [SF_6], nitrogen trifluoride [NF_3], and indirect CO_2), precursors (nitrogen oxides [NO_x], carbon monoxide [CO], and non-methane volatile organic compounds [NMVOC]), and sulfur oxides [SO_x]. Methodological details of the LULUCF sector accounting in the Nationally Determined Contribution (NDC) is presented as well, as other additional information.

The structure of this document is prepared in line with the structure specified in the *Outline of the National Inventory Document, Pursuant to the Modalities, Procedures and Guidelines for the Transparency Framework for Action and Support Referred to in Article 13 of the Paris Agreement* (Decision 5/CMA.3 Annex).

The Executive Summary focuses on the latest trends in emissions and removals of greenhouse gases in Japan. Chapter 1 deals with background information on the greenhouse gas inventory, national inventory arrangements, the inventory preparation process, methodologies and data sources used, key category analysis, and results of uncertainty assessment. Chapter 2 describes the latest information on trends in emissions and removals of greenhouse gases in Japan. Chapters 3 to 7 provide the details of estimation methods for the sources and sinks in the main five sectors. Chapter 8 comprises current status of reporting of the emissions from other sources. Chapter 9 provides the current status of reporting of indirect emissions of CO_2 and N_2O. Chapter 10 provides the explanations on improvements and recalculations (data revision, addition of new categories, etc.) made since the previous submission. Annexes offer information to assist further understanding of Japan's inventory and other additional information.

For the latest updates or changes in data, refer to the website (https://www.nies.go.jp/gio/en/index.html) of the Greenhouse Gas Inventory Office of Japan (GIO).

April, 2026
Decarbonized Society Promotion Office
Global Environment Bureau
Ministry of the Environment

Preface

The GHG inventory of Japan including this document represents the combined knowledge of 70 experts in a range of fields from universities, industrial bodies, regional governments, relevant government departments and agencies, and relevant research institutes, who are members of the Committee for the Greenhouse Gas Emissions Estimation Methods established by the Environment Agency (the current Ministry of the Environment) in November 1999 and held every year since.

In compiling the GHG inventory, the Greenhouse Gas Inventory Office of Japan (GIO) would like to acknowledge the contribution not only of the Committee members in seeking to develop the methodology, but of other experts who provided the latest scientific knowledge, the industrial bodies and government departments and agencies that provided the data necessary for compiling the inventory, and the secretariat members of the above-mentioned Committee. We would like to express our gratitude to the Decarbonized Society Promotion Office of the Global Environment Bureau of the Ministry of the Environment, for their support to GIO.

Upon preparation of this document, we have made efforts to improve it through receiving feedback from many internal and external experts. We hope this document will help fulfill our international obligations such as that under the Paris Agreement and is used widely as an index that shows the extent of Japan's measures implemented against global warming.

My appreciation also extends to Ms. Rumiko Usu, Ms. Kyoko Tawada, Ms. Takako Takagi, and Ms. Sachiyo Harigae, our assistants, who supported us with the smooth operation of GIO.

April, 2026

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Executive Summary of the National GHG Inventory Document of Japan

E.S.1. Background Information on the GHG Inventory

Japan hereby reports its Greenhouse Gas (GHG) Inventory, which contains the information on emissions and removals of GHGs, including indirect GHGs and SO_x in Japan for FY1990 to FY2024[1], on the basis of Articles 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC) and Article 13 of the Paris Agreement.

Estimation methodologies of GHGs inventories are required to be in line with the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (hereafter *2006 IPCC Guidelines*) which was developed by the Intergovernmental Panel on Climate Change (IPCC), and Japan's estimation methodologies are basically in line with these guidelines. In order to enhance transparency, consistency, comparability, completeness and accuracy of the inventory, Japan also applies the *2013 Supplement to the 2006 IPCC Guidelines: Wetlands* (hereafter *Wetlands Guidelines*) and *the 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol* (hereafter *KP Supplement*), and the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (hereafter *2019 Refinement*).

Japan's national inventory is reported in accordance with the *Modalities, Procedures and Guidelines for the Transparency Framework for Action and Support Referred to in Article 13 of the Paris Agreement* (hereafter, *MPGs*, Decision 18/CMA.1 Annex) as decided by the Conference of the Parties.

[1] "FY" (fiscal year), from April of the reporting year through March of the next year, is used because CO_2 is the primary GHGs and estimated on a fiscal year basis.

E.S.2. Summary of National Emission and Removal Related Trends

Total GHGs emissions[2] in FY2024 (excluding LULUCF[3], including indirect CO_2[4], hereafter, definition omitted) were 1,046 million tonnes (in CO_2 eq.). They decreased by 17.7% from FY1990, decreased by 24.9% from FY2013, and decreased by 1.9% compared to the previous year.

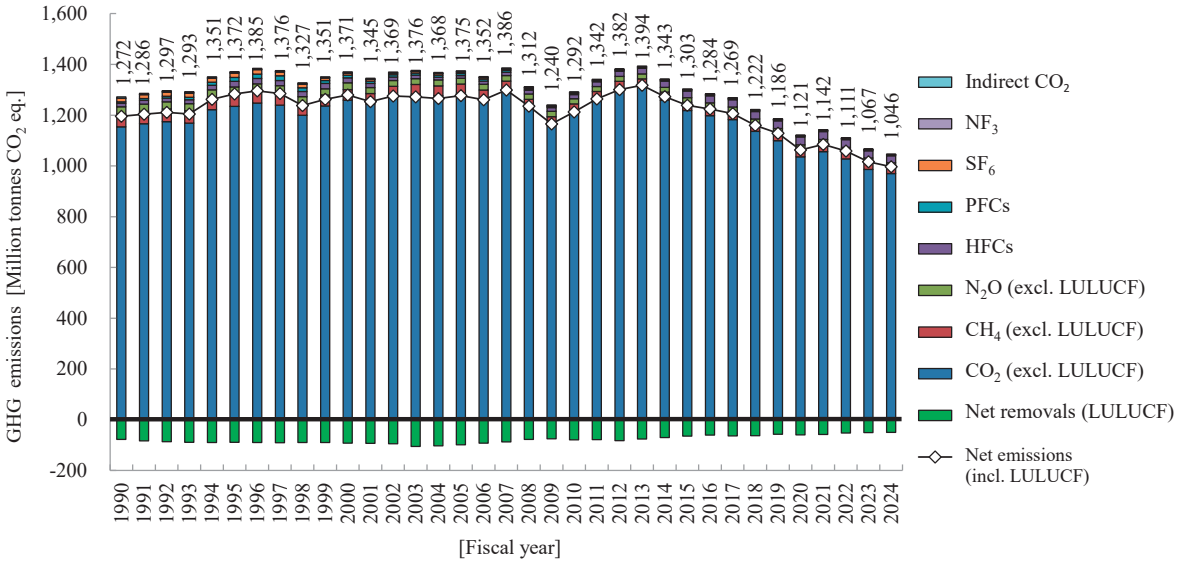

Figure 1 Trends in GHG emissions and removals in Japan

[2] The sum of CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, and NF_3 emissions converted to CO_2 equivalents multiplied by their respective global warming potential (GWP). The GWP is a coefficient by means of which greenhouse gas effects of a given gas are made relative to those of an equivalent amount of CO_2. The coefficients (100-year time horizon) are drawn from the *Fifth Assessment Report* (2013) issued by the IPCC.

[3] Abbreviation of "Land Use, Land-Use Change and Forestry"

[4] Carbon monoxide (CO), methane (CH_4) and non-methane volatile organic compounds (NMVOC) are oxidized in the atmosphere in the long term and converted to CO_2. Indirect CO_2 means value in CO_2 equivalent of these emissions. However, emissions of CO, CH_4 and NMVOC derived from combustion origin and biomass origin are excluded to avoid double counting.

Table 1 Trends in GHGs emissions and removals in Japan

[Fiscal year]

[Million tonnes CO_2 eq.]	GWP	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CO_2 (excl. LULUCF) *1	1	1,154.2	1,166.0	1,174.8	1,168.5	1,222.0	1,234.5	1,247.4	1,239.4	1,199.6	1,236.5	1,258.7	1,244.5	1,273.9	1,282.2	1,277.4	1,284.7	1,261.7	1,297.1	1,226.6	1,158.7
CO_2 (incl. LULUCF) *1	1	1,076.6	1,082.3	1,088.2	1,079.8	1,132.4	1,145.6	1,157.9	1,148.4	1,109.4	1,146.6	1,166.8	1,151.5	1,179.4	1,177.1	1,174.4	1,186.1	1,169.5	1,209.5	1,148.9	1,083.1
CO_2 (LULUCF only)	1	-77.6	-83.7	-86.6	-88.8	-89.6	-88.9	-89.5	-90.9	-90.1	-90.0	-91.9	-93.0	-94.6	-105.1	-103.0	-98.5	-92.3	-87.6	-77.7	-75.5
CH_4 (excl. LULUCF)	28	50.0	49.3	49.2	48.2	48.3	46.9	45.5	45.0	43.1	42.7	41.9	40.6	39.7	38.6	38.3	38.2	37.6	36.9	36.0	35.4
CH_4 (incl. LULUCF)	28	50.2	49.4	49.3	48.4	48.4	47.1	45.7	45.1	43.2	42.8	42.0	40.7	39.8	38.7	38.4	38.3	37.7	37.0	36.1	35.5
N_2O (excl. LULUCF)	265	28.9	28.6	28.6	28.6	29.6	29.8	30.8	31.4	30.1	24.6	26.8	23.5	22.9	23.0	23.0	22.7	22.6	22.2	21.2	20.7
N_2O (incl. LULUCF)	265	29.7	29.4	29.5	29.4	30.4	30.6	31.5	32.1	30.8	25.3	27.5	24.2	23.6	23.7	23.7	23.3	23.2	22.8	21.8	21.2
HFCs	HFC-134a: 1,300 etc.	13.4	14.6	15.0	15.4	17.9	21.5	21.1	21.0	20.5	21.0	19.8	16.9	14.2	14.1	10.8	10.8	11.8	12.9	14.4	15.1
PFCs	PFC-14: 6,630 etc.	6.2	7.0	7.1	10.1	12.4	16.2	16.7	18.2	15.0	11.8	10.5	8.7	8.2	8.0	8.3	7.8	8.2	7.2	5.2	3.7
SF_6	23,500	13.8	15.2	16.8	16.8	16.1	17.6	18.3	15.8	14.5	10.3	8.2	6.9	6.6	6.2	6.2	5.8	5.9	5.4	4.7	2.7
NF_3	16,100	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.1	0.2	0.3	0.3	0.3	0.3	0.4	0.4	1.4	1.3	1.5	1.4	1.3
Indirect CO_2	1	5.6	5.4	5.1	4.9	4.9	4.8	4.8	4.6	4.3	4.3	4.3	3.9	3.7	3.5	3.4	3.4	3.3	3.1	2.8	2.6
Gross Total (excluding LULUCF, excluding indirect CO_2)		1,266.5	1,280.7	1,291.5	1,287.7	1,346.3	1,366.8	1,379.9	1,371.0	1,323.0	1,347.2	1,366.2	1,341.4	1,365.8	1,372.5	1,364.4	1,371.4	1,349.0	1,383.1	1,309.5	1,237.5
Net Total (including LULUCF, excluding indirect CO_2)		1,189.8	1,198.0	1,205.8	1,199.9	1,257.7	1,278.8	1,291.3	1,280.9	1,233.6	1,258.0	1,275.1	1,249.2	1,272.0	1,268.2	1,262.2	1,273.6	1,257.5	1,296.2	1,232.5	1,162.6
Gross Total (excluding LULUCF, including indirect CO_2)		1,272.1	1,286.1	1,296.6	1,292.6	1,351.2	1,371.6	1,384.8	1,375.6	1,327.2	1,351.4	1,370.5	1,345.3	1,369.5	1,376.0	1,367.9	1,374.7	1,352.3	1,386.2	1,312.3	1,240.1
Net Total (including LULUCF, including indirect CO_2)		1,195.4	1,203.4	1,210.9	1,204.8	1,262.6	1,283.6	1,296.1	1,285.5	1,237.9	1,262.3	1,279.5	1,253.1	1,275.7	1,271.7	1,265.7	1,276.9	1,260.8	1,299.3	1,235.3	1,165.2

[Million tonnes CO_2 eq.]	GWP	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	Changes in emissions/removals (2024)		
																	1990	2013	Previous year
CO_2 (excl. LULUCF) *1	1	1,209.3	1,259.5	1,300.4	1,310.0	1,258.5	1,218.0	1,198.0	1,182.3	1,136.5	1,099.8	1,035.6	1,056.6	1,027.6	986.3	969.6	-16.0%	-26.0%	-1.7%
CO_2 (incl. LULUCF) *1	1	1,129.9	1,181.1	1,217.9	1,234.0	1,188.2	1,153.3	1,137.8	1,118.7	1,073.4	1,042.3	976.2	998.3	974.9	935.4	919.5	-14.6%	-25.5%	-1.7%
CO_2 (LULUCF only)	1	-79.3	-78.5	-82.4	-76.0	-70.3	-64.7	-60.2	-63.6	-63.1	-57.5	-59.3	-58.4	-52.7	-50.9	-50.1	-35.4%	-34.0%	-1.5%
CH_4 (excl. LULUCF)	28	34.9	33.6	32.8	32.8	32.2	31.8	31.8	31.6	31.1	30.8	30.5	30.5	29.9	29.5	27.9	-44.2%	-14.8%	-5.4%
CH_4 (incl. LULUCF)	28	35.0	33.6	32.9	32.8	32.3	31.9	31.9	31.7	31.2	30.9	30.5	30.6	30.0	29.6	28.2	-43.8%	-14.3%	-4.8%
N_2O (excl. LULUCF)	265	20.3	20.0	19.6	19.6	19.1	18.8	18.4	18.6	17.7	17.3	16.8	16.8	16.0	15.2	14.8	-48.8%	-24.6%	-2.7%
N_2O (incl. LULUCF)	265	20.8	20.5	20.1	20.1	19.5	19.2	18.8	19.0	18.1	17.7	17.3	17.2	16.5	15.6	15.2	-48.8%	-24.1%	-2.5%
HFCs	HFC-134a: 1,300 etc.	16.7	18.4	20.3	22.0	24.1	26.4	27.8	28.5	29.0	30.1	30.9	31.0	29.8	28.5	27.6	105.6%	25.5%	-3.4%
PFCs	PFC-14: 6,630 etc.	3.8	3.4	3.1	3.0	3.1	3.0	3.1	3.2	3.2	3.2	3.2	2.9	3.0	3.1	2.5	-59.7%	-16.9%	-18.8%
SF_6	23,500	2.8	2.5	2.5	2.3	2.3	2.4	2.4	2.3	2.3	2.2	2.2	2.2	2.1	2.1	2.0	-85.4%	-14.3%	-3.0%
NF_3	16,100	1.4	1.7	1.4	1.5	1.0	0.5	0.6	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2	542.3%	-88.1%	-12.8%
Indirect CO_2	1	2.5	2.4	2.4	2.4	2.3	2.3	2.2	2.2	2.1	2.1	1.9	1.9	1.9	1.9	1.9	-66.6%	-21.1%	-1.3%
Gross Total (excluding LULUCF, excluding indirect CO_2)		1,289.2	1,339.1	1,380.1	1,391.2	1,340.3	1,301.0	1,282.0	1,266.8	1,220.0	1,183.7	1,119.5	1,140.5	1,108.9	1,064.9	1,044.5	-17.5%	-24.9%	-1.9%
Net Total (including LULUCF, excluding indirect CO_2)		1,210.5	1,261.2	1,298.2	1,315.7	1,270.5	1,236.8	1,222.2	1,203.8	1,157.4	1,126.6	1,060.6	1,082.6	1,056.7	1,014.5	995.1	-16.4%	-24.4%	-1.9%
Gross Total (excluding LULUCF, including indirect CO_2)		1,291.7	1,341.5	1,382.5	1,393.5	1,342.5	1,303.2	1,284.2	1,269.0	1,222.2	1,185.7	1,121.4	1,142.4	1,110.8	1,066.7	1,046.4	-17.7%	-24.9%	-1.9%
Net Total (including LULUCF, including indirect CO_2)		1,213.0	1,263.6	1,300.6	1,318.1	1,272.8	1,239.0	1,224.5	1,206.0	1,159.6	1,128.7	1,062.6	1,084.5	1,058.5	1,016.4	997.0	-16.6%	-24.4%	-1.9%

*1 Excluding indirect CO_2

*2 LULUCF: Land Use, Land-Use Change and Forestry

E.S.3. Overview of Source and Sink Category Emission Estimates and Trends

The breakdown of GHGs emissions and removals in FY2024 by sector[5] shows that the energy (excluding indirect CO_2) accounts for 88.8% of total GHGs emissions. It is followed by the industrial processes and product use sector (excluding indirect CO_2) (6.7%), the agriculture sector (2.9%), the waste sector (1.5%), and indirect CO_2 emissions (0.2%).

Net removals by the LULUCF in FY2024 were equivalent to 4.7% of total GHGs emissions.

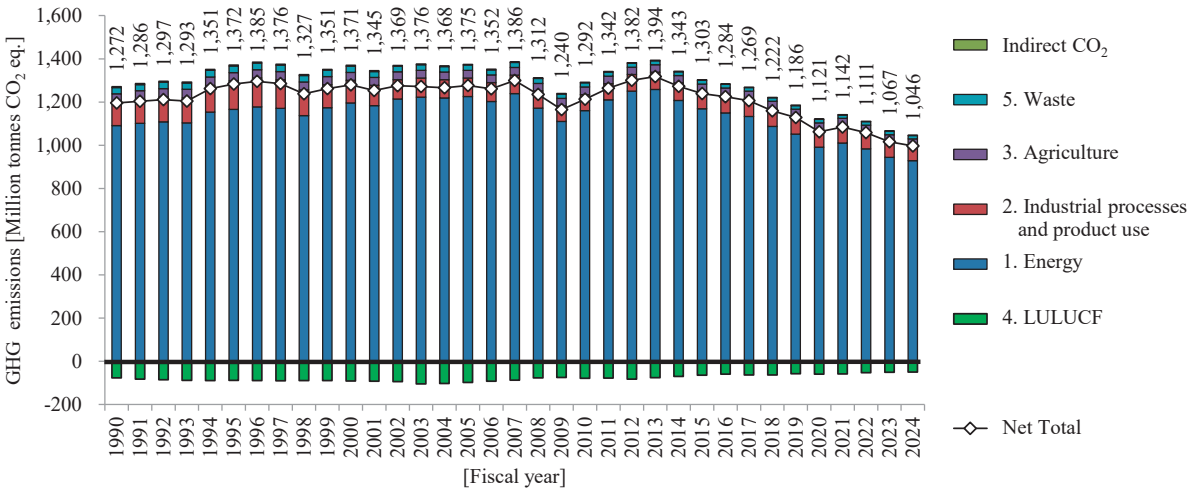

Figure 2 Trends in GHGs emissions and removals in each sector

[5] As indicated in the *2006 IPCC Guidelines* and the CRTs.

Table 2 Trends in GHGs emissions and removals in each sector

[Fiscal year]

[Million tonnes CO_2 eq.]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1. Energy*1	1,091.0	1,101.4	1,108.8	1,103.4	1,153.6	1,165.6	1,177.2	1,171.2	1,137.2	1,173.9	1,195.5	1,183.0	1,214.5	1,223.2	1,218.8	1,225.6	1,202.9	1,238.8	1,171.3	1,110.2
2. Industrial processes and product use*1	107.4	111.8	113.7	115.7	122.5	131.8	133.9	130.9	118.7	106.8	104.8	94.7	88.7	87.6	84.7	85.4	87.2	85.4	80.0	71.8
3. Agriculture	39.3	38.9	39.8	39.8	40.0	39.0	38.2	38.3	37.0	37.1	37.0	36.2	36.4	35.9	35.7	36.1	35.9	36.2	35.1	34.9
4. LULUCF*2	-76.6	-82.7	-85.7	-87.8	-88.6	-88.0	-88.6	-90.1	-89.3	-89.2	-91.1	-92.2	-93.8	-104.3	-102.2	-97.8	-91.6	-86.9	-77.0	-74.9
5. Waste	28.8	28.6	29.2	28.9	30.3	30.4	30.7	30.5	30.0	29.4	28.9	27.4	26.2	25.9	25.2	24.3	23.0	22.6	23.1	20.6
Indirect CO_2	5.6	5.4	5.1	4.9	4.9	4.8	4.8	4.6	4.3	4.3	4.3	3.9	3.7	3.5	3.4	3.4	3.3	3.1	2.8	2.6
Gross Total (excluding LULUCF, excluding indirect CO_2)	1,266.5	1,280.7	1,291.5	1,287.7	1,346.3	1,366.8	1,379.9	1,371.0	1,323.0	1,347.2	1,366.2	1,341.4	1,365.8	1,372.5	1,364.4	1,371.4	1,349.0	1,383.1	1,309.5	1,237.5
Net Total (including LULUCF, excluding indirect CO_2)	1,189.8	1,198.0	1,205.8	1,199.9	1,257.7	1,278.8	1,291.3	1,280.9	1,233.6	1,258.0	1,275.1	1,249.2	1,272.0	1,268.2	1,262.2	1,273.6	1,257.5	1,296.2	1,232.5	1,162.6
Gross Total (excluding LULUCF, including indirect CO_2)	1,272.1	1,286.1	1,296.6	1,292.6	1,351.2	1,371.6	1,384.8	1,375.6	1,327.2	1,351.4	1,370.5	1,345.3	1,369.5	1,376.0	1,367.9	1,374.7	1,352.3	1,386.2	1,312.3	1,240.1
Net Total (including LULUCF, including indirect CO_2)	1,195.4	1,203.4	1,210.9	1,204.8	1,262.6	1,283.6	1,296.1	1,285.5	1,237.9	1,262.3	1,279.5	1,253.1	1,275.7	1,271.7	1,265.7	1,276.9	1,260.8	1,299.3	1,235.3	1,165.2

[Million tonnes CO_2 eq.]	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
1. Energy*1	1,159.8	1,210.5	1,250.7	1,258.3	1,207.7	1,168.5	1,149.7	1,133.8	1,087.4	1,051.9	990.7	1,010.0	983.6	944.5	929.1
2. Industrial processes and product use*1	74.3	75.1	76.3	79.6	80.7	80.8	81.8	83.1	82.6	82.0	80.0	81.2	76.9	72.8	69.9
3. Agriculture	35.2	34.4	34.1	34.4	34.0	33.8	33.9	33.9	33.2	33.2	33.1	33.5	32.6	31.8	30.3
4. LULUCF*2	-78.7	-77.9	-81.9	-75.4	-69.7	-64.2	-59.7	-63.1	-62.6	-57.0	-58.8	-57.9	-52.2	-50.4	-49.4
5. Waste	19.8	19.0	19.0	18.9	17.9	17.9	16.6	16.2	16.8	16.5	15.6	15.9	15.7	15.8	15.3
Indirect CO_2	2.5	2.4	2.4	2.4	2.3	2.3	2.2	2.2	2.1	2.1	1.9	1.9	1.9	1.9	1.9
Gross Total (excluding LULUCF, excluding indirect CO_2)	1,289.2	1,339.1	1,380.1	1,391.2	1,340.3	1,301.0	1,282.0	1,266.8	1,220.0	1,183.7	1,119.5	1,140.5	1,108.9	1,064.9	1,044.5
Net Total (including LULUCF, excluding indirect CO_2)	1,210.5	1,261.2	1,298.2	1,315.7	1,270.5	1,236.8	1,222.2	1,203.8	1,157.4	1,126.6	1,060.6	1,082.6	1,056.7	1,014.5	995.1
Gross Total (excluding LULUCF, including indirect CO_2)	1,291.7	1,341.5	1,382.5	1,393.5	1,342.5	1,303.2	1,284.2	1,269.0	1,222.2	1,185.7	1,121.4	1,142.4	1,110.8	1,066.7	1,046.4
Net Total (including LULUCF, including indirect CO_2)	1,213.0	1,263.6	1,300.6	1,318.1	1,272.8	1,239.0	1,224.5	1,206.0	1,159.6	1,128.7	1,062.6	1,084.5	1,058.5	1,016.4	997.0

*1 Excluding indirect CO_2

*2 LULUCF: Land Use, Land-Use Change and Forestry

E.S.4. Brief Description of Key Categories

Key category analysis was carried out in accordance with the *2006 IPCC Guidelines* (Approach 1 and Approach 2 level/trend assessment), for all of the inventory categories and for both cases of including and excluding the LULUCF sector.

As a result, in the case of including the LULUCF sector, 47 and 41 sources and sinks were identified as Japan's key categories for FY2024 and FY1990, respectively. On the other hand, in the case of excluding the LULUCF sector, 38 and 37 sources were identified as the key categories for FY2024 and FY1990, respectively. More detailed information is described in Annex 1.

E.S.5. Improvements Introduced

Improvements in descriptions of the NID and calculation methodologies were made after the previous inventory submission. More detailed information is provided in Section 10.4.1. of Chapter 10.

Chapter 1. National Institutional Arrangements and Cross-cutting Information

1.1. Background Information on Japan's Greenhouse Gas Inventory and Climate Change

Japan hereby reports its greenhouse gas (GHG) inventory, which contains information on emissions and removals of GHGs, including precursors (nitrogen oxides [NO_X], carbon monoxide [CO], non-methane volatile organic compounds [NMVOC]), and sulfur oxides (SO_X) in Japan from FY1990 to FY2024[1], on the basis of Articles 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC) and Article 13 of the Paris Agreement.

Estimation methodologies for the GHG inventory are required to be in line with the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (*2006 IPCC Guidelines*), prepared by the Intergovernmental Panel on Climate Change (IPCC), and Japan's estimation methodologies for emissions and removals are basically in line with these guidelines. In order to enhance transparency, consistency, comparability, completeness, and accuracy of the inventory, Japan also applies the *2013 Supplement to the 2006 IPCC Guidelines: Wetlands* (*Wetlands Guidelines*), the *2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol* (*KP Supplement (2013)*), and the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (*2019 Refinement*).

Japan's national inventory is reported in accordance with the *Modalities, Procedures and Guidelines for the Transparency Framework for Action and Support Referred to in Article 13 of the Paris Agreement* (hereafter, *MPGs*, Decision 18/CMA.1 Annex) as decided by the Conference of the Parties.

1.2. Description of Japan's National Circumstances and Inventory Arrangements

1.2.1. Japan's National Entity for Inventory Preparation and Other Institutional, Legal and Procedural Arrangements

1.2.1.1. Institutional and Legal Arrangements for the Inventory Preparation

The Government of Japan is to calculate the emissions and removals of GHGs for Japan and disclose the results every year, in accordance with Article 7, the Act on Promotion of Global Warming Countermeasures,[2] which determines the domestic measures for the UNFCCC, etc. The Ministry of the Environment (MOE), with the cooperation of relevant ministries, agencies and organizations, annually prepares Japan's national inventory and compiles other additional information.

As the national entity for inventory preparation, MOE assumes overall responsibilities for the national inventory and organizes the Committee for the Greenhouse Gas Emission Estimation Methods (Committee) in order to integrate the latest scientific knowledge into the inventory and to modify it to meet international requirements. The estimation of GHG emissions and removals are then carried out by taking the decisions of the Committee into consideration. Substantial activities, such as the

[1] "FY (fiscal year)" is used because CO_2, which constitutes the largest part of the emission estimate, is on the fiscal year basis (April to March).
[2] Enacted in October 1998. The enforcement of the latest amendment was made on January 1, 2026.

estimation of emissions and removals and the preparation of the Common Reporting Tables (CRT) and National Inventory Document (NID), are done by the Greenhouse Gas Inventory Office of Japan (GIO), which belongs to the Center for Global Environmental Research in the Earth System Division of the National Institute for Environmental Studies. The relevant ministries, agencies and organizations provide the GIO with the appropriate data (e.g., activity data, emission factors, and GHG emissions and removals) through compiling various statistics and providing other additional information, etc. The relevant ministries and agencies check the inventory, including the spreadsheets that are actually utilized for the estimation (Japan National Greenhouse gas Inventory files, hereinafter referred to as "JNGI files"), as a part of the Quality Control (QC) activities.

The checked inventory is determined as Japan's official GHG emission/removal values. The inventory is then published and submitted to the UNFCCC Secretariat.

Figure 1-1 shows the overall institutional arrangement for Japan's inventory preparation. More detailed information on the roles and responsibilities of relevant ministries, agencies and organizations in the inventory preparation process is described below.

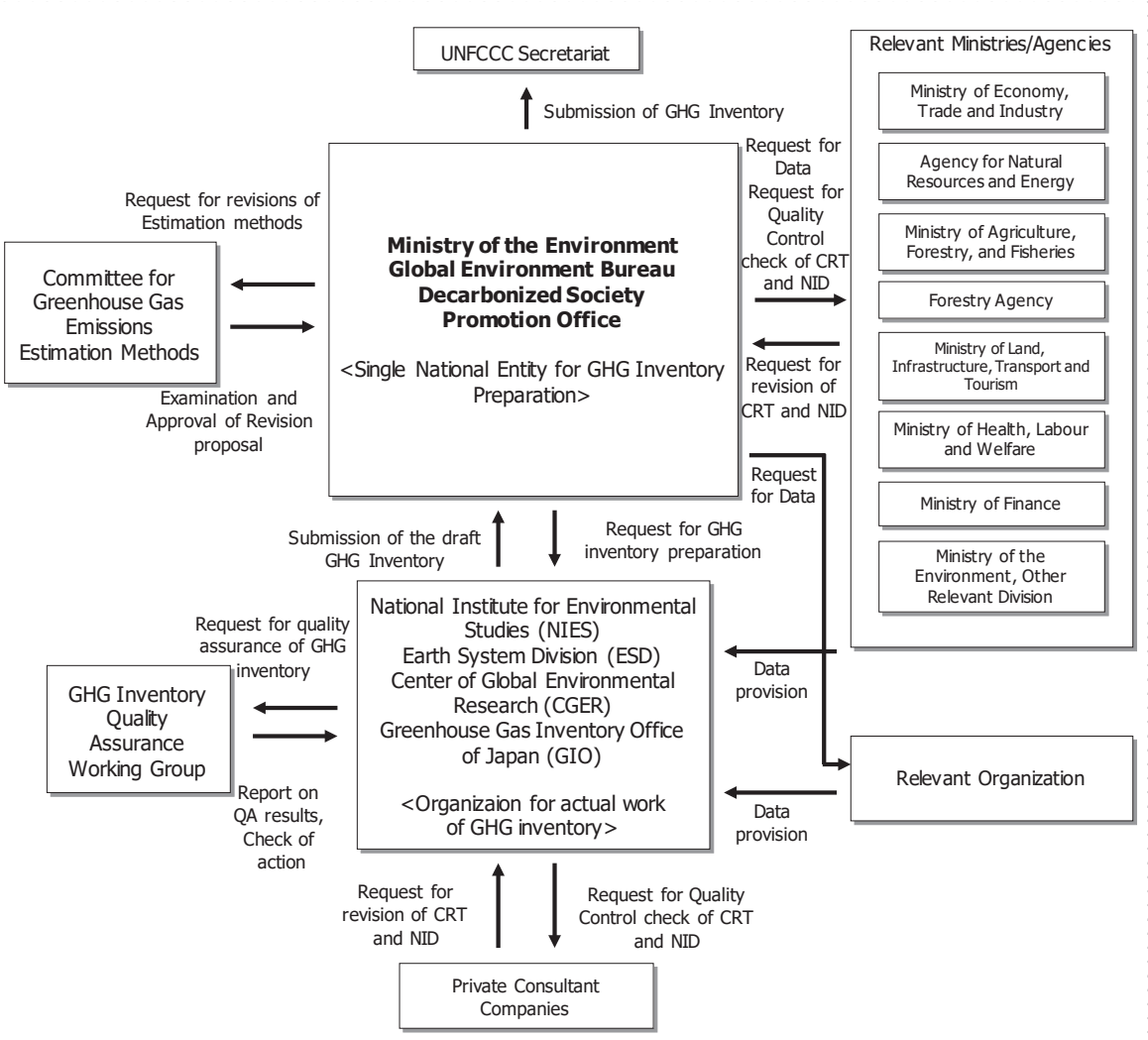

Figure 1-1 Japan's institutional arrangement for the national inventory preparation

1.2.1.2. Roles and Responsibilities of Each Entity Involved in the Inventory Preparation Process

The following are the agencies involved in the inventory compilation process, and the roles of those agencies.

1) Ministry of the Environment (Decarbonized Society Promotion Office, Global Environment Bureau)

- The single national agency responsible for preparing Japan's inventory, which was designated pursuant to the *MPGs*.
- It is responsible for editing and submitting the inventory.
- It coordinates the Quality Assurance and Quality Control (QA/QC) activities for the inventory.
- It checks and approves the revised draft of the QA/QC plan.
- It checks and approves the inventory improvement plan.

2) Greenhouse Gas Inventory Office of Japan (GIO), Center for Global Environmental Research, Earth System Division, National Institute for Environmental Studies

- Performs the actual work of inventory compilation. Responsible for inventory calculations, editing, preparation of part of the activity data necessary to prepare the inventory, and the archiving and management of all data.
- Prepares the revised draft of the QA/QC plan.
- Prepares the draft of the inventory improvement plan.

3) Relevant Ministries/Agencies

The relevant ministries and agencies have the following roles and responsibilities regarding inventory compilation.

- Preparation and provision of data such as activity data and emission factors required for the preparation of the inventory.
- Confirmation of data provided for the preparation of the inventory.
- Confirmation of the inventory (CRT, NID, JNGI files, and other information) prepared by the GIO (Category-specific QC).
- (When necessary), responding to questions from Technical Expert Review Teams (TERTs) about the statistics controlled by relevant ministries and agencies, or about certain data they have prepared, and preparing comments on draft review reports.
- (When necessary), responding to in-country review by TERTs.

4) Relevant Organizations

Relevant organizations have the following roles and responsibilities regarding inventory compilation.

- Preparation and provision of data such as activity data and emission factors required for the preparation of the inventory.
- Confirmation of data provided for the preparation of the inventory.

- (When necessary), responding to questions from TERTs about the statistics controlled by relevant organizations, or about certain data they have prepared, and preparing comments on draft review reports.

5) Committee for the Greenhouse Gas Emissions Estimation Methods

The Committee for the Greenhouse Gas Emissions Estimation Methods (the Committee) is a committee created and run by the MOE. Its role is to consider the methods for calculating inventory emissions and removals, and the selection of parameters such as activity data (AD) and emission factors (EFs). Under the Committee, the inventory working group (WG) that examines cross-cutting issues, and breakout groups that consider sector-specific issues (Breakout group on Energy and Industrial Processes, Breakout group on Transport, Breakout group on F-gases [HFCs, PFCs, SF_6, and NF_3], Breakout group on Agriculture, Breakout group on Waste, Breakout group on LULUCF, Breakout group on Carbon Capture and Utilization (CCU), and Breakout group on NMVOC) are set up. The inventory WG and the breakout groups/sub-breakout group comprise experts in various fields and consider suggestions for inventory improvements.

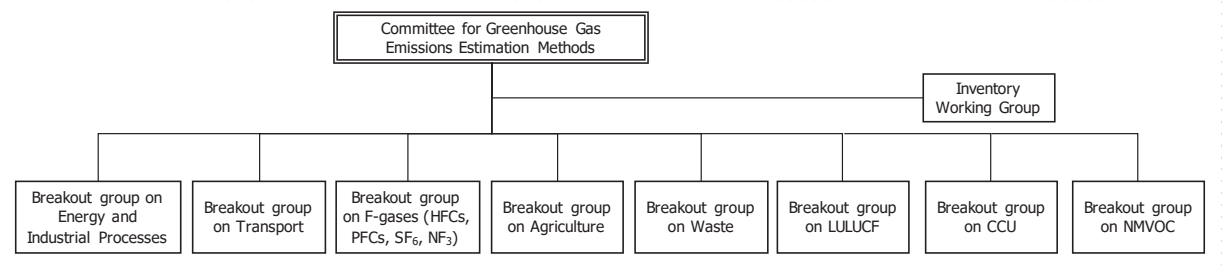

Figure 1-2 Structure of the Committee for the Greenhouse Gas Emissions Estimation Methods

6) Private Consulting Companies

Private consultant companies that are contracted by the MOE to perform tasks related to inventory compilation play the following roles in inventory compilation based on their contracts.

- Quality Control (QC) of the inventory (CRT, NID, JNGI files) compiled by the MOE and the GIO.
- (When necessary), providing support for responding to questions from TERTs and for preparing comments on draft review reports.
- (When necessary), providing support for responding to in-country review by TERTs.

7) GHG Inventory Quality Assurance Working Group (QAWG)

The GHG Inventory Quality Assurance Working Group (the QAWG) is an organization for QA activities and comprises experts who are not directly involved in inventory compilation. Its role is to assure inventory quality and to identify places that need improvement by conducting detailed reviews of each emission source and sink in the inventory.

1.2.1.3. Response for Inventory Review

The inventory that Japan submits each year is to be reviewed pursuant to the *MPGs*. Specifically, rigorous checks are performed from perspectives including whether emissions and removals are accurately and completely estimated and reported, or whether transparent explanations are provided for estimation methods, or whether QA/QC activities and uncertainty assessments are performed appropriately in accordance with the designated guidelines[3].

In view of the fact that ensuring the transparency of Japan's inventory is a matter of importance, the system shown in Figure 1-3 is used for responding to reviews.

[Basic structure]

The MOE (Decarbonized Society Promotion Office, Global Environment Bureau), which in Japan is responsible for editing and submitting the inventory, is assigned to be the agency with overall control (responsibility) for review response, while the GIO performs the actual work, such as preparing source materials and communicating with the UNFCCC Secretariat. The relevant ministries and agencies, relevant organizations, and private consultant companies[4] that are involved in inventory compilation cooperate with review response through activities including providing relevant information, support for source material preparation, and QC implementation.

[3] The *MPGs* and the *2006 IPCC Guidelines*.
[4] Private consultant companies cooperate in responding to reviews based on the operating agreement with MOE.

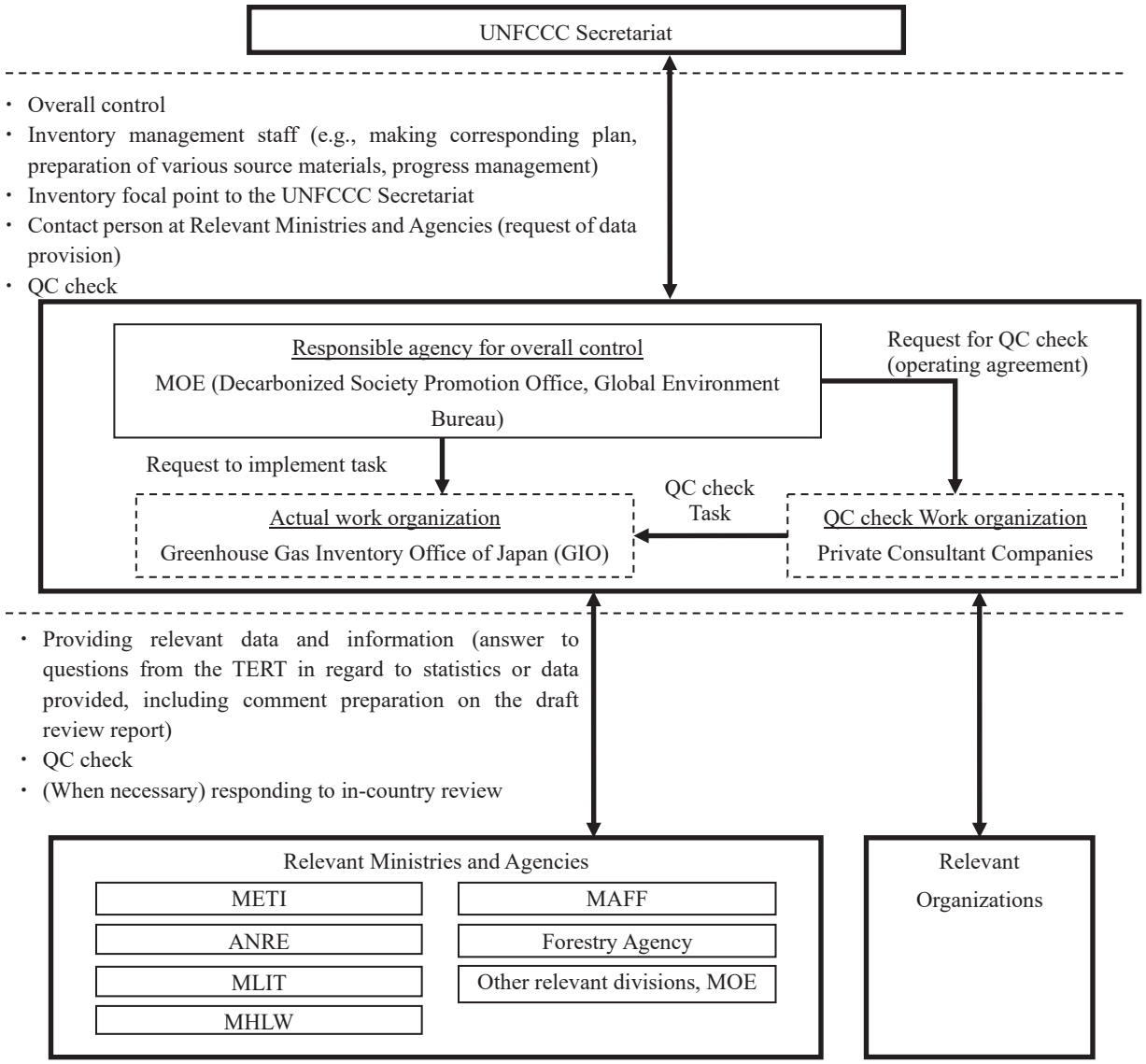

Figure 1-3 Basic structure of Japan's national system to respond to inventory review

1.2.2. Inventory Preparation Process

1.2.2.1. Annual Cycle of Inventory Preparation

Table 1-1 shows the annual cycle of inventory preparation. The inventory preparation cycle is set in conjunction with Japan's fiscal year calendar (starting April 1 and ending March 31 of the next year).

Table 1-1 Annual cycle of the fiscal year n inventory preparation

	Process	Relevant Entities	Calender Year n+1								CY n+2			
			Fiscal Year n+1											FY n+2
			May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr
1	Holding the meeting of the QAWG	MOE, GIO	→	→	→	→								
2	Discussion on inventory improvement	MOE, GIO		→	→	→	→							
3	Holding the meeting of the Committee	MOE, (GIO, Private consultant)		→	→	→	→	→	→	→	→			
4	Collection of data for the national inventory	MOE, GIO, Relevant Ministries/Agencies, Relevant organization, Private consultant								→	→	→	→	
5	Preparation of the draft CRT tables	GIO, Private consultant									→	→	→	
6	Preparation of the draft NID	GIO, Private consultant									→	→	→	
7	Implementation of external QC and coordination with relevant ministries and agencies	MOE, GIO, Relevant Ministries/Agencies, Private consultant										→	→	→
8	Correction of the draft CRTs and NID	MOE, GIO, Private consultant											→	→
9	Submission and official announcement of the national inventory	MOE, GIO												★

1.2.2.2. Process of the Inventory Preparation

1) Holding the Meeting of the Greenhouse Gas Inventory Quality Assurance Working Group (QAWG) (Step 1)

The QAWG, which is composed of experts who are not directly involved in nor related to the inventory preparation process, is organized in order to conduct peer review and assure the inventory's quality and to find possible improvements.

This QAWG reviews the appropriateness of the estimation methodologies, AD, EFs, and the contents of the CRT and NID. The GIO utilizes the items identified for improvement by the QAWG in discussions on the inventory estimation methods and in subsequent inventory preparation.

2) Discussion on Inventory Improvements (Step 2)

The MOE and the GIO identify the items that need to be addressed by the Committee, based on the results of the previous inventory review, the recommendations of the QAWG, the items needing improvement as identified at former Committee meetings, and any other items requiring revision, as determined during previous inventory preparations. The schedule for the expert evaluation (step 3) is developed by taking the above-mentioned information into account.

3) Holding Meetings of the Committee for the Greenhouse Gas Emission Estimation Methods [Evaluation and Examination of Estimation Methods by Experts] (Step 3)

The MOE holds meetings of the Committee, in which estimation methodologies for an annual inventory and the issues that require technical reviews are discussed by experts with different scientific backgrounds.

4) Collection of Data for the National Inventory (Step 4)

The data required for preparing the national inventory and other additional information are collected.

5) Preparation of a Draft of the CRT [Including the Implementation of the Key Category Analysis and the Uncertainty Assessment] (Step 5)

The data input and estimation of emissions and removals are carried out simultaneously by utilizing JNGI files, which have interconnecting links based on the calculation formulas for emissions and removals. Subsequently, the key category analysis and the uncertainty assessment are also carried out.

6) Preparation of a Draft of NID (Step 6)

The GIO identifies the points that need to be revised in the NID or that require an additional description by taking the discussion at step 2 into account. The organization of the NID is generally the same every year, but if large modifications such as changes in chapters are envisaged, this is proposed to the MOE and approval is sought. The GIO prepares the new NID draft by updating the data and by adding and revising descriptions.

7) Implementation of the External QC and the Coordination with the Relevant Ministries and Agencies (Step 7)

As a QC activity, private consulting companies check the JNGI files and the initial draft of the CRT (the 0^{th} draft) prepared by the GIO (external QC). The companies not only check the input data and the calculation formulas for the emissions and removals in the files but also check the estimations by calculating the GHG emissions and removals by utilizing the same files. Because of this crosscheck, any possible data input and emission estimation mistakes are avoided. They also check the content and descriptions of the initial draft of the NID (the 0^{th} draft) prepared by the GIO. JNGI files, draft CRT and draft NID, which have been checked by the private consulting companies, are regarded as the primary draft of the inventory.

Subsequently, the GIO sends out the primary drafts of the inventory and press release as electronic computer files to the MOE and the relevant ministries and agencies and asks them to check the contents. The data, which are estimated based on confidential data, are only sent out for confirmation to the ministries and/or agencies that provided the confidential data.

For some sources/sinks, emissions/removals are estimated by entities other than GIO, and the QC implemented in these entities are checked.

8) Correction of the Drafts of CRT and NID (Step 8)

When revisions are requested as a result of the check of the primary drafts of the inventory and press release by the relevant ministries and agencies (step 7), the MOE, GIO, and relevant ministries and/or agencies that submit requests for revision then coordinate the details of any revision, revise the primary drafts, and prepare the secondary drafts. The secondary drafts are sent out again to the relevant ministries and/or agencies for conclusive confirmation. If there is no additional request for revision, the secondary drafts are considered the final versions.

9) Submission and Official Announcement of the National Inventory (Step 9)

The completed inventory is submitted to the UNFCCC Secretariat. At the same time of the submission, information on the estimated GHG emissions and removals are officially announced and published on the MOE's website (https://www.env.go.jp/earth/ondanka/ghg-mrv/index.html) with additional relevant information. The inventory is also published on the GIO's website (https://www.nies.go.jp/gio/en/index.html).

1.2.3. Documentation and Archiving of Inventory Information

In Japan, the information needed for inventory compilation is documented and as a rule archived by the agency which compiles the inventory (GIO).

The main files (JNGI files, NID word files, and CRTs) needed for inventory compilation is electronically archived at MOE as well.

1.2.3.1. Documentation of Information

The GIO documents all the inventory-related information in electronic or printed form and archives it. Examples of information that must be archived follow.

- NID and CRT files submitted every year to the UNFCCC Secretariat
- JNGI files
- Published materials
- Statistical data and provided data (including data providers, time period when provided, and other related information) used in compiling the inventory and part of the activity data
- Information on the discussion process and discussion results related to the selection of AD, estimation methods, EFs, and other items (relevant source materials for the discussion process by the Committee for the Greenhouse Gas Emissions Estimation Methods)
- Records of communications with related entities in the inventory compilation process
- Information on inventory recalculations (such as reasons for recalculations, and when performed)
- QA/QC Plan and records of QA/QC activities conducted, including holding the QAWG
- Comments by experts on the inventory
- In relation to inventory reviews, review reports and records of questions and answers with TERTs

1.2.3.2. Archiving of Electronic Information

1) Inventory-related Electronic Information

- Each year's JNGI files and CRT- and NID-related files have file names with the year when the estimation was performed, and files are saved in folders prescribed for each year.
- Electronic files of statistical data, provided data, etc. used to prepare the inventory's emissions/removals estimates and other related data are given file names, etc. with the date on which the data were obtained and the data provider, and saved in prescribed folders.
- Source materials in electronic form (files in Word, PDF, or other format) used when considering emissions/removals estimation methods are labeled with the source material title and the date the file was obtained (and if necessary, the file provider), and saved in prescribed folders.
- If the exchange of information on the inventory has been conducted by email, the email files are saved in prescribed folders.

2) Backup and Risk Management of Electronic Information

- The National Institute for Environmental Studies, which GIO is a part of, and is responsible for storing inventory-related information, uses a cloud storage system that is automatically backed up.
- Once a year, after submission of the annual inventory to the UNFCCC Secretariat, all inventory-related electronic information is saved to DVD-R and other electronic media and archived.

1.2.3.3. Archiving in Printed Form

- Books of statistics, data and source materials in printed form that have been provided, and other source materials in printed form that have been used in inventory emissions/removals estimates are filed in a prescribed storage location.

1.2.4. Process for Official Consideration and Approval of the Inventory

The MOE, supported by GIO, goes through the following processes for official consideration and approval of the inventory (See also steps 7 and 8 in section 1.2.2.2.):

The primary drafts of the inventory and press release prepared by GIO are sent out to the MOE and the relevant ministries and agencies in order to have the contents checked.

When revisions are requested as a result of the check of the primary drafts of the inventory and official announcements by the relevant ministries and agencies, the MOE, GIO, and relevant ministries and/or agencies that submit requests for revision then coordinate the details of any revision, revise the primary drafts, and prepare the secondary drafts.

The secondary drafts are sent out again to the relevant ministries and/or agencies for conclusive confirmation. If there is no additional request for revision, the secondary drafts are considered the final versions.

The checked inventory is determined as Japan's official GHG emission/removal values. The inventory is then published and submitted to the UNFCCC Secretariat.

1.3. Brief General Description of Methodologies (Including Tiers Used) and Data Sources Used

The methodology used in estimation of GHG emissions or removals is basically in accordance with the *2006 IPCC Guidelines*. The country-specific methodologies are also used for some source/sink categories in order to more accurately reflect the actual status of emissions and removals in Japan.

The results of the actual measurements or estimates based on research conducted in Japan are used to determine the EFs (country-specific emissions factors). The default values given in the *2006 IPCC Guidelines* are used for some categories, emissions of which are assumed to be quite low (e.g., "1.B.2.a.iii fugitive emissions from fuel (oil - transport (CO_2 and CH_4))") etc.

1.3.1. Collection of Activity Data

When the AD needed for calculations are available from sources such as publications and the internet, the necessary data are gathered from these media. Data that are not released in publications, the internet, or in other media, and unpublished data that are used when compiling the inventory are obtained by the MOE or the GIO by requesting them from the relevant ministries and agencies and the relevant organizations which control those data. The main relevant ministries, agencies, and relevant organizations, and their statistics and data are as shown in Table 1-2.

Table 1-2 Main relevant ministries, agencies, and the relevant organizations, and their statistics and data

Ministries/Agencies/Organizations		Major statistics / data
Relevant Ministries/ Agencies	MOE	*General Survey of the Emissions of Air Pollutants*/ *Waste Treatment in Japan*/ *Survey on the State of Cyclical Use of Waste*/ *Survey of Industrial Waste Treatment Facilities*
	METI	*General Energy Statistics* / *Current Production Statistics* / *Documents of Fluorocarbons etc Measures Working Group, Group for Chemical Substance Policy, Manufacturing Industries Sub-Group, Industrial Structure Council* / Data on the amount of nitric acid production
	MLIT	*Statistical Yearbook of Motor Vehicle Fuel Consumption* / *Land Use Status Survey*
	MAFF	*Livestock Statistics* / *Statistics of Arable and Planted Land Area* / *Yearbook of Fertilizer Statistics (Pocket Edition)*/ *A Move and Conversion of Cropland* / *National Forest Resources Database*/ *Report on Forest GHG Inventory Information Development Project*
Relevant Organizations	Federation of Electric Power Companies	Data on the amount of fuel used by pressurized fluidized bed boilers
	Japan Carbon Frontier Organization	*History of Coal Policy*/ Data on coal production
	Japan Cement Association	*Cement Handbook* / Data on the amount of clinker production
	Japan Iron and Steel Federation	Data on the emissions from coke oven covers, desulfurization towers, and desulfurization recycling towers
	Japan Paper Association	Data on the amount of final disposal of industrial waste / Data on the amount of RPF incineration

1.3.2. Selection of Emission Factors and Estimation Methods

Calculation methods for Japan's emissions and removals are determined by having the Committee explore calculation methods suited to Japan's situation for all the activity categories necessary for calculating Japan's greenhouse gas emissions and removals, based on the *2006 IPCC Guidelines*.

1.3.3. Improvement Process of Estimations for Emissions and Removals

In Japan, improvements in the calculation methods are considered in accordance with necessity whenever an inventory item requiring improvement is identified because of, for example, an inventory review or an observation by the QAWG, progress in international negotiations such as the creation of new guidelines, progress or changes in scientific research or in the compilation of statistics, or the acquisition of new information by the Mandatory GHG Accounting and Reporting System. Proposals for improving the estimation of emissions and removals are considered by scientific research or the Committee, and the results are incorporated into the inventory. Figure 1-4 is a diagram of the inventory improvement process.

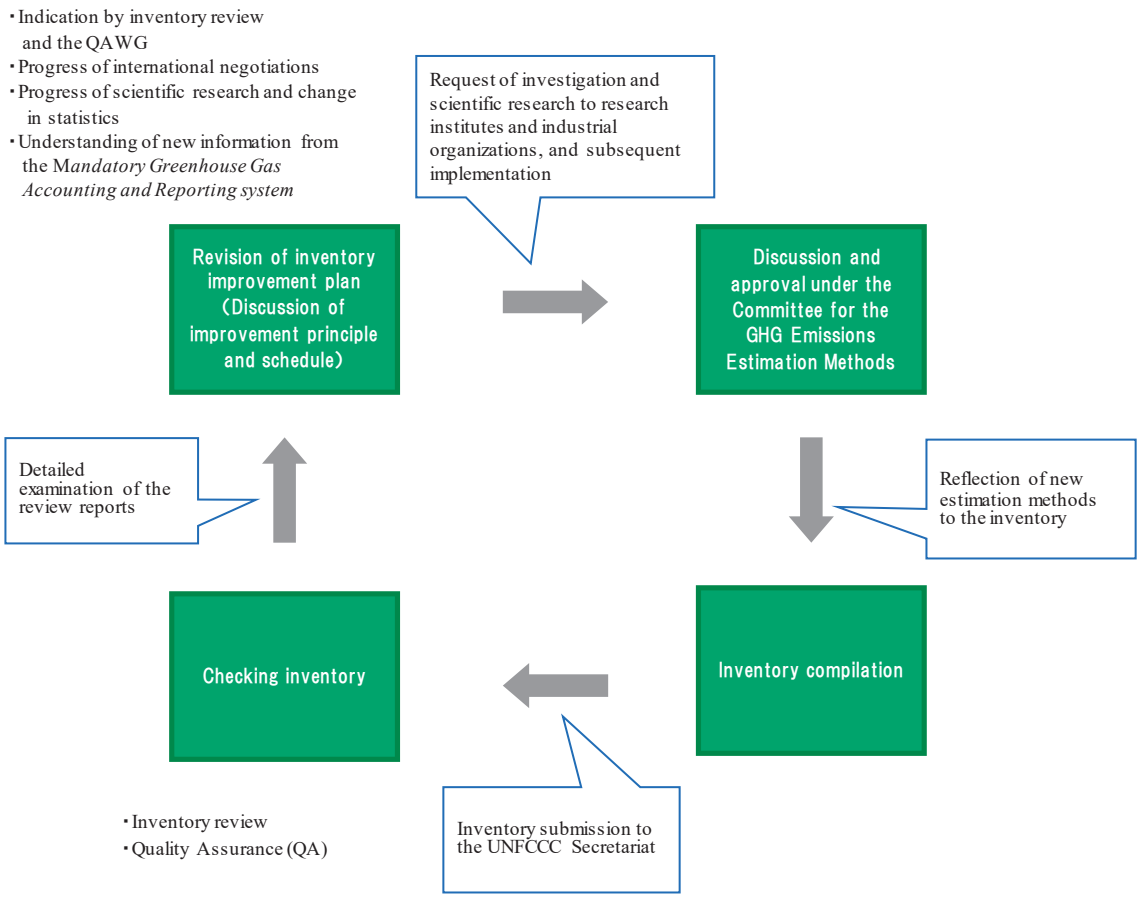

Figure 1-4 Diagram of the inventory improvement process

1.4. Brief Description of Key Categories

Key category analysis was carried out in accordance with the *2006 IPCC Guidelines* (Approach 1 and Approach 2 level/trend assessment), for all of the inventory categories and for both cases of including and excluding the LULUCF sector.

As a result, in the case of including the LULUCF sector, 47 and 41 sources and sinks were identified as Japan's key categories for FY2024 and FY1990, respectively (Table 1-3 and Table 1-4). On the other hand, in the case of excluding the LULUCF sector, 38 and 37 sources were identified as the key categories for FY2024 and FY1990, respectively (Table 1-5 and Table 1-6). More detailed information is described in Annex 1.

Table 1-3 Japan's key categories (FY2024, including the LULUCF sector)

	A Code	B Category		C GHGs	Ap1-L	Ap1-T	Ap2-L	Ap2-T
#1	1.A.1.	Energy Industries	Solid Fuels	CO_2	#1	#1	#1	#1
#2	1.A.3.	Transport	b. Road Transportation	CO_2	#2	#14	#6	
#3	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	#3	#7	#2	#6
#4	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	#4	#4	#8	#17
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	#5	#6	#21	#20
#6	4.A.	Forest Land	1. Forest Land Remaining Forest Land	CO_2	#6	#5	#3	#3
#7	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	#7	#3	#26	#16
#8	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	#8	#9	#27	#28
#9	1.A.1.	Energy Industries	Liquid Fuels	CO_2	#9	#2	#32	#8
#10	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	#10	#10	#33	
#11	2.F.	Product Uses as Substitutes for ODS	1. Refrigeration and Air Conditioning Equipment	HFCs	#11	#8	#11	#11
#12	2.A.	Mineral Industry	1. Cement Production	CO_2	#12	#11	#25	#24
#13	3.C.	Rice Cultivation		CH_4	#13		#29	
#14	1.A.3.	Transport	a. Domestic Aviation	CO_2	#14	#21		
#15	1.A.3.	Transport	d. Domestic Navigation	CO_2	#15			
#16	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	#16	#23	#13	#23
#17	5.C.	Incineration and Open Burning of Waste		CO_2	#17		#14	
#18	3.A.	Enteric Fermentation		CH_4	#18		#7	
#19	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	#19	#19	#17	#19
#20	1.A.4.	Other Sectors	Solid Fuels	CO_2	#20	#17		
#21	2.C.	Metal Industry	1. Iron and Steel Production	CO_2	#21			
#22	4.E.	Settlements	2. Land Converted to Settlements	CO_2	#22	#20	#10	#5
#23	2.A.	Mineral Industry	2. Lime Production	CO_2	#23			
#24	4.B.	Cropland	1. Cropland Remaining Cropland	CO_2			#23	
#25	3.B.	Manure Management		N_2O			#4	
#26	2.D.	Non-energy Products from Fuels and Solvent Use		CO_2			#15	
#27	2.F.	Product Uses as Substitutes for ODS	2. Foam Blowing Agents	HFCs			#16	#14
#28	3.D.	Agricultural Soils	1. Direct Emissions	N_2O			#12	#22
#29	2.B.	Chemical Industry	Other Production Except Ammonia	CO_2			#18	#29
#30	5.D.	Wastewater Treatment and Discharge		N_2O			#30	
#31	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O			#5	#12
#32	5.A.	Solid Waste Disposal		CH_4		#15		#9
#33	2.G.	Other Product Manufacture and Use		SF_6		#16	#9	#2
#34		Indirect CO_2	from IPPU Sector	Ind CO_2			#28	#13
#35	2.E.	Electronics Industry		PFCs			#22	
#36	5.C.	Incineration and Open Burning of Waste		N_2O			#24	
#37	1.A.3.	Transport	b. Road Transportation	N_2O			#19	#10
#38	4.F.	Other Land	2. Land Converted to Other Land	CO_2				#21
#39	4.A.	Forest Land	2. Land Converted to Forest Land	CO_2		#13		#18
#40	1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	CH_4		#22		#4
#41	4.(III)	N_2O Emissions from N Mineralization/Immobilization		N_2O			#31	#26
#42	2.E.	Electronics Industry		SF_6			#20	#15
#43	2.B.	Chemical Industry	2. Nitric Acid Production	N_2O				#27
#44	2.B.	Chemical Industry	9. Fluorochemical Production	HFCs		#12		
#45	2.B.	Chemical Industry	9. Fluorochemical Production	SF_6		#24		
#46	2.B.	Chemical Industry	3. Adipic Acid Production	N_2O		#18		#25
#47	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O				#7

Note: Ap1-L: Approach 1-Level Assessment, Ap1-T: Approach 1-Trend Assessment,
Ap2-L: Approach 2-Level Assessment, Ap2-T: Approach 2-Trend Assessment
Figures recorded in the Level and Trend columns indicate the ranking of individual level and trend assessments.

Table 1-4 Japan's key categories (FY1990, including the LULUCF sector)

	A Code	B Category		C GHGs	Ap1-L	Ap2-L
#1	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	#1	#2
#2	1.A.3.	Transport	b. Road Transportation	CO_2	#2	#11
#3	1.A.1.	Energy Industries	Liquid Fuels	CO_2	#3	#12
#4	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	#4	#18
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	#5	#19
#6	1.A.1.	Energy Industries	Solid Fuels	CO_2	#6	#4
#7	4.A.	Forest Land	1. Forest Land Remaining Forest Land	CO_2	#7	#3
#8	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	#8	#24
#9	2.A.	Mineral Industry	1. Cement Production	CO_2	#9	#22
#10	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	#10	
#11	1.A.3.	Transport	d. Domestic Navigation	CO_2	#11	
#12	3.C.	Rice Cultivation		CH_4	#12	
#13	2.B.	Chemical Industry	9. Fluorochemical Production	HFCs	#13	
#14	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	#14	
#15	4.E.	Settlements	2. Land Converted to Settlements	CO_2	#15	#7
#16	5.A.	Solid Waste Disposal		CH_4	#16	#14
#17	3.A.	Enteric Fermentation		CH_4	#17	#10
#18	5.C.	Incineration and Open Burning of Waste		CO_2	#18	#23
#19	4.A.	Forest Land	2. Land Converted to Forest Land	CO_2	#19	#32
#20	2.G.	Other Product Manufacture and Use		SF_6	#20	#1
#21	2.C.	Metal Industry	1. Iron and Steel Production	CO_2	#21	
#22	1.A.3.	Transport	a. Domestic Aviation	CO_2	#22	
#23	2.A.	Mineral Industry	2. Lime Production	CO_2	#23	
#24	4.B.	Cropland	1. Cropland Remaining Cropland	CO_2	#24	#21
#25	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	#25	#28
#26	2.B.	Chemical Industry	3. Adipic Acid Production	N_2O	#26	
#27	1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	CH_4	#27	#8
#28		Indirect CO_2	from IPPU Sector	Ind CO_2	#28	#15
#29	3.D.	Agricultural Soils	1. Direct Emissions	N_2O		#17
#30	3.B.	Manure Management		N_2O		#6
#31	2.B.	Chemical Industry	Other Production Except Ammonia	CO_2		#20
#32	1.A.3.	Transport	b. Road Transportation	N_2O		#9
#33	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O		#5
#34	4.F.	Other Land	2. Land Converted to Other Land	CO_2		#26
#35	2.D.	Non-energy Products from Fuels and Solvent Use		CO_2		#27
#36	5.D.	Wastewater Treatment and Discharge		N_2O		#31
#37	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O		#16
#38	2.E.	Electronics Industry		PFCs		#29
#39	5.C.	Incineration and Open Burning of Waste		N_2O		#30
#40	2.E.	Electronics Industry		SF_6		#13
#41	4.(III)	N_2O Emissions from N Mineralization/Immobilization		N_2O		#25

Note: Ap1-L: Approach 1-Level Assessment, Ap2-L: Approach 2-Level Assessment
Figures recorded in the Level columns indicate the ranking of individual level assessments.

Table 1-5 Japan's key categories (FY2024, excluding the LULUCF sector)

	A Code	B Category		C GHGs	Ap1-L	Ap1-T	Ap2-L	Ap2-T
#1	1.A.1.	Energy Industries	Solid Fuels	CO_2	#1	#1	#1	#1
#2	1.A.3.	Transport	b. Road Transportation	CO_2	#2	#10	#5	
#3	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	#3	#6	#2	#7
#4	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	#4	#4	#7	#15
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	#5	#5	#19	#17
#6	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	#6	#3	#23	#14
#7	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	#7	#8	#24	#22
#8	1.A.1.	Energy Industries	Liquid Fuels	CO_2	#8	#2	#28	#5
#9	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	#9	#9		
#10	2.F.	Product Uses as Substitutes for ODS	1. Refrigeration and Air Conditioning Equipment	HFCs	#10	#7	#9	#9
#11	2.A.	Mineral Industry	1. Cement Production	CO_2	#11	#11	#22	#21
#12	3.C.	Rice Cultivation		CH_4	#12		#26	
#13	1.A.3.	Transport	a. Domestic Aviation	CO_2	#13	#18		
#14	1.A.3.	Transport	d. Domestic Navigation	CO_2	#14			
#15	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	#15	#20	#11	#19
#16	5.C.	Incineration and Open Burning of Waste		CO_2	#16		#12	
#17	3.A.	Enteric Fermentation		CH_4	#17		#6	
#18	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	#18	#17	#15	#16
#19	1.A.4.	Other Sectors	Solid Fuels	CO_2	#19	#15		
#20	3.B.	Manure Management		N_2O			#3	
#21	2.D.	Non-energy Products from Fuels and Solvent Use		CO_2			#13	
#22	2.F.	Product Uses as Substitutes for ODS	2. Foam Blowing Agents	HFCs			#14	#11
#23	3.D.	Agricultural Soils	1. Direct Emissions	N_2O			#10	#18
#24	2.B.	Chemical Industry	Other Production Except Ammonia	CO_2			#16	#24
#25	5.D.	Wastewater Treatment and Discharge		N_2O			#27	
#26	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O			#4	#10
#27	5.A.	Solid Waste Disposal		CH_4		#13		#6
#28	2.G.	Other Product Manufacture and Use		SF_6		#14	#8	#2
#29		Indirect CO_2	from IPPU Sector	Ind CO_2			#25	#12
#30	2.E.	Electronics Industry		PFCs			#20	
#31	5.C.	Incineration and Open Burning of Waste		N_2O			#21	
#32	1.A.3.	Transport	b. Road Transportation	N_2O			#17	#8
#33	1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	CH_4		#19		#3
#34	2.E.	Electronics Industry		SF_6			#18	#13
#35	2.B.	Chemical Industry	2. Nitric Acid Production	N_2O				#23
#36	2.B.	Chemical Industry	9. Fluorochemical Production	HFCs		#12		
#37	2.B.	Chemical Industry	3. Adipic Acid Production	N_2O		#16		#20
#38	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O				#4

Note: Ap1-L: Approach1-Level Assessment, Ap1-T: Approach1-Trend Assessment,
Ap2-L: Approach2-Level Assessment, Ap2-T: Approach2-Trend Assessment
Figures recorded in the Level and Trend columns indicate the ranking of individual level and trend assessments.

Table 1-6 Japan's key categories (FY1990, excluding the LULUCF sector)

	A Code	B Category		C GHGs	Ap1-L	Ap2-L
#1	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	#1	#1
#2	1.A.3.	Transport	b. Road Transportation	CO_2	#2	#7
#3	1.A.1.	Energy Industries	Liquid Fuels	CO_2	#3	#8
#4	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	#4	#14
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	#5	#15
#6	1.A.1.	Energy Industries	Solid Fuels	CO_2	#6	#3
#7	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	#7	#21
#8	2.A.	Mineral Industry	1. Cement Production	CO_2	#8	#19
#9	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	#9	
#10	1.A.3.	Transport	d. Domestic Navigation	CO_2	#10	
#11	3.C.	Rice Cultivation		CH_4	#11	#26
#12	2.B.	Chemical Industry	9. Fluorochemical Production	HFCs	#12	
#13	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	#13	
#14	5.A.	Solid Waste Disposal		CH_4	#14	#11
#15	3.A.	Enteric Fermentation		CH_4	#15	#10
#16	5.C.	Incineration and Open Burning of Waste		CO_2	#16	#20
#17	2.G.	Other Product Manufacture and Use		SF_6	#17	#2
#18	2.C.	Metal Industry	1. Iron and Steel Production	CO_2	#18	
#19	1.A.3.	Transport	a. Domestic Aviation	CO_2	#19	
#20	2.A.	Mineral Industry	2. Lime Production	CO_2	#20	
#21	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	#21	#23
#22	2.B.	Chemical Industry	3. Adipic Acid Production	N_2O	#22	
#23	1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	CH_4	#23	#6
#24		Indirect CO_2	from IPPU Sector	Ind CO_2	#24	#18
#25	3.D.	Agricultural Soils	1. Direct Emissions	N_2O		#17
#26	3.B.	Manure Management		N_2O		#5
#27	2.B.	Chemical Industry	Other Production Except Ammonia	CO_2		#16
#28	5.D.	Wastewater Treatment and Discharge		CH_4		#29
#29	1.A.3.	Transport	b. Road Transportation	N_2O		#13
#30	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O		#4
#31	2.D.	Non-energy Products from Fuels and Solvent Use		CO_2		#22
#32	5.D.	Wastewater Treatment and Discharge		N_2O		#27
#33	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O		#12
#34	2.E.	Electronics Industry		PFCs		#24
#35	5.C.	Incineration and Open Burning of Waste		N_2O		#25
#36	2.E.	Electronics Industry		SF_6		#9
#37	2.B.	Chemical Industry	2. Nitric Acid Production	N_2O		#28

Note: Ap1-L: Approach1-Level Assessment, Ap2-L: Approach2-Level Assessment
Figures recorded in the Level columns indicate the ranking of individual level assessments.

1.5. Brief General Description of the QA/QC Plan and Implementation

QA/QC procedures are implemented in the inventory preparation and are documented as the QA/QC plan (See Annex 4 for details).

1.6. General Uncertainty Assessment, Including Data Pertaining to the Overall Uncertainty of the Inventory Total

Total net GHG emissions in Japan for FY2024 were approximately 997 million tonnes (CO_2 eq.). The total net emissions uncertainties calculated by approach 1 (propagation of error) were -3% to +2% and the uncertainties introduced into the trend in the total emissions were -3% to +2%. More detailed information on the uncertainty assessment is described in Annex 2.

Table 1-7 Uncertainty of Japan's total net emissions

A	B	C	D	G-1990		G-2024		I	J	
Category	GHGs	FY1990 emissions / removals	FY2024 emissions / removals	Combined uncertainty in FY1990		Combined uncertainty in FY2024		Inventory trend in national emissions for FY2024 increase with respect to FY1990	Uncertainty introduced into the trend in total national emissions	
		kt-CO_2 eq.	kt-CO_2 eq.	(-) %	(+) %	(-) %	(+) %	%	(-) %	(+) %
1A. Fuel Combustion (CO_2)	CO_2	1,077,488	922,614	-2%	+1%	-3%	+2%	-14.4%	-2.9%	+1.9%
1A. Fuel Combustion (Stationary:CH_4,N_2O)	CH_4, N_2O	3,710	3,824	-22%	+28%	-24%	+27%	3.1%	0.0%	+0.0%
1A. Fuel Combustion (Transport:CH_4,N_2O)	CH_4, N_2O	3,719	1,427	-30%	+89%	-28%	+82%	-61.6%	0.0%	+0.0%
1B. Fugitive Emissions from Fuels	CO_2, CH_4, N_2O	6,113	1,202	-36%	+76%	-17%	+35%	-80.3%	0.0%	+0.0%
2. IPPU (CO_2,CH_4,N_2O)	CO_2, CH_4, N_2O	74,033	37,647	-5%	+5%	-5%	+5%	-49.1%	-0.1%	+0.1%
2. IPPU (HFCs,PFCs,SF_6,NF_3)	HFCs, PFCs, SF_6, NF_3	33,364	32,245	-11%	+40%	-8%	+10%	-3.4%	-0.3%	+0.3%
3. Agriculture	CO_2, CH_4, N_2O	39,280	30,278	-11%	+25%	-10%	+22%	-22.9%	-0.1%	+0.1%
4. LULUCF	CO_2, CH_4, N_2O	-76,648	-49,421	-12%	12%	-11%	+11%	-35.5%	-0.4%	+0.4%
5. Waste	CO_2, CH_4, N_2O	28,785	15,310	-11%	+11%	-12%	+12%	-46.8%	-0.2%	+0.2%
Indirect CO_2	Ind CO_2	5,565	1,861	-25%	+46%	-24%	+43%	-66.6%	0.0%	+0.0%
Total Net Emissions		1,195,409	996,986	-2.1%	+2.2%	-2.6%	+2.0%	-16.6%	-2.9%	+2.0%

1.7. General Assessment of the Completeness

1.7.1. Information on Completeness

In this inventory document, emissions from some categories are not estimated and reported as "NE (Not Estimated)" in the CRTs. Source categories reported as "NE" in this year's report include those whose emissions are thought to be very small, those whose emissions are unknown, and those for which emission estimation methods have not been developed. For these categories, further investigation on their emission possibility and the development of estimation methodologies will be carried out in accordance with Japan's QA/QC plan.

1.7.2. Description of Insignificant Categories

For a list of the source categories reported as "NE" in this year's report whose emissions are thought to be insignificant, see Table A6-2 of Annex 6.

1.7.3. Total Aggregate Emissions Considered Insignificant

The approximate total amount of emissions from emission sources (excluding removals) considered insignificant is 122 kt (in CO_2 eq.) at maximum, and therefore is not expected to exceed 0.1% of the national total emissions (approximately 1.05 Mt in CO_2 eq. for Japan). See Table A6-2 in Annex 6 for details on the likely level of emissions.

1.8. Metrics Used

As per paragraph 37 of the *MPGs*, Japan applies the 100-year time-horizon global warming potential (GWP) values from the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (2013).

References

1. IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2006.
2. IPCC, *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*, 2014.
3. IPCC, *2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol*, 2014.
4. IPCC, *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2019.
5. IPCC, *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, 2013.
6. UNFCCC, *Modalities, Procedures and Guidelines for the Transparency Framework for Action and Support Referred to in Article 13 of the Paris Agreement*, Decision 18/CMA.1 Annex, FCCC/PA/CMA/2018/3/Add.2, 2019.

Chapter 2. Trends in GHG Emissions and Removals

2.1. Description and Interpretation of Emission and Removal Trends for Aggregate GHGs

2.1.1. Overview of GHGs Emissions and Removals

Total GHG emissions in FY2024[1,2] (excluding LULUCF[3], including indirect CO_2[4], hereafter, definition omitted) were 1,046 million tonnes (in CO_2 eq.). They decreased by 17.7% from FY1990, decreased by 24.9% from FY2013, and decreased by 1.9% compared to the previous year.

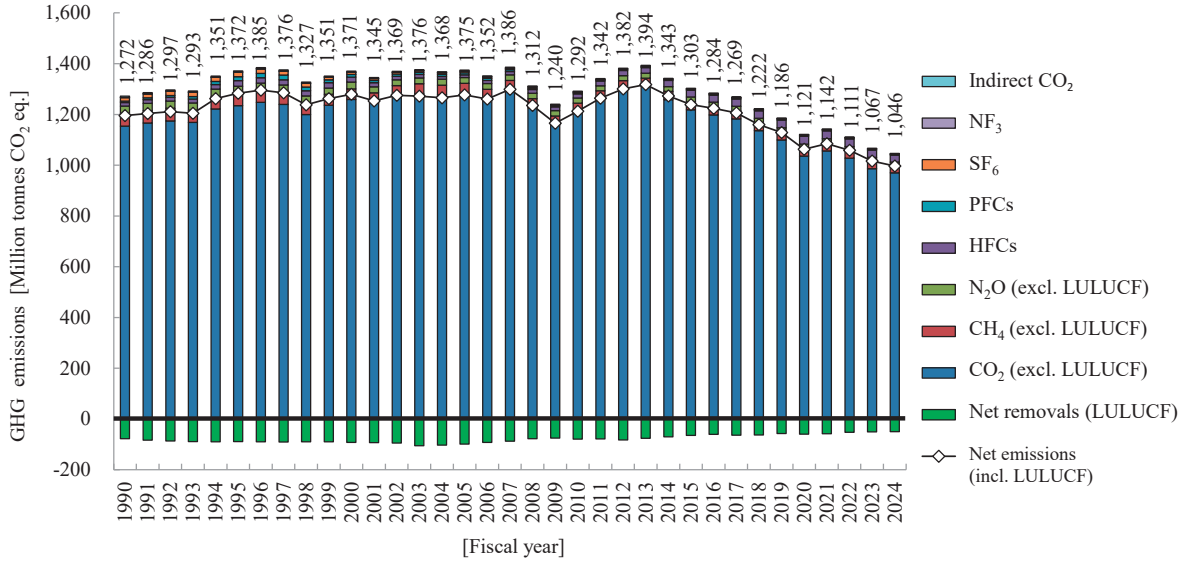

Figure 2-1 Trends in GHG emissions and removals in Japan

CO_2 emissions in FY2024 were 970 million tonnes (excluding LULUCF, excluding indirect CO_2, hereafter, definition omitted), accounting for 92.7% of total GHG emissions. They decreased by 16.0% from FY1990, decreased by 26.0% from FY2013, and decreased by 1.7% compared to the previous year. CO_2 removals in FY2024 were 50.1 million tonnes, which were equivalent to 4.8% of total GHG emissions. They decreased by 35.4% from FY1990, decreased by 34.0% from FY2013, and decreased by 1.5% compared to the previous year.

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1 Fiscal year (FY), from April of the reporting year through March of the next year, is used because CO_2 is the primary GHGs emissions and estimated on a fiscal year basis. "CY" stands for calendar year.

2 The sum of CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, and NF_3 emissions converted to CO_2 equivalents, multiplied by their respective global warming potential (GWP). The GWP is a coefficient by means of which greenhouse gas effects of a given gas are made relative to those of an equivalent amount of CO_2. The coefficients (100-year time horizon) are drawn from the *Fifth Assessment Report* (2013) issued by the Intergovernmental Panel on Climate Change (IPCC).

3 Abbreviation of "Land Use, Land-Use Change and Forestry"

4 Carbon monoxide (CO), methane (CH_4) and non-methane volatile organic compounds (NMVOC) are oxidized in the atmosphere in the long term and converted to CO_2. Indirect CO_2 means the CO_2 equivalent value of these emissions. However, emissions derived from combustion-origin and biomass-origin CO, CH_4, and NMVOC are excluded to avoid double counting.

Table 2-1 Trends in GHG emissions and removals in Japan

[Fiscal year]

[Million tonnes CO_2 eq.]	GWP	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CO_2 (excl. LULUCF) *1	1	1,154.2	1,166.0	1,174.8	1,168.5	1,222.0	1,234.5	1,247.4	1,239.4	1,199.6	1,236.5	1,258.7	1,244.5	1,273.9	1,282.2	1,277.4	1,284.7	1,261.7	1,297.1	1,226.6	1,158.7
CO_2 (incl. LULUCF) *1	1	1,076.6	1,082.3	1,088.2	1,079.8	1,132.4	1,145.6	1,157.9	1,148.4	1,109.4	1,146.6	1,166.8	1,151.5	1,179.4	1,177.1	1,174.4	1,186.1	1,169.5	1,209.5	1,148.9	1,083.1
CO_2 (LULUCF only)	1	-77.6	-83.7	-86.6	-88.8	-89.6	-88.9	-89.5	-90.9	-90.1	-90.0	-91.9	-93.0	-94.6	-105.1	-103.0	-98.5	-92.3	-87.6	-77.7	-75.5
CH_4 (excl. LULUCF)	28	50.0	49.3	49.2	48.2	48.3	46.9	45.5	45.0	43.1	42.7	41.9	40.6	39.7	38.6	38.3	38.2	37.6	36.9	36.0	35.4
CH_4 (incl. LULUCF)	28	50.2	49.4	49.3	48.4	48.4	47.1	45.7	45.1	43.2	42.8	42.0	40.7	39.8	38.7	38.4	38.3	37.7	37.0	36.1	35.5
N_2O (excl. LULUCF)	265	28.9	28.6	28.6	28.6	29.6	29.8	30.8	31.4	30.1	24.6	26.8	23.5	22.9	23.0	23.0	22.7	22.6	22.2	21.2	20.7
N_2O (incl. LULUCF)	265	29.7	29.4	29.5	29.4	30.4	30.6	31.5	32.1	30.8	25.3	27.5	24.2	23.6	23.7	23.7	23.3	23.2	22.8	21.8	21.2
HFCs	HFC-134a: 1,300 etc.	13.4	14.6	15.0	15.4	17.9	21.5	21.1	21.0	20.5	21.0	19.8	16.9	14.2	14.1	10.8	10.8	11.8	12.9	14.4	15.1
PFCs	PFC-14: 6,630 etc.	6.2	7.0	7.1	10.1	12.4	16.2	16.7	18.2	15.0	11.8	10.5	8.7	8.2	8.0	8.3	7.8	8.2	7.2	5.2	3.7
SF_6	23,500	13.8	15.2	16.8	16.8	16.1	17.6	18.3	15.8	14.5	10.3	8.2	6.9	6.6	6.2	6.2	5.8	5.9	5.4	4.7	2.7
NF_3	16,100	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.1	0.2	0.3	0.3	0.3	0.3	0.4	0.4	1.4	1.3	1.5	1.4	1.3
Indirect CO_2	1	5.6	5.4	5.1	4.9	4.9	4.8	4.8	4.6	4.3	4.3	4.3	3.9	3.7	3.5	3.4	3.4	3.3	3.1	2.8	2.6
Gross Total (excluding LULUCF, excluding indirect CO_2)		1,266.5	1,280.7	1,291.5	1,287.7	1,346.3	1,366.8	1,379.9	1,371.0	1,323.0	1,347.2	1,366.2	1,341.4	1,365.8	1,372.5	1,364.4	1,371.4	1,349.0	1,383.1	1,309.5	1,237.5
Net Total (including LULUCF, excluding indirect CO_2)		1,189.8	1,198.0	1,205.8	1,199.9	1,257.7	1,278.8	1,291.3	1,280.9	1,233.6	1,258.0	1,275.1	1,249.2	1,272.0	1,268.2	1,262.2	1,273.6	1,257.5	1,296.2	1,232.5	1,162.6
Gross Total (excluding LULUCF, including indirect CO_2)		1,272.1	1,286.1	1,296.6	1,292.6	1,351.2	1,371.6	1,384.8	1,375.6	1,327.2	1,351.4	1,370.5	1,345.3	1,369.5	1,376.0	1,367.9	1,374.7	1,352.3	1,386.2	1,312.3	1,240.1
Net Total (including LULUCF, including indirect CO_2)		1,195.4	1,203.4	1,210.9	1,204.8	1,262.6	1,283.6	1,296.1	1,285.5	1,237.9	1,262.3	1,279.5	1,253.1	1,275.7	1,271.7	1,265.7	1,276.9	1,260.8	1,299.3	1,235.3	1,165.2

[Million tonnes CO_2 eq.]	GWP	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	Changes in emissions/removals (2024) from		
																	1990	2013	Previous year
CO_2 (excl. LULUCF) *1	1	1,209.3	1,259.5	1,300.4	1,310.0	1,258.5	1,218.0	1,198.0	1,182.3	1,136.5	1,099.8	1,035.6	1,056.6	1,027.6	986.3	969.6	-16.0%	-26.0%	-1.7%
CO_2 (incl. LULUCF) *1	1	1,129.9	1,181.1	1,217.9	1,234.0	1,188.2	1,153.3	1,137.8	1,118.7	1,073.4	1,042.3	976.2	998.3	974.9	935.4	919.5	-14.6%	-25.5%	-1.7%
CO_2 (LULUCF only)	1	-79.3	-78.5	-82.4	-76.0	-70.3	-64.7	-60.2	-63.6	-63.1	-57.5	-59.3	-58.4	-52.7	-50.9	-50.1	-35.4%	-34.0%	-1.5%
CH_4 (excl. LULUCF)	28	34.9	33.6	32.8	32.8	32.2	31.8	31.8	31.6	31.1	30.8	30.5	30.5	29.9	29.5	27.9	-44.2%	-14.8%	-5.4%
CH_4 (incl. LULUCF)	28	35.0	33.6	32.9	32.8	32.3	31.9	31.9	31.7	31.2	30.9	30.5	30.6	30.0	29.6	28.2	-43.8%	-14.3%	-4.8%
N_2O (excl. LULUCF)	265	20.3	20.0	19.6	19.6	19.1	18.8	18.4	18.6	17.7	17.3	16.8	16.8	16.0	15.2	14.8	-48.8%	-24.6%	-2.7%
N_2O (incl. LULUCF)	265	20.8	20.5	20.1	20.1	19.5	19.2	18.8	19.0	18.1	17.7	17.3	17.2	16.5	15.6	15.2	-48.8%	-24.1%	-2.5%
HFCs	HFC-134a: 1,300 etc.	16.7	18.4	20.3	22.0	24.1	26.4	27.8	28.5	29.0	30.1	30.9	31.0	29.8	28.5	27.6	105.6%	25.5%	-3.4%
PFCs	PFC-14: 6,630 etc.	3.8	3.4	3.1	3.0	3.1	3.0	3.1	3.2	3.2	3.2	3.2	2.9	3.0	3.1	2.5	-59.7%	-16.9%	-18.8%
SF_6	23,500	2.8	2.5	2.5	2.3	2.3	2.4	2.4	2.3	2.3	2.2	2.2	2.2	2.1	2.1	2.0	-85.4%	-14.3%	-3.0%
NF_3	16,100	1.4	1.7	1.4	1.5	1.0	0.5	0.6	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2	542.3%	-88.1%	-12.8%
Indirect CO_2	1	2.5	2.4	2.4	2.4	2.3	2.3	2.2	2.2	2.1	2.1	1.9	1.9	1.9	1.9	1.9	-66.6%	-21.1%	-1.3%
Gross Total (excluding LULUCF, excluding indirect CO_2)		1,289.2	1,339.1	1,380.1	1,391.2	1,340.3	1,301.0	1,282.0	1,266.8	1,220.0	1,183.7	1,119.5	1,140.5	1,108.9	1,064.9	1,044.5	-17.5%	-24.9%	-1.9%
Net Total (including LULUCF, excluding indirect CO_2)		1,210.5	1,261.2	1,298.2	1,315.7	1,270.5	1,236.8	1,222.2	1,203.8	1,157.4	1,126.6	1,060.6	1,082.6	1,056.7	1,014.5	995.1	-16.4%	-24.4%	-1.9%
Gross Total (excluding LULUCF, including indirect CO_2)		1,291.7	1,341.5	1,382.5	1,393.5	1,342.5	1,303.2	1,284.2	1,269.0	1,222.2	1,185.7	1,121.4	1,142.4	1,110.8	1,066.7	1,046.4	-17.7%	-24.9%	-1.9%
Net Total (including LULUCF, including indirect CO_2)		1,213.0	1,263.6	1,300.6	1,318.1	1,272.8	1,239.0	1,224.5	1,206.0	1,159.6	1,128.7	1,062.6	1,084.5	1,058.5	1,016.4	997.0	-16.6%	-24.4%	-1.9%

*1 Excluding indirect CO_2

*2 LULUCF: Land Use, Land-Use Change and Forestry

CH_4 emissions in FY2024 (excluding LULUCF) were 27.9 million tonnes (in CO_2 eq.), accounting for 2.7% of total GHG emissions. They decreased by 44.2% from FY1990, decreased by 14.8% from FY2013, and decreased by 5.4% compared to the previous year.

N_2O emissions in FY2024 (excluding LULUCF) were 14.8 million tonnes (in CO_2 eq.), accounting for 1.4% of total GHG emissions. They decreased by 48.8% from FY1990, decreased by 24.6% from FY2013, and decreased by 2.7% compared to the previous year.

HFC emissions in CY2024 were 27.6 million tonnes (in CO_2 eq.), accounting for 2.6% of total GHG emissions. They increased by 106% from CY1990, increased by 25.5% from CY2013, and decreased by 3.4% compared to the previous year.

PFC emissions in CY2024 were 2.5 million tonnes (in CO_2 eq.), accounting for 0.2% of total GHG emissions. They decreased by 59.7% from CY1990, decreased by 16.9% from CY2013, and decreased by 18.8% compared to the previous year.

SF_6 emissions in CY2024 were 2.0 million tonnes (in CO_2 eq.), accounting for 0.2% of total GHG emissions. They decreased by 85.4% from CY1990, decreased by 14.3% from CY2013, and decreased by 3.0% compared to the previous year.

NF_3 emissions in CY2024 were 0.2 million tonnes (in CO_2 eq.), accounting for 0.02% of total GHG emissions. They increased by 542% from CY1990, decreased by 88.1% from CY2013, and decreased by 12.8% compared to the previous year.

Indirect CO_2 emissions in FY2024 were 1.9 million tonnes (in CO_2 eq.), accounting for 0.2% of total GHG emissions. They decreased by 66.6% from FY1990, decreased by 21.1% from FY2013, and decreased by 1.3% compared to the previous year.

2.1.2. CO_2

CO_2 emissions in FY2024 were 970 million tonnes, accounting for 92.7% of total GHG emissions. They decreased by 16.0% from FY1990, decreased by 26.0% from FY2013, and decreased by 1.7% compared to the previous year.

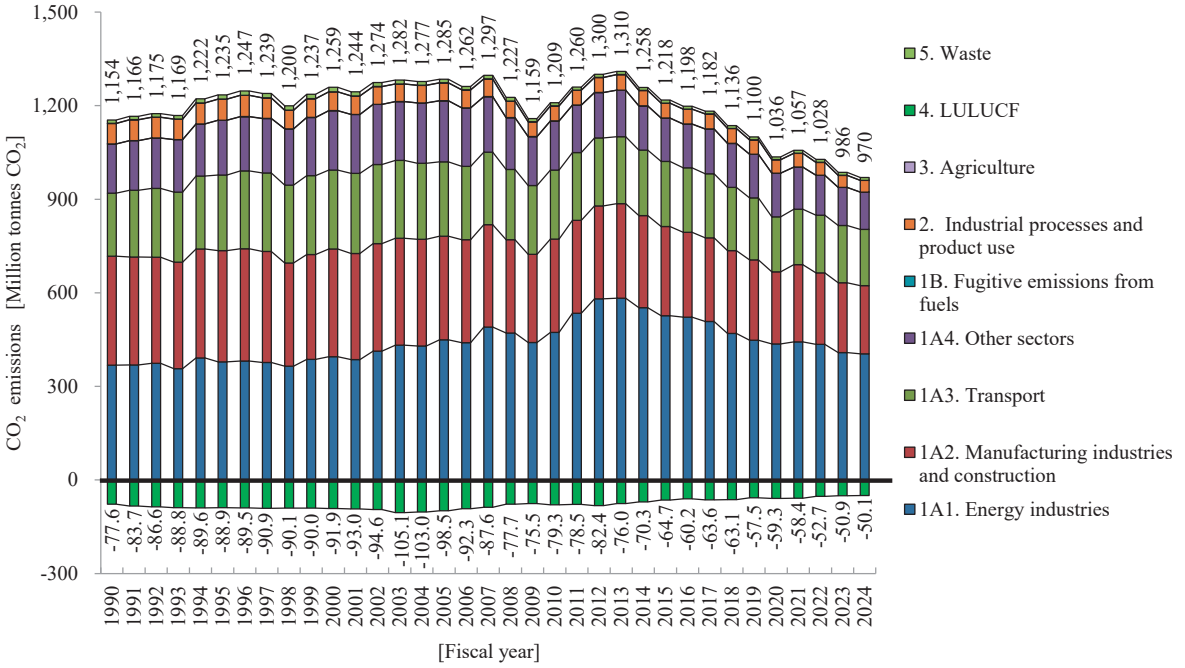

Figure 2-2 Trends in CO_2 emissions

The breakdown of CO_2 emissions in FY2024 shows that fuel combustion accounts for 95.2% and is followed by industrial processes and product use (3.8%) and waste sectors (0.9%). As for the breakdown of CO_2 emissions within the fuel combustion category, energy industries accounts for 41.7% and is followed by manufacturing industries and construction at 22.5%, transport at 18.6%, and other sectors[5] at 12.3%. The main driving factor for the decrease in CO_2 emissions compared to the previous year is the decrease in CO_2 emissions from the manufacturing industries and construction sector.

By looking at the changes in emissions by sector, emissions from fuel combustion in the energy industries increased by 9.9% from FY1990, decreased by 30.6% from FY2013, and decreased by 0.9% compared to the previous year. The main driving factor for the increase compared to the emissions in FY1990 is the increased emissions from solid and gaseous fuel consumption for electricity power generation, despite the reduced emissions from liquid fuel consumption. Emissions from manufacturing industries and construction decreased by 37.5% from FY1990, decreased by 27.9% from FY2013, and decreased by 2.6% compared to the previous year. The main driving factor for the decrease compared to the emissions in FY1990 is the decreased emissions from solid fuel consumption for the iron and steel industry. Emissions from transport decreased by 10.6% compared to FY1990, decreased by 16.0% from FY2013, and decreased by 1.6% compared to the previous year. The main driving factor for the decrease compared to the emissions in FY1990 is the decrease in emissions from diesel fuel in road transportation. Emissions from other sectors decreased by 24.6% from FY1990, decreased by 20.1% from FY2013, and decreased by 2.3% compared to the previous year. The main driving factor for the decrease compared to the emissions in FY1990 is the decreased emissions from the liquid fuel consumption for the commercial/institutional sub-sectors.

CO_2 removals in FY2024 were 50.1 million tonnes, which were equivalent to 4.8% of total GHG emissions. They decreased by 35.4% from FY1990, decreased by 34.0% from FY2013, and decreased by 1.5% compared to the previous year.

[5] It covers emissions from commercial/institutional, residential and agriculture/forestry/fishing.

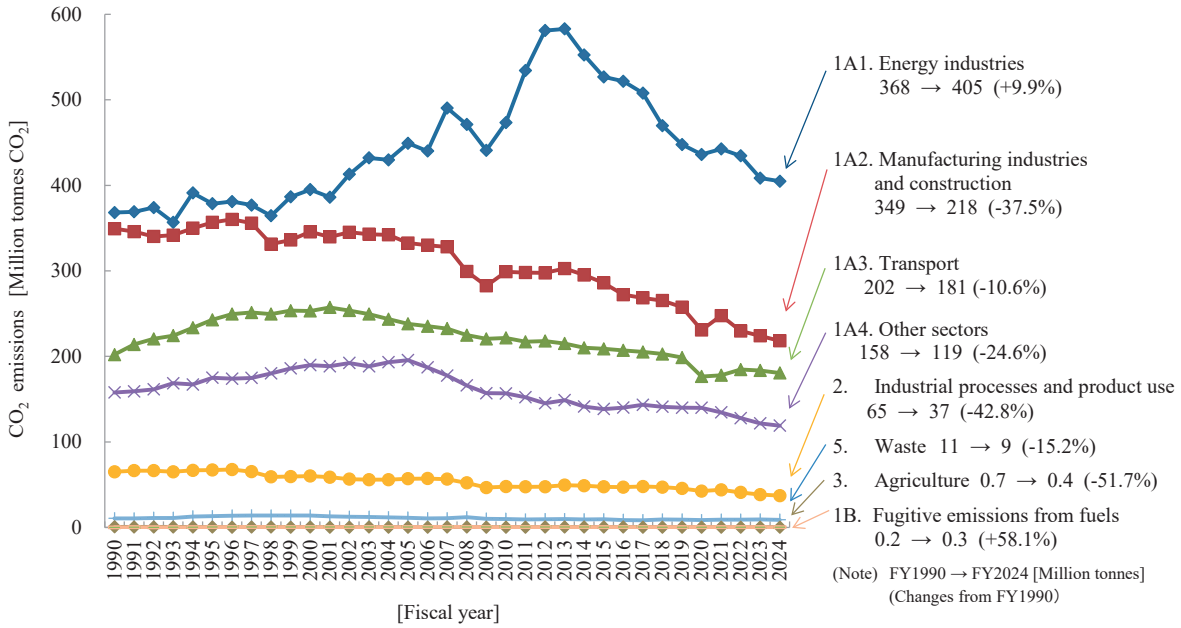

Figure 2-3 Trends in CO_2 emissions in each sector

Note: Figures in brackets indicate relative increase or decrease to the FY1990 values

Table 2-2 Trends in CO_2 emissions and removals in each sector

[Thousand tonnes CO_2]

Category	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
1A. Fuel combustion	1,077,488	1,153,096	1,183,661	1,215,314	1,150,591	1,249,622	1,159,943	983,516	1,002,796	976,752	937,806	922,614
1A1. Energy industries	368,155	378,495	395,020	449,108	473,254	582,892	526,734	436,110	442,453	434,493	408,445	404,753
a. Public electricity and heat production	303,055	317,587	330,118	378,044	404,239	521,862	468,474	392,293	395,403	387,428	365,039	361,983
b. Petroleum refining	36,020	40,673	46,502	50,330	47,120	42,356	41,088	28,918	30,678	31,116	29,191	28,093
c. Manufacture of solid fuels and other energy industries	29,080	20,234	18,400	20,734	21,895	18,674	17,172	14,899	16,372	15,950	14,214	14,677
1A2. Manufacturing industries and construction	349,273	356,719	345,661	332,513	298,951	302,737	285,820	230,880	247,733	229,740	224,027	218,206
a. Iron and steel	150,631	143,009	151,989	153,979	153,050	157,467	148,743	111,881	124,673	114,068	112,788	108,727
b. Non-ferrous metals	8,450	7,405	6,338	5,711	3,980	3,760	3,257	2,778	3,048	2,934	2,881	2,707
c. Chemicals	58,041	64,343	59,523	54,959	50,125	48,274	45,587	39,603	42,705	41,072	40,215	39,409
d. Pulp, paper and print	27,113	31,436	31,679	29,738	22,643	23,833	23,310	17,853	17,756	15,808	15,350	15,244
e. Food processing, beverages and tobacco	7,691	10,188	11,524	12,233	9,873	9,857	8,564	8,105	8,304	7,823	7,773	8,122
f. Non-metallic minerals	43,691	46,519	40,089	35,261	28,396	29,433	27,644	24,568	24,433	21,684	20,781	20,143
g. Other	53,656	53,820	44,519	40,631	30,883	30,112	28,714	26,092	26,813	26,351	24,241	23,854
1A3. Transport	202,140	242,797	253,091	238,065	221,660	215,115	208,875	176,576	178,044	184,649	183,562	180,630
a. Domestic aviation	7,162	10,278	10,677	10,799	9,193	10,149	10,067	5,238	6,819	9,705	10,190	10,303
b. Road transportation	180,367	217,028	226,690	213,605	201,148	193,437	187,641	160,907	160,349	163,923	163,031	160,162
c. Railways	935	822	711	647	574	540	523	468	450	455	449	449
d. Domestic navigation	13,675	14,669	15,012	13,014	10,745	10,989	10,645	9,963	10,427	10,567	9,892	9,717
1A4. Other sectors	157,920	175,085	189,889	195,627	156,726	148,877	138,514	139,950	134,565	127,869	121,772	119,026
a. Commercial/institutional	79,337	88,507	98,457	106,175	75,234	74,299	67,265	67,485	68,297	63,132	61,176	59,023
b. Residential	57,641	66,855	71,579	69,777	63,693	59,806	54,967	55,360	51,140	49,612	46,200	45,735
c. Agriculture/forestry/fishing	20,942	19,723	19,853	19,676	17,800	14,772	16,281	17,105	15,129	15,125	14,397	14,268
1A5. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1B. Fugitive emissions from fuels	203	526	527	532	500	462	446	408	374	349	336	321
1C. CO_2 transport and storage	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO
2. Industrial processes and product use	65,162	67,174	60,102	57,016	47,815	49,437	47,567	42,600	44,059	40,992	38,431	37,305
3. Agriculture	732	473	501	428	427	594	474	381	351	310	353	353
4. LULUCF	-77,636	-88,867	-91,891	-98,542	-79,350	-75,982	-64,711	-59,329	-58,394	-52,705	-50,894	-50,116
5. Waste	10,652	13,243	13,941	11,380	9,930	9,897	9,595	8,647	9,066	9,156	9,379	9,028
Total (including LULUCF)	1,076,600	1,145,646	1,166,842	1,186,129	1,129,914	1,234,029	1,153,313	976,223	998,251	974,854	935,411	919,506
Total (excluding LULUCF)	1,154,237	1,234,513	1,258,733	1,284,670	1,209,263	1,310,012	1,218,024	1,035,552	1,056,646	1,027,559	986,305	969,621

*1 Excluding indirect CO_2

*2 LULUCF: Land Use, Land-Use Change and Forestry

CO_2 emissions per capita in FY2024 were 7.83 tonnes. They decreased by 16.1% from FY1990, decreased by 23.8% from FY2013, and decreased by 1.3% compared to the previous year.

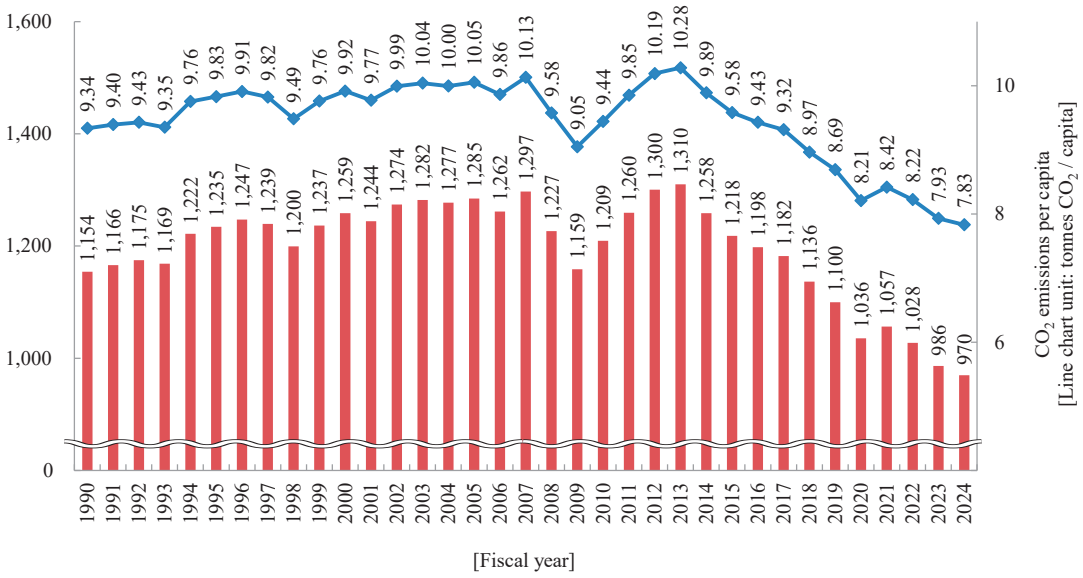

Figure 2-4 Trends in total CO_2 emissions and CO_2 emissions per capita
Reference of population data: *Population Census* and *Annual Report of Population Estimates* (Ministry of Internal Affairs and Communications, Statistics Bureau)

CO_2 emissions per unit of Real GDP (million yen) in FY2024 were 1.74 tonnes. They decreased by 35.1% from FY1990, decreased by 29.4% from FY2013, and decreased by 2.2% compared to the previous year.

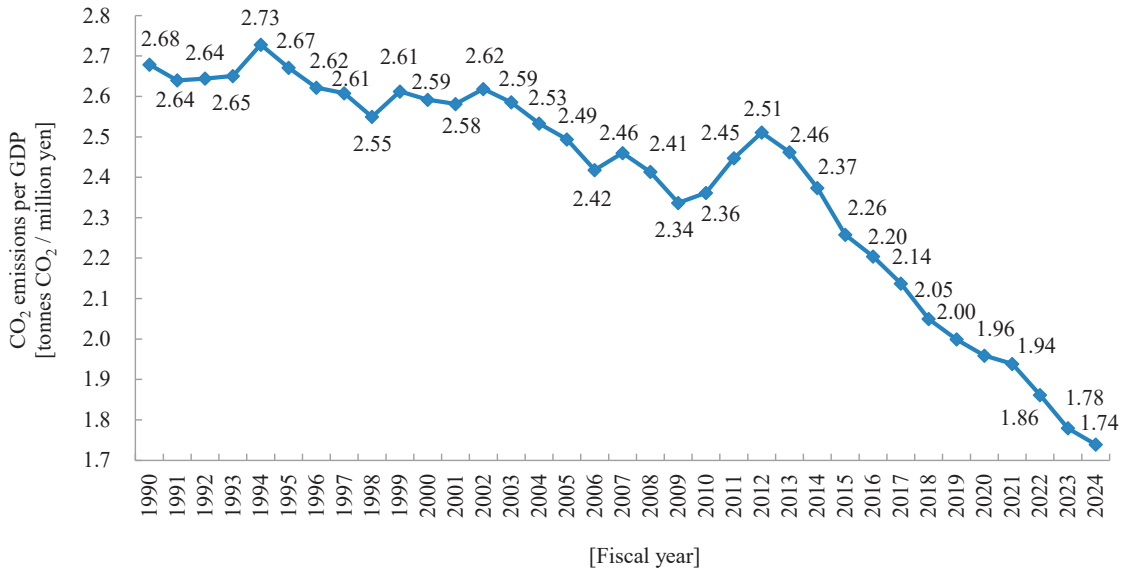

Figure 2-5 Trends in CO_2 emissions per unit of Real GDP
Reference of Real GDP data: *Annual Report on National Accounts* (Cabinet Office, Government of Japan) (Expenditure Approach, chained 2015 yen)

2.1.3. CH_4

CH_4 emissions in FY2024 were 28.2 million tonnes (in CO_2 eq., including LULUCF), accounting for 2.7% of total GHG emissions. They decreased by 43.8% from FY1990, decreased by 14.3% from FY2013, and decreased by 4.8% compared to the previous year. Their decrease since FY1990 is mainly a result of a 78.3% decrease in emissions from the waste sector (e.g. solid waste disposal).

The breakdown of the FY2024 emissions showed that the largest source was rice cultivation accounting for 42.0%. It is followed by enteric fermentation (30.0%) and manure management (8.8%).

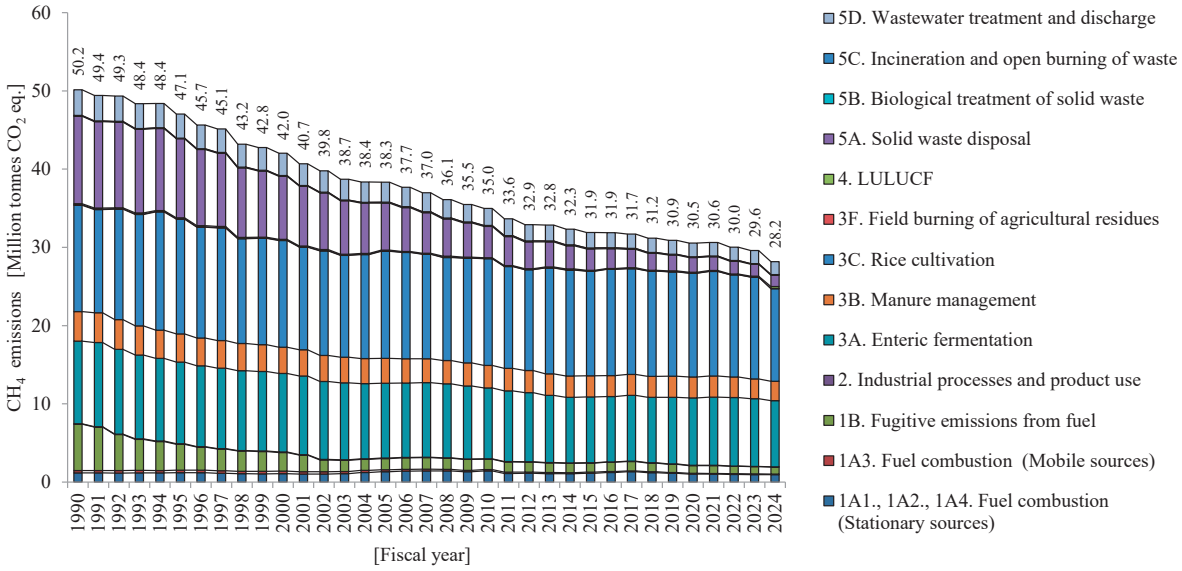

Figure 2-6 Trends in CH_4 emissions

Table 2-3 Trends in CH_4 emissions

[Thousand tonnes CO_2 eq.]

Category	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
1A. Fuel combustion	1,482	1,518	1,397	1,578	1,586	1,222	1,260	1,115	1,108	1,067	1,054	1,033
1A1. Energy industries	514	448	295	278	302	268	310	230	230	213	207	196
1A2. Manufacturing industries and construction	403	425	415	495	602	555	590	527	547	521	530	524
1A3. Transport	298	315	318	250	173	147	132	98	95	99	97	95
1A4. Other sectors	266	330	368	555	509	252	229	260	236	233	220	218
1B. Fugitive emissions from fuels	5,909	3,319	2,380	1,430	1,334	1,217	1,161	992	992	946	917	881
1B1. Solid fuels	5,482	2,822	1,847	788	672	633	615	525	526	510	508	486
1B2. Oil and natural gas and other emissions	427	497	533	642	663	585	546	467	466	435	410	395
2. Industrial processes and product use	68	65	61	60	60	52	54	43	49	43	35	28
3. Agriculture	28,002	28,764	27,100	26,477	25,610	24,913	24,514	24,582	24,803	24,465	24,223	22,803
3A. Enteric fermentation	10,554	10,437	10,042	9,569	9,051	8,592	8,401	8,604	8,718	8,756	8,646	8,459
3B. Manure management	3,786	3,595	3,365	3,176	2,877	2,757	2,707	2,687	2,694	2,612	2,527	2,477
3C. Rice cultivation	13,585	14,663	13,636	13,682	13,649	13,527	13,374	13,260	13,359	13,068	13,021	11,841
3F. Field burning of agricultural residues	78	69	56	49	34	36	32	30	32	28	28	26
4. LULUCF	117	107	99	98	88	84	85	79	87	80	87	252
5. Waste	14,575	13,278	10,998	8,689	6,308	5,363	4,821	3,734	3,588	3,417	3,280	3,167
5A. Solid waste disposal	11,189	10,105	8,051	6,009	4,003	3,209	2,737	1,888	1,760	1,634	1,535	1,447
5B. Biological treatment of solid waste	60	60	61	107	104	112	114	83	86	77	73	72
5C. Incineration and open burning of waste	31	33	23	20	13	13	11	10	9	10	10	9
5D. Wastewater treatment and discharge	3,295	3,080	2,863	2,553	2,188	2,029	1,959	1,753	1,733	1,695	1,663	1,639
Total (including LULUCF)	50,153	47,051	42,035	38,332	34,986	32,850	31,896	30,544	30,626	30,018	29,597	28,164
Total (excluding LULUCF)	50,036	46,944	41,936	38,234	34,898	32,766	31,811	30,465	30,539	29,938	29,510	27,912

* LULUCF: Land Use, Land-Use Change and Forestry

2.1.4. N_2O

N_2O emissions in FY2024 were 15.2 million tonnes (in CO_2 eq., including LULUCF), accounting for 1.5% of total GHG emissions. They decreased by 48.8% from FY1990, decreased by 24.1% from FY2013, and decreased by 2.5% compared to the previous year. Their decrease since FY1990 is mainly a result of a 96.4% decrease in emissions from industrial processes and product use (e.g. adipic acid production in the chemical industry). There is a sharp decline in emissions from the industrial processes and product use from FY1998 to 1999, as N_2O abatement equipment came on stream in the adipic acid production plant in March 1999. However, the N_2O emissions increased in FY2000 because of a decrease in the equipment's operation rate due to mechanical failure; the emissions decreased again in FY2001 with the resumption of normal operation.

Breakdown of the FY2024 emissions showed that the largest source was agricultural soils accounting for 26.6%. It is followed by manure management (20.2%) and fuel combustion (stationary sources) (19.0%).

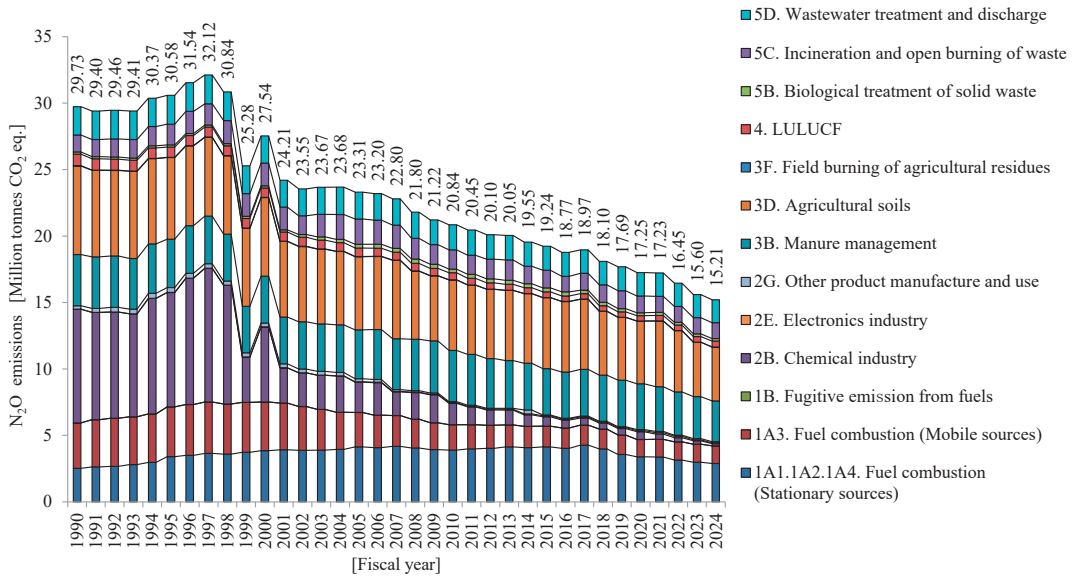

Figure 2-7 Trends in N_2O emissions

Table 2-4 Trends in N_2O emissions

[Thousand tonnes CO_2 eq.]

Category	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
1A. Fuel combustion	5,947	7,152	7,512	6,731	5,803	5,791	5,699	4,692	4,706	4,523	4,341	4,217
1A1. Energy industries	791	1,203	1,435	1,812	1,786	2,029	2,050	1,602	1,628	1,558	1,496	1,409
1A2. Manufacturing industries and construction	1,121	1,518	1,671	1,661	1,533	1,567	1,544	1,306	1,300	1,147	1,065	1,053
1A3. Transport	3,421	3,753	3,660	2,597	1,907	1,659	1,561	1,305	1,323	1,374	1,351	1,331
1A4. Other sectors	613	677	747	660	577	536	543	479	454	444	428	424
1B. Fugitive emissions from fuels	2	2	2	1	1	1	1	1	0	0	0	0
2. Industrial processes and product use	8,803	8,975	5,947	2,528	1,738	1,251	844	742	594	502	426	314
2B. Chemical industry	8,555	8,595	5,645	2,275	1,612	1,120	709	589	397	301	254	164
2E. Electronics industry	3	6	10	25	41	65	77	77	110	109	78	56
2G. Other product manufacture and use	245	374	291	228	85	67	58	75	87	92	95	94
3. Agriculture	10,546	9,796	9,447	9,205	9,172	8,878	8,831	8,175	8,317	7,868	7,256	7,122
3B. Manure management	3,865	3,638	3,529	3,676	3,860	3,599	3,484	3,448	3,370	3,255	3,156	3,066
3D. Agricultural soils	6,658	6,137	5,902	5,515	5,303	5,269	5,338	4,719	4,938	4,605	4,092	4,049
3F. Field burning of agricultural residues	23	21	16	14	10	10	9	8	9	8	8	7
4. LULUCF	871	767	707	632	521	453	425	402	407	411	422	443
5. Waste	3,558	3,890	3,920	4,210	3,607	3,677	3,440	3,240	3,203	3,151	3,153	3,114
5B. Biological treatment of solid waste	161	159	161	284	275	298	302	220	226	204	193	190
5C. Incineration and open burning of waste	1,274	1,562	1,713	1,898	1,451	1,528	1,335	1,261	1,214	1,194	1,224	1,196
5D. Wastewater treatment and discharge	2,123	2,169	2,046	2,028	1,881	1,851	1,803	1,760	1,762	1,752	1,737	1,729
Total (including LULUCF)	29,726	30,582	27,535	23,306	20,842	20,050	19,239	17,252	17,227	16,455	15,598	15,211
Total (excluding LULUCF)	28,855	29,816	26,828	22,674	20,321	19,598	18,814	16,850	16,820	16,044	15,176	14,768

* LULUCF: Land Use, Land-Use Change and Forestry

2.1.5. HFCs

HFC emissions in CY2024[6] were 27.6 million tonnes (in CO_2 eq.), accounting for 2.6% of total GHG emissions. They increased by 106% from CY1990, increased by 25.5% from CY2013, and decreased by 3.4% compared to the previous year. Their increase since CY1990 is mainly a result of an expansion in emissions from refrigeration and air conditioning (+24.4 million tonnes CO_2 eq.) substituting for HCFC (an ozone depleting substance), despite a decrease in emissions of HFC-23 (-100%) produced as a by-product of HCFC-22 production due to regulation under the Act on the Protection of the Ozone Layer Through the Control of Specified Substances and Other Measures. (Act No.53, 1988) The decrease compared to the previous year is mainly due to the increase in HFC recovery amounts at disposal and the decrease in leaks during operation from household stationary air-conditioning.

The breakdown of the CY2024 emissions showed that the largest source was refrigerants of refrigeration and air conditioning equipment accounting for 88.6%. It is followed by foam blowing agents (9.3%).

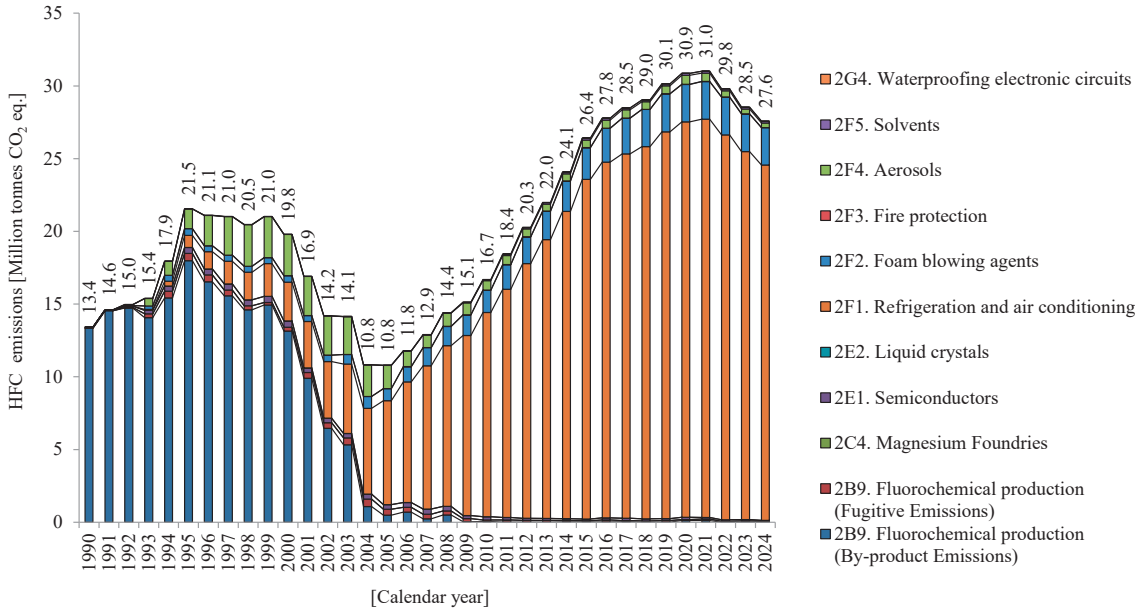

Figure 2-8 Trends in HFC emissions

Table 2-5 Trends in HFC emissions

[Thousand tonnes CO_2 eq.]

Category	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
2B9. Fluorochemical production	13,347	18,483	13,408	898	160	132	100	187	220	66	88	64
a. By-product emissions	13,346	17,980	13,144	491	45	14	25	118	110	4	2	4
b. Fugitive emissions	1	503	264	407	115	119	75	69	109	63	85	60
2C4. Magnesium production	NO	NO	NO	NO	NO	1	1	1	2	1	2	1
2E. Electronics industry	55	416	434	315	220	131	126	151	111	97	98	65
2E1. Semiconductors	55	415	432	312	217	129	124	150	110	96	97	64
2E2. Liquid crystals	0.001	0.2	2	2	3	2	2	1	1	1	1	1
2F. Product uses as substitutes for ODS	1	2,645	5,948	9,575	16,297	21,714	26,182	30,524	30,673	29,630	28,348	27,442
2F1. Refrigeration and air conditioning	NO	828	2,668	7,142	14,037	19,165	23,348	27,189	27,380	26,474	25,298	24,427
2F2. Foam blowing agents	1	452	440	829	1,538	1,957	2,179	2,571	2,586	2,591	2,589	2,570
2F3. Fire protection	NO	NO	4	7	8	8	9	9	9	9	9	9
2F4. Aerosols	NO	1,365	2,835	1,592	653	473	519	626	568	426	323	310
2F5. Solvents	NO	NO	NO	6	61	110	127	128	129	129	129	125
2G4. Waterproofing electronic circuits	6.5	5.4	6.5	4.4	3.3	2.3	2.4	5.3	5.5	5.7	5.7	5.3
Total	13,410	21,549	19,796	10,792	16,680	21,980	26,412	30,869	31,010	29,800	28,541	27,577

[6] Emissions of HFCs, PFCs, SF_6, and NF_3 are estimated on a calendar year (CY) basis.

2.1.6. PFCs

PFC emissions in CY2024 were 2.5 million tonnes (in CO_2 eq.), accounting for 0.2% of total GHG emissions. They decreased by 59.7% from CY1990, decreased by 16.9% from CY2013, and decreased by 18.8% compared to the previous year. Their decrease since CY1990 is mainly the result of a decrease in emissions from solvents. (-74.6%)

The breakdown of the CY2024 emissions showed that the largest source was semiconductor manufacturing accounting for 52.3%. It is followed by solvents such as those for washing metals (43.2%).

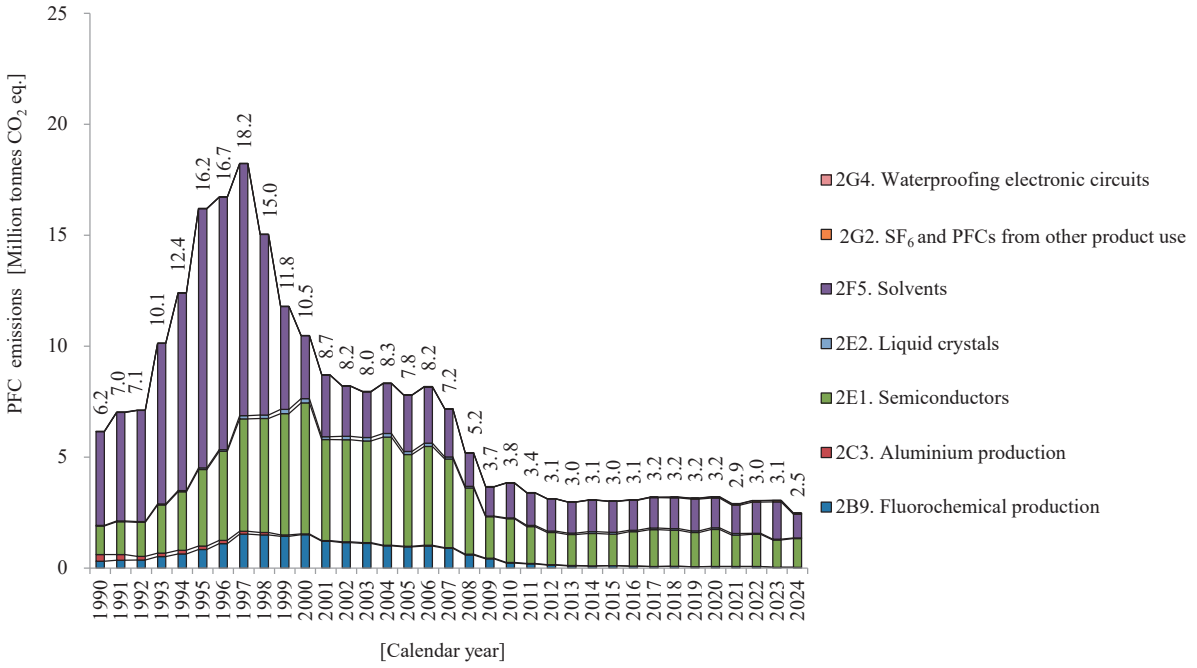

Figure 2-9 Trends in PFC emissions

Table 2-6 Trends in PFC emissions

[Thousand tonnes CO_2 eq.]

Category	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
2B9. Fluorochemical production	304	840	1,499	955	227	100	104	67	72	67	37	32
2C3. Aluminium production	301	153	39	32	23	14	NO	NO	NO	NO	NO	NO
2E. Electronics industry	1,314	3,521	6,097	4,263	2,015	1,461	1,507	1,744	1,483	1,503	1,261	1,322
2E1. Semiconductors	1,286	3,443	5,905	4,126	1,973	1,393	1,429	1,675	1,413	1,452	1,231	1,297
2E2. Liquid crystals	28	78	192	137	42	68	78	69	70	52	30	25
2F5. Solvents	4,228	11,684	2,834	2,542	1,567	1,395	1,394	1,343	1,279	1,406	1,682	1,072
2G. Other product manufacture and use	15	12	15	10	11	14	12	60	71	72	75	55
2G2. SF_6 and PFCs from other product use	NO	NO	NO	0.2	4	9	7	48	58	60	62	43
2G4. Waterproofing electronic circuits	15	12	15	10	7	5	5	12	12	13	13	12
Total	6,163	16,210	10,483	7,802	3,843	2,985	3,017	3,214	2,905	3,049	3,055	2,481

2.1.7. SF_6

SF_6 emissions in CY2024 were 2.0 million tonnes (in CO_2 eq.), accounting for 0.2% of total GHG emissions. They decreased by 85.4% from CY1990, decreased by 14.3% from CY2013, and decreased by 3.0% compared to the previous year. Their decrease since CY1990 is mainly a result of a decrease from electrical equipment, due to an enhancement of gas management system such as gas recovery largely in electric power companies. (-92.6%)

The breakdown of the CY2024 emissions showed that the largest source was other product use (e.g. accelerators, etc.) accounting for 41.0%. It is followed by electrical equipment (30.7%) and semiconductor (15.8%).

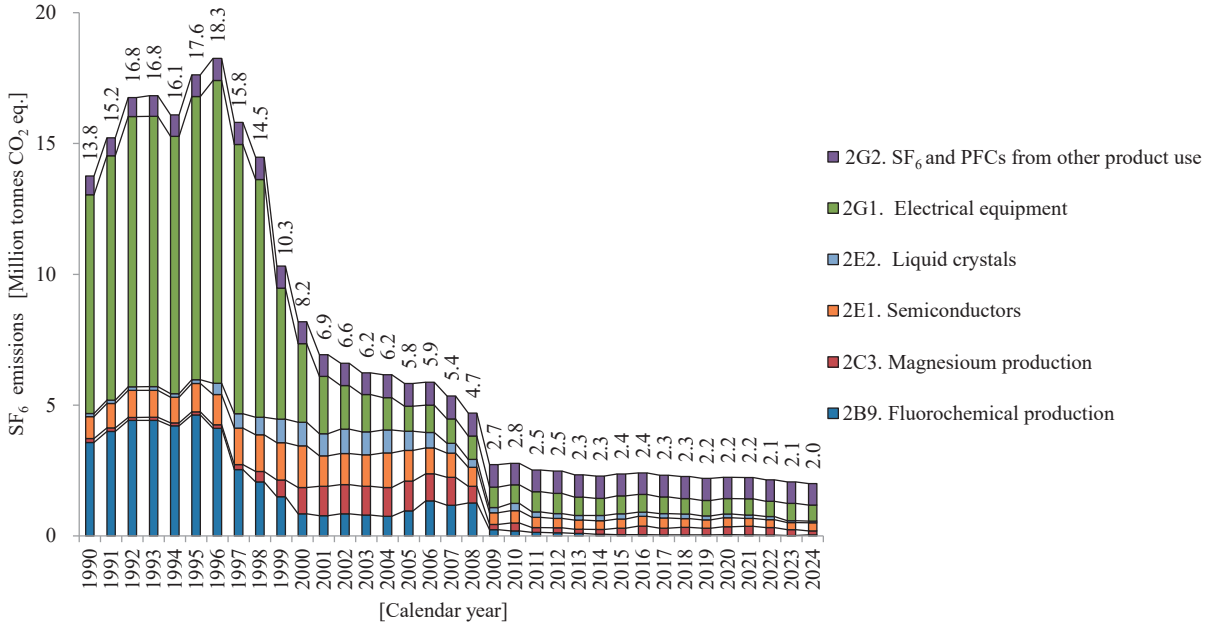

Figure 2-10 Trends in SF_6 emissions

Table 2-7 Trends in SF_6 emissions

[Thousand tonnes CO_2 eq.]

Category	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
2B9. Fluorochemical production	3,577	4,630	846	959	195	96	54	54	47	34	24	41
2C3. Magnesium production	151	118	1,009	1,138	303	161	242	301	324	291	217	151
2E. Electronics industry	951	1,230	2,496	1,907	750	531	554	486	433	423	345	377
2E1. Semiconductor	838	1,084	1,592	1,174	473	356	357	343	300	299	273	316
2E2. Liquid crystals	113	146	904	734	277	175	197	143	133	124	72	60
2G. Other product manufacture and use	9,085	11,647	3,839	1,824	1,531	1,555	1,523	1,401	1,429	1,397	1,483	1,438
2G1. Electrical equipment	8,362	10,821	2,999	956	706	699	686	589	616	581	662	615
2G2. SF_6 and PFCs from other product use	723	826	840	868	825	856	837	812	813	816	821	822
Total	13,764	17,624	8,189	5,828	2,779	2,343	2,373	2,242	2,234	2,145	2,068	2,007

2.1.8. NF_3

NF_3 emissions in CY2024 were 0.2 million tonnes (in CO_2 eq.), accounting for 0.02% of total GHG emissions. They increased by 542% from CY1990, decreased by 88.1% from CY2013, and decreased by 12.8% compared to the previous year. The increase since CY1990 is mainly a result of an increase in emissions from semiconductor manufacture, owing to shifts to use NF_3. (by 599%)

The breakdown of the CY2024 emissions showed that the largest source was semiconductor manufacture accounting for 89.4%. It is followed by fluorochemical production (6.8%) and liquid crystal manufacture (3.8%).

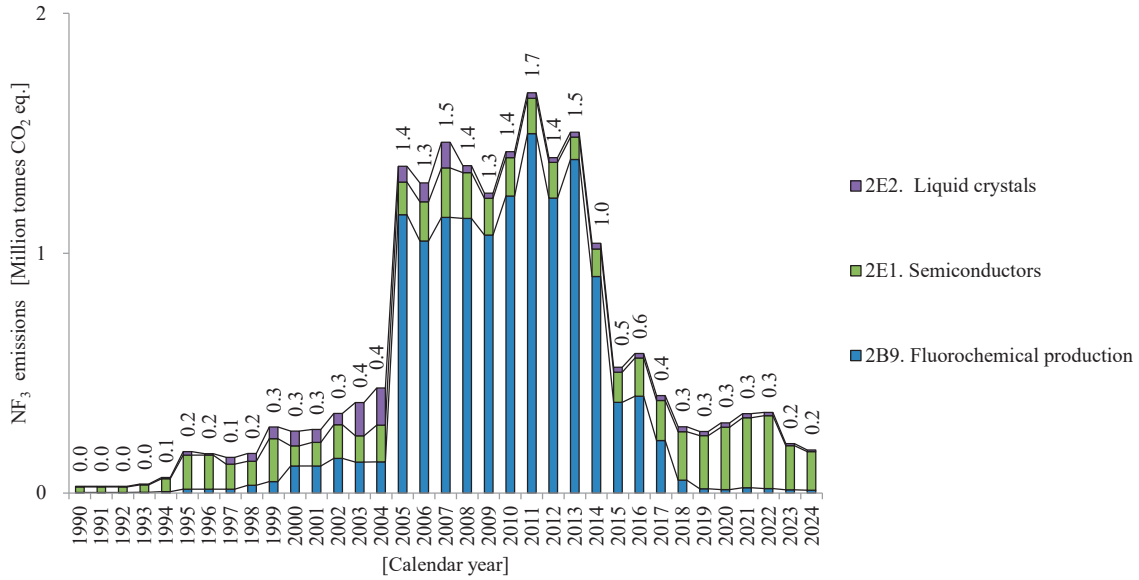

Figure 2-11 Trends in NF_3 emissions

Table 2-8 Trends in NF_3 emissions

[Thousand tonnes CO_2 eq.]

Category	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
2B9. Fluorochemical production	3	16	113	1,161	1,238	1,391	378	14	22	19	14	12
2E. Electronics industry	25	156	145	202	185	113	146	279	309	317	193	167
2E1. Semiconductors	23	142	84	136	161	93	125	261	291	303	184	161
2E2. Liquid crystals	2	15	62	66	25	20	21	18	18	14	8	7
Total	28	172	258	1,363	1,423	1,504	524	293	332	336	206	180

2.1.9. Indirect CO_2

Indirect CO_2 emissions[7] in FY2024 were 1.9 million tonnes (in CO_2 eq.), accounting for 0.2% of total GHG emissions. They decreased by 66.6% from FY1990, decreased by 21.1% from FY2013, and decreased by 1.3% compared to the previous year. Their decrease since FY1990 was due to the decrease in emissions from the use of paint through the wider use of low VOC paint and VOC removal by adsorption devices.

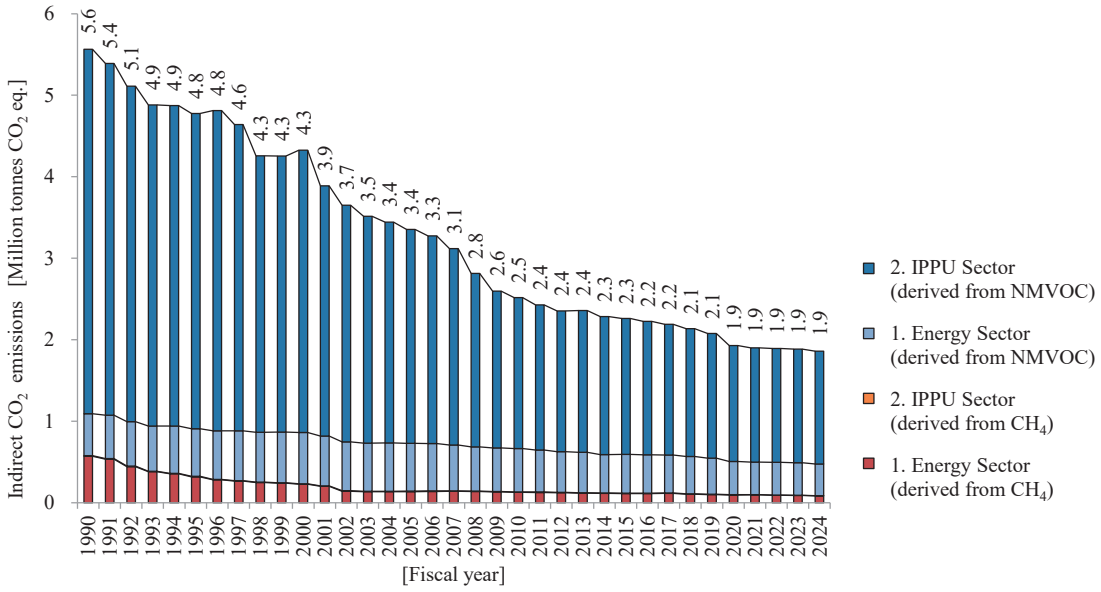

Figure 2-12 Trends in Indirect CO_2 emissions

Table 2-9 Trends in Indirect CO_2 emissions

[Thousand tonnes CO_2 eq.]

Emission Source	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Derived from CH_4	578	323	232	141	133	121	116	99	100	95	92	87
1. Energy Sector	571	317	226	136	127	116	111	95	95	91	88	85
2. IPPU Sector	7	6	6	6	6	5	5	4	5	4	3	3
Derived from NMVOC	4,987	4,452	4,094	3,211	2,385	2,237	2,145	1,829	1,799	1,798	1,793	1,773
1. Energy Sector	514	585	629	586	531	497	476	407	397	401	400	388
2. IPPU Sector	4,473	3,868	3,465	2,625	1,854	1,741	1,669	1,422	1,402	1,397	1,393	1,385
Total	5,565	4,776	4,326	3,353	2,518	2,359	2,261	1,928	1,899	1,894	1,885	1,861

[7] Emissions derived from fuel combustion-origin, waste incineration-origin, and biomass-origin CO, CH_4, and NMVOC are excluded to avoid double counting.

2.2. Description and Interpretation of Emission and Removal Trends by Categories

The breakdown of GHG emissions and removals in FY2024 by sector[8] showed that energy (excluding indirect CO_2, hereafter, definition omitted) accounted for 88.8% of total GHG emissions. It is followed by industrial processes and product use (excluding indirect CO_2, hereafter, definition omitted) (6.7%), agriculture (2.9%), waste (1.5%), and indirect CO_2 emissions (0.2%).

Net removals by LULUCF in FY2024 were equivalent to 4.7% of total GHG emissions.

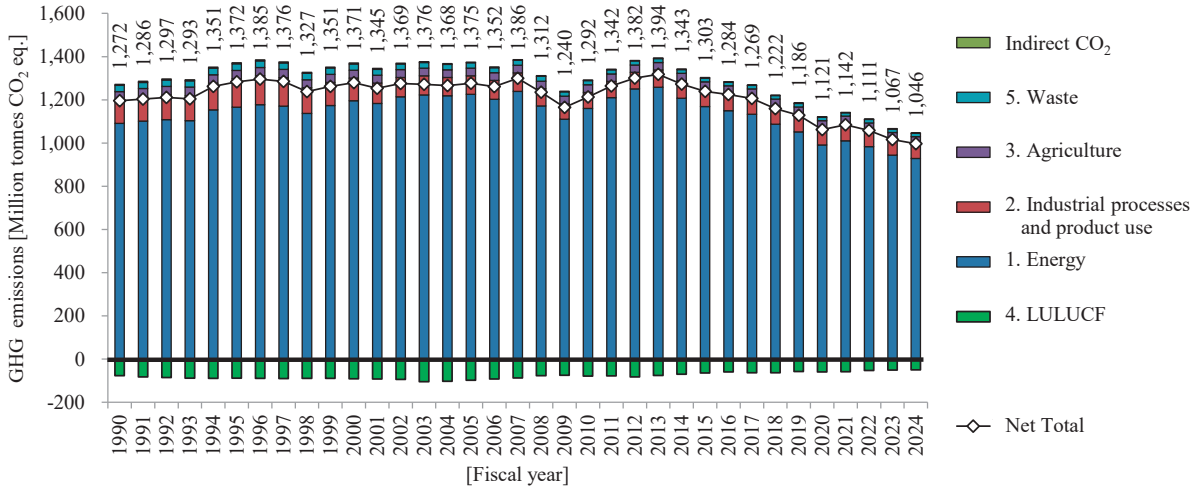

Figure 2-13 Trends in GHG emissions and removals in each sector

[8] As indicated in the *2006 IPCC Guidelines* and the CRT.

Table 2-10 Trends in GHG emissions and removals in each sector

[Fiscal year]

[Million tonnes CO_2 eq.]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1. Energy*1	1,091.0	1,101.4	1,108.8	1,103.4	1,153.6	1,165.6	1,177.2	1,171.2	1,137.2	1,173.9	1,195.5	1,183.0	1,214.5	1,223.2	1,218.8	1,225.6	1,202.9	1,238.8	1,171.3	1,110.2
2. Industrial processes and product use*1	107.4	111.8	113.7	115.7	122.5	131.8	133.9	130.9	118.7	106.8	104.8	94.7	88.7	87.6	84.7	85.4	87.2	85.4	80.0	71.8
3. Agriculture	39.3	38.9	39.8	39.8	40.0	39.0	38.2	38.3	37.0	37.1	37.0	36.2	36.4	35.9	35.7	36.1	35.9	36.2	35.1	34.9
4. LULUCF*2	-76.6	-82.7	-85.7	-87.8	-88.6	-88.0	-88.6	-90.1	-89.3	-89.2	-91.1	-92.2	-93.8	-104.3	-102.2	-97.8	-91.6	-86.9	-77.0	-74.9
5. Waste	28.8	28.6	29.2	28.9	30.3	30.4	30.7	30.5	30.0	29.4	28.9	27.4	26.2	25.9	25.2	24.3	23.0	22.6	23.1	20.6
Indirect CO_2	5.6	5.4	5.1	4.9	4.9	4.8	4.8	4.6	4.3	4.3	4.3	3.9	3.7	3.5	3.4	3.4	3.3	3.1	2.8	2.6
Gross Total (excluding LULUCF, excluding indirect CO_2)	1,266.5	1,280.7	1,291.5	1,287.7	1,346.3	1,366.8	1,379.9	1,371.0	1,323.0	1,347.2	1,366.2	1,341.4	1,365.8	1,372.5	1,364.4	1,371.4	1,349.0	1,383.1	1,309.5	1,237.5
Net Total (including LULUCF, excluding indirect CO_2)	1,189.8	1,198.0	1,205.8	1,199.9	1,257.7	1,278.8	1,291.3	1,280.9	1,233.6	1,258.0	1,275.1	1,249.2	1,272.0	1,268.2	1,262.2	1,273.6	1,257.5	1,296.2	1,232.5	1,162.6
Gross Total (excluding LULUCF, including indirect CO_2)	1,272.1	1,286.1	1,296.6	1,292.6	1,351.2	1,371.6	1,384.8	1,375.6	1,327.2	1,351.4	1,370.5	1,345.3	1,369.5	1,376.0	1,367.9	1,374.7	1,352.3	1,386.2	1,312.3	1,240.1
Net Total (including LULUCF, including indirect CO_2)	1,195.4	1,203.4	1,210.9	1,204.8	1,262.6	1,283.6	1,296.1	1,285.5	1,237.9	1,262.3	1,279.5	1,253.1	1,275.7	1,271.7	1,265.7	1,276.9	1,260.8	1,299.3	1,235.3	1,165.2

[Million tonnes CO_2 eq.]	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
1. Energy*1	1,159.8	1,210.5	1,250.7	1,258.3	1,207.7	1,168.5	1,149.7	1,133.8	1,087.4	1,051.9	990.7	1,010.0	983.6	944.5	929.1
2. Industrial processes and product use*1	74.3	75.1	76.3	79.6	80.7	80.8	81.8	83.1	82.6	82.0	80.0	81.2	76.9	72.8	69.9
3. Agriculture	35.2	34.4	34.1	34.4	34.0	33.8	33.9	33.9	33.2	33.2	33.1	33.5	32.6	31.8	30.3
4. LULUCF*2	-78.7	-77.9	-81.9	-75.4	-69.7	-64.2	-59.7	-63.1	-62.6	-57.0	-58.8	-57.9	-52.2	-50.4	-49.4
5. Waste	19.8	19.0	19.0	18.9	17.9	17.9	16.6	16.2	16.8	16.5	15.6	15.9	15.7	15.8	15.3
Indirect CO_2	2.5	2.4	2.4	2.4	2.3	2.3	2.2	2.2	2.1	2.1	1.9	1.9	1.9	1.9	1.9
Gross Total (excluding LULUCF, excluding indirect CO_2)	1,289.2	1,339.1	1,380.1	1,391.2	1,340.3	1,301.0	1,282.0	1,266.8	1,220.0	1,183.7	1,119.5	1,140.5	1,108.9	1,064.9	1,044.5
Net Total (including LULUCF, excluding indirect CO_2)	1,210.5	1,261.2	1,298.2	1,315.7	1,270.5	1,236.8	1,222.2	1,203.8	1,157.4	1,126.6	1,060.6	1,082.6	1,056.7	1,014.5	995.1
Gross Total (excluding LULUCF, including indirect CO_2)	1,291.7	1,341.5	1,382.5	1,393.5	1,342.5	1,303.2	1,284.2	1,269.0	1,222.2	1,185.7	1,121.4	1,142.4	1,110.8	1,066.7	1,046.4
Net Total (including LULUCF, including indirect CO_2)	1,213.0	1,263.6	1,300.6	1,318.1	1,272.8	1,239.0	1,224.5	1,206.0	1,159.6	1,128.7	1,062.6	1,084.5	1,058.5	1,016.4	997.0

*1 Excluding indirect CO_2

*2 LULUCF: Land Use, Land-Use Change and Forestry

2.2.1. Energy

Emissions from the energy sector in FY2024 were 929 million tonnes (in CO_2 equivalents). They decreased by 14.8% from FY1990, decreased by 26.2% from FY2013, and decreased by 1.6% compared to the previous year.

The breakdown of the FY2024 emissions showed that CO_2 from fuel combustion accounted for 99.3%. The largest source within fuel combustion[9] was solid fuel CO_2, which accounted for 41.9%, and is then followed by liquid fuel CO_2 (35.3%) and gaseous fuel CO_2 (20.4%).

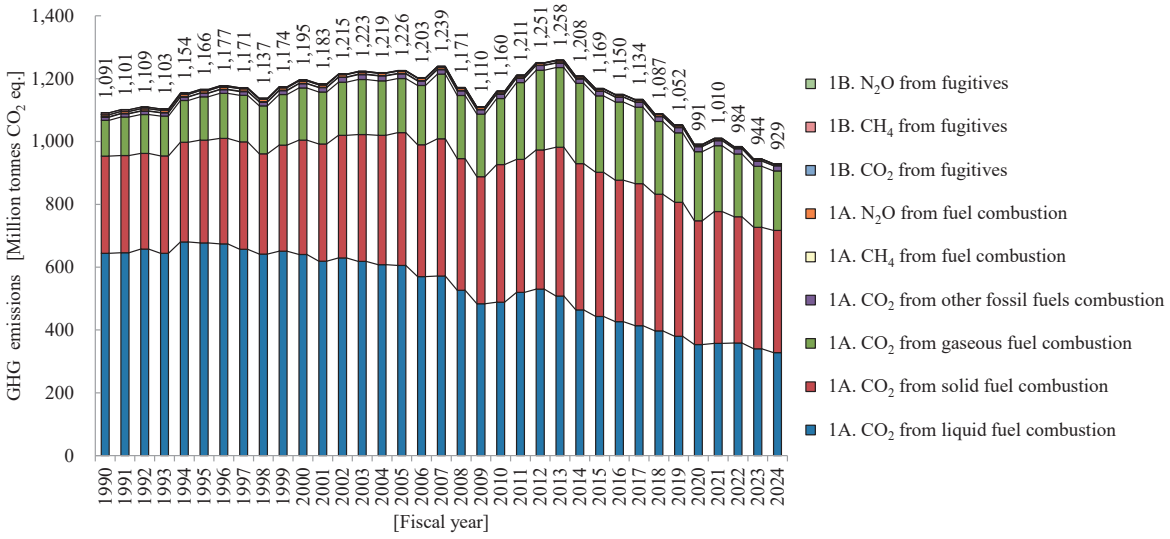

Figure 2-14 Trends in GHG emissions from the energy sector

Table 2-11 Trends in GHG emissions from the energy sector

[Thousand tonnes CO_2 eq.]

Source category	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
1A. Fuel combustion	1,084,917	1,161,766	1,192,570	1,223,623	1,157,980	1,256,634	1,166,902	989,323	1,008,610	982,341	943,201	927,865
Liquid fuel CO_2	643,926	677,004	640,191	605,554	488,244	507,858	443,324	353,587	357,284	358,461	340,449	328,074
Solid fuel CO_2	309,413	327,102	363,994	422,371	438,504	473,807	458,745	393,826	420,018	402,231	386,488	389,003
Gaseous fuel CO_2	114,167	137,927	166,073	172,415	209,932	253,378	243,368	220,218	209,301	199,804	194,315	189,116
Other fossil fuels (Waste) CO_2	9,983	11,063	13,404	14,973	13,911	14,579	14,507	15,885	16,193	16,256	16,554	16,422
CH_4	1,482	1,518	1,397	1,578	1,586	1,222	1,260	1,115	1,108	1,067	1,054	1,033
N_2O	5,947	7,152	7,512	6,731	5,803	5,791	5,699	4,692	4,706	4,523	4,341	4,217
1B. Fugitive emissions from fuels	6,113	3,847	2,909	1,963	1,835	1,679	1,607	1,401	1,366	1,295	1,253	1,202
CO_2	203	526	527	532	500	462	446	408	374	349	336	321
CH_4	5,909	3,319	2,380	1,430	1,334	1,217	1,161	992	992	946	917	881
N_2O	1.9	1.9	1.6	1.1	0.9	0.8	0.7	0.5	0.5	0.5	0.5	0.4
1C. CO_2 transport and storage	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO
Total	1,091,030	1,165,613	1,195,479	1,225,586	1,159,815	1,258,314	1,168,509	990,723	1,009,976	983,636	944,454	929,067

2.2.2. Industrial Processes and Product Use

Emissions from the industrial processes and product use sector in FY2024 were 69.9 million tonnes (in CO_2 eq.). They decreased by 34.9% from FY1990, decreased by 12.1% from FY2013, and decreased by 3.9% compared to the previous year.

The breakdown of GHG emissions from this sector in FY2024 showed that the largest source was HFC emissions from product uses as ODS substitutes, accounting for 39.3%. It was followed by the mineral industry emissions such as CO_2 emissions from cement production (37.4%) and CO_2 emissions from the metal industry (6.8%).

9 Fuel types are categorized in accordance with classification indicated in the *2006 IPCC Guidelines* and the CRT.

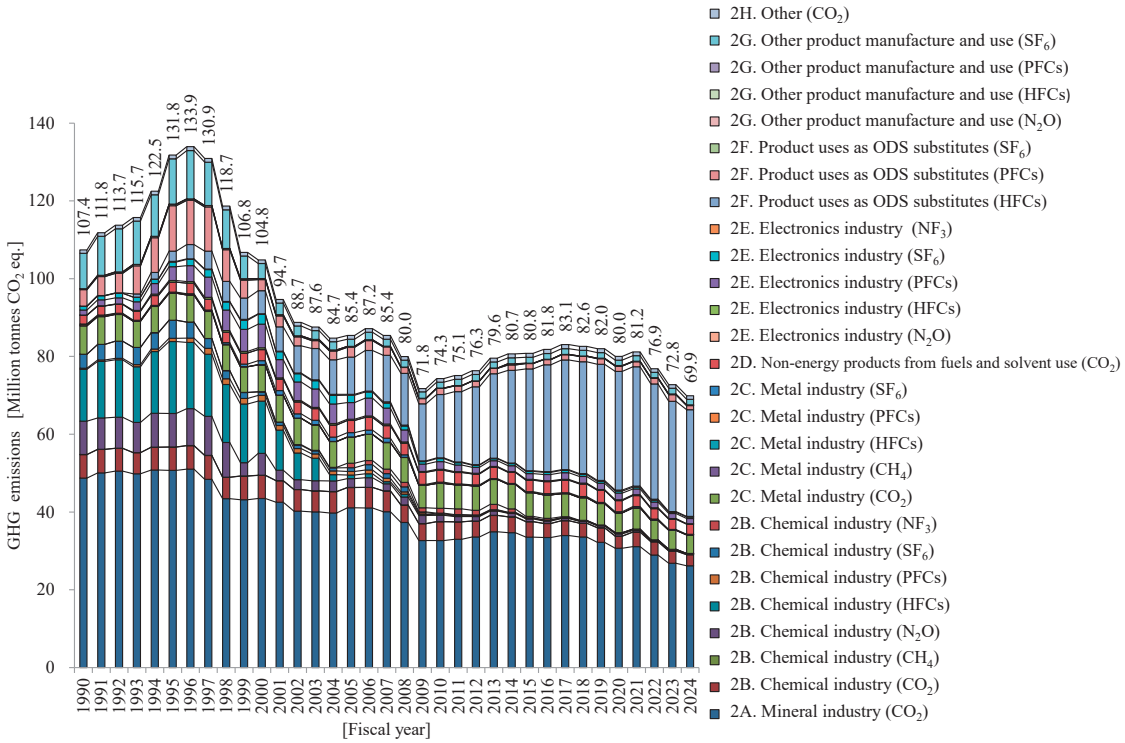

Figure 2-15 Trends in GHG emissions from the industrial processes and product use sector

Table 2-12 Trends in GHG emissions from the industrial processes and product use sector

[Thousand tonnes CO_2 eq.]

Category	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
2A. Mineral industry (CO_2)	48,714	50,689	43,487	41,112	32,676	34,930	33,528	30,705	31,086	28,927	26,816	26,167
2B. Chemical industry	31,874	38,623	27,474	11,455	8,292	7,048	5,348	4,013	4,540	3,934	3,617	3,183
CO_2	6,047	6,019	5,924	5,170	4,819	4,177	3,967	3,075	3,753	3,421	3,183	2,856
CH_4	42	42	38	38	41	32	36	27	30	26	19	13
N_2O	8,555	8,595	5,645	2,275	1,612	1,120	709	589	397	301	254	164
HFCs	13,347	18,483	13,408	898	160	132	100	187	220	66	88	64
PFCs	304	840	1,499	955	227	100	104	67	72	67	37	32
SF_6	3,577	4,630	846	959	195	96	54	54	47	34	24	41
NF_3	3	16	113	1,161	1,238	1,391	378	14	22	19	14	12
2C. Metal industry	7,770	7,230	7,939	7,873	6,713	6,593	6,361	5,369	5,770	5,347	5,108	4,938
CO_2	7,292	6,935	6,869	6,680	6,368	6,397	6,099	5,051	5,425	5,037	4,874	4,771
CH_4	26	24	22	23	20	20	19	16	19	17	16	15
HFCs	NO	NO	NO	NO	NO	1	1	1	2	1	2	1
PFCs	301	153	39	32	23	14	NO	NO	NO	NO	NO	NO
SF_6	151	118	1,009	1,138	303	161	242	301	324	291	217	151
2D. Non-energy products from fuels and solvent use (CO_2)	2,229	2,570	2,882	3,104	3,024	2,957	2,955	2,829	2,832	2,666	2,621	2,589
2E. Electronics industry	2,349	5,330	9,182	6,712	3,211	2,301	2,409	2,737	2,446	2,449	1,974	1,987
N_2O	3	6	10	25	41	65	77	77	110	109	78	56
HFCs	55	416	434	315	220	131	126	151	111	97	98	65
PFCs	1,314	3,521	6,097	4,263	2,015	1,461	1,507	1,744	1,483	1,503	1,261	1,322
SF_6	951	1,230	2,496	1,907	750	531	554	486	433	423	345	377
NF_3	25	156	145	202	185	113	146	279	309	317	193	167
2F. Product uses as substitutes for ODS	4,230	14,328	8,781	12,117	17,864	23,108	27,576	31,867	31,952	31,036	30,030	28,515
HFCs	1	2,645	5,948	9,575	16,297	21,714	26,182	30,524	30,673	29,630	28,348	27,442
PFCs	4,228	11,684	2,834	2,542	1,567	1,395	1,394	1,343	1,279	1,406	1,682	1,072
SF_6	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2G. Other product manufacture and use	9,351	12,039	4,151	2,066	1,630	1,638	1,595	1,541	1,593	1,567	1,659	1,592
N_2O	245	374	291	228	85	67	58	75	87	92	95	94
HFCs	6	5	6	4	3	2	2	5	6	6	6	5
PFCs	15	12	15	10.2	11	14	12	60	71	72	75	55
SF_6	9,085	11,647	3,839	1,824	1,531	1,555	1,523	1,401	1,429	1,397	1,483	1,438
2H. Other (CO_2)	880	962	940	951	928	976	1,017	940	963	941	937	921
Total	107,397	131,770	104,837	85,389	74,339	79,552	80,791	80,002	81,182	76,867	72,763	69,891

Despite the increase in HFC emissions from product uses as substitutes for ODS, due to regulation under the Act on the Protection of the Ozone Layer Through the Control of Specified Substances and Other Measures, emissions from the industrial processes and product use sector decreased compared to FY1990. The main driving factors for the decrease in emissions since FY1990 were the decrease in CO_2

emissions from cement production as the clinker production declined (mineral industry) and the decrease in emissions of HFC-23 produced as a by-product of HCFC-22 production (chemical industry).

2.2.3. Agriculture

Emissions from the agriculture sector in FY2024 were 30.3 million tonnes (in CO_2 eq.). They decreased by 22.9% from FY1990, decreased by 11.9% from FY2013, and decreased by 4.9% compared to the previous year.

The breakdown of the FY2024 emissions from this sector showed that the largest source was the rice cultivation (CH_4) accounting for 39.1%. It was followed by enteric fermentation (CH_4) (27.9%), and agricultural soils (N_2O) (13.4%) as a result of the nitrogen-based fertilizer applications.

The main driving factor for the decrease in emissions since FY1990 was the decrease in N_2O emissions from agricultural soils due to the decrease in the amount of inorganic nitrogen fertilizers applied and organic fertilizers from livestock manure applied, and the decrease in CH_4 emissions from enteric fermentation due to the decrease in the number of cattle.

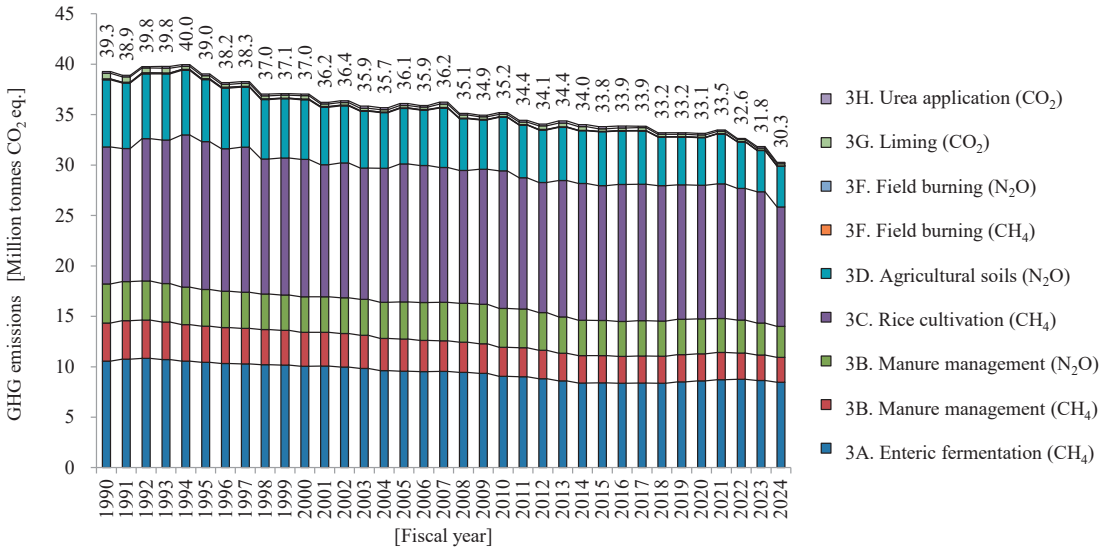

Figure 2-16 Trends in GHG emissions from the agriculture sector

Table 2-13 Trends in GHG emissions from the agriculture sector

[Thousand tonnes CO_2 eq.]

Category	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
3A. Enteric fermentation (CH_4)	10,554	10,437	10,042	9,569	9,051	8,592	8,401	8,604	8,718	8,756	8,646	8,459
3B. Manure management	7,651	7,234	6,894	6,852	6,736	6,356	6,191	6,135	6,064	5,867	5,683	5,543
CH_4	3,786	3,595	3,365	3,176	2,877	2,757	2,707	2,687	2,694	2,612	2,527	2,477
N_2O	3,865	3,638	3,529	3,676	3,860	3,599	3,484	3,448	3,370	3,255	3,156	3,066
3C. Rice cultivation (CH_4)	13,585	14,663	13,636	13,682	13,649	13,527	13,374	13,260	13,359	13,068	13,021	11,841
3D. Agricultural soils (N_2O)	6,658	6,137	5,902	5,515	5,303	5,269	5,338	4,719	4,938	4,605	4,092	4,049
3F. Field burning of agricultural residues	101	90	73	63	44	46	41	39	41	36	36	33
CH_4	78	69	56	49	34	36	32	30	32	28	28	26
N_2O	23	21	16	14	10	10	9	8	9	8	8	7
3G. Liming (CO_2)	550	304	333	231	243	380	259	224	221	203	205	205
3H. Urea application (CO_2)	182	170	168	197	184	214	215	157	130	107	148	148
Total	39,280	39,034	37,048	36,110	35,209	34,384	33,819	33,138	33,470	32,643	31,832	30,278

2.2.4. Land Use, Land Use Change and Forestry (LULUCF)

Net removals (including CO_2, CH_4 and N_2O emissions) from the LULUCF sector in FY2024 was 49.4 million tonnes (in CO_2 eq.). They decreased by 35.5% from FY1990, decreased by 34.5% from FY2013, and decreased by 1.9% compared to the previous year. The long-term declining trend in removals from 2004 is largely due to the maturity of Japanese forests.

The breakdown of the FY2024 emissions and removals from this sector showed that the largest was CO_2 removals from forest land of 57.0 million tonnes, accounting for 115% of this sector's net total emissions / removals.

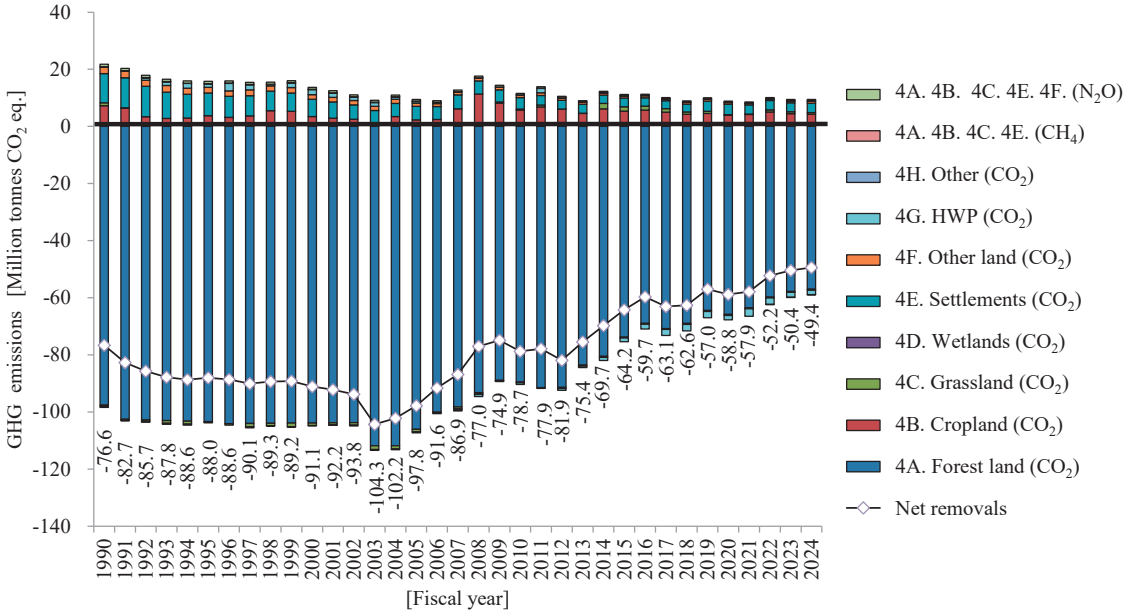

Figure 2-17 Trends in GHG emissions and removals from the LULUCF sector

Table 2-14 Trends in GHG emissions and removals from the LULUCF sector

[Thousand tonnes CO_2 eq.]

Category	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
4A. Forest land	-97,441	-103,262	-103,713	-105,940	-89,379	-83,486	-73,672	-65,733	-63,464	-59,638	-57,633	-56,714
CO_2	-97,557	-103,380	-103,830	-106,059	-89,490	-83,598	-73,785	-65,849	-63,592	-59,761	-57,765	-57,025
CH_4	11	12	10	12	5	4	7	3	11	4	12	177
N_2O	105	106	106	107	106	107	107	113	117	119	121	134
4B. Cropland	7,381	3,858	3,525	2,370	5,818	4,603	5,401	3,953	4,287	5,152	4,573	4,301
CO_2	7,286	3,777	3,456	2,307	5,760	4,546	5,344	3,895	4,228	5,093	4,513	4,241
CH_4	54	52	51	49	47	46	45	44	43	43	42	42
N_2O	41	29	18	14	11	12	12	15	16	16	17	18
4C. Grassland	1,025	-186	-861	-839	352	134	1,603	224	149	703	664	606
CO_2	995	-215	-890	-868	323	105	1,573	195	120	674	635	577
CH_4	17	17	17	17	17	17	17	17	17	17	17	17
N_2O	14	13	13	13	12	13	12	12	12	12	12	12
4D. Wetlands	-450	-188	-64	-346	-271	-336	-291	-314	-292	-301	-297	-317
CO_2	-450	-188	-64	-346	-271	-336	-291	-314	-292	-301	-297	-317
CH_4	NA,NE,NE	NA,NE,NE	NA,NE,NE	NA,NE,NE	NA,NE,NE	NA,NE,NE	NA,NE,NE	NA,NE,NE	NA,NE,NE	NA,NE,NE	NA,NE,NE	NA,NE,NE
N_2O	IE,NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO	IE,NO,NA	IE,NO,NA	IE,NO,NA	IE,NO,NA	IE,NO,NA	IE,NO,NA	IE,NO,NA	IE,NO,NA
4E. Settlements	10,892	8,507	6,549	5,183	4,384	3,393	3,344	3,906	3,455	3,575	3,406	3,574
CO_2	10,248	7,955	6,038	4,734	4,026	3,098	3,074	3,660	3,207	3,324	3,147	3,308
CH_4	35	26	22	20	19	16	15	16	17	16	17	16
N_2O	609	526	489	429	340	279	254	229	231	234	242	250
4F. Other land	2,350	2,073	1,713	1,148	933	762	737	653	574	543	678	675
CO_2	2,247	1,980	1,631	1,079	882	719	697	621	543	514	649	646
CH_4	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA
N_2O	102	93	82	69	51	43	40	33	31	29	29	29
4G. HWP (CO_2)	-404	1,205	1,768	611	-578	-516	-1,323	-1,537	-2,609	-2,249	-1,776	-1,546
4H. Other (CO_2)	NO	NO	NO	NO	NO	NO	NO	NO	NO	-0.01	-0.10	-0.10
Total	-76,648	-87,993	-91,084	-97,812	-78,740	-75,446	-64,201	-58,847	-57,901	-52,215	-50,385	-49,421

2.2.5. Waste

Emissions from the waste sector in FY2024 were 15.3 million tonnes (in CO_2 eq.). They decreased by 46.8% from FY1990, decreased by 19.2% from FY2013, and decreased by 3.2% compared to the previous year.

The breakdown of the FY2024 emissions from this sector showed that the largest source was waste incineration, etc (CO_2), associated with waste derived from fossil fuels such as waste plastic and waste oil, accounting for 55.3%. It was followed by wastewater treatment and discharge (N_2O) (11.3%), wastewater treatment and discharge (CH_4) (10.7%).

The main driving factor for the decrease in emissions since FY1990 was the decrease in CH_4 emissions from solid waste disposal on land as a result of decrease in the amount of disposal of biodegradable waste due to improvement in the volume reduction ratio by intermediate treatment under the Waste Management and Public Cleansing Act (Act No.137, 1970) and the Basic Law for Establishing the Recycling-based Society (Act No.110, 2000), and other recycling law.

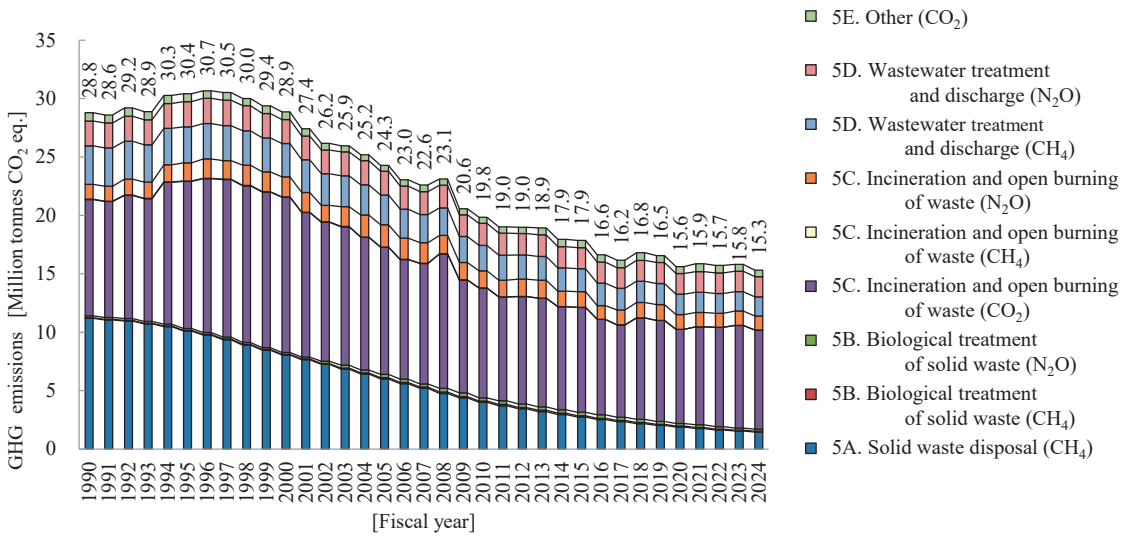

Figure 2-18 Trends in GHG emissions from the waste sector

Table 2-15 Trends in GHG emissions from the waste sector

[Thousand tonnes CO_2 eq.]

Category	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
5A. Solid waste disposal (CH_4)	11,189	10,105	8,051	6,009	4,003	3,209	2,737	1,888	1,760	1,634	1,535	1,447
5B. Biological treatment of solid waste	221	219	222	391	379	410	416	303	312	282	266	262
CH_4	60	60	61	107	104	112	114	83	86	77	73	72
N_2O	161	159	161	284	275	298	302	220	226	204	193	190
5C. Incineration and open burning of waste	11,255	14,171	15,022	12,791	10,867	10,834	10,316	9,320	9,611	9,706	10,015	9,673
CO_2	9,949	12,576	13,285	10,873	9,403	9,293	8,970	8,049	8,387	8,502	8,782	8,468
CH_4	31	33	23	20	13	13	11	10	9	10	10	9
N_2O	1,274	1,562	1,713	1,898	1,451	1,528	1,335	1,261	1,214	1,194	1,224	1,196
5D. Wastewater treatment and discharge	5,417	5,249	4,909	4,581	4,069	3,880	3,762	3,512	3,495	3,448	3,399	3,367
CH_4	3,295	3,080	2,863	2,553	2,188	2,029	1,959	1,753	1,733	1,695	1,663	1,639
N_2O	2,123	2,169	2,046	2,028	1,881	1,851	1,803	1,760	1,762	1,752	1,737	1,729
5E. Other (CO_2)	703	668	656	507	527	605	625	597	679	654	597	560
Total	28,785	30,411	28,859	24,278	19,844	18,937	17,856	15,621	15,857	15,724	15,812	15,310

2.2.6. Indirect CO_2

See Section 2.1.9. above.

2.3. Description and Interpretation of Emission Trends for Indirect GHGs and SOx

Under the *MPGs*, it is required to report emissions not only of the 7 types of GHGs (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, and NF_3), but also emissions of indirect GHGs (NO_X, CO, and NMVOC) as well as SO_X. Their emission trends are indicated below.

Nitrogen oxide (NO_X) emissions in FY2024 were 1.0 million tonnes. They decreased by 46.9% from FY1990, decreased by 26.7% from FY2013, and decreased by 2.2% compared to the previous year.

Carbon monoxide (CO) emissions in FY2024 were 2.1 million tonnes. They decreased by 50.8% from FY1990, decreased by 21.0% from FY2013, and decreased by 1.7% compared to the previous year[10].

Non-methane volatile organic compounds (NMVOC) emissions in FY2024 were 0.8 million tonnes.

[10] The reason for the increase in CO emissions in FY2010 compared to the previous year was the change in the EF for road transportation, and the reason for the decrease in CO emissions in FY2011 compared to the previous year was the change in the share of furnace types in the iron and steel industry, etc.

They decreased by 63.6% from FY1990, decreased by 19.4% from FY2013, and decreased by 1.5% compared to the previous year.

Sulfur oxide (SO_X)[11] emissions in FY2024 were 0.3 million tonnes. They decreased by 72.2% from FY1990, decreased by 51.6% from FY2013, and decreased by 0.5% compared to the previous year.

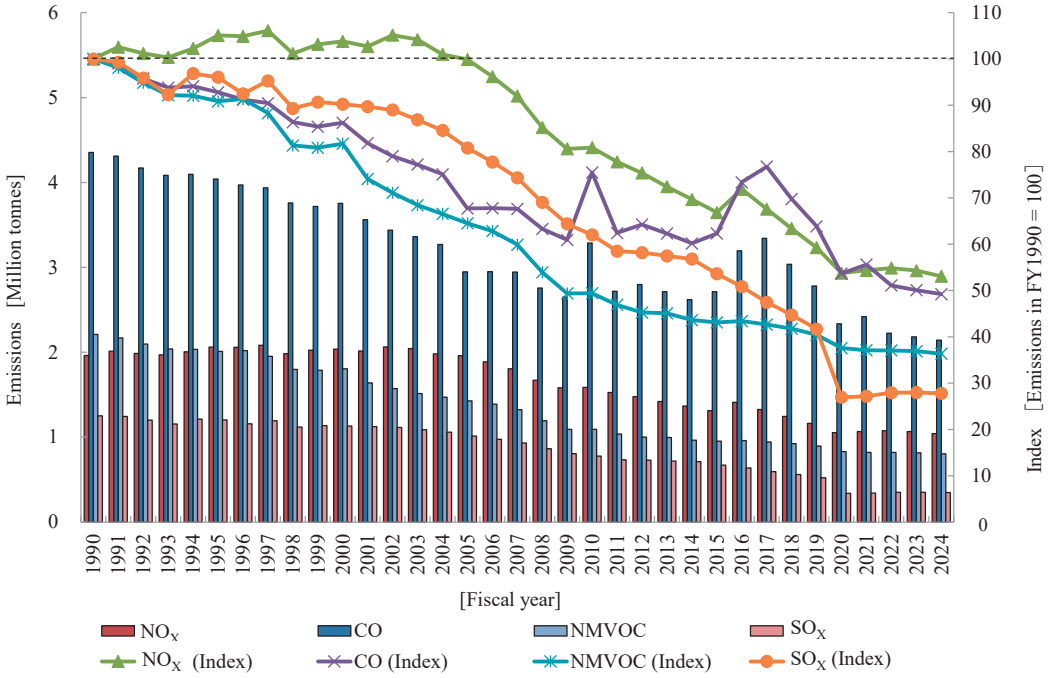

Figure 2-19 Trends in emissions of indirect GHGs and SO_X

Note: The line chart shows the trend as an index of FY1990 emissions set at 100.

References

1. Cabinet Office, Government of Japan, *Annual Report on National Accounts.*
2. IPCC, *Fifth Assessment Report,* 2013.
3. Ministry of Internal Affairs and Communications, Statistics Bureau, *Annual Report of Population Estimates.*
4. Ministry of Internal Affairs and Communications, Statistics Bureau, *Population Census*.

[11] Most SO_X consists of SO_2. For major sources, SO_2 emissions are estimated.

Chapter 3. Energy (CRT sector 1)

3.1. Overview of Sector

The energy sector consists of two main categories: fuel combustion and fugitive emissions from fuels. Fuel combustion includes greenhouse gases released into the atmosphere when fossil fuels (e.g., coal, oil products, and natural gas) are combusted. Fugitive emissions are intentional or unintentional releases of greenhouse gases from fossil fuels by anthropogenic activities.

In Japan, fossil fuels are used to produce energy for a wide variety of purposes (e.g., production, transportation, and consumption of energy products) and CO_2 (carbon dioxide), CH_4 (methane), N_2O (nitrous oxide), NO_X (nitrogen oxide), CO (carbon monoxide), and NMVOC (non-methane volatile organic compounds) are emitted in the process.

In FY2024, GHG emissions (CO_2, CH_4 and N_2O) from the energy sector accounted for 929,067 kt-CO_2 eq., and represented 88.8% of Japan's total GHG emissions (excluding LULUCF). The emissions from the energy sector had decreased by 14.8% compared to FY1990.

The methodologies are shown in the table below.

Table 3-1 Methodologies used in the energy sector

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2		CH_4		N_2O	
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
1.A. Fuel combustion	CS,T2	CS	CS,T1,T2,T3	CR,CS,D	CS,T1,T2,T3	CR,CS,D
1. Energy industries	CS,T2	CS	CS,T3	CS	CS,T3	CS
2. Manufacturing industries and construction	CS,T2	CS	CS,T1,T3	CR,CS,D	CS,T1,T3	CR,CS,D
3. Transport	T2	CS	T1,T2,T3	CS,D	T1,T2,T3	CS,D
4. Other sectors	CS,T2	CS	CS,T1,T3	CR,CS,D	CS,T1,T3	CR,CS,D
5. Other						
1.B. Fugitive emissions from fuels	CS,T1,T2,T3	CS,D	CS,T1,T2,T3	CS,D	T1	D
1. Solid fuels	CS,T2	CS	T1,T2,T3	CS,D	T1	D
2. Oil and natural gas	CS,T1,T3	CS,D	CS,T1,T2	CS,D	T1	D
1.C. CO_2 transport and storage						

Note:
D: IPCC default, T1: IPCC Tier 1, T2: IPCC Tier 2, T3: IPCC Tier 3, CS: country-specific method or EF, CR: CORINAIR

3.2. Fuel Combustion (1.A)

This category covers GHG emissions from combustion of fossil fuels such as coal, oil, and natural gas, and incineration of waste for energy purposes and with energy recovery.[1]

This section includes GHG emissions from five sources: energy industries (1.A.1): emissions mainly from power generation and heat supply; manufacturing industries and construction (1.A.2): emissions from manufacturing industry and construction; transport (1.A.3): emissions from transport of passenger and freight; other sectors (1.A.4): emissions from commercial/institutional, residential, and agriculture/forestry/fishing sources; and other (1.A.5): emissions from other sources.

[1] The emissions from waste incineration had been reported in the waste sector until the 2008 submission, regardless of their use as energy or energy recovery. However, to comply with the IPCC Guidelines, the emissions with energy recovery are reported in the energy sector since the 2009 submission.

Table 3-2 Trends in GHGs emissions from fuel combustion (1.A)

Gas	Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
CO_2	1.A.1. Energy industries	kt-CO_2	368,155	378,495	395,020	449,108	473,254	582,892	526,734	436,110	442,453	434,493	408,445	404,753
	a. Public electricity and heat production	kt-CO_2	303,055	317,587	330,118	378,044	404,239	521,862	468,474	392,293	395,403	387,428	365,039	361,983
	b. Petroleum refining	kt-CO_2	36,020	40,673	46,502	50,330	47,120	42,356	41,088	28,918	30,678	31,116	29,191	28,093
	c. Manufacture of solid fuels and other energy industries	kt-CO_2	29,080	20,234	18,400	20,734	21,895	18,674	17,172	14,899	16,372	15,950	14,214	14,677
	1.A.2. Manufacturing industries and construction	kt-CO_2	349,273	356,719	345,661	332,513	298,951	302,737	285,820	230,880	247,733	229,740	224,027	218,206
	a. Iron and steel	kt-CO_2	150,631	143,009	151,989	153,979	153,050	157,467	148,743	111,881	124,673	114,068	112,788	108,727
	b. Non-ferrous metals	kt-CO_2	8,450	7,405	6,338	5,711	3,980	3,760	3,257	2,778	3,048	2,934	2,881	2,707
	c. Chemicals	kt-CO_2	58,041	64,343	59,523	54,959	50,125	48,274	45,587	39,603	42,705	41,072	40,215	39,409
	d. Pulp, paper and print	kt-CO_2	27,113	31,436	31,679	29,738	22,643	23,833	23,310	17,853	17,756	15,808	15,350	15,244
	e. Food processing, beverages and tobacco	kt-CO_2	7,691	10,188	11,524	12,233	9,873	9,857	8,564	8,105	8,304	7,823	7,773	8,122
	f. Non-metallic minerals	kt-CO_2	43,691	46,519	40,089	35,261	28,396	29,433	27,644	24,568	24,433	21,684	20,781	20,143
	g. Other	kt-CO_2	53,656	53,820	44,519	40,631	30,883	30,112	28,714	26,092	26,813	26,351	24,241	23,854
	1.A.3. Transport	kt-CO_2	202,140	242,797	253,091	238,065	221,660	215,115	208,875	176,576	178,044	184,649	183,562	180,630
	a. Domestic aviation	kt-CO_2	7,162	10,278	10,677	10,799	9,193	10,149	10,067	5,238	6,819	9,705	10,190	10,303
	b. Road transportation	kt-CO_2	180,367	217,028	226,690	213,605	201,148	193,437	187,641	160,907	160,349	163,923	163,031	160,162
	c. Railways	kt-CO_2	935	822	711	647	574	540	523	468	450	455	449	449
	d. Domestic navigation	kt-CO_2	13,675	14,669	15,012	13,014	10,745	10,989	10,645	9,963	10,427	10,567	9,892	9,717
	e. Other transportation	kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	1.A.4. Other sectors	kt-CO_2	157,920	175,085	189,889	195,627	156,726	148,877	138,514	139,950	134,565	127,869	121,772	119,026
	a. Commercial/institutional	kt-CO_2	79,337	88,507	98,457	106,175	75,234	74,299	67,265	67,485	68,297	63,132	61,176	59,023
	b. Residential	kt-CO_2	57,641	66,855	71,579	69,777	63,693	59,806	54,967	55,360	51,140	49,612	46,200	45,735
	c. Agriculture/forestry/fishing	kt-CO_2	20,942	19,723	19,853	19,676	17,800	14,772	16,281	17,105	15,129	15,125	14,397	14,268
	1.A.5 Other	kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	a. Stationary	kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	b. Mobile	kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Total	kt-CO_2	1,077,488	1,153,096	1,183,661	1,215,314	1,150,591	1,249,622	1,159,943	983,516	1,002,796	976,752	937,806	922,614
CH_4	1.A.1. Energy industries	kt-CH_4	18.37	16.01	10.53	9.94	10.79	9.57	11.08	8.21	8.21	7.62	7.41	6.98
	a. Public electricity and heat production	kt-CH_4	0.82	1.02	1.31	1.21	1.19	3.61	5.63	3.27	3.14	3.06	2.95	2.75
	b. Petroleum refining	kt-CH_4	0.09	0.11	0.22	1.51	2.50	0.12	0.21	0.09	0.09	0.09	0.09	0.09
	c. Manufacture of solid fuels and other energy industries	kt-CH_4	17.46	14.88	9.01	7.22	7.10	5.84	5.24	4.85	4.98	4.47	4.36	4.15
	1.A.2. Manufacturing industries and construction	kt-CH_4	14.41	15.16	14.83	17.69	21.52	19.83	21.06	18.82	19.55	18.61	18.93	18.73
	a. Iron and steel	kt-CH_4	4.67	4.28	5.03	7.03	9.19	6.84	7.82	4.36	4.96	4.59	4.69	4.70
	b. Non-ferrous metals	kt-CH_4	0.39	0.36	0.29	0.23	0.18	0.24	0.24	0.24	0.29	0.25	0.26	0.26
	c. Chemicals	kt-CH_4	0.31	0.32	0.49	1.27	2.38	0.87	0.72	1.22	1.29	1.27	1.23	1.20
	d. Pulp, paper and print	kt-CH_4	1.06	1.06	1.13	1.34	1.60	1.43	1.51	1.44	1.51	1.39	1.41	1.38
	e. Food processing, beverages and tobacco	kt-CH_4	0.09	0.13	0.15	0.16	0.14	0.50	0.76	0.53	0.54	0.51	0.51	0.54
	f. Non-metallic minerals	kt-CH_4	4.16	4.96	3.95	3.63	3.08	3.18	2.98	3.45	3.41	3.06	2.93	2.88
	g. Other	kt-CH_4	3.74	4.04	3.80	4.03	4.95	6.76	7.03	7.58	7.54	7.53	7.89	7.77
	1.A.3. Transport	kt-CH_4	10.64	11.27	11.37	8.92	6.17	5.24	4.70	3.50	3.39	3.54	3.45	3.40
	a. Domestic aviation	kt-CH_4	0.23	0.26	0.29	0.22	0.07	0.07	0.06	0.04	0.06	0.07	0.06	0.06
	b. Road transportation	kt-CH_4	10.10	10.68	10.76	8.43	5.87	4.95	4.42	3.26	3.12	3.26	3.19	3.14
	c. Railways	kt-CH_4	0.05	0.05	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
	d. Domestic navigation	kt-CH_4	0.25	0.27	0.28	0.24	0.20	0.20	0.19	0.18	0.19	0.19	0.18	0.18
	e. Other transportation	kt-CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	1.A.4. Other sectors	kt-CH_4	9.52	11.77	13.15	19.82	18.17	8.99	8.17	9.28	8.42	8.33	7.85	7.78
	a. Commercial/institutional	kt-CH_4	1.31	3.09	4.33	10.31	8.97	2.09	1.76	2.43	2.19	2.27	2.19	2.17
	b. Residential	kt-CH_4	7.00	7.66	7.83	7.65	6.85	6.35	5.79	5.77	5.26	5.12	4.76	4.71
	c. Agriculture/forestry/fishing	kt-CH_4	1.21	1.02	0.99	1.86	2.35	0.55	0.62	1.08	0.96	0.94	0.91	0.89
	1.A.5 Other	kt-CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	a. Stationary	kt-CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	b. Mobile	kt-CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Total	kt-CH_4	52.94	54.21	49.88	56.37	56.64	43.63	45.00	39.81	39.57	38.10	37.64	36.89
		kt-CO_2 eq.	1,482	1,518	1,397	1,578	1,586	1,222	1,260	1,115	1,108	1,067	1,054	1,033
N_2O	1.A.1. Energy industries	kt-N_2O	2.98	4.54	5.41	6.84	6.74	7.66	7.74	6.05	6.14	5.88	5.65	5.32
	a. Public electricity and heat production	kt-N_2O	1.72	3.09	3.72	5.06	4.91	6.36	6.42	5.14	5.14	4.91	4.68	4.48
	b. Petroleum refining	kt-N_2O	1.05	1.31	1.58	1.61	1.61	1.21	1.26	0.85	0.95	0.92	0.92	0.79
	c. Manufacture of solid fuels and other energy industries	kt-N_2O	0.22	0.14	0.12	0.17	0.21	0.09	0.06	0.06	0.06	0.05	0.05	0.05
	1.A.2. Manufacturing industries and construction	kt-N_2O	4.23	5.73	6.31	6.27	5.78	5.91	5.83	4.93	4.91	4.33	4.02	3.97
	a. Iron and steel	kt-N_2O	1.12	1.34	1.40	1.47	1.50	1.32	1.34	1.16	1.12	0.99	1.01	0.95
	b. Non-ferrous metals	kt-N_2O	0.25	0.23	0.21	0.08	0.05	0.06	0.05	0.04	0.05	0.05	0.04	0.04
	c. Chemicals	kt-N_2O	0.74	1.19	1.20	1.04	0.96	1.07	1.00	0.88	0.96	0.80	0.81	0.71
	d. Pulp, paper and print	kt-N_2O	0.48	0.91	0.95	0.98	1.14	1.23	1.26	0.84	0.87	0.78	0.73	0.70
	e. Food processing, beverages and tobacco	kt-N_2O	0.04	0.05	0.07	0.08	0.08	0.07	0.06	0.04	0.04	0.04	0.04	0.04
	f. Non-metallic minerals	kt-N_2O	0.80	1.06	1.73	1.98	1.56	1.65	1.66	1.51	1.38	1.21	0.94	1.09
	g. Other	kt-N_2O	0.81	0.95	0.76	0.64	0.50	0.52	0.45	0.46	0.48	0.47	0.44	0.44
	1.A.3. Transport	kt-N_2O	12.91	14.16	13.81	9.80	7.20	6.26	5.89	4.92	4.99	5.18	5.10	5.02
	a. Domestic aviation	kt-N_2O	0.21	0.29	0.32	0.32	0.28	0.30	0.30	0.15	0.20	0.28	0.30	0.30
	b. Road transportation	kt-N_2O	11.60	12.77	12.41	8.53	6.12	5.19	4.85	4.08	4.09	4.18	4.12	4.05
	c. Railways	kt-N_2O	0.37	0.32	0.28	0.25	0.23	0.21	0.20	0.18	0.17	0.18	0.17	0.17
	d. Domestic navigation	kt-N_2O	0.73	0.78	0.79	0.69	0.57	0.56	0.54	0.51	0.53	0.54	0.51	0.50
	e. Other transportation	kt-N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	1.A.4. Other sectors	kt-N_2O	2.31	2.56	2.82	2.49	2.18	2.02	2.05	1.81	1.71	1.67	1.62	1.60
	a. Commercial/institutional	kt-N_2O	1.51	1.78	2.08	1.79	1.57	1.50	1.53	1.28	1.24	1.21	1.17	1.16
	b. Residential	kt-N_2O	0.28	0.32	0.35	0.34	0.29	0.27	0.24	0.23	0.21	0.20	0.19	0.18
	c. Agriculture/forestry/fishing	kt-N_2O	0.53	0.45	0.38	0.36	0.32	0.26	0.28	0.29	0.26	0.27	0.25	0.25
	1.A.5 Other	kt-N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	a. Stationary	kt-N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	b. Mobile	kt-N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Total	kt-N_2O	22.44	26.99	28.35	25.40	21.90	21.85	21.50	17.71	17.76	17.07	16.38	15.91
		kt-CO_2 eq.	5,947	7,152	7,512	6,731	5,803	5,791	5,699	4,692	4,706	4,523	4,341	4,217
Total of all gases		kt-CO_2 eq.	1,084,917	1,161,766	1,192,570	1,223,623	1,157,980	1,256,634	1,166,902	989,323	1,008,610	982,341	943,201	927,865

In FY2024, GHG emissions from fuel combustion (1.A) category were 927,865 kt-CO_2 eq., which accounted for 88.7% of Japan's total GHG emissions (excluding LULUCF). By looking at the share of the emissions by gas, CO_2 comprises 99.4% of the GHG emissions from fuel combustion.

The CO_2 emissions in FY2024 decreased by 1.6% compared to the previous year. The main driving factor for the decrease is the CO_2 emissions from the manufacturing industries and construction (1.A.2).

By looking at the changes in CO_2 emissions by subcategory, emissions from the energy industries (1.A.1) increased by 9.9% since FY1990 and decreased by 0.9% compared to the previous year. The main driving factor for the increase compared to the emissions in FY1990 is the increase in thermal power generation. From FY1990 to FY2007, the emissions increased with an increase in electricity demand. From FY2011 to FY2013, the emissions increased mainly due to an increase in the share of thermal power generation as a result of the suspension of operation of the nuclear power plants triggered by the Great East Japan Earthquake. Since then, the enhancement of introduction of renewable energy and the resumption of operation of the nuclear power plants are in progress.

The CO_2 emissions from manufacturing industries and construction (1.A.2) decreased by 37.5% since FY1990 and decreased by 2.6% compared to the previous year. The main driving factor for the decrease compared to the emissions in FY1990 is the decreased liquid fuel consumption. The emissions are considered to have a moderate correlation with the *Indices of Industrial Production* (IIP) (Ministry of Economy, Trade and Industry (METI)). In the middle of 2000s, the CO_2 emissions were stable while the IIP increased, that implies the improvement of energy efficiency. (Agency for Natural Resources and Energy, 2020)

The CO_2 emissions from transport (1.A.3) decreased by 10.6% compared to FY1990 and decreased by 1.6% compared to the previous year. The main driving factor for the decrease compared to the emissions in FY1990 is the decrease in emissions from freight transportation, compensating for the increase in emissions from passenger vehicles. Although the emissions from road transportation increased in 1990s due to an increase in distance traveled, the emissions have decreased in the 2000s mainly due to an improvement of fuel efficiency. The distance traveled significantly dropped in FY2020-FY2021 due to the influence of COVID-19 pandemic, and it has been lower than the FY2019 level.

The CO_2 emissions from other sectors (1.A.4) decreased by 24.6% since FY1990 and decreased by 2.3% compared to the previous year. The main driving factor for the decrease compared to the emissions in FY1990 is the decreased liquid fuel consumption. The CO_2 emissions from commercial/institutional (1.A.4.a) are considered to have a moderate correlation with the *Indices of Tertiary Industry Activity* (METI) until 2005. The emissions have decreased since then due to the decrease in the demand of liquid fuels.

The table below provides some indicators that might have relations to the emission trends of the fuel combustion (1.A). Please note that these indicators are not used for estimating the emissions. Also, please refer to Chapter 2 for the charts of emission trends.

Table 3-3 Trends in indicators that might have relations to the GHGs emissions from fuel combustion (1.A)

No.	Related subcategories	Indicators	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
1	1.A. Fuel combustion	Final electricity consumption	TWh	765	872	973	1,025	1,035	990	949	913	924	902	875	881
2	1.A.2. Manufacturing industries and construction	Indices of Industrial Production	CY2020=100	120.6	114.2	119.0	120.8	111.9	111.7	110.3	99.7	105.2	104.9	102.9	101.5
3	1.A.3.b. Road transportation	Vehicle kilometers traveled (VKT)	billion VKT	585	673	728	727	708	724	721	666	650	692	688	689
4	1.A.4.a.Commercial/ institutional	Indices of Tertiary Industry Activity	CY2019-2020 average=100	84.7	91.8	96.2	101.8	98.6	101.8	101.4	95.5	97.7	99.9	101.5	102.9

Reference: 1: *General Energy Statistics* by Agency for Natural Resources and Energy (ANRE), 2: Ministry of Economy, Trade and Industry (METI), 3: *Statistical Yearbook of Motor Vehicle Fuel Consumption*, etc. by Ministry of Land, Infrastructure, Transport and Tourism (MLIT), 4: METI

3.2.1. Comparison of the Sectoral Approach with the Reference Approach

This chapter explains a comparison between reference approach and sectoral approach in accordance with the *Modalities, procedures and guidelines for the transparency framework for action and support referred to in Article 13 of the Paris Agreement* (Decision 18/CMA.1 Annex, hereafter MPGs), paragraph 36. For the methodological issues of the sectoral approach, please refer to section 3.2.4. b). Since the reference approach does not consider carbon captured, the results should be compared to the CO_2 emissions before those amounts are subtracted out, according to the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (Vol.2, page 6.11). The captured amount is not subtracted only in this section.

3.2.1.1. Detailed Description of the Reference Approach (CRT Table 1.A(b))

The reference approach is to calculate the CO_2 emissions from combustion, using a country's energy supply data. The CO_2 emissions estimated by the reference approach are not included in the national total and used for verification purpose. The CO_2 emissions by the reference approach are estimated by the following formula:

$$E = \sum_i [(A_i - N_i) \times GCV_i \times 10^{-3} \times EF_i \times OF_i] \times 44/12$$

E : CO_2 emissions from fossil fuel combustion [kt-CO_2]
A : Apparent energy consumption (original unit [kt, 10^3 kL, 10^6 m^3])
N : Non-energy use of fossil fuels [kt, 10^3 kL, 10^6 m^3]
GCV : Gross calorific value (higher heating value) [MJ/kg, MJ/L, MJ/m^3]
EF : Carbon content of the fuel [t-C/TJ]
OF : Oxidation factor
i : Type of fuel

The apparent energy consumptions *A* are estimated by the following formula:

Primary fuels: $A = P + IM - EX \pm SC - IB$

Secondary fuels: $A = IM - EX \pm SC - IB$

Table 3-4 Sources of each term of reference approach estimation equation

Symbol	Term	Source[2]
P	Production	• Indigenously Produced (#110000) in Agency for Natural Resources and Energy's *General Energy Statistics* (Japan's Energy Balance Tables) • (Waste only) Consumption of sectoral approach
IM	Imports	Imported (#120000) in the statistics + International bunker fuels (see section 3.2.2.)
EX	Exports	Export (#160000) in the statistics
SC	Stock change	Stockpile Change / Supply (#170000) in the statistics
IB	International bunkers	See section 3.2.2.
N	Non-energy use	Non-energy and feedstock use (#950000) in the statistics (see section 3.2.3.)

Emissions from wastes used for energy and from the incineration of wastes with energy recovery are not reported in waste incineration (5.C.1) but reported in fuel combustion (1.A.) in accordance with the *2006 IPCC Guidelines*.

The carbon contents of the fuels, the oxidation factors and the gross calorific values are in common with the sectoral approach (refer to section 3.2.4. b).

The details of estimation results by reference approach are shown in the Common Reporting Table (CRT) table 1.A(b). The correspondence between fuels of the *General Energy Statistics* and those of the table is shown in Annex 3.

➢ ***Discrepancies between the figures reported in the CRT tables and the IEA statistics***

Some discrepancies exist between the fuel data of energy supply and demand in the CRT tables and the data of energy supply and demand reported in the International Energy Agency (IEA) statistics. Please refer to the details of discrepancies and their reasons in Annex 3 (A3.1).

3.2.1.2. Results of the Comparison of National Estimates of Emissions with Those Obtained Using the Reference Approach (CRT Table 1.A(c))

3.2.1.2.a. Difference in Energy Consumption

As shown in Table 3-5, fluctuations of difference[3] of energy consumption between the reference approach and the sectoral approach during FY1990-2024 range between -1.77% (FY2012) and +2.08% (FY2022).

There is a large difference between those two approaches for solid fuels in FY2004 (+10.63%). It means that, in FY2004, because stocks of the coal on the consumer side (steel making coal [$0110[4]]) increased, the large difference occurred between the reference approach estimated from the provider side and the sectoral approach estimated from the consumer side. In addition, there is a large difference between those two approaches for solid fuels in FY2008 (+6.82%). This is because stocks of the coal on the consumer side (imported steam coal [$0121]) increased, like in FY2004. It should be noted that the stock changes explained here are not 'Stockpile change / supply' in 'Primary energy supply' sector, but 'Transformation and consumption stockpile change' in 'Energy transformation & own use' sector and

[2] Numbers with # indicate the corresponding sector (row) numbers in the *General Energy Statistics* (Japan's Energy Balance Tables).
[3] Difference = (RA-SA)/SA
RA: Reference Approach, SA: Sectoral Approach
[4] Numbers with $ indicate the corresponding energy source (column) numbers in the *General Energy Statistics* (Japan's Energy Balance Tables).

'Final energy consumption' sector.

3.2.1.2.b. Difference in CO_2 Emissions

As shown in Table 3-6, fluctuations of a difference of CO_2 emissions between the reference approach and the sectoral approach during FY1990-2024 range between -0.74% (FY1990) and +3.83% (FY2004).

The differences between both approaches for solid fuels were large values in FY2004 and FY2008 (+9.94%, +6.24%), and small values in FY2005 and FY2009 (+2.05%, -1.92%). It is because of the same reason as the difference of energy consumption which is described in the previous section.

Table 3-5 Comparison of energy consumption[5]

	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Reference Approach (PJ)	**15,138**	**16,517**	**17,041**	**17,411**	**16,585**	**18,020**	**16,748**	**14,309**	**14,628**	**14,449**	**13,440**	**13,360**
Liquid fuels	9,526	10,132	9,443	8,920	7,179	7,395	6,501	5,162	5,363	5,365	5,062	4,938
Solid fuels	3,285	3,603	4,180	4,763	4,979	5,284	5,137	4,401	4,791	4,678	4,272	4,278
Gaseous fuels	2,042	2,465	3,050	3,275	3,979	4,882	4,650	4,261	3,990	3,928	3,618	3,661
Other fossil fuels	284	317	368	453	448	459	460	485	483	479	489	482
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Sectoral Approach (PJ)	**15,321**	**16,554**	**17,030**	**17,395**	**16,621**	**18,084**	**16,796**	**14,428**	**14,545**	**14,155**	**13,592**	**13,331**
Liquid fuels	9,459	9,973	9,451	8,949	7,260	7,463	6,542	5,242	5,299	5,303	5,051	4,878
Solid fuels	3,368	3,598	3,986	4,638	4,819	5,223	5,049	4,382	4,661	4,463	4,241	4,261
Gaseous fuels	2,209	2,667	3,226	3,355	4,093	4,939	4,744	4,319	4,102	3,910	3,811	3,709
Other fossil fuels	284	317	368	453	448	459	460	485	483	479	489	482
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Difference (%)	**−1.19%**	**−0.23%**	**+0.07%**	**+0.09%**	**−0.21%**	**−0.35%**	**−0.29%**	**−0.83%**	**+0.57%**	**+2.08%**	**−1.12%**	**+0.22%**
Liquid fuels	+0.71%	+1.60%	−0.08%	−0.33%	−1.11%	−0.90%	−0.63%	−1.52%	+1.21%	+1.16%	+0.20%	+1.23%
Solid fuels	−2.46%	+0.15%	+4.87%	+2.70%	+3.32%	+1.17%	+1.73%	+0.43%	+2.79%	+4.81%	+0.72%	+0.40%
Gaseous fuels	−7.56%	−7.58%	−5.43%	−2.38%	−2.80%	−1.16%	−1.99%	−1.35%	−2.73%	+0.46%	−5.06%	−1.29%
Other fossil fuels	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE

Table 3-6 Comparison of CO_2 emissions

	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Reference Approach (Mt-CO_2)	**1,070**	**1,163**	**1,204**	**1,235**	**1,170**	**1,251**	**1,165**	**980**	**1,018**	**1,004**	**937**	**930**
Liquid fuels	659.9	701.9	656.3	621.1	501.8	512.2	450.1	355.2	370.1	369.5	348.7	339.9
Solid fuels	295.7	323.8	377.9	431.1	450.8	474.5	462.1	392.3	428.5	418.1	387.8	388.0
Gaseous fuels	104.4	126.1	155.9	167.4	203.5	249.9	238.0	216.6	202.8	199.8	183.6	185.8
Other fossil fuels	10.0	11.1	13.4	15.0	13.9	14.6	14.5	15.9	16.2	16.3	16.6	16.4
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Sectoral Approach (Mt-CO_2)	**1,078**	**1,154**	**1,184**	**1,216**	**1,151**	**1,250**	**1,161**	**984**	**1,003**	**977**	**938**	**923**
Liquid fuels	644.3	677.4	640.7	606.1	488.8	508.4	443.9	354.2	357.9	359.1	341.1	328.7
Solid fuels	309.5	327.2	364.1	422.4	438.5	473.8	458.8	393.9	420.0	402.3	386.5	389.0
Gaseous fuels	114.2	137.9	166.1	172.4	209.9	253.4	243.4	220.2	209.3	199.8	194.3	189.1
Other fossil fuels	10.0	11.1	13.4	15.0	13.9	14.6	14.5	15.9	16.2	16.3	16.6	16.4
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Difference (%)	**−0.74%**	**+0.80%**	**+1.63%**	**+1.54%**	**+1.63%**	**+0.08%**	**+0.36%**	**−0.42%**	**+1.42%**	**+2.69%**	**−0.20%**	**+0.74%**
Liquid fuels	+2.42%	+3.62%	+2.43%	+2.48%	+2.66%	+0.74%	+1.41%	+0.29%	+3.40%	+2.90%	+2.23%	+3.42%
Solid fuels	−4.47%	−1.05%	+3.80%	+2.05%	+2.79%	+0.15%	+0.72%	−0.40%	+2.03%	+3.94%	+0.33%	−0.27%
Gaseous fuels	−8.56%	−8.61%	−6.11%	−2.89%	−3.07%	−1.39%	−2.21%	−1.66%	−3.10%	−0.02%	−5.52%	−1.74%
Other fossil fuels	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE

3.2.1.2.c. Comparison Between Differences in Energy Consumption and that of CO_2 Emissions

The difference in energy consumption and the difference in CO_2 emissions generally show a similar

[5] In this chapter, solid fuels (coal based fuels) mean coal and coal products (including coal derived gas), liquid fuels (oil based fuels) mean crude oil and oil products (including LPG, etc.), and gaseous fuels (gas based fuels) mean natural gas (including LNG, etc.) and city gas, unless otherwise specified. (cf. *2006 IPCC Guidelines*, Vol.2, Table 1.1) Peat is included in solid fuels.

tendency for their trends.

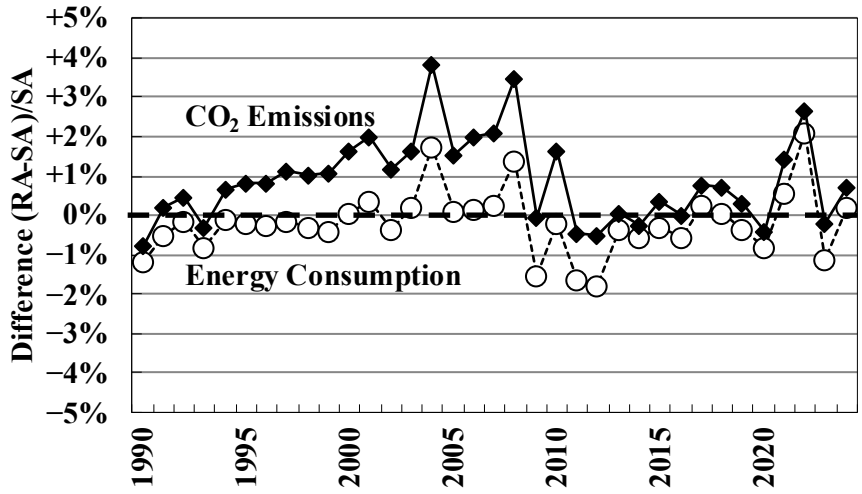

Figure 3-1 Trends in difference of energy consumption and CO_2 emissions

Note: RA: Reference Approach, SA: Sectoral Approach

3.2.1.2.d. Causes of the Difference Between Reference Approach and Sectoral Approach

The difference in energy consumption and in CO_2 emissions can be explained mainly by the difference of the amount of non-energy use which was deducted under energy transformation & own use sector of the *General Energy Statistics*.

1) Matters not sufficiently considered in the calculation process of Reference Approach

In the current estimation of reference approach, the energy consumption amount, which is obtained by subtracting the amount of non-energy use from the amount supplied inside the country, is assumed to be completely combusted. However, in real situation, some of the energy amount is not combusted but stored, and the increase or decrease of the stored amount is not reflected in reference approach.

- ***Other Transformation [#289000]***

In Energy transformation & own use sector such as oil refining, energy source shipment/drawdown amounts do not necessarily match production/receipt amounts. Other than energy received through one's own imports or that produced by refining, factors involved include returns from consumption/sales sectors of products once shipped, transactions of small amounts of byproduct energy from other companies, stock buildups and drawdowns due to product storage tank installation or decommissioning at factories and business sites, and losses due to accidents or fires.

When energy source inconsistencies due to such causes in the Energy transformation & own use sector are determined, the other transformation sector represents its amount. However, this input/output are not reflected in reference approach emission calculation.

- ***Transformation and Consumption Stockpile Change [#350000]***

This sector represents the increase or decrease of stock in Energy transformation & own use sector and Final energy consumption sector. However, this increase/decrease was not reflected in reference approach emission calculation.

- ***Other factors***

Some emissions are not calculated for the sources that the emissions are relatively low compared to total emissions in reference approach, in order not to be too complicated (cf. *2006 IPCC Guidelines*, Vol.2, page 6.12). For example, the emissions from lubricants used in two stroke engines are not accounted for in the reference approach emission calculation.

2) Matters which cannot be avoided for the characteristics of survey data

- ***Statistical Discrepancy [#400000]***

Statistical discrepancy is originally the intrinsic error arising at the sampling stage in statistical studies (source error), and mutual discrepancies among the statistics for supply, transformation, and consumption. It is sometimes difficult to guess where the discrepancies come from (relative error). These errors induce the discrepancies among domestic supply, transformation, and final energy consumption, calculated as difference between both approaches.

3) Matters related to the difference of energy and carbon balance between energy input and output

- ***Coal Blending [#211000], Oil Product Blending [#221000], Coal Products Secondary Transformation [#281000], Oil Products Secondary Transformation [#282000]***

This sector represents energy transformation that does not belong to any of the sectors from Coke production [#212000] to Steel process gas [#215000] and from Oil refinery [#222000] to Heat supply [#270000], and actions considered to be energy transformation in which coal or oil product brands are changed by only simple operations such as blending or moisture adjustment. Carbon weight is considered to be consistent before and after blending or transformation. However, given that carbon content per calorific value is changed following such as blending, in statistics, carbon weight could be varied before and after blending or transformation. This difference can generate the variation between two approaches.

- ***Oil Refinery [#222000]***

This sector represents the production processes of various petroleum products such as fuel oils or feedstock oils mainly from crude oil through refining, cracking and separation. In this sector, the process of oil refining is modeled by dividing into six processes, and regarding four of these processes, the carbon balance difference between inputs and outputs are deemed to be emissions. However, regarding the process of vacuum distillation and cracking, carbon balance is unstable throughout the time-series, and it is considered to be an accumulation of errors, therefore the carbon balance difference is not deemed to be emissions.

On the other hand, in reference approach, all crude oil supplied inside the country is considered to become CO_2 emissions, and this difference can generate the variation between two approaches.

- ***Petrochemical [#225000]***

In this sector, byproduction of various petroleum products such as refinery gas, LPG, or asphalt through the production processes of basic chemical materials from naphtha or reformed feedstock oil is represented as energy transformation. Carbon weight is considered to be consistent before and after transformation. However, given that carbon content per calorific value is changed, in statistics, carbon weight could be varied before and after transformation. This difference can generate the variation between two approaches.

4) Matters related to the transformation to another fuel type

- ***Gas Conversion and Production [#230000]***

This sector represents energy transformation arising from city gas production from liquefied natural gas (LNG), liquefied petroleum gas (LPG) and other fuels. City gas is made from liquid and solid fuels such as LPG and coke oven gas (COG) as well as gaseous fuels such as LNG. Thus, the fact that some liquid and solid fuels are converted to gaseous fuels is not reflected in reference approach emission calculation. The emissions calculated by the sectoral approach tend to be larger than those by reference approach for gaseous fuels and smaller for liquid and solid fuels. This sector does not affect the difference between two approaches in total.

Table 3-7 Comparison of CO_2 emissions (detail)

	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
RA	**1,070**	**1,163**	**1,204**	**1,235**	**1,170**	**1,251**	**1,165**	**980**	**1,018**	**1,004**	**937**	**930**
Liquid fuels	659.9	701.9	656.3	621.1	501.8	512.2	450.1	355.2	370.1	369.5	348.7	339.9
Solid fuels	295.7	323.8	377.9	431.1	450.8	474.5	462.1	392.3	428.5	418.1	387.8	388.0
Gaseous fuels	104.4	126.1	155.9	167.4	203.5	249.9	238.0	216.6	202.8	199.8	183.6	185.8
Other fossil fuels	10.0	11.1	13.4	15.0	13.9	14.6	14.5	15.9	16.2	16.3	16.6	16.4
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
SA	**1,078**	**1,154**	**1,184**	**1,216**	**1,151**	**1,250**	**1,161**	**984**	**1,003**	**977**	**938**	**923**
Liquid fuels	644.3	677.4	640.7	606.1	488.8	508.4	443.9	354.2	357.9	359.1	341.1	328.7
Solid fuels	309.5	327.2	364.1	422.4	438.5	473.8	458.8	393.9	420.0	402.3	386.5	389.0
Gaseous fuels	114.2	137.9	166.1	172.4	209.9	253.4	243.4	220.2	209.3	199.8	194.3	189.1
Other fossil fuels	10.0	11.1	13.4	15.0	13.9	14.6	14.5	15.9	16.2	16.3	16.6	16.4
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
RA-SA	**-8.0**	**9.2**	**19.3**	**18.7**	**18.8**	**1.0**	**4.2**	**-4.2**	**14.2**	**26.2**	**-1.8**	**6.9**
Liquid fuels	15.6	24.5	15.6	15.0	13.0	3.8	6.2	1.0	12.2	10.4	7.6	11.2
Solid fuels	-13.8	-3.4	13.8	8.6	12.2	0.7	3.3	-1.6	8.5	15.9	1.3	-1.1
Gaseous fuels	-9.8	-11.9	-10.1	-5.0	-6.4	-3.5	-5.4	-3.6	-6.5	0.0	-10.7	-3.3
Other fossil fuels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Peat	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Statistical Discrepancy	**-12.0**	**4.6**	**13.1**	**11.6**	**9.0**	**-1.6**	**0.9**	**5.4**	**18.1**	**11.9**	**7.5**	**3.2**
Liquid fuels	1.4	7.2	0.9	0.5	-0.5	-2.4	-0.1	0.3	4.2	0.5	0.0	-0.3
Solid fuels	-14.3	-2.7	13.0	11.1	11.0	-0.7	1.2	2.9	12.8	10.0	8.0	2.4
Gaseous fuels	0.9	0.0	-0.7	0.0	-1.5	1.5	-0.2	2.2	1.1	1.4	-0.5	1.1
Coal Blending	**0.3**	**0.4**	**0.5**	**0.7**	**0.7**	**-0.2**	**0.0**	**0.1**	**-0.1**	**-0.3**	**0.6**	**0.5**
Liquid fuels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Solid fuels	0.3	0.4	0.5	0.7	0.7	-0.2	0.0	0.1	-0.1	-0.3	0.6	0.5
Gaseous fuels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Oil Product Blending	**-1.8**	**-0.5**	**0.2**	**0.4**	**0.1**	**-1.4**	**-1.4**	**-1.3**	**-1.3**	**-1.4**	**-1.3**	**-1.2**
Liquid fuels	-1.8	-0.5	0.2	0.4	0.1	-1.4	-1.4	-1.3	-1.3	-1.4	-1.3	-1.2
Solid fuels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gaseous fuels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other Energy Transformation[1)]	**0.6**	**-0.2**	**2.6**	**3.6**	**4.2**	**0.0**	**0.4**	**-8.0**	**-1.5**	**-0.5**	**-1.3**	**1.8**
Liquid fuels	0.6	-0.2	2.5	3.6	4.1	0.0	0.3	-7.7	-1.2	-0.5	-1.1	1.9
Solid fuels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gaseous fuels	0.1	0.1	0.0	0.0	0.0	0.1	0.0	-0.3	-0.3	-0.1	-0.3	-0.2
Transformation and Consumption Stockpile Change	**2.6**	**1.7**	**2.4**	**-0.3**	**2.6**	**0.7**	**1.8**	**-6.0**	**-5.1**	**13.8**	**-10.6**	**-2.4**
Liquid fuels	0.7	1.5	-0.9	-0.1	0.5	-2.9	-1.5	-2.2	-0.7	1.0	-0.6	-1.0
Solid fuels	1.9	0.6	3.0	-1.6	2.4	3.7	4.3	-2.9	-2.5	7.9	-5.8	-2.6
Gaseous fuels	0.0	-0.3	0.3	1.4	-0.3	-0.1	-0.9	-0.9	-2.0	4.8	-4.2	1.2
Oil Refining[2)]	**0.4**	**0.7**	**-2.5**	**-0.8**	**-0.9**	**-0.3**	**-1.2**	**3.2**	**1.2**	**-0.2**	**0.3**	**1.9**
Liquid fuels	0.4	0.7	-2.5	-0.8	-0.9	-0.3	-1.2	3.2	1.2	-0.2	0.3	1.9
Solid fuels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gaseous fuels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Petrochemical	**2.3**	**2.9**	**3.6**	**3.9**	**3.6**	**4.6**	**4.4**	**3.1**	**3.6**	**3.5**	**3.5**	**3.4**
Liquid fuels	2.6	3.2	4.0	4.3	3.9	4.9	4.7	3.2	3.7	3.6	3.6	3.5
Solid fuels	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gaseous fuels	-0.3	-0.3	-0.4	-0.4	-0.4	-0.3	-0.3	-0.1	-0.1	-0.1	-0.1	-0.1
Gas Conversion and Production	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Liquid fuels	9.7	10.9	9.0	5.9	4.4	4.7	4.1	4.6	5.2	6.1	5.7	5.5
Solid fuels	0.8	0.5	0.4	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gaseous fuels	-10.5	-11.4	-9.4	-6.0	-4.4	-4.7	-4.1	-4.6	-5.2	-6.1	-5.7	-5.5
Total	**-7.6**	**9.6**	**19.8**	**19.1**	**19.2**	**1.7**	**4.9**	**-3.5**	**14.9**	**26.9**	**-1.3**	**7.3**
Liquid fuels	13.5	22.7	13.1	13.8	11.6	2.5	4.8	0.1	11.1	9.2	6.7	10.3
Solid fuels	-11.4	-1.2	16.9	10.3	14.1	2.7	5.5	0.1	10.3	17.7	2.7	0.3
Gaseous fuels	-9.8	-11.9	-10.1	-5.0	-6.5	-3.6	-5.4	-3.7	-6.5	-0.1	-10.7	-3.3
(RA-SA)-(Total)	**-0.4**	**-0.4**	**-0.5**	**-0.5**	**-0.3**	**-0.8**	**-0.7**	**-0.7**	**-0.7**	**-0.6**	**-0.5**	**-0.4**
Liquid fuels	2.1	1.8	2.5	1.2	1.4	1.2	1.4	0.9	1.0	1.2	0.9	0.9
Solid fuels	-2.4	-2.2	-3.0	-1.7	-1.8	-2.0	-2.1	-1.6	-1.8	-1.8	-1.5	-1.3
Gaseous fuels	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0

Unit: Mt-CO_2

1) Other Energy Transformation (#280000) is the aggregated category of Coal Products Secondary Transformation (#281000), Oil Products Secondary Transformation (#282000), and Other Transformation (#289000).

2) Only the process of vacuum distillation and cracking

3.2.2. International Bunker Fuels (CRT Table 1.D)

a) Category Description

This section provides the estimation methods for determining CO_2, CH_4, and N_2O emissions from the fuel consumed for international navigation and aviation.

The emissions from bunker fuels used for international navigation and aviation are not included in the national totals but are reported as the memo item in the CRTs in accordance with the *2006 IPCC Guidelines*.

b) Methodological Issues

- ***Estimation Method***

The emissions of CO_2, CH_4 and N_2O from this source are derived by multiplying the consumption of each fuel type handled by bonds by the emission factor.

- ***Emission Factors***

➢ ***CO_2***

The emission factors used for CO_2 are the same as those from 1.A.1 fuel combustion (CO_2) in the energy sector (Refer to section 3.2.4. b)).

The Japanese carbon emission factor (EF) for jet kerosene until FY2012 (18.3 t-C/TJ based on the gross calorific value (GCV)) is lower than the default EF for jet kerosene in the *2006 IPCC Guidelines* (Vol.2, Table 1.4, 18.5 t-C/TJ based on GCV[6]). However, Japan considers that this country-specific EF is appropriate value, comparing to the default value, because of the following reasons. The Japanese EF for jet kerosene is obtained from actual measurement. In addition, the 95% confidence interval of the default EF for jet kerosene is 18.1-19.3 t-C/TJ (based on GCV) and the Japanese EF is inside the range.

➢ ***CH_4, N_2O***

The default values given in the *2006 IPCC Guidelines* are used for CH_4 and N_2O emission factors.

Table 3-8 Emission factors for CH_4 and N_2O from international bunkers

Transport mode	Type of fuel	CH_4 emission factor [kg-CH_4/TJ(NCV)]	N_2O emission factor [kg-N_2O/TJ(NCV)]
Aircraft	Jet fuel	0.5 1)	2 1)
Shipping	Fuel oil A, fuel oil B, fuel oil C, diesel oil, kerosene	7 2)	2 2)

Note:
1) *2006 IPCC Guidelines* Vol. 2, Table 3.6.5
2) *2006 IPCC Guidelines* Vol. 2, Table 3.5.3. According to the *2006 IPCC Guidelines* Vol. 3 page 5.7, CH_4 and N_2O emissions from lubricants are very small in comparison to CO_2, and these can be neglected for the greenhouse gas calculation. Therefore, the emissions are not estimated.

- ***Activity Data***

The totals for bonded imports and bonded exports given in *Yearbook of Mineral Resources and Petroleum Products Statistics* (former *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*) (METI) are used for the emissions of CO_2, CH_4, and N_2O from the relevant source.

A and B in the diagram below correspond to the items under bonded exports and bonded imports, respectively, in the *Yearbook of Mineral Resources and Petroleum Products Statistics* (former *Yearbook*

[6] The conversion factor in the *2006 IPCC Guidelines* (Vol.2, page 1.16) is used.

of Production, Supply and Demand of Petroleum, Coal and Coke). C equals to the sum of A and B and it is used as the activity data for this source of emissions. This is considered to be approximately equivalent to the amount of the fuels sold in Japan for international aviation and navigation.

It is assumed that jet fuel is used by aircrafts, while fuel oil A, B, C, diesel oil, kerosene and lubricants are used by vessels. Fuel oil A, B, and C are used for the propulsion of international water-borne vessels. Diesel oil and kerosene are used only for fuels of private power generators (e.g. air heating). All lubricants are assumed to be oxidized during use from the viewpoint of conservativeness as lubricants consumption by type is unknown.

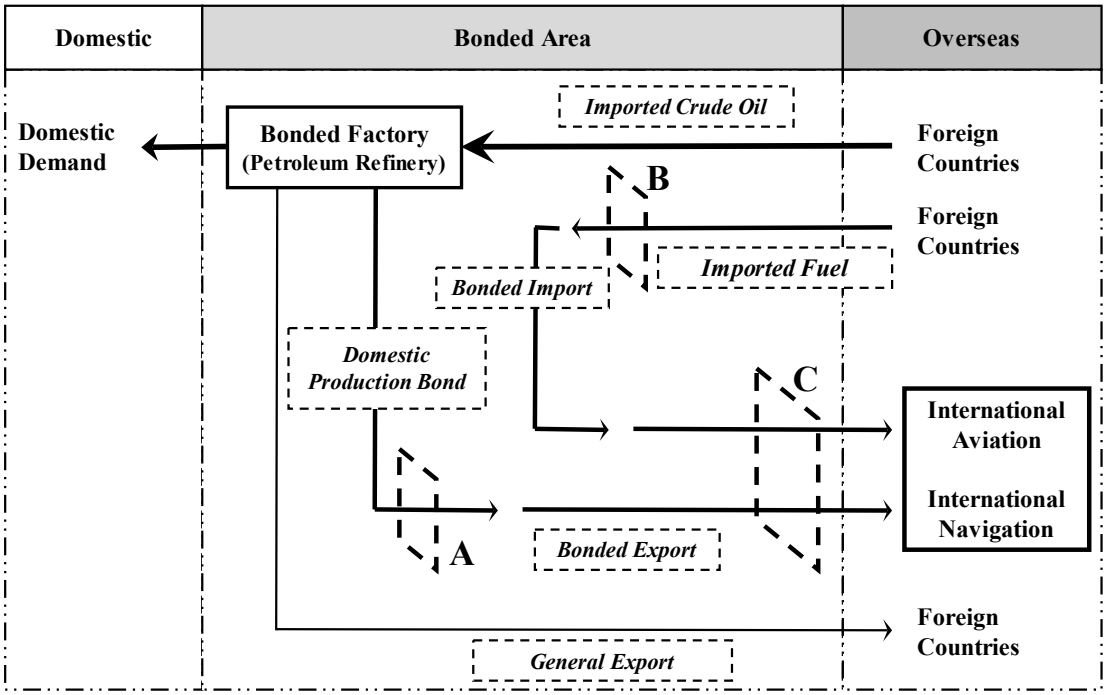

Figure 3-2 Activity data for international bunkers

- ***CO_2***

The kiloliter-based consumption data given in the *Yearbook of Mineral Resources and Petroleum Products Statistics* (former *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*) are converted to Joule-based data using the actual calorific values given in the *General Energy Statistics*.

- ***CH_4, N_2O***

The *2006 IPCC Guidelines* provide default emission factors that are based on net calorific values. Therefore, the activity data in gross calorific values are converted to net calorific values by multiplying them by the conversion rate.

- ***Glossary***

Bonded Jet Fuel

Under the Tariff Law, aircraft (Japanese and non-Japanese) flying international routes are deemed to be "aircraft for international use", and the fuel they consume is tariff-free, subject to the completion of the required procedures. The application of this legislation means that if fuel is refined from crude oil imported to Japanese refinery, both the crude oil import tariff and the petroleum and coal tax are waived. Similarly, if fuel has been imported as a product, the product import tariff is waived. The foregoing is termed as "bonded jet fuel".

Bonded Fuel Oil

Vessels that ply between Japan and other countries are deemed to be “foreign trade vessels”, under the Tariff Law. The majority of their fuel is consumed outside Japanese territorial waters, and, therefore, both the tariffs and the petroleum and coal tax are waived. The foregoing is termed as “bonded fuel oil”.

Bonded Export

The demand for fuel supplied to aircraft (Japanese and non-Japanese) flying international routes and ships (Japanese and non-Japanese) that ply foreign ocean routes is termed as “bonded demand”. Jet fuel is supplied to aircraft while fuel oil is supplied to ships. Of these bonded demands, the fuel supplied from products that was produced from crude oil is counted as bonded export by *Yearbook of Mineral Resources and Petroleum Products Statistics*.

Bonded Import (Bond to Bond)

Fuel products that are imported from foreign countries, landed in a bonded area and supplied from the bonded area to bonded demand without going through domestic customs, is counted as bonded import by *Yearbook of Mineral Resources and Petroleum Products Statistics*.

3.2.3. Feedstocks and Non-Energy Use of Fuels (CRT Table 1.A(d))

The *General Energy Statistics* is used as the activity data for estimating GHG emissions from fuel combustion (1.A.). The Total energy consumption (#500000) in the statistics includes the amount of energy used as feedstocks without the combustion and oxidation process. The energy consumption in the category of Non-energy and feedstock use (#950000) represents such amount of energy. For the purpose of estimating the emissions, the consumption in the category of Non-energy and feedstock use was deducted from Total energy consumption.

The consumption in the category of Non-energy and feedstock use includes the following: (1) Consumption which can be confirmed as clearly non-energy uses by official statistics, such as surveys of feedstock inputs according to the *Yearbook of the Current Survey of Energy Consumption* (METI) which is the reference of the *General Energy Statistics*; and (2) Amount of products which are produced for the purpose of non-energy use from the beginning, such as lubricants and asphalt (bitumen). (However, the portion which is confirmed from official statistics such as the *Yearbook of the Current Survey of Energy Consumption* as having been employed for energy uses is treated as energy consumption and is excluded from non-energy use.)

The feedstocks and non-energy use of fuels are reported in “Fuel quantity for NEU” and “Carbon excluded” columns of the Common Reporting Table (CRT) table 1.A(d). The correspondence between fuels of the *General Energy Statistics* and those of the table is shown in Annex 3.

The CO_2 emissions from combustion or oxidation of the fuel used for non-energy purpose such as feedstock use of products in any process of manufacturing, use and abandonment of products are separately reported in other sectors shown in Table 3-9. (For detail, see each related chapter.) The emissions are reported in “Reported CO_2 emissions” column of the CRT table 1.A(d).

Among emissions from manufacturing processes of iron and steel and non-ferrous metals, emissions from fuel combustion should be reported in Energy sector (1.A) and emissions from reducing agent

should be reported in Industrial processes and product use sector (2.C). Both emissions are reported together in Energy sector (1.A), because Japan considers that it is the most appropriate to grasp all emissions from manufacturing processes of iron and steel, and non-ferrous metals comprehensively from the viewpoints of accuracy, and avoiding double-counting and omissions. Each manufacturing process and category is shown in Table 3-10.

Table 3-9 Allocation of CO_2 emissions from fuel used for non-energy purpose such as feedstock

CO_2 emitting process	CRT Category	Type of fuel used for non-energy purpose such as feedstock	Emission factors
Ammonia production	2.B.1	Naphtha (until FY2016)	Carbon emission factors: See Table 3-11 Calorific values: See Table 3-17
		Liquefied petroleum gas (LPG), (until FY2002)	
		Refinery gas (off-gas) (until FY2011)	
		Indigenous natural gas	
		Coal (steam coal, imports)	
		Petroleum coke	
		Liquefied natural gas (LNG)	
		Coke oven gas (COG) (until FY2001)	
Silicon carbide production	2.B.5.a	Petroleum coke	2.3 [t-CO_2/t] (per petroleum coke consumption amount)
Calcium carbide production	2.B.5.b	Coke	From reducing agent in production: 1.09 [t-CO_2/t] (confidential information in and after FY2008), from use: 1.10 [t-CO_2/t] (both EFs per calcium carbide production amount)
Titanium dioxide production	2.B.6	Petroleum coke, etc.	Rutile TiO_2: confidential information Synthetic rutile: 1.43 [t-CO_2/t] (per production amount)
Methanol production	2.B.8.a	Natural gas (until FY1995)	0.67 [t-CO_2/t] (per methanol production amount)
Ethylene production	2.B.8.b	Naphtha, LPG, etc.	Confidential information
Carbon black production	2.B.8.f	Coal tar, etc.	2.06 [t-CO_2/t] (per carbon black production amount)
Maleic anhydride production	2.B.8.g	LPG	1.65 [t-CO_2/t] (per maleic anhydride production amount made by oxidation of n-butane)
Hydrogen production	2.B.10.a	Natural gas, etc.	Report by member companies of the Japan Industrial and Medical Gases Association
Automobile and marine engine oils (excluding total loss type) [1)]	2.D.1	Lubricants	Carbon emission factors: See Table 3-11 Calorific values: See Table 3-17
Paraffin wax use	2.D.2	Bitumen	Carbon emission factors: See Table 3-11 Calorific values: See Table 3-17

Note:

1) CO_2 emissions from automobile and marine engine oils (total loss type) are included in Transport (1.A.3).

2) CO_2 emissions from fuel used for non-energy purpose may occur when fossil-fuel derived waste is incinerated or decomposed, and when fossil-fuel derived chemical products are used as feedstock to produce other chemical products. These CO_2 emissions are reported under the following categories: Other fossil fuels under Fuel combustion (1.A), the subcategories under Petrochemical and carbon black production (2.B.8) not specified in this table, NMVOC incineration (2.D.3.d.-), Urea used as a catalyst (2.D.3.d.-), Urea application (3.H), Incineration and open burning of waste (5.C), and Decomposition of fossil-fuel derived surfactants (5.E). However, This table and "Reported CO_2 emissions" column of CRT table 1.A(d) do not include these emissions in accordance with the *2006 IPCC Guidelines*, Vol.3, page 1.16.

Table 3-10 Reported category of CO_2 emissions from iron and steel and non-ferrous metals process

CO_2 emitting process	Main fuel used for non-energy purpose such as feedstock	Allocation as per IPCC Guidelines	Allocation used by the Party
Production of Steel and Pig iron	Coke, pulverized coal, waste plastics, coke oven gas, blast furnace gas	2.C.1	1.A.2.a (Iron and steel)
Sinter production	Coke	2.C.1	1.A.2.a (Iron and steel)
Pellet production	Coke	2.C.1	1.A.2.a (Iron and steel)
Ferroalloys production	Coke, steam coal	2.C.2	1.A.2.a (Iron and steel)
Aluminium production	Coke (Main ingredient in the anode paste)	2.C.3	1.A.2.f (Non-metallic minerals)
Lead production	Coke	2.C.5	1.A.2.b (Non-ferrous metals)
Zinc production	Coke	2.C.6	1.A.2.b (Non-ferrous metals)

3.2.4. CO_2 Emissions from Energy Industries (1.A.1: CO_2)

a) Category Description

This section provides the methods for estimating CO_2 emissions from public electricity and heat production (1.A.1.a), petroleum refining (1.A.1.b), and manufacture of solid fuels and other energy industries (1.A.1.c). In Japan, manufacture of solid fuels and other energy industries (1.A.1.c) includes city gas production as well as coke production.

In FY2024, CO_2 emissions from this category accounted for 404,753 kt-CO_2, and represented 38.7% of Japan's total GHG emissions (excluding LULUCF). Public electricity and heat production (1.A.1.a) accounts for 89.4% and is the largest subcategory in energy industries (1.A.1).

The CO_2 emissions from liquid fuels in Public electricity and heat production (1.A.1.a) has been on a long-term decreasing trend. In FY1970, about 60% of electricity was generated by oil (ANRE, 2022). However, since the Oil Crisis in 1970s, the oil consumption at the oil power plants has decreased because Japan has diversified electricity sources. The electricity generation by oil temporarily increased in FY2011 and 2012, since the operation of nuclear power plants was suspended due to the Great East Japan Earthquake in 2011. However, the share of oil to the total electricity generation became less than 10% in FY2015.

The CO_2 emissions from gaseous fuels in Manufacture of solid fuels and other energy industries (1.A.1.c) are considerably lower for 2019 and 2020 than the previous years. It is caused by the decrease in the activity data, mainly "own use" of "city gas conversion and production" under the *General Energy Statistics*. This was because a duplication was found since FY2019 between the city gas consumptions for power generation reported under the *Electric Power Statistics* and the amount of own use reported under the *Current Survey of Production Concerning Gas Industry*. The amount of the duplication was subtracted from own use of city gas conversion and production. The background that caused the duplication was that electricity companies can sell city gas as well as city gas companies can now sell electricity due to the liberalization of electricity retail since FY2016 and the liberalization of city gas retail since FY2017.

The IEFs (Implied Emission Factors)[7] of CO_2 emissions from solid fuels in Manufacture of solid fuels and other energy industries (1.A.1.c) have been pulled up and down by fluctuation of carbon balances

[7] Indicators obtained by dividing the emissions in the common reporting table (CRT) by the activity data in the CRT.

derived from the transformation of solid fuels by the manufacture of solid fuels. The apparent annual change of this category is caused by the mass-balance, energy-balance and carbon-balance between coking coal, coke and other coal products, and may be influenced by statistical error, unobserved stockpiles in the process and/or spontaneous input-output unbalance.

b) Methodological Issues

- ***Estimation Method***

The Tier 2 Sectoral Approach has been used in accordance with the decision tree of the *2006 IPCC Guidelines* to calculate emissions (Vol.2, Page 1.9, Fig. 1.2) because country-specific emission factors are available.

$$E = \sum_{ij} \left[(A_{ij} - N_{ij}) \times GCV_i \times 10^{-3} \times EF_i \times OF_i \right] \times 44/12 - C_{i,j}$$

E : CO_2 emissions from fossil fuel combustion [kt-CO_2]
A : Energy consumption (original unit [kt, 10^3 kL, 10^6 m^3])
N : Non-energy use of fossil fuels [kt, 10^3 kL, 10^6 m^3]
GCV : Gross calorific value [MJ/kg, MJ/L, MJ/m^3]
EF : Carbon content of the fuel [t-C/TJ]
OF : Oxidation factor
C : Amount captured
i : Type of fuel
j : Sector

Please refer to section 3.2.12. for the emissions from waste incineration with energy recovery.

The CO_2 emissions from biomass are not included in the national totals[8] but are reported in the CRTs as reference in accordance with the *2006 IPCC Guidelines*. In the *General Energy Statistics*, the consumptions of biofuels are included in those of gasoline and diesel oil, but the CO_2 emissions from biofuels are not considered as fossil fuel origin by adjusting the calorific value and the carbon emission factors of gasoline and diesel oil.

- ***Emission Factors***

➢ ***Carbon emission factors***

The carbon content of fuels expressed as the unit of gross calorific value (higher heating value) was used for carbon emission factors (CEF). The emission factors are mostly country-specific values.

The emission factors were developed based on three different concepts: (a) Energy sources other than Blast Furnace Gas (BFG) and City gas, (b) BFG, and (c) City gas.

Table 3-11 provides the emission factors for CO_2 by fuel types.

The CEFs for the residual and straight-run fuel oil for refinery use declined by 8.0% between 2012 and 2013, because the GCVs of the fuel increased by around 8.3% between 2012 and 2013 as a result of the survey conducted by METI and the Ministry of the Environment (MOE) on the GCVs and CEFs in FY2013 and FY2014 (see page 3-22). The crude oil for refinery use is major (99.9% of input volume to atmospheric distillation units in 2018), and the residual and straight-run fuel oil for refinery use is minor (0.1%) and it is not used for direct combustion.

[8] The reason that the CO_2 emissions from biomass are not included in the national totals is to avoid double counting with the CO_2 emissions resulting from carbon stock changes estimated in LULUCF sector. (See *2006 IPCC Guidelines*, Vol.2, Page 2.33.)

Table 3-11 Carbon emission factors for fuel combustion in gross calorific value (Unit: t-C/TJ)

Fuel	Code [1]	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Solid fuels (coal based fuels)													
Coal	$0100												
Steel making coal	$0110												
Coking coal [2]	$0111	24.5	24.5	24.5	24.5	24.5	24.4	24.4	24.5	24.5	24.5	24.5	24.5
Pulverized coal injection (PCI) coal	$0112	24.5	24.5	24.5	24.5	24.5	25.1	25.1	25.1	25.1	25.1	24.8	24.8
Imported steam coal	$0121												
Imported steam coal for general use	$0122	24.7	24.7	24.7	24.7	24.7	24.4	24.4	24.3	24.3	24.3	24.8	24.8
Imported steam coal for power generation use	$0123	24.7	24.7	24.7	24.7	24.7	24.4	24.4	24.3	24.3	24.3	24.8	24.8
Indigenous produced steam coal	$0124	24.9	24.9	24.9	24.9	24.9	23.7	23.7	24.2	24.2	24.2	24.2	24.2
Hard coal, anthracite & lignite [2]	$0130	25.5	25.5	25.5	25.5	25.5	25.9	25.9	25.9	25.9	25.9	26.4	26.4
Coal products	$0200												
Coke	$0211	29.4	29.4	29.4	29.4	29.4	30.2	30.2	29.9	29.9	29.9	29.7	29.7
Coal tar	$0212	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9
Coal briquette	$0213	29.4	29.4	29.4	29.4	29.4	25.9	25.9	25.9	25.9	25.9	25.9	25.9
Coke oven gas	$0221	11.0	11.0	11.0	11.0	11.0	10.9	10.9	10.9	10.9	10.9	10.8	10.8
Blast furnace gas	$0222	27.2	26.9	26.7	26.5	26.4	26.5	26.5	26.4	26.3	26.3	26.1	26.1
Converter furnace gas	$0225	38.4	38.4	38.4	38.4	38.4	41.7	41.7	42.0	42.0	42.0	41.9	41.9
Liquid fuels (oil based fuels)													
Crude oil	$0300												
Crude oil for refinery use	$0310												
Crude oil for refinery use	$0311	19.1	19.0	19.0	19.1	19.1	19.0	19.0	19.0	19.0	19.0	18.9	18.9
Residual and straight run fuel oil for refinery use [2]	$0312	21.3	21.4	21.4	21.4	21.4	19.7	19.5	19.3	19.3	19.1	19.1	19.1
Crude oil for power generation use	$0320	19.1	19.1	19.2	19.6	19.2	19.2	19.3	19.5	19.1	19.1	19.1	19.1
Bituminous mixture fuel [4]	$0321	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0
NGL/condensate [5]	$0330												
NGL/condensate for refinery use [2]	$0331	17.4	18.1	18.0	18.3	18.4	18.3	18.3	18.3	18.3	18.5	18.4	18.3
NGL/condensate for power generation use	$0332	17.5	17.6	17.6	18.2	17.9	18.2	18.2	18.2	18.2	18.2	18.2	18.2
NGL/condensate for petrochemical use	$0333	15.6	16.2	16.8	17.6	18.0	18.3	18.2	18.2	18.2	18.2	18.2	18.2
Oil products	$0400												
For material and feedstock	$0410												
Pure naphtha	$0420	18.2	18.2	18.2	18.2	18.2	18.6	18.6	18.6	18.6	18.6	18.6	18.6
Reformate	$0421	18.3	18.3	18.3	18.3	18.3	19.3	19.3	19.3	19.3	19.3	19.2	19.2
Fuel oil	$0430												
Gasoline (crude oil origin) [2]	$0431	18.3	18.3	18.3	18.3	18.3	18.7	18.7	18.7	18.7	18.7	18.7	18.7
Gasoline (biofuel blended) [3]		18.3	18.3	18.3	18.3	18.2	18.6	18.6	18.5	18.5	18.5	18.5	18.5
Jet fuel oil	$0432	18.3	18.3	18.3	18.3	18.3	18.6	18.6	18.6	18.6	18.6	18.6	18.6
Kerosene	$0433	18.5	18.5	18.5	18.5	18.5	18.7	18.7	18.7	18.7	18.7	18.7	18.7
Gas oil or diesel oil (crude oil origin) [2]	$0434	18.7	18.7	18.7	18.7	18.7	18.8	18.8	18.8	18.8	18.8	18.8	18.8
Gas oil or diesel oil (biofuel blended) [3]		18.7	18.7	18.7	18.7	18.7	18.8	18.8	18.8	18.8	18.8	18.8	18.8
Fuel oil A	$0436	18.9	18.9	18.9	18.9	18.9	19.3	19.3	19.3	19.3	19.3	19.2	19.2
Fuel oil B	$0438	19.2	19.2	19.2	19.2	19.2	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Fuel oil C for general use	$0439	19.5	19.5	19.5	19.5	19.5	20.2	20.2	20.2	20.2	20.2	20.0	20.0
Fuel oil C for power generation use	$0440	19.5	19.5	19.5	19.5	19.5	19.8	19.8	20.1	20.0	20.0	20.0	19.9
Miscellaneous oil products	$0450												
Lubricant oil	$0451	19.2	19.2	19.2	19.2	19.2	19.9	19.9	19.9	19.9	19.9	19.9	19.9
Other heavy oil products [6]	$0452	20.8	20.8	20.8	20.8	20.8	20.4	20.4	20.8	20.8	20.8	20.8	20.8
Oil coke	$0455	25.4	25.4	25.4	25.4	25.4	24.5	24.5	24.5	24.8	24.8	24.8	24.8
Galvanic furnace gas	$0456	38.4	38.4	38.4	38.4	38.4	41.7	41.7	42.0	42.0	42.0	41.9	41.9
Refinery gas	$0457	14.2	14.2	14.2	14.2	14.2	14.4	14.4	14.4	14.4	14.4	14.4	14.4
Liquefied petroleum gas (LPG)	$0458	16.5	16.5	16.5	16.5	16.5	16.4	16.4	16.3	16.3	16.3	16.3	16.3
Gaseous fuels (gas based fuels)													
Natural gas	$0500												
Liquefied natural gas (LNG)	$0510	13.9	13.9	13.9	13.9	14.0	14.0	14.0	13.9	13.9	13.9	13.8	13.8
Indigenous natural gas	$0520	13.9	13.9	13.9	13.9	13.9	14.0	14.0	13.9	13.9	13.9	13.9	13.9
Indigenous natural gas	$0521	13.9	13.9	13.9	13.9	13.9	14.0	14.0	13.9	13.9	13.9	13.9	13.9
Coal mining gas [2]	$0522	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5	13.5
Boil off gas from crude oil	$0523	13.9	13.9	13.9	13.9	13.9	14.0	14.0	13.9	13.9	13.9	13.9	13.9
City gas	$0600												
City gas (general gas)	$0610	14.4	14.4	14.2	14.1	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0
Small scale community gas	$0620	16.5	16.5	16.5	16.5	16.5	16.4	16.4	16.3	16.3	16.3	16.3	16.3
(Reference) Biomass	$N130												
Woods	$N131	30.2	30.2	30.2	30.9	30.9	29.6	29.6	29.6	29.6	29.6	29.6	29.6
Waste woods	$N132	30.2	30.2	30.2	30.9	30.9	29.6	29.6	29.6	29.6	29.6	29.6	29.6
Bioethanol	$N134	17.2	17.2	17.2	17.2	17.2	17.6	17.6	17.6	17.6	17.6	17.6	17.6
Biodiesel	$N135	17.2	17.2	17.2	17.2	17.2	17.6	17.6	17.6	17.6	17.6	17.6	17.6
Thermal use of black liquor	$N136	26.8	26.8	26.8	25.6	25.6	24.9	24.9	24.9	24.9	24.9	24.9	24.9
Gas biomass	$N137	12.4	12.4	12.4	12.4	12.4	13.5	13.5	13.5	13.5	13.5	13.5	13.5

1) Code number for fuels of the *General Energy Statistics* (Japan's Energy Balance Tables)
2) Used in the reference approach.
3) Used in the sectoral approach.
4) Orimulsion
5) NGL: Natural gas liquids
6) Include asphalt, grease and paraffin wax.

Table 3-12 References and methodologies of carbon emission factors for fuel combustion

Fuel	Code	References and methodologies
Coking coal	\$0111	FY1990-2012: Kainou (2005) FY2013-2017: Simple average of CEFs obtained from actual measurements provided by JISF FY2018-2022: Updated with the same method as the previous survey FY2023 onward: Weighted average of CEFs using receipts. The CEFs were obtained from actual measurements provided by JISF
Pulverized coal injection (PCI) coal	\$0112	FY1990-2012: Value of Coking coal (\$0111) FY2013-2017: Simple average of CEFs obtained from actual measurements provided by JISF FY2018-2022: Updated with the same method as the previous survey FY2023 onward: Weighted average of CEFs using receipts. The CEFs were obtained from actual measurements provided by JISF.
Imported steam coal	\$0121	FY1990-2012: Environmental Agency (1992) FY2013-2017: Weighted average of CEFs using receipts. The CEFs were estimated from actual measurements provided by power generation operators. FY2018-2022: Updated with the same method as the previous survey FY2023 onward: Updated with the same method as the previous survey
Indigenous produced steam coal	\$0124	FY1990-2012: Environmental Agency (1992) FY2013-2017: Weighted average of CEFs using receipts. The CEFs were estimated from actual measurements provided by power generation operators. FY2018 onward: Updated with the same method as the previous survey
Hard coal, anthracite & lignite	\$0130	FY1990-2012: Kainou (2005) FY2013-2022: Estimated by interpolating by the approximate equation of imported steam coal (Kainou, 2014) FY2023 onward: Estimated by interpolating by the updated approximate equation of imported steam coal
Coke	\$0211	FY1990-2012: Environmental Agency (1992) FY2013-2017: Simple average of CEFs obtained from actual measurements provided by JISF FY2018-2022: Updated with the same method as the previous survey FY2023 onward: Weighted average of CEFs using receipts. The CEFs were obtained from actual measurements provided by JISF.
Coal tar	\$0212	Kainou (2005)
Coal briquette	\$0213	FY1990-2012: Environmental Agency (1992) FY2013 onward: The FY2013 value of Hard coal, anthracite & lignite (\$0130)
Coke oven gas	\$0221	FY1990-2012: Kainou (2005) FY2013-2017: Simple average of CEFs estimated from actual measurements provided by JISF FY2018-2022: Updated with the same method as the previous survey FY2023 onward: Updated with the same method as the previous survey
Blast furnace gas	\$0222	Estimated annually from the carbon balance in blast furnaces and converter furnaces in the *General Energy Statistics*
Converter furnace gas	\$0225	FY1990-2012: Kainou (2005) FY2013-2017: Simple average of CEFs estimated from actual measurements provided by JISF FY2018-2022: Updated with the same method as the previous survey FY2023 onward: Updated with the same method as the previous survey

Table 3-12 References and methodologies of carbon emission factors for fuel combustion (continued)

Fuel	Code	References and methodologies
Crude oil for refinery use	\$0310	FY1990-2022: Weighted average of brand-specific CEFs based on imports by brand for each FY. The brand-specific CEFs were estimated by the approximate equation of crude oil (Kainou, 2014) based on brand-specific GCV obtained from actual measurements provided by oil refining operators. FY2023 onward: Weighted average of brand-specific CEFs based on imports by brand for each FY. The brand-specific CEFs were estimated by the approximate equation of crude oil (Kainou, 2014) based on density and sulfur content from the *Oil Import Survey* (ANRE).
Crude oil for power generation use	\$0320	FY1990-2017: Weighted average of monthly CEFs using monthly receipts. The monthly CEFs were estimated by the approximate equation of crude oil (Kainou, 2014) using GCV from *Electric Power Statistics* (ANRE). FY2018 onward: Weighted average of brand-specific CEFs obtained in the survey for the FY2013 values using annual imports for electricity generation.
Bituminous mixture fuel	\$0321	Kainou (2005)
NGL/condensate	\$0330	The same method as Crude oil for refinery use (\$0310)
Pure naphtha	\$0420	FY1990-2012: Environmental Agency (1992) FY2013-2022: Value of regular gasoline, which is simple average of CEFs obtained from actual measurements provided by oil refining operators FY2023 onward: Weighted average of refinery-specific CEFs of regular gasoline using production amount of regular gasoline by oil refinery. The CEFs of each gasoline were obtained from actual measurements provided by oil refining operators.
Reformate	\$0421	FY1990-2012: Values of Gasoline (crude oil origin) (\$0431) FY2013-2022: Value of premium gasoline, which is simple average of CEFs obtained from actual measurements provided by oil refining operators FY2023 onward: Weighted average of refinery-specific CEFs of premium gasoline using production amount of premium gasoline by oil refinery. The CEFs of each gasoline were obtained from actual measurements provided by oil refining operators.
Gasoline (crude oil origin)	\$0431	FY1990-2012: Environmental Agency (1992) FY2013-2022: Weighted average of CEFs of regular and premium gasoline using domestic shipments by type. The CEFs of each gasoline were obtained from actual measurements provided by oil refining operators. FY2023 onward: Updated with the same method as the previous survey
Gasoline (biofuel blended)	\$0431	Weighted average of CEFs of crude oil origin and biomass origin based on the share of domestic consumption for each FY
Jet fuel oil	\$0432	FY1990-2012: Environmental Agency (1992) FY2013-2022: Weighted average of CEFs of kerosene type jet fuel and gasoline type jet fuel using the final consumptions by type for each FY in the *General Energy Statistics*. The CEFs of each type were obtained from actual measurements provided by oil refining operators. FY2023 onward: Weighted average of CEFs of kerosene type jet fuel and gasoline type jet fuel using the final consumptions by type for each FY in the *General Energy Statistics*. The CEFs of kerosene type jet fuel were obtained from actual measurements provided by oil refining operators. The CEFs of gasoline type jet fuel were the existing value.
Kerosene	\$0433	FY1990-2012: Environmental Agency (1992) FY2013-2022: Simple average of CEFs obtained from actual measurements provided by oil refining operators FY2023 onward: Weighted average of refinery-specific CEFs using production amount by oil refinery. The CEFs of each refinery were obtained from actual measurements provided by oil refining operators.
Gas oil or diesel oil (crude oil origin)	\$0434	FY1990-2012: Environmental Agency (1992) FY2013-2022: Simple average of CEFs obtained from actual measurements provided by oil refining operators FY2023 onward: Weighted average of refinery-specific CEFs using production amount by oil refinery. The CEFs of each refinery were obtained from actual measurements provided by oil refining operators.
Gas oil or diesel oil (biofuel blended)	\$0434	Weighted average of CEFs of crude oil origin and biomass origin based on the share of domestic consumption for each FY

Table 3-12 References and methodologies of carbon emission factors for fuel combustion (continued)

Fuel	Code	References and methodologies
Fuel oil A	$0436	FY1990-2012: Environmental Agency (1992) FY2013-2022: Simple average of CEFs obtained from actual measurements provided by oil refining operators FY2023 onward: Weighted average of refinery-specific CEFs using production amount by oil refinery. The CEFs of each refinery were obtained from actual measurements provided by oil refining operators.
Fuel oil B	$0438	FY1990-2012: Environmental Agency (1992) FY2013 onward: Estimated by interpolating by approximate equation of oil products using GCV obtained from actual measurements provided by oil refining operators
Fuel oil C for general use	$0439	FY1990-2012: Environmental Agency (1992) FY2013-2022: Simple average of CEFs obtained from actual measurements provided by oil refining operators FY2023 onward: Weighted average of refinery-specific CEFs using production amount by oil refinery. The CEFs of each refinery were obtained from actual measurements provided by oil refining operators.
Fuel oil C for power generation use	$0440	FY1990-2012: Environmental Agency (1992) FY2013-2017: Estimated by the approximate equation of oil products (Kainou, 2014) using GCV from *Electric Power Statistics* (ANRE) FY2018 onward: Estimated annually by the approximate equation of oil products (Kainou, 2014) using GCV for each FY from *Electric Power Statistics* (ANRE)
Lubricant oil	$0451	FY1990-2012: Environmental Agency (1992) FY2013 onward: Estimated by interpolating by the approximate equation of oil products (Kainou, 2014) based on GCV obtained from actual measurements provided by oil refining operators
Other heavy oil products	$0452	FY1990-2012: Environmental Agency (1992) FY2013-2017: Estimated by interpolating by the approximate equation of oil products (Kainou, 2014) based on GCV estimated from energy balance of slack fuel oil input and fuel oil C output FY2018-2022: Updated with the same method as the previous survey FY2023 onward: Updated with the same method as the previous survey
Petroleum coke	$0455	FY1990-2012: Environmental Agency (1992) FY2013-2020: Simple average of CEFs obtained from actual measurements provided by JCIA FY2021 onward: Weighted average of CEFs using receipts. Each CEF was obtained from actual measurements provided by cement operators and chemical operators.
Galvanic furnace gas	$0456	Values of Converter furnace gas ($0225)
Refinery gas	$0457	FY1990-2012: Environmental Agency (1992) FY2013-2022: Simple average of CEFs estimated from actual measurements provided by oil refining operators FY2023 onward: Weighted average of refinery-specific CEFs using production amount by oil refinery. The CEFs of each refinery were obtained from actual measurements provided by oil refining operators.
Liquefied petroleum gas (LPG)	$0458	FY1990-2012: Weighted average of theoretical CEFs of propane and butane based on the share of these matters in indigenous production and imports of the fuel for each FY FY2013-2022: Weighted average of theoretical CEFs of propane and butane using domestic supply amount of each gas for each FY FY2018 onward: Weighted average of updated theoretical CEFs of propane and butane using domestic supply amount of each gas for each FY

Table 3-12 References and methodologies of carbon emission factors for fuel combustion (continued)

Fuel	Code	References and methodologies
Liquefied natural gas (LNG)	\$0510	FY1990-2012: Weighted average of CEFs by production area based on the share of imports by country for each FY FY2013-2017: Weighted average of CEFs by production area using imports by country for each FY. The CEFs by production area were estimated from *Gas Industry Handbook* (JGA). FY2018-2022: Weighted average of CEFs by production area using imports by country for each FY. The CEFs by production area were estimated from actual measurements provided by power generation operators and city gas operators. FY2023 onward: Updated with the same method as the previous survey
Indigenous natural gas	\$0520	FY1990-2012: Kainou (2005) FY2013-2017: Weighted average of CEFs by gas field using productions by gas field. The CEFs by gas field were estimated from actual measurements provided by domestic natural gas production operators. FY2018-2022: Updated with the same method as the previous survey FY2023 onward: Updated with the same method as the previous survey
Indigenous natural gas	\$0521	Values of Indigenous natural gas (\$0520)
Coal mining gas	\$0522	FY1990-2012: Environmental Agency (1992) FY2013 onward: CEF of natural gas from water-soluble gas fields, which was estimated from actual measurements provided by domestic natural gas production operators.
Boil off gas from crude oil	\$0523	Values of Indigenous natural gas (\$0520)
City gas (general gas)	\$0610	Estimated annually from the carbon balance of "city gas conversion and production" in the *General Energy Statistics*
Small scale community gas	\$0620	Values of Liquefied petroleum gas (\$0458)
Woods	\$N131	Values of Waste woods (\$N132)
Waste woods	\$N132	Carbon content obtained by actual measurements provided by JPA was divided by the standard GCVs
Bioethanol	\$N134	FY1990-2012: Theoretical CEF of ethanol in normal condition FY2013 onward: Theoretical CEF of ethanol in SATP condition
Biodiesel	\$N135	Values of Bioethanol (\$N134)
Thermal use of black liquor	\$N136	Carbon content obtained by actual measurements provided by JPA was divided by the standard GCVs
Gas biomass	\$N137	FY1990-2012: Theoretical CEF of methane in normal condition FY2013 onward: Theoretical CEF of methane in SATP condition

Note:
FEPC: Federation of Electric Power Companies of Japan, JCIA: Japan Chemical Industry Association, JGA: Japan Gas Association,
JISF: Japan Iron and Steel Federation, JNGA: Japan Natural Gas Association, JPA: Japan Paper Association,
PAJ: Petroleum Association of Japan, SATP: Standard ambient temperature and pressure

(a) Energy sources other than Blast Furnace Gas (BFG) and City gas

The carbon emission factors (CEFs) of energy sources other than blast furnace gas (BFG) and city gas were established based on Environmental Agency (1992), Ministry of the Environment (2002a), Kainou (2005, 2014, 2015), and Agency for Natural Resources and Energy (2020, 2025).

- ***Methodological issues of carbon emission factors from FY1990 to FY2012***

The results of the evaluation conducted in 2005 were adopted for setting CEFs (Kainou, 2005). An adequacy assessment was conducted to the CEFs in Environmental Agency (1992), which were used in the inventories submitted up to 2005. These were assessed based on the following three criteria. The values assessed as adequate continue to be used in this inventory.

1) Evaluation and analysis by comparison of theoretical upper and lower limits

The validity of CEFs is evaluated by comparing the intended emission factor and the emission factor calculated theoretically from standard enthalpy change of the formation of pure matter, such as hydrogen,

methane and carbon monoxide, because most of the fuels for which CEFs are required to be evaluated are hydrocarbons containing a few impurities, and because a physicochemical correspondence exists between the GCVs of pure hydrocarbons and CEFs.

2) Evaluation and analysis by comparison with the *Revised 1996 IPCC Guidelines* default values

The validity of CEFs is judged by using the *Revised 1996 IPCC Guidelines* default values or the *2006 IPCC Guidelines* reference values[9] and their statistical reliability (uncertainty) information. However, because the average properties of fuels envisaged in the IPCC Guidelines and those of the fuels used in Japan are not necessarily the same, CEFs can be evaluated based on the statistical examination of the group evaluation and analysis mentioned below even when figures deviate, as long as a valid reason for the deviation exists.

3) Group evaluation and analysis by carbon balance using the *General Energy Statistics*

The validity of CEFs for some fuels in oil products and coal products can be evaluated as a group using the *General Energy Statistics* to analyze the carbon balance in the sectors of manufacture of oil products and coal products.

With regard to those judged there is no validity, the values shown in Ministry of the Environment (2002a) and *2006 IPCC Guidelines* were compared and verified, and values considered valid were used.

After that, during the process of establishing the CEFs for the period of FY2013-2017, the estimation method for that period was also applied to FY1990-2012 for crude oil, NGL/condensate, LPG, LNG and small-scale community gas because it contributed to the improvement of energy and carbon balance of the oil refinery sector under the *General Energy Statistics* and other improvement. (Kainou, 2015)

- ***Methodological issues of carbon emission factors from FY2013 to FY2017***

The values through the survey conducted by METI and MOE on the calorific values (CVs) and carbon emission factors (CEFs) in FY2013 and FY2014 were adopted. The outline is described below.

1) Outline of the Survey

The METI and MOE collected the data such as physical properties of various energy sources that relevant industrial associations had, and conducted the survey on the actual measurements of physical properties of samples provided by relevant industrial associations and relevant companies in FY2013 and FY2014. The CVs and CEFs from FY2013 were established using the methodologies presented in Kainou (2014) based on the physical properties of various energy sources obtained from the survey.

2) Basic Methodology of Estimation of Carbon Emission Factors

The CVs and CEFs by energy source were established, based on the properties and priority in accuracy of various energy sources, by the following methods: (1) estimation from theoretical values; (2) estimation from the actual measurements provided by the relevant industrial associations and the actual measurements by the METI and MOE; (3) estimation from the values of major energy sources, and from the weighted average and/or regression analysis using those values; (4) continuous use of the existing values.

The estimation methods of the CVs and CEFs of solid, liquid and gaseous fuels based on the theoretical

[9] When Kainou (2005) was submitted, the *2006 IPCC Guidelines* had not been published yet. These values were reference values, and some of these reference values were revised.

values and the actual measurements (corresponding to the methods (1) and (2)) are as follows:

Gaseous fuels
In the cases where component composition can be measured by such techniques as gas chromatography in some energy sources like gaseous fuels, CVs and CEFs are derived by weighted average of those of pure matters by composition. Theoretical CVs and CEFs of pure matters such as methane and propane are estimated from physical properties like standard enthalpy change of the formation.

Solid and liquid fuels
In the cases where energy sources are solid fuels or liquid fuels that the weighted average by pure matters are not feasible, CVs and carbon contents are estimated by statistical treatment of the actual measurements of physical properties such as gross calorific values and carbon contents.

The method (3) is that the CVs and CEFs of subject energy sources are estimated by interpolating by the approximate equations. The equations were established based on the actual measurements of steam coal, crude oil and oil products, and they can estimate CVs and CEFs from the physical properties such as density and water content.

3) Quality Control

The CVs and CEFs estimated above were compared with the current values and the default values of the *2006 IPCC Guidelines*, and then the validity is confirmed.

- ***Methodological issues of carbon emission factors from FY2018 to FY2022***

The CEFs from FY2018 to FY2022 were established in combination of the CVs, based on the survey conducted by METI and MOE on the CVs and CEFs in FY2017 through FY2019. The fuels to be revised were selected, considering that the major revision of the CVs and CEFs has already been done in FY2013, the composition of some fuels does not significantly change during five years or so, the balance between cost and workload of the measurements and impact on emissions.

The CVs and CEFs were established basically by the following methods: (1) They were established in place of the current values using the data provided by industry organizations and companies; (2) They were established in place of the current values using the existing statistics and references, the estimation equations, and other means; (3) The existing values were used continuously. For (1) and (2), Kainou (2014) was referred to if the same estimation methodologies and references were adopted as in FY2013 values.

The CVs and CEFs estimated above were compared with the FY2013 values and the default values of the *2006 IPCC Guidelines* to evaluate the validity. In addition, the balance of energy and carbon in the coal products manufacturing and petroleum product manufacturing categories was confirmed: the output did not exceed the input due to the establishment of the CV and CEF described above.

- ***Methodological issues of carbon emission factors from FY2023 onward***

The CEFs from FY2023 onward were established in combination of the CVs, based on the survey conducted by METI and MOE on the CVs and CEFs in FY2022 through FY2024. The fuels to be revised were selected, considering the balance between cost and workload of the measurements and impact on emissions. The CVs and CEFs were established in principle by the same estimation methodologies as the previous revision.

(b) Blast Furnace Gas (BFG)

During the iron and steel production process, in the blast furnace and converter furnace, the amount of energy and carbon contained in coke and Pulverized Coal Injection (PCI) coal which are injected to the processes and those contained in BFG and Converter Furnace Gas (CFG, or Linz-Donawitz converter gas (LDG)) which are calculated should be theoretically balanced. Since the composition of BFG is unstable, the emission factors for BFG were established with annually calculated values in order to keep the carbon balance in the blast furnace and converter furnace during the iron and steel production process.

The amount of carbon (excluding the carbon contained in CFG from the carbon contained in 'Coke' and 'PCI coal') injected to the blast furnace indicated under 'Steel process gas' is considered to be carbon contained in BFG. The emission factor for BFG was established as the carbon described above divided by the calorific value of the BFG generated. The equation for the emission factor, the overview of the carbon flow for iron and steel and the calculation process are shown below.

The calculation to establish the emission factor for BFG is conducted every year.

$$EF_{BFG} = [(A_{coal} \times EF_{coal} + A_{coke} \times EF_{coke}) - A_{CFG} \times EF_{CFG}] / A_{BFG}$$

EF	: Carbon emission factor [t-C/TJ]
A	: Fuel consumption [TJ]
BFG	: Blast Furnace Gas
coal	: PCI coal
coke	: Coke
CFG	: Converter Furnace Gas

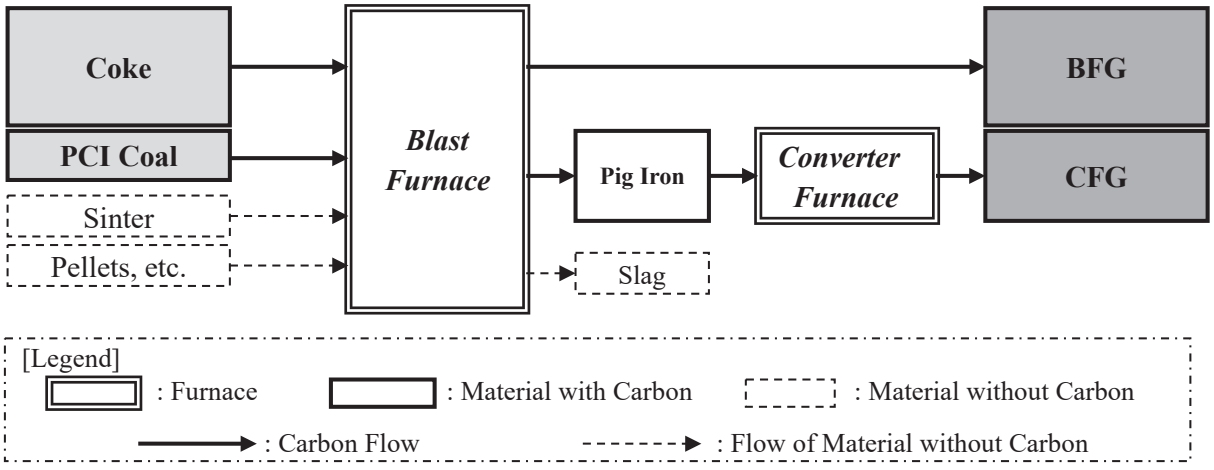

Figure 3-3 Overview of carbon flow for iron & steel manufacturing

Table 3-13 Calculation process of emission factors for BFG

Steel process gas		1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024	Note
Input														
PCI coal	kt-C	1,650	2,619	3,351	3,014	3,444	4,401	4,180	2,965	4,035	3,491	3,528	3,456	A
Coke	kt-C	12,739	11,400	12,221	11,497	11,194	10,870	10,270	7,833	8,757	7,899	7,497	7,017	B
Input total	kt-C	14,389	14,019	15,572	14,511	14,637	15,271	14,449	10,799	12,792	11,390	11,024	10,473	C: A + B
Output														
CFG (LDG)	kt-C	2,541	2,359	2,726	2,804	2,798	2,955	2,778	2,066	2,309	2,113	1,899	1,805	D
Difference	kt-C	11,848	11,660	12,846	11,707	11,839	12,316	11,671	8,733	10,483	9,277	9,126	8,668	E: C - D
Output														
BFG	PJ	434.8	433.5	481.8	441.4	448.7	464.5	440.1	331.1	398.9	353.1	349.4	332.6	F
EF BFG	t-C/TJ	27.2	26.9	26.7	26.5	26.4	26.5	26.5	26.4	26.3	26.3	26.1	26.1	E / F

(c) City gas

"City gas" consists of "city gas" (general gas) provided by gas retailers, general gas pipeline companies, and specified gas pipeline companies (former general gas suppliers, etc.) and "small-scale community gas" provided by gas retailers that generate gas in specified gas generation facilities and supply it through conduits (former small-scale community gas suppliers).

Small-scale community gas:
Because most of the small-scale community gas is LPG, the same emission factor was adopted as for LPG.

General gas:
City gas (general gas) is produced from a mixture of raw materials and air dilution. In order to calculate the city gas emission factors, the total carbon contained in fossil fuel used as raw materials was divided by the total calorific value of the produced city gas. The emission factors for city gas were established based on the carbon balance in "city gas production". To calculate the city gas emission factors, the total carbon in fossil fuel inputs used as raw materials (COG, Kerosene, Refinery gas, LPG, LNG and Indigenous natural gas) was divided by the total calorific value of the city gas production.

The calculation to establish the emission factor for city gas is conducted every year.

$$EF_{CG} = \sum_i (A_i \times EF_i) / P_{CG}$$

EF : Carbon emission factor [t-C/TJ]
A : Fuel consumption [TJ]
P : Calorific value of the city gas production [TJ]
CG : City gas (general gas)
i : Feedstocks (COG, Kerosene, Refinery gas, LPG, LNG, Indigenous natural gas)

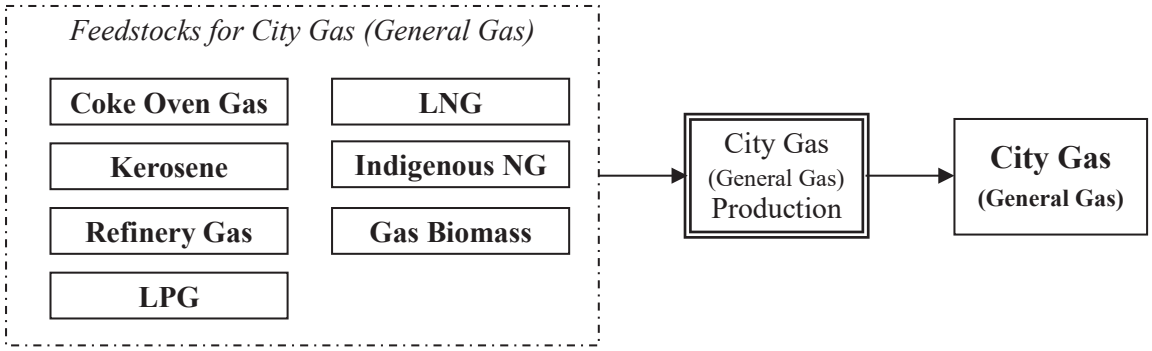

Figure 3-4 Manufacturing flow for city gas (general gas)

Table 3-14 Calculation process of emission factors for city gas (general gas)

City gas (general gas)		1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024	Note
Input														
COG	kt-C	211	134	105	22	0	0	0	0	0	0	0	0	a1
Kerosene	kt-C	200	275	69	6	0	0	0	0	0	0	0	0	a2
Refinery gas	kt-C	186	199	186	145	89	67	37	81	83	87	74	90	a3
LPG	kt-C	1,957	2,129	1,809	1,092	786	930	818	932	1,108	1,350	1,269	1,187	a4
LNG	kt-C	6,473	9,429	12,051	17,146	21,357	21,709	21,868	21,239	22,085	21,241	20,374	20,340	a5
Indigenous NG	kt-C	551	661	848	1,190	1,603	1,498	1,435	991	950	854	842	815	a6
Input total	kt-C	9,577	12,827	15,068	19,601	23,834	24,205	24,159	23,243	24,226	23,531	22,558	22,433	A: Σa
Output														
City gas	PJ	664.7	892.3	1,061.1	1,392.0	1,700.3	1,724.3	1,722.1	1,664.7	1,732.9	1,678.5	1,612.6	1,604.4	B
EF City gas	t-C/TJ	14.4	14.4	14.2	14.1	14.0	14.0	14.0	14.0	14.0	14.0	14.0	14.0	A/B

- ***Oxidation factor***

For each type of energy, country-specific oxidation factors were established considering the actual conditions of fuel combustion in Japan based on survey on related industrial associations, manufacturing corporations and experts.

Gaseous Fuels

Every measurement result of soot concentration of boilers to generate power by the Federation for Electric Power Companies Japan (FEPC) in 2004 for gaseous fuels combustion showed that no soot was emitted; therefore, it is assumed that gaseous fuels are completely combusted. The results of questionnaires also showed that gaseous fuels were completely combusted. Hence, the oxidation factor for gaseous fuel combustion was set to 1.0.

Liquid Fuels

The carbon contained in liquid fuels is considered to be almost completely combusted; however, unburned fuel loss, about 0.5%, may occur depending on its fired condition. Because data of actual measurements were not available, considering meticulous combustion management and smoke treatment in Japan, the oxidation factor for liquid fuels combustion was set to 1.0.

Solid Fuels

The oxidation factor for solid fuels varies depending on the fired condition, type of furnace, and coal property; therefore, it is quite difficult to obtain a representational data set of actual measurements of unburned fuel loss. Meanwhile, almost all the unburned carbon generated during combustion in furnace is considered to be contained in coal ash. Coal ash is effectively utilized or landfilled. Carbon contained in coal ash which is used as raw material of cement is oxidized to CO_2 and emitted into the atmosphere during the calcinations process.

The average oxidation factor from 1990 to 2003 considering unburned carbon oxidized in the firing process of coal ash was 0.996, expressed as 3 digits. Usually 2 digits are considered to be adequate in the view of other coefficients' accuracy; therefore, the oxidation factor for solid fuels was set to 1.0 rounded off to two digits.

- ***Activity Data***

The fuel consumption data given in the *General Energy Statistics* (Japan's energy balance tables) were used for the activity data. Table 3-15 shows the trend of energy consumption.

Table 3-15 Energy consumptions in Energy Industries (1.A.1) (unit: PJ)

Fuel	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Liquid fuels	2,596	2,198	1,618	1,669	1,352	1,866	1,312	675	781	784	645	582
Solid fuels	1,235	1,542	1,951	2,586	2,757	3,121	3,038	2,752	2,899	2,878	2,699	2,765
Gaseous fuels	1,564	1,786	2,167	2,021	2,624	3,488	3,300	2,925	2,642	2,500	2,428	2,310
Other fossil fuels	IE	IE	0	5	5	0	1	1	1	1	2	2
Biomass	0	0	0	26	28	31	32	156	186	202	230	230
Total	5,395	5,526	5,737	6,308	6,767	8,506	7,683	6,510	6,508	6,365	6,005	5,889

Note: Fuel type is in accordance with the Common Reporting Table (CRT).

Please refer to Annex 3 (A3.2) for the objectives, overview, and the simplified energy balance tables of the *General Energy Statistics*.

The activity data for energy industries (1.A.1) include the data reported in the following sectors under the "energy transformation and own use" [#200000] in the *General Energy Statistics*: "manufacture of coal products" [#210000]; "oil products" [#220000]; "gas conversion and production" [#230000]; "power generation" [#240000]; "heat supply" [#270000]; "own use" [#301000]. "Power generation" reports energy consumption associated with electric power generation by electric power suppliers; "heat supply" provides energy consumption associated with heat energy and cold energy by thermal energy suppliers and electric power suppliers; "own use" reports energy consumption associated with captive (own) use of energy industries. "Other energy transformation" [#280000] and "transformation and consumption stockpile change" [#350000] are not subject to the activity data.

The category "manufacture of coal products" [#210000] corresponds to the balance between input amount of feedstock and output amount of coal products under coke manufacturing process. The difference between the coke-making carbon input and carbon output is considered to be the portion that is oxidized in the atmosphere (burned) from the time that red-hot coke is extruded from a coke oven until it enters the coke dry quenching facility. It was considered appropriate to count this as CO_2 emissions, and it was calculated as carbon emissions from this category.

The category "oil products" [#220000] corresponds to the balance between input amount of feedstock and output amount of oil products under oil refining process. The difference between the carbon input and carbon output is considered to be the burned carbon precipitated on catalysts in fluid catalytic cracking facilities (so-called FCC coke). The burning is aimed at recovering the catalytic activities lowered by the cracking reaction of slack fuel oil. The difference is also considered to be heat recovery at boilers of the off-gas, mainly consisting of carbon monoxide, generated in the fluid catalytic cracking facilities. The difference is also regarded as CO_2 as by-product of hydrogen generating facilities. It was considered appropriate to count the difference as CO_2 emissions, and it was calculated as carbon

emissions from this category.

The *2006 IPCC Guidelines* require CO_2 emitted from auto power generation, etc., to be counted in the corresponding sector. In the *General Energy Statistics*, fuel consumption used for auto power generation and auto steam generation are presented under “auto power generation” [#250000] and “auto steam generation” [#260000] in the “energy transformation and own use” sector. These categories have breakdowns by industry, and most of auto power generation and auto steam generation actually belong to manufacturing industries, but some belong to other industries. Hence, fossil fuel consumption from “auto power generation” and “auto steam generation” are allocated to the activity data of “Energy industries” (1.A.1), “Manufacturing industries and construction” (1.A.2), or “Other sectors” (1.A.4) according to the industry breakdowns.

The fossil fuel consumption of “Auto power production” in “production, transmission and distribution of electricity” [#255330] is included in the “Energy industries” (1.A.1) from FY1990 to FY2015, and “Other sectors” (1.A.4) since FY2016. This is because electricity utilities whose main business is power generation should be included in public electricity and heat production (1.A.1.a) in accordance with the *2006 IPCC Guidelines*, and “production, transmission and distribution of electricity” until FY2015 includes independent power producers (IPP) whose main business is power generation. Since the definition and coverage of the sector of “Electric Utilities” was changed due to the enforcement of the revised Electricity Business Act, which stipulates the full liberalization of the electricity retail market in April 2016, electricity utilities whose main business is power generation such as IPP from FY2016 onwards are included in not “production, transmission and distribution of electricity” [#255330] but “power generation” [#240000].

Table 3-16 shows the correspondence between the sectors of Japan’s Energy Balance Tables from the *General Energy Statistics* and those of the CRT.

Table 3-16 Correspondence between sectors of Japan’s Energy Balance Tables and those of the CRT (1.A.1)

CRT			General Energy Statistics	
1.A.1	Energy industries			
	1.A.1.a	Public electricity and heat production	Public power generation	#240000
			Own use; Public power generation	#301400
			Heat supply	#270000
			Own use; Heat supply	#301500
			Auto power generation; Production, transmission and distribution of electricity (until FY2015)	#255330
	1.A.1.b	Petroleum refining	Oil products	#220000
			Own use; Oil products	#301200
			Auto power generation; Manufacture of petroleum products	#253171
			Auto steam generation, Manufacture of petroleum products	#263171
			Final energy consumption, Manufacture of petroleum products	#626510
			Non-energy and feedstock use; Manufacture of petroleum products	#951540
	1.A.1.c	Manufacture of solid fuels and other energy industries	Manufacture of coal products	#210000
			Own use; Coal products	#301100
			Auto power generation; Manufacture of coal products, miscellaneous	#253175
			Auto steam generation, Manufacture of coal products, miscellaneous	#263175
			Final energy consumption; Manufacture of coal products, miscellaneous	#626550
			Gas conversion and production	#230000
			Own use; Gas conversion and production	#301300

Note: #95xxxx items are subtracted as non-energy use activities.

- ***Gross calorific values***

The gross calorific values (GCV) used in *General Energy Statistics* are adopted. Table 3-17 shows the trends in GCV for each fuel type. *General Energy Statistics* adopts "actual calorific values" calculated based on annual official statistics for some fuel types which can be recalculated. For other fuel types

which cannot be recalculated and whose composition is stable, "standard calorific values" based on latest measurement data available at the time, relevant official statistics and documents are adopted.

The "standard calorific values" are revised approximately once in every 5 years. The revision was conducted to the values of FY2000, 2005, 2013, 2018 and 2023.

The GCV trends for solid fuels are declining since 1990. From 1970 to 1990, Japanese steel manufacturers used conventional coking coal for feedstock for coke, but due to the shortage of coking coal and the increase of price, they developed a new coke making technology to use steam coal with pre-treatment as feedstock for coke instead. Similarly, they changed PCI coal from coking coal and steam coal mixture to steam coal with pre-treatment. The Japanese steel manufacturers have been trying to make high-quality coke from cheap coal for economic reasons. Because conventional coking coal has a higher carbon content and GCV than steam coal, and because the new technology was introduced gradually, the apparent GCV gradually decreased in these years.

Table 3-17 Trends in gross calorific value of each fuel type

Fuel	Code	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Solid fuels (coal based fuels)														
Coal	$0100													
Steel making coal	$0110													
Coking coal	$0111	MJ/kg	31.8	30.5	29.1	29.1	29.1	28.9	28.9	28.9	28.9	28.9	28.8	28.8
Pulverized coal injection (PCI) coal	$0112	MJ/kg	31.8	30.5	28.2	28.2	28.2	28.0	28.0	28.3	28.3	28.3	29.1	29.1
Imported steam coal	$0121													
Imported steam coal for general use	$0122	MJ/kg	26.0	26.0	26.6	25.7	25.7	26.0	26.0	26.1	26.1	26.1	25.9	25.9
Imported steam coal for power generation use	$0123	MJ/kg	24.9	26.1	26.4	25.5	25.3	26.0	25.3	24.4	24.8	24.7	24.9	24.9
Indigenous produced steam coal	$0124	MJ/kg	24.3	24.3	22.5	22.5	22.5	25.3	25.3	24.2	24.2	24.2	24.2	24.2
Hard coal, anthracite & lignite	$0130	MJ/kg	27.2	27.2	27.2	26.9	26.9	27.8	27.8	27.8	27.8	27.8	26.6	26.6
Coal Products	$0200													
Coke	$0211	MJ/kg	30.1	30.1	30.1	29.4	29.4	29.2	29.2	29.0	29.0	29.0	29.4	29.4
Coal tar	$0212	MJ/kg	37.3	37.3	37.3	37.3	37.3	37.3	37.3	37.3	37.3	37.3	37.3	37.3
Coal briquette	$0213	MJ/kg	23.9	23.9	23.9	23.9	23.9	23.9	23.9	23.9	23.9	23.9	23.9	23.9
Coke oven gas	$0221	MJ/m^3	21.5	21.6	21.3	21.4	21.3	18.9	18.9	18.4	18.4	18.4	18.2	18.2
Blast furnace gas	$0222	MJ/m^3	3.51	3.59	3.64	3.41	3.41	3.24	3.24	3.23	3.23	3.23	3.18	3.18
Converter furnace gas	$0225	MJ/m^3	8.37	8.37	8.41	8.41	8.41	7.54	7.54	7.53	7.53	7.53	7.49	7.49
Liquid fuels (oil based fuels)														
Crude oil	$0300													
Crude oil for refinery use	$0310													
Crude oil for refinery use	$0311	MJ/L	38.3	38.3	38.2	38.1	38.2	38.2	38.2	38.1	38.1	38.1	38.0	38.0
Residual and straight run fuel oil for refinery use	$0312	MJ/L	38.3	38.3	38.2	38.1	38.2	41.3	40.6	39.9	39.8	39.0	39.0	39.0
Crude oil for power generation use	$0320	MJ/L	39.1	39.2	39.6	38.5	39.7	39.3	39.8	40.4	40.5	39.3	39.1	39.1
Bituminous mixture fuel	$0321	MJ/kg	30.1	30.3	29.9	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4
Natural gas liquid (NGL) / condensate	$0330													
NGL/condensate for refinery use	$0331	MJ/L	35.7	35.5	35.4	35.0	34.8	34.8	34.7	34.6	34.6	35.9	35.3	35.1
NGL/condensate for power generation use	$0332	MJ/L	35.7	35.5	35.4	35.0	34.8	34.2	34.2	34.2	34.5	34.5	34.5	34.5
NGL/condensate for petrochemical use	$0333	MJ/L	35.7	35.5	35.4	35.0	34.8	34.6	34.4	34.3	34.5	34.5	34.5	34.5
Oil products	$0400													
For material and feedstock	$0410													
Pure naphtha	$0420	MJ/L	33.6	33.6	33.6	33.5	33.5	33.3	33.3	33.3	33.3	33.3	33.3	33.3
Reformate	$0421	MJ/L	35.1	35.1	35.1	35.1	35.1	33.7	33.7	33.7	33.7	33.7	33.7	33.7
Fuel oil	$0430													
Gasoline (crude oil origin)[1]	$0431	MJ/L	34.6	34.6	34.6	34.6	34.6	33.4	33.4	33.4	33.4	33.4	33.4	33.4
Gasoline (biofuel blended)[2]		MJ/L	34.6	34.6	34.6	34.6	34.5	33.3	33.2	33.1	33.2	33.2	33.1	33.1
Jet fuel oil	$0432	MJ/L	36.4	36.4	36.7	36.7	36.7	36.3	36.2	36.3	36.3	36.5	36.4	36.5
Kerosene	$0433	MJ/L	36.8	36.8	36.8	36.7	36.7	36.5	36.5	36.5	36.5	36.5	36.6	36.6
Gas oil or diesel oil (crude oil origin)[1]	$0434	MJ/L	38.1	38.1	38.2	37.8	38.1	38.0	38.0	38.0	38.0	38.0	37.9	37.9
Gas oil or diesel oil (biofuel blended)[2]		MJ/L	38.1	38.1	38.2	37.8	38.1	38.0	38.0	38.0	38.0	38.0	37.9	37.9
Fuel oil A	$0436	MJ/L	39.7	39.6	39.3	39.1	39.9	38.9	38.9	38.9	38.9	38.9	38.8	38.8
Fuel oil B	$0438	MJ/L	40.2	40.2	40.4	40.4	40.4	40.4	40.4	40.4	40.4	40.4	40.4	40.4
Fuel oil C for general use	$0439	MJ/L	40.2	40.3	40.3	40.3	40.4	41.2	41.4	41.1	41.0	41.0	41.0	41.1
Fuel oil C for power generation use	$0440	MJ/L	41.1	41.1	41.3	41.2	41.3	41.2	41.0	41.6	41.5	41.5	41.5	41.3
Miscellaneous oil products	$0450													
Lubricant oil	$0451	MJ/L	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2
Other heavy oil products	$0452	MJ/kg	39.2	39.3	39.4	39.4	39.4	40.2	40.4	40.1	40.0	40.0	40.0	40.1
Oil coke	$0455	MJ/kg	35.6	35.6	35.6	29.9	29.9	33.3	33.3	33.3	34.1	34.1	34.1	34.1
Galvanic furnace gas	$0456	MJ/m^3	8.37	8.37	8.41	8.41	8.41	7.54	7.54	7.53	7.53	7.53	7.49	7.49
Refinery gas	$0457	MJ/m^3	39.3	39.3	44.9	44.9	44.9	46.1	46.1	46.1	46.1	46.1	42.4	42.4
Liquefied petroleum gas (LPG)	$0458	MJ/kg	50.5	50.6	50.7	50.7	50.8	50.1	50.1	50.1	50.1	50.1	50.1	50.1
Gaseous fuels (gas based fuels)														
Natural Gas	$0500													
Liquefied natural gas (LNG)	$0510	MJ/kg	54.5	54.5	54.5	54.5	54.5	54.5	54.5	54.7	54.7	54.7	54.7	54.6
Indigenous natural gas	$0520	MJ/m^3	42.1	42.4	42.6	42.9	44.7	39.6	39.6	38.4	38.4	38.4	38.4	38.4
Indigenous natural gas	$0521	MJ/m^3	42.1	42.4	42.6	42.9	44.7	39.6	39.6	38.4	38.4	38.4	38.4	38.4
Coal mining gas	$0522	MJ/m^3	36.0	36.0	16.7	16.7	16.7	15.1	15.1	15.1	15.1	15.1	15.1	15.1
Boil off gas from crude oil	$0523	MJ/m^3	42.1	42.4	42.6	42.9	44.7	39.6	39.6	38.4	38.4	38.4	38.4	38.4
City gas	$0600													
City gas (general gas)	$0610	MJ/m^3	41.9	41.9	41.1	44.8	44.8	40.8	40.7	39.9	40.0	40.4	40.0	40.0
Small scale community gas	$0620	MJ/m^3	105	104	102	102	101	96.0	95.3	94.3	94.1	94.2	94.3	93.9
(Reference) Biomass	$N130													
Woods	$N131	MJ/kg	15.4	15.4	15.4	19.9	17.4	17.6	17.0	14.5	14.8	14.1	14.4	14.4
Waste woods	$N132	MJ/kg	16.7	16.7	16.7	16.3	16.3	17.1	17.1	17.1	17.1	17.1	18.4	18.4
Bioethanol	$N134	MJ/L	23.9	23.9	23.9	23.9	23.9	23.4	23.4	23.4	23.4	23.4	23.4	23.4
Biodiesel	$N135	MJ/L	23.9	23.9	23.9	23.9	23.9	23.4	23.4	23.4	35.6	35.6	35.6	35.6
Thermal use of black liquor	$N136	MJ/kg	12.6	12.6	12.6	13.2	13.2	13.6	13.6	13.6	13.6	13.6	13.5	13.5
Gas biomass	$N137	MJ/m^3	23.4	23.4	23.4	23.4	23.4	21.2	21.2	21.2	21.2	21.2	21.2	21.2

1) Used in the reference approach.

2) Used in the sectoral approach.

3) Until FY2012, in principle, the values of gases are indicated at 0 °C and 1 atm (273.15 K, 101.325 kPa) (normal condition), those of liquids are indicated at normal temperature, those of solids are indicated "with moisture and ash" state. After FY2013, in principle, the values of gases and liquids are indicated at 25 °C and 1 bar (298.15 K, 100 kPa) (standard ambient temperature and pressure (SATP)), and those of solids are indicated "with moisture and ash" state.

- ***Amount captured***

CO_2 generated from an oil refinery plant is partially captured and then directly utilized as products such as dry ice or liquified carbonated gas, and finally emitted to the atmosphere. Also, CO_2 generated from oil refinery plants was captured and geologically stored from fiscal year 2004 to 2007 and 2016 through 2019. Those captured CO_2 are reported under "CO_2 amount captured"[10] in 1.A.1.b Petroleum refining of the CRT table 1.A(a)s1, and the amount is subtracted from the emissions. (CO_2 directly utilized is reported as emissions under the IPPU sector. If fugitive emissions in the process of storage occur, the emissions are reported under "1.C. CO_2 transport and storage".) Please refer to section 4.9.1 of Chapter 4 for the details of direct utilization of CO_2, and refer to section 3.4.4. of this chapter for details of CO_2 storage.

The amount captured for FY2016-FY2019 increased due to the implementation of the large-scale demonstration of geological storage of CO_2. The amount captured for liquified carbonated gas increased since FY1990 mainly due to the increase in carbonated gas as a by-product since desulfurization units in oil refineries increased.

Table 3-18 CO_2 amount captured in Energy industries (1.A.1) and its usage

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Amount captured	kt	-376	-412	-476	-558	-595	-587	-576	-594	-601	-619	-620	-584
Liquefied carbonated gas	kt	-244	-278	-310	-363	-397	-379	-362	-375	-377	-404	-411	-387
Dry ice	kt	-132	-134	-166	-195	-198	-208	-213	-219	-224	-215	-210	-197
Geological storage	kt	NO	NO	NO	-0	NO	NO	NO	NO	NO	NO	NO	NO

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For solid, liquid and gaseous fuels, the uncertainties of emission factors are set by the upper and lower limits of 95% confidence intervals derived from the actual measurements of carbon emission factors. The upper and lower limits of uncertainties of activity data are set by the standard deviations of the statistical discrepancies [#400000] divided by domestic primary energy supply [#190000] from FY1990 to FY2024 for solid, liquid and gaseous fuels respectively, taking account of difficulty to set the uncertainties of energy consumption by each fuel and sector from the *General Energy Statistics*, or the reference of activity data. As a result, the uncertainty was determined to be −2% to +2% for CO_2 emissions from combustion of solid, liquid and gaseous fuels as a whole for the fuel combustion category.

As the uncertainties in the CO_2 captured amount are not available, the values shown in the *2006 IPCC Guidelines* (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes) from fugitive emissions from oil and natural gas systems) are used instead. See section 4.9.1 for the uncertainties of the CO_2 captured amount for direct utilization.

See section 7.4.3 for the uncertainty of CO_2 emissions from waste incineration for energy purposes and with energy recovery.

[10] As it is impossible to identify the origin of the captured CO_2, the captured amount is collectively reported under the liquid fuels and the captured amounts of the other fuel categories are reported as "IE".

- ***Time-series Consistency***

The emissions were calculated in a consistent manner in all time-series.

The carbon emission factors of all energy sources have been calculated by a consistent estimation method in all time-series.

The activity data was used from data in the *General Energy Statistics* in all time-series, and the statistics were made by a consistent estimation method in all time-series.

The fossil fuel consumption of "Production, Transmission and Distribution of Electricity" [#255330] under "Auto power production" of the *General Energy Statistics* for the period of FY1990 through FY2015 are included in the activity data of Public electricity and heat production subcategory (1.A.1.a) in light of time-series consistency. See the Activity Data section under 3.2.4. b).

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines.* The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC procedures are summarized in Annex 4.

e) Category-specific Recalculations

Due to the updates of the activity data based on the update of the *General Energy Statistics*, the emissions for the period of FY1990-2023were recalculated.

Updating the statistical data and improving the estimation methodology in the waste sector, CO_2 emissions from other fossil fuels for the period of FY2010-FY2020 and FY2023 were recalculated. See section 7.4.3 for details.

See Chapter 10 for impact on trend.

- ***Recalculations made to the General Energy Statistics***

The past data in the *General Energy Statistics* were revised due to the following reasons.

1) Change of the estimation methodology for compiling the General Energy Statistics

- ***Change of data source for diesel oil consumption in the "National government" category***

The diesel oil consumption in the "National government" category was based on the data from the *Structural Survey of Energy Consumption*. Upon investigation triggered by the increase in "Not elsewhere specified" category since FY2013, it was found that the amount recorded in the *Survey on Diesel Oil Delivery Tax*, compiled by the Ministry of Internal Affairs and Communications (MIC), was larger than the *Structural Survey of Energy Consumption*. Therefore, the values in the *Survey on Diesel Oil Delivery Tax* were adopted.

- ***Elimination of the double counting of small-scale community gas included in the LPG consumption from the Residential sector***

The LPG consumption in the "Residential" sector was based on the data from the *Family Income and Expenditure Survey* (MIC). An investigation revealed that small-scale community gas was aggregated as propane gas in the survey, leading to double counting in the *General Energy Statistics*, where the consumption of small-scale community gas was included both in the consumption of city gas and that of LPG. Therefore, it was corrected to subtract the consumption of small-scale community gas from the

consumption of LPG. The amount subtracted from the regional LPG consumption was identified proportionally based on each region's share of national LPG consumption.

2) Change due to the update of the statistical data used in the General Energy Statistics

Various statistical data related to energy are used for compiling the *General Energy Statistics*, and they are sometimes revised in the next year. For example, respondents of statistical surveys may correct their reported values due to mistakes. In this case, the *General Energy Statistics* may reflect these updated statistical values. The table below shows the FY2023 data that were updated during the compilation of the *General Energy Statistics* in FY2024.

Table 3-19 Update of the statistical data used for the *General Energy Statistics*

No	Statistical data used for the *General Energy Statistics*	Place where the data are reflected in the *General Energy Statistics*
1	*Mineral Resources and Petroleum Products Statistics* (The data for Jan. - Mar. 2024 after the annual revision was applied.)	$0300 Crude oil, $0500 Natural Gas; #110000 Indigenously Produced, #120000 Imports, #160000 Exports, #170000 Stockpile Change / Supply. $0400 Oil Products, #120000 Imports, #160000 Exports, #190000 Stockpile Change / Supply, #222000 Oil Refinery
2	*Trade Statistics of Japan*	$0100 Coal, $0200 Coal Products, $0455 Petroleum Coke, $0458 LPG, $0510 LNG; #120000 Imports, #160000 Exports
3	*Current Survey of Energy Consumption* (The data for Jan. - Mar. 2024 after the annual revision was applied.)	Large scale manufacturing industries under #250000 Auto Power Generation, #260000 Auto Steam Generation, and #500000 Final Energy Consumption. #355000 Manufacturing Industry, Large Scale, Stockpile Change
4	*Current Survey of Production Concerning Gas Industry (former small-scale community gas suppliers)*	#232000 Small-scale Community Gas Conversion and Production, #650000 Commerce, public services and Not elsewhere specified, #700000 Residential; $0620 Small-scale Community Gas
5	*Statistical Survey of Motor Vehicle Fuel Consumption*	#811000 Passenger Vehicle, #811500 Bus, #851000 Truck and Lorry; $0431 Gasoline, $0434 Gas Oil/Diesel Oil, etc.
6	*Structural Survey of Energy Consumption*	Agriculture, Mining and Construction; Small and medium scale manufacturing industries; Commerce and public services
7	*Statistical Survey on Farm Management*	Estimation for #611100 Agriculture
8	*Statistical Survey on Agriculture Commodity Price Index*	Estimation for #611100 Agriculture
9	*Survey on Petroleum Products Retail Price*	Estimation for #611100 Agriculture, #611200 Forestry, #611300 Fishery Except Aquaculture
10	*Census of Fisheries*	Estimation for #611300 Fishery Except Aquaculture
11	*Statistical Survey on Fishery Management*	Estimation for #611300 Fishery Except Aquaculture
12	*Input-Output Tables for Japan*	Estimation for #611200 Forestry, #611300 Fishery Except Aquaculture
13	*Forestry Output*	Estimation for #611200 Forestry
14	Distance travelled of compressed natural gas vehicles by type	#811190 Passenger Vehicle - Industrial Use and Others, #811590 Bus - Common Omnibus Industry Use, #851100 Truck and Lorry - Freight Transport Industry Use; $0610 City Gas
15	Gasoline consumption of motorcycle	#812000 Motorcycle
16	*Railway Statistical Yearbook*	$0434 Diesel oil; $1200 Electricity; #813000 Railway Passenger Transport, #852000 Railway Freight Transport
17	Coal consumption of steam locomotive	$0122 Imported Steam Coal for General Use, #813000 Railway Passenger Transport
18	Heavy fuel oil for water passenger transport	$0435 Heavy Fuel Oil; #814000 Water Passenger Transport

Note: "$0000" means a column number of the *General Energy Statistics*. "#000000" means a row number of the statistics.

For some energy types, if total supply amount is more than total demand amount, the supply excess amount is regarded as the consumption by unknown sectors, and it is allocated to "Not elsewhere specified" under the "Commerce, public services and Not elsewhere specified" sector and/or "Own Use"

under the “Energy Transformation & Own Use” sector.

If total demand amount is more than total supply amount, the demand excess amount is proportionally subtracted from the sectors where sample surveys (the *Structural Survey of Energy Consumption* and the *Statistical Survey of Motor Vehicle Fuel Consumption*) are used for estimation, because overestimation can occur in these sectors.

Therefore, the consumption under the sectors such as “Manufacturing”, “Commerce, public services and Not elsewhere specified”, and “Transportation” can slightly change for these energy types if the consumption under sectors elsewhere changes due to the updates of data. In any cases, the total consumption remains unchanged because it is capped with the supply amount.

3) Change due to the revision of the GCV used in the General Energy Statistics

The GCV of “Waste plastics” had been fixed as 29.3 MJ/kg as established in the FY2000 revision. Since material composition might change, an update reflecting the latest conditions had been under consideration. In this submission, the GCV of waste plastics was revised as 28.71 MJ/kg since the FY2023 values, aligned with the timing of applying the revision of the GCVs for other energy sources.

f) Category-specific Planned Improvements

It is planned to revise the "standard calorific values" and their corresponding carbon emission factors approximately once in every 5 years. The consideration of the next revision will be initiated in a timely manner.

3.2.5. CH_4 and N_2O Emissions from Energy Industries (1.A.1: CH_4, N_2O)

a) Category Description

This section provides the methods for estimating CH_4 and N_2O emissions from public electricity and heat production (1.A.1.a), petroleum refining (1.A.1.b), and manufacture of solid fuels and other energy industries (1.A.1.c).

CH_4 is generated as a result of incomplete combustion, and as such, if sufficient care is taken to ensure complete combustion, CH_4 will not be generated. N_2O is generated through the reaction of nitrogen monoxide (NO), which is generated by combustion, with nitrogen-containing volatile components in fuels. Consequently, the higher the nitrogen content of the fuel used, the more likely it is that N_2O will be generated. However, the reaction that produces N_2O is also dependent on temperature, with N_2O more likely to be generated at lower temperatures. More N_2O will accordingly be generated by furnaces such as fluidized bed boilers that burn fuel at low temperatures (800–900°C). N_2O can also be generated when NO_X contacts catalysts for NO_X removal.

The contribution of CH_4 and N_2O emissions from this category relative to total GHG emissions is small in Japan. The N_2O emissions from fluidized bed boilers are relatively large in this category. The N_2O emissions from fluidized bed boilers contributed to the increase of GHG emissions from this category, since fluidized bed boilers have been introduced in Japan from 1990. The N_2O emissions from solid fuel in 1.A.1.a (Public electricity and heat production) increased between FY1994 and FY1995. The reason for the increase was that a new large sized fluidized-bed boiler for power generation was introduced in FY1995. As a result, the solid fuel consumption of fluidized-bed boilers for public power generation increased in FY1995, resulting in an increase of N_2O emissions from solid fuels in this

category. In recent years, some fluidized bed boilers have been decommissioned, resulting in an decrease of the emissions.

CH_4 emitted in coke production is reported in this category. We have no measurements of the concentration of N_2O in the gas leaking from coking furnace lids, but we decided that N_2O emissions from this source are not applicable the reason being that experts say that N_2O is likely not produced because the atmosphere in a coke oven is normally at least 1,000°C, and is reducing.

b) Methodological Issues

- ***Estimation Method***

➢ ***Furnaces***

Because it is possible to use fuel-specific, sector-specific and furnace-specific activity data, and also to set country-specific emission factors by furnace, CH_4 and N_2O emissions from fuel combustion in this category are calculated by using Tier 3 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol.2, Page 1.9, Fig. 1.2).

The estimation equation is as follows. The emissions were calculated by multiplying fuel-specific, furnace-specific and sector-specific activity data by fuel-specific and furnace-specific emission factors.

$$E = \sum_{ij} \left(EF_{ij} \times A_{ijk} \right)$$

E : Emissions from combustion of fuel by stationary sources [kg-CH_4, kg-N_2O]
EF_{ij} : Emission factor for fuel type i, furnace type j [kg-CH_4/TJ, kg-N_2O/TJ]
A_{ijk} : Fuel consumption for fuel type i, furnace type j, sector k [TJ]
i : Fuel type
j : Furnace type
k : Sector

➢ ***Biomass boilers***

Because it is possible to use country-specific emission factors of power generation facility and heat utilization facility, CH_4 and N_2O emissions from combustion in biomass boilers are calculated by using Tier 3 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol.2, Page 1.9, Fig. 1.2). However, CH_4 and N_2O emissions of gas biomass are calculated by using Tier 1, as country-specific emission factors are not available.

➢ ***Coke Production***

CH_4 emissions from coke production were calculated by multiplying coke production amount by Japan's country-specific emission factor, based on the method given in the *2006 IPCC Guidelines*. The emissions were reported under manufacture of solid fuels and other energy industries (1.A.1.c).

➢ ***Incineration of waste for energy purposes and with energy recovery***

See section 7.4.3

- ***Emission Factors***

➢ ***Furnaces***

Chimney flue CH_4, N_2O and O_2 concentrations, theoretical (dry) exhaust gas volumes, theoretical air volumes, and higher heating values (gross calorific values (GCV)) shown in Table 3-20 were employed based on data obtained from surveys conducted in Japan (Table 3-21) to establish emission factors for each kind of facility using the following combustion calculation formula.

$$EF = C_{CH_4,N_2O} \times \{G_0{}' + (m-1) \times A_0\} \times MW/V_m/GCV$$

EF	:	Emission factor [kg-CH_4/TJ, kg-N_2O/TJ]
$C_{CH4\ or\ N2O}$	:	CH_4 or N_2O concentration in exhaust gas [ppm]
G_0'	:	Theoretical exhaust gas volume for each fuel combustion (dry) [m^3N/original unit]
A_0	:	Theoretical air volume for each fuel combustion [m^3N/original unit]
m	:	Air ratio = actual air volume / theoretical air volume [-]
MW	:	Molecular weight of CH_4 (constant) =16 [g/mol] Molecular weight of N_2O (constant) =44 [g/mol]
V_m	:	One mole ideal gas volume in standardized condition (constant) =22.4 [$10^{-3}m^3$/mol]
GCV	:	Gross calorific value for each fuel combustion [MJ/ original unit]

However, the air ratio "*m*" is approximately provided with oxygen concentration in exhaust gas, as shown in the equation below.

$$m = \frac{21}{21 - C_{O_2}}$$

C_{O_2}	:	Oxygen concentration in exhaust gas [%]

CH_4 and N_2O emission factors by each fuel and furnace types were averaged after dividing the emission factor of each kind of facilities according to fuel and furnace types (Table 3-22, Table 3-23). Anomalous values were excluded according to t-testing or expert judgment when calculating the average values. Please refer to MOE (2006a) for the actual measurement data to establish the emission factors.

- ***Emission Factors with Air-Intake Adjustment***

In Japan, until the GHG inventory was submitted in 2005, based on the results of past discussions (e.g., Japan Society for Atmospheric Environment (1996) relating to methodologies for calculating emissions, the non-CO_2 emission factors from stationary combustion were established after accounting for the differences between emission gas concentrations and intake gas concentrations (i.e., air-intake adjustment). With this methodology, it was possible to obtain negative emission factors for some emission sources if the measurement data showed that concentrations in emission gas were lower than those in intake gas, possibly because CH_4 and N_2O present in the intake gas had been either oxidized or decomposed through the combustion process.

However, during the in-country review that was conducted in 2003, the Expert Review Team recommended Japan to replace negative emission factors by the corresponding positive ones, because, in the interest of enabling better international comparisons, the *Revised 1996 IPCC Guidelines* as well as *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories* (hereinafter referred to as *GPG2000*) indicate that positive emission factors should be used for calculations of emissions based on actual emissions of CH_4 and N_2O in the flue gases, though air-intake adjustments might enable accurate determination of emissions. Thus, in the inventories submitted in 2006 and thereafter, the air-intake adjustments were not made, and emission factors were determined by using the actual measured CH_4 and N_2O concentrations in emission gases.

Table 3-20 Theoretical exhaust gas and air volumes, and higher heating values for different fuels

Fuel type	Original unit	Theoretical exhaust gas volume (dry) G_0' [1)]	Gross calorific value GCV [2)]	Theoretical air volume A_0 [1)]	Remarks
		m^3N/L, kg, m^3N	kJ/L, kg, m^3N	m^3N/L, kg, m^3N	
Fuel oil A	L	8.900	39,100	9.500	a
Fuel oil B	L	9.300	40,400	9.900	a
Fuel oil C	L	9.500	41,700	10.100	a
Diesel oil	L	8.800	38,200	9.400	a
Kerosene	L	8.400	36,700	9.100	a
Crude oil	L	8.747	38,200	9.340	a
Naphtha	L	7.550	34,100	8.400	a
Other liquid fuels	L	9.288	37,850	9.687	b
Other liquid fuels (heavy)	L	9.064	37,674	9.453	b
Other liquid fuels (light)	L	9.419	35,761	9.824	b
Steam coal	kg	7.210	26,600	7.800	a
Coke	kg	7.220	30,100	7.300	a
Harvested wood	kg	3.450	14,367	3.720	b
Charcoal	kg	7.600	30,500	7.730	c
Other solid fuels	kg	7.000	33,141	7.000	b
City gas	m^3	9.850	46,047	10.949	b
Coke oven gas (COG)	m^3	4.500	21,100	4.800	a
Blast furnace gas (BFG)	m^3	1.460	3,410	0.626	a
Liquefied natural gas (LNG)	kg	11.766	54,500	13.093	a
Liquefied petroleum gas (LPG)	kg	11.051	50,200	12.045	a
Converter furnace gas (CFG) (Linz-Donawitz gas: LDG)	m^3	2.200	8,410	1.500	a
Refinery gas (off-gas)	m^3	11.200	44,900	12.400	a
Other gaseous fuels	m^3	4.587	28,465	4.096	b
Other gaseous fuels (petroleum)	m^3	7.889	40,307	7.045	b
Other gaseous fuels (steel)	m^3	2.812	19,097	2.511	b
Other gaseous fuels (mining)	m^3	3.396	38,177	3.032	b
Other gaseous fuels (other)	m^3	4.839	23,400	4.321	b
Pulping waste liquor	kg	3.245	13,898	3.499	b

Note:

1) Theoretical exhaust gas and air volumes are the standard values given in the *General Survey of the Emissions of Air Pollutants* (MOE), except for city gas, LNG, and LPG, for which values calculated from constituent data were used. For city gas, the constituents of city gas (13A) were considered to be representative.

2) Regarding higher heating value, the standard calorific values given in the *General Energy Statistics* were used for items marked a, and the standard values given in *General Survey of the Emissions of Air Pollutants* (based on the 1992 survey) for items marked b in the Remarks column. The higher heating value for steam coal (imported) was used as the higher heating value of steam coal. The item marked c in the Remarks column was set by the 2005 Committee for the Greenhouse Gases Emissions Estimation Methods based on reference materials.

Table 3-21 References for measurement data used in the establishment of emission factors

	References
1	Hokkaido Prefecture, *Report of GHG Emissions Intensity from Stationary Combustion*, 1991
2	Hyogo Prefecture, *Report of GHG Emissions Intensity from Stationary Combustion*, 1991
3	Osaka Prefecture, *Study of GHG Emissions Intensity from Stationary Combustion*, 1991
4	Hokkaido Prefecture, *Report of GHG Emissions Intensity from Stationary Combustion*, 1992
5	Hyogo Prefecture, *Report of GHG Emissions Intensity from Stationary Combustion*, 1992
6	City of Kitakyushu, *Report of GHG Emissions Intensity from Stationary Combustion*, 1992
7	Hyogo Prefecture, *Study of GHG Emission Factors from Stationary Combustion*, 1993
8	Hyogo Prefecture, *Report of GHG Emissions Intensity from Stationary Combustion*, 1994
9	Kanagawa Prefecture, *Study of GHG Emission Factors from Stationary Combustion*, 1995
10	Niigata Prefecture, *Study of GHG Emission Factors from Stationary Combustion*, 1995
11	Osaka Prefecture, *Study of GHG Emission Factors from Stationary Combustion*, 1995
12	Hiroshima Prefecture, *Study of GHG Emission Factors from Stationary Combustion*, 1995
13	Fukuoka Prefecture, *Report of GHG Emission Factors from Stationary Combustion*, 1995
14	City of Osaka, *Study of GHG Emission Factors from Stationary Combustion*, 1995
15	City of Kobe, *Study of GHG Emission Factors from Stationary Combustion*, 1995
16	Hokkaido Prefecture, *Study of GHG Emission Factors from Stationary Combustion*, 1996
17	Ishikawa Prefecture, *Study of GHG Emission Factors from Stationary Combustion*, 1996
18	Kyoto Prefecture, *Study of GHG Emission Factors from Stationary Combustion*, 1996
19	Osaka Prefecture, *Study of GHG Emission Factors from Stationary Combustion*, 1996
20	Hyogo Prefecture, *Study of GHG Emission Factors from Stationary Combustion*, 1996
21	Hiroshima Prefecture, *Study of GHG Emission Factors from Stationary Combustion*, 1996
22	Fukuoka Prefecture, *Report of GHG Emission Factors from Stationary Combustion*, 1996
23	Kyoto Prefecture, *Report of GHG Emission Factors from Stationary Combustion*, 1997
24	Hyogo Prefecture, *Study of GHG Emission Factors from Stationary Combustion*, 1997
25	Fukuoka Prefecture, *Report of GHG Emission Factors from Stationary Combustion*, 1997
26	Japan Society for Atmospheric Environment, *Report on Emission Factor Results for Combustion Facilities*, 1996
27	Osaka Prefecture, *Study of GHG Emission Factors from Stationary Combustion*, 1999
28	Hyogo Prefecture, *Report of GHG Emission Factors from Stationary Combustion*, 2000
29	The Institute of Applied Energy, *Report for Trend of Fuel Quality in Lowering Environmental Atmospheric Quality*, 2000
30	MOE, Measurement Data prepared by the Committee for the Greenhouse Gases Emissions Estimation Methods in FY1999, 1999
31	Data prepared by the Federation of Electric Power Companies of Japan
32	IPCC, *2006 IPCC Guidelines*, 2006
33	Forestry Agency Wood Use Promotion Division, *Promotion of Wood Use and Energy-saving and CO_2 Reduction Demonstration Project Fiscal Year 2014*, 2015
34	MOE, *Survey on Grasp of the Actual Condition of Greenhouse Gas Emissions from Biomass Boilers Fiscal Year 2017*, 2018

Table 3-22 CH_4 emission factors for different fuels and furnaces in GCV basis (unit: kg-CH_4/TJ)

Fuel			Code[1]	Boilers	Industrial furnaces									Internal combustion engines		
				Boiler	Sintering furnace for smelting of metals (except copper, lead, and zinc)	Pelletizing furnace (steel and non-ferrous metal)	Metal rolling furnace, metal treating furnace, metal forging furnace	Oil and gas furnaces	Catalytic regenerator	Kilns for ceramic products (except cement kiln)	Drying kilns for aggregate, cement raw material, brick raw material and mold	Detergent drying kiln, Other drying kilns	Other industrial furnaces	Gas turbine	Diesel engine	Gas engine, gasoline engine
				0100	0306 0307	0312 0313	0600	0202 0700	0801	0906 - 0914	1101 - 1104	1105 1106	2)	2900	3000	3100 3200
Coal	Steel Making Coal		$0110	0.13	31	1.7	13	13	NA	1.5	29	6.6	13	NA	NA	NA
	Coking Coal		$0111													
	Pulverized Coal Injection Coal		$0112													
	Imported Steam Coal		$0121													
	Imported Coal for General Use		$0122													
	Imported Coal for Power Generation		$0123													
	Indigenous Produced Steam Coal		$0124													
	Hard Coal, Anthracite & Lignite		$0130													
Coal Products	Coke		$0211	0.13	31	1.7	13	13	0.054	1.5	29	6.6	13	NA	NA	NA
	Coal Tar		$0212													
	Coal Briquette		$0213													
	Coke Oven Gas		$0221	0.23			0.43	0.16	NA				2.3	0.81	0.70	54
	Blast Furnace Gas		$0222													
	Converter Furnace Gas		$0225													
Oil	Crude Oil for Refinery		$0310	0.10	31	1.7	0.43	0.16	NA	1.5	29	6.6	0.83	0.81	0.70	54
	Crude Oil for Power Generation		$0320													
	Bituminous Mixture Fuel		$0321													
	Natural Gas Liquid & Condensate		$0330													
Oil Products	Pure Naphtha		$0420	0.26	31	1.7	0.43	0.16	NA	1.5	29	6.6	0.83	0.81	0.70	54
	Reformate		$0421													
	Gasoline		$0431													
	Jet Fuel Oil		$0432													
	Kerosene		$0433													
	Gas Oil / Diesel Oil		$0434													
	Fuel Oil A		$0436													
	Fuel Oil C		$0437	0.10												
	Fuel Oil B		$0438													
	Fuel Oil C for General Use		$0439													
	Fuel Oil C for Power Generation		$0440													
	Lublicant Oil		$0451	0.26												
	Other Heavy Oil Products		$0452	0.13			13	13	0.054				13	NA	NA	NA
	Petroleum Coke		$0455													
	Galvanic Furnace Gas		$0456	0.23			0.43	0.16	NA				2.3	0.81	0.70	54
	Refinary Gas		$0457													
	Liquified Petroleum Gas		$0458													
Natural Gas	Liquefied Natural Gas		$0510	0.23	31	1.7	0.43	0.16	NA	1.5	29	6.6	2.3	0.81	0.70	54
	Indigenous Natural Gas		$0520													
	Indigenous Natural Gas		$0521													
	Coal Mining Gas		$0522													
	Boil Off Gas from Crude Oil		$0523													
City Gas	City Gas		$0610	0.23	31	1.7	0.43	0.16	NA	1.5	29	6.6	2.3	0.81	0.70	54
	Small Scale Community Gas		$0620													
Biomass Energy	Woods	Power generation	$N131	0.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Heat utilization		16	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Waste Wood	Power generation	$N132	0.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Heat utilization		16	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Thermal Use of Black Liquor		$N136	4.3	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Gas Biomass		$N137	0.9	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Non Specified Biomass		$N138	16	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

1) The code of energy sources is from the *General Energy Statistics,* and the code of furnaces is from the *General Survey of the Emissions of Air Pollutants.*
2) Other industrial furnaces include industrial furnaces (0200-1100, 1400-2801) not specified in this table. However, for gas producing furnace (0201), blast furnace, converter furnace and open-hearth furnace (except for smelting copper, lead, and zinc) (0400), emission factors are not established in order to avoid double-counting with the generated gas used in the other furnaces. For coke oven (2801), the emission factor is established otherwise (see main text). For electric arc furnace (1200), see Chapter 4.

Table 3-23 N_2O emission factors for different fuels and furnaces in GCV basis (unit: kg-N_2O/TJ)

				Boilers			Industrial furnaces					Internal-combustion engines		
				Boiler (other than fluidized-bed boiler)	Normal pressure fluidized-bed boiler	Pressurized fluidized-bed boiler	Blast furnace (except for smelting copper, lead, and zinc)	Oil and gas furnaces	Catalytic regenerator	Coke oven	Other industrial furnaces	Gas turbine	Diesel engine	Gas engine, gasoline engine
Fuel			Code 1)	0100	0100	0100	0401 0402	0202 0700	0801	2801	2)	2900	3000	3100 3200
Coal	Steel Making Coal		$0110	0.85	54	0.85	NA	1.1	NA	NA	1.1	NA	NA	NA
	Coking Coal		$0111											
	Pulverized Coal Injection Coal		$0112											
	Imoorted Steam Coal		$0121			5.2								
	Imported Coal for General Use		$0122											
	Imported Coal for Power Generation		$0123											
	Indigenous Produced Steam Coal		$0124											
	Hard Coal, Anthracite & Lignite		$0130			0.85								
Coal Products	Coke		$0211	0.85	54	0.85	NA	1.1	7.3	NA	1.1	NA	NA	NA
	Coal Tar		$0212											
	Coal Briquette		$0213											
	Coke Oven Gas		$0221	0.17	0.17	0.17	0.047	0.21	NA	0.14	1.2	0.58	2.2	0.85
	Blast Furnace Gas		$0222				NA							
	Converter Furnace Gas		$0225											
Oil	Crude Oil for Refinery		$0310	0.22	0.22	0.22	NA	0.21	NA	NA	1.8	0.58	2.2	0.85
	Crude Oil for Power Generation		$0320											
	Bituminous Mixture Fuel		$0321											
	Natural Gas Liquid & Condensate		$0330											
Oil Products	Pure Naphtha		$0420	0.19	0.19	0.19	NA	0.21	NA	NA	1.8	0.58	2.2	0.85
	Reformate		$0421											
	Gasoline		$0431											
	Jet Fuel Oil		$0432											
	Kerosene		$0433											
	Gas Oil / Diesel Oil		$0434											
	Fuel Oil A		$0436											
	Fuel Oil C		$0437	0.22	0.22	0.22								
	Fuel Oil B		$0438											
	Fuel Oil C for General Use		$0439											
	Fuel Oil C for Power Generation		$0440											
	Lublicant Oil		$0451	0.19	0.19	0.19								
	Other Heavy Oil Products		$0452	0.85	54	0.85		1.1	7.3		1.1	NA	NA	NA
	Petroleum Coke		$0455											
	Galvanic Furnace Gas		$0456	0.17	0.17	0.17		0.21	NA	0.14	1.2	0.58	2.2	0.85
	Refinary Gas		$0457											
	Liquified Petroleum Gas		$0458							NA				
Natural Gas	Liquefied Natural Gas		$0510	0.17	0.17	0.17	NA	0.21	NA	NA	1.2	0.58	2.2	0.85
	Indigenous Natural Gas		$0520							0.14				
	Indigenous Natural Gas		$0521											
	Coal Mining Gas		$0522											
	Boil Off Gas from Crude Oil		$0523											
City Gas	City Gas		$0610	0.17	0.17	0.17	NA	0.21	NA	0.14	1.2	0.58	2.2	0.85
	Small Scale Community Gas		$0620											
Biomass Energy	Woods	Power generation	$N131	0.87	0.87	0.87	NA	NA	NA	NA	NA	NA	NA	NA
		Heat utilization		1.6	1.6	1.6	NA	NA	NA	NA	NA	NA	NA	NA
	Waste Wood	Power generation	$N132	0.87	0.87	0.87	NA	NA	NA	NA	NA	NA	NA	NA
		Heat utilization		1.6	1.6	1.6	NA	NA	NA	NA	NA	NA	NA	NA
	Thermal Use of Black Liquor		$N136	0.17	0.17	0.17	NA	NA	NA	NA	NA	NA	NA	NA
	Gas Biomass		$N137	0.09	0.09	0.09	NA	NA	NA	NA	NA	NA	NA	NA
	Non Specified Biomass		$N138	1.6	1.6	1.6	NA	NA	NA	NA	NA	NA	NA	NA

1) The code of energy sources is from the *General Energy Statistics,* and the code of furnaces is from the *General Survey of the Emissions of Air*
2) Other industrial furnaces include industrial furnaces (0200-1100, 1400-2801) not specified in this table. However, for gas producing furnace (0201), converter furnace (except for smelting copper, lead, and zinc) (0403, 0404) and open-hearth furnace (0405, 0406), emission factors are not established in order to avoid double-counting with the generated gas used in the other furnaces. For electric arc furnace (1200), see Chapter 4.

➢ ***Biomass boilers***

CH_4 and N_2O emission factors by each fuel and each facility in biomass boilers are shown in Table 3-22 and Table 3-23.

The country-specific emission factors of woods, waste woods and non-specified biomass were established based on the actual measurements from MOE (2018) and Forestry Agency (2015), considering the utilization situation of woody biomass.

The emission factors of black liquor were established by using theoretical (dry) exhaust gas volumes, theoretical air volumes, and higher heating values shown in Table 3-20.

For the emission factors of gas biomass, the default values of the *2006 IPCC Guidelines* (Vol.2, page 2.16-2.23, table 2.2-2.5) were adopted. As the default values are based on net calorific values, they were converted to the GCV basis by multiplying them by 0.9 (for fuels with gaseous state) (*2006 IPCC Guidelines*, Vol.2, page 1.16).

➢ ***Coke production***

CH_4 emissions from coke production come from two sources: CH_4 in combustion exhaust gas from gas leakage from the carbonization chamber to the combustion chamber, and CH_4 emitted from the coking furnace lid, the desulfurization tower, or the desulfurization recycling tower, in the carbonization process of coal.

- ***Combustion exhaust gas***

The concentration of CH_4 in the exhaust gas from coking furnaces operated by five companies at seven operating sites (surveyed by the Japan Iron and Steel Federation (JISF), actual results for FY1999) was weighted by the production amount of coke to derive a weighted average, which was established as the emission factor. The emission factor is 0.089 [kg-CH_4/t].

- ***Coking furnace lid, desulfurization tower, and desulfurization recycling tower***

JISF has had a voluntary plan in place since FY1997 to manage noxious atmospheric pollutants, and CH_4 emissions have been estimated from emissions of other substances from the lid of coking furnaces. The emission factor has been established by taking a weighted average using this data and the amount of production of coke.

Table 3-24 Emission factor of CH_4 from coking furnace lids, desulfurization towers, and desulfurization recycling towers

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Emission factors	kg-CH_4/t	0.238	0.238	0.119	0.043	0.031	0.039	0.036	0.028	0.034	0.029	0.028	0.028

Reference: JISF data

Note: Emission factor change is assumed to be small for FY1990-1996. Therefore, actual data values for FY1995 is used for other years with no data. For FY1997-1999, it is assumed that values for 1998 and 1999 are the same as those of 1997 (0.18). For FY2000 and on, actual data values are adopted.

- ***CH_4 emission factor for coke production***

The aforementioned Combustion Exhaust Gas and Coking Furnace Lids, Desulfurization Towers, and Desulfurization Recycling Towers have been added, and the resulting figure has been used as the emission factor.

- ***Activity Data***

➢ ***Furnaces***

In the estimation of the activity data, data on the *General Survey of the Emissions of Air Pollutants* (MOE) (see next page for the outline of this survey), which provides details of the fuel consumption for each type of furnace and fuel, and data on each fuel consumption statistics (*Yearbook of the Current Survey of Energy Consumption in the Selected Industries* (METI), *Structural Survey of Energy Consumption* (ANRE), *Electric Power Statistics* (ANRE), and *Current Survey of Production Concerning Gas Industry* (ANRE)) are used, because data on stationary combustion fuel consumption for each type of furnace are not available in the *General Energy Statistics*.

The fuel consumption by each sector (energy transformation & own use, industry, commercial & others) for each type of fuels as presented in the *General Energy Statistics* was further divided among each furnace type proportionally to the fuel consumption ratio for each furnace type estimated from the *General Survey of the Emissions of Air Pollutants* and from the fuel consumption statistics to obtain the activity data for each sector, each fuel type and each furnace type. However, because the data in the *General Survey of the Emissions of Air Pollutants* do not differentiate between pressurized fluidized-bed boilers, normal pressure fluidized-bed boilers, and other boilers, the fuel consumption of these fluidized-bed boilers is calculated separately. The fuel consumption data of pressurized fluidized-bed furnaces were provided by the Federation of Electric Power Companies. The fuel consumption data of normal pressure fluidized-bed furnaces were provided from companies which had past operation records of normal pressure fluidized-bed furnaces since 1990.

The data of solid fuel boilers excluding fluidized-bed furnaces were estimated by subtracting the data of fluidized-bed furnace from the data of whole solid fuel boilers.

The *General Survey of the Emissions of Air Pollutants* for all facilities emitting soot and smoke is exhaustively carried out approximately every three years. The fuel consumption ratio for each furnace type and each fiscal year is assumed as shown in Table 3-25.

Table 3-25 The method to set the fuel consumption ratio for each furnace type

Fiscal year	Setting method
1990 – 1991	Set by linear interpolation using the FY1989 and FY1992 survey results
1992	FY1992 survey result is used
1993 – 1994	Set by linear interpolation using the FY1992 and FY1995 survey results
1995	FY1995 survey result is used
1996	FY1996 survey result is used
1997 – 1998	Set by linear interpolation using the FY1996 and FY1999 survey results
1999	FY1999 survey result is used
2000 – 2007	Set by linear interpolation using the FY1999 and FY2008 survey results
2008	FY2008 survey result is used
2009 – 2010	FY2008 survey result is intentionally used [1)]
2011	FY2011 survey result is used
2012 – 2013	Set by linear interpolation using the FY2011 and FY2014 survey results
2014	FY2014 survey result is used
2015 – 2016	Set by linear interpolation using the FY2014 and FY2017 survey results
2017	FY2017 survey result is used
2018 – 2019	Set by linear interpolation using the FY2017 and FY2020 survey results
2020	FY2020 survey result is used
2021 –	FY2020 survey result is intentionally used

Note:
1) The survey result of FY2011 is quite different from that of FY2008 because of the influence of the Great East Japan Earthquake which occurred in March 2011, thus the FY2008 data is intentionally used without interpolation.

The procedure for calculating activity data is as follows:

1) Fuel consumption data from the *General Survey of the Emissions of Air Pollutants* is collated respectively for each fuel type, furnace type and sector.

2) The percentage of fuel consumption accounted for by each furnace type is calculated for each fuel type and sector.

3) Fuel consumption for different fuel types and sectors provided in the *General Energy Statistics* is multiplied by the percentage calculated in (2) to obtain fuel-specific, furnace-specific, and sector-specific activity data.

$$A_{ijk} = A_{EB_{ik}} \times w_{ijk}$$

$$w_{ijk} = A_{MAP_{ijk}} / \sum_m A_{MAP_{ijk}}$$

A_{EBik} : Fuel consumption for fuel type *i*, sector *k* from the *General Energy Statistics* [TJ]
w_{ijk} : Ratio of furnace type *j* associated with consumption of fuel type *i* in sector *k*
i : Fuel type
j : Furnace type
k : Sector
A_{MAPijk} : Fuel consumption for fuel type *i*, furnace type *j*, sector *k* according to the *General Survey of the Emissions of Air Pollutants* [TJ]

- ***Outline of the General Survey of the Emissions of Air Pollutants***

The *General Survey of the Emissions of Air Pollutants* is a statistical survey conducted to (1) promote a reasonable and effective atmospheric environmental policy, (2) obtain information on current activities within the context of the Air Pollutant Control Law (e.g., the current status of regulation of stationary sources that emit soot and smoke in facilities registered to a local government and in facilities emitting ordinary soot or particular soot, and the current status of air pollutant control), (3) develop the submitted data on facilities emitting soot and smoke, and (4) estimate the amounts of air pollutant emissions from facilities that emit soot and smoke. This survey is conducted in the form of questionnaires. The response sheets and this survey's explanations are distributed to the target facilities mentioned above.

- ***Influence of Great East Japan Earthquake on Fuel Consumption Ratio by Furnace Type***

The Great East Japan Earthquake which occurred on March 2011 largely influences the result of the *General Survey of the Emissions of Air Pollutants* in FY2011. It leads to the fluctuation of the fuel consumption ratio by furnace type in some categories in the previous and following fiscal years.

The IEFs of gaseous fuels for Petroleum refining category (1.A.1.b) largely reduced in CH_4 emissions from FY2010 (6.32 kg/TJ) to FY2011 (0.28 kg/TJ) and also in N_2O emissions from FY2010 (0.42 kg/TJ) to FY2011 (0.20 kg/TJ) (The IEF values are in the 2018 submission). This is because the fuel consumption ratio by furnace type in this survey has been reflected in the activity data, and the gaseous fuel consumption by the furnaces with high emission factors such as "Gas Engine" (CH_4 EF: 54 kg/TJ, N_2O EF: 0.85 kg/TJ) and "Other Industrial Furnaces" (CH_4 EF: 2.29 kg/TJ, N_2O EF: 1.2 kg/TJ) is significantly reduced from FY2010 to FY2011.

On the other hand, the recalculated IEFs of gaseous fuels for the same category submitted in 2018 are larger than those in 2017 for FY2012-2015. Specifically, the CH_4 IEFs increased by 15.3% in FY2012, by 33.9% in FY2013, by 50.7% in FY2014 and by 36.5% in FY2015 respectively, and the N_2O IEFs

increased by 15.1% in FY2012, by 33.0% in FY2013, by 49.4% in FY2014 and by 37.6% in FY2015 respectively. This is because, on the contrary to the former case, the fuel consumption ratio by furnace type in the *General Survey of the Emissions of Air Pollutants* in FY2014 has been adopted to the inventory in the same fiscal year. In FY2014 survey, the consumption of some gaseous fuels by furnaces with high emission factors such as "Gas Turbine" (CH_4 EF: 0.81 kg/TJ, N_2O EF: 0.58 kg/TJ) and "Other Industrial Furnaces" (see above for EFs) have significantly increased from the FY2011 survey conducted right after the Earthquake. In the 2017 inventory submission, the fuel consumption ratio by furnace type in FY2011 survey was applied to the FY2011-2015 activity data. In the 2018 inventory submission, the fuel consumption ratio by furnace type in FY2014 survey has been reflected to the FY2014 activity data by furnace type at first, then the interpolation of fuel consumption ratio by furnace type has been adopted to FY2012-2013 activity data and FY2014 survey data has been used for FY2015 activity data. As a result of the recalculation, the emissions and the IEFs from FY2012 to FY2015 have largely increased.

➢ ***Biomass boilers***

As the activity data of woods, waste woods, black liquor, gas biomass and non-specified biomass for the biomass boilers, the fuel consumption by each sector in the *General Energy Statistics* was used. It was assumed that woods and waste woods under "power generation sector" and "Auto power generation sector" of the *General Energy Statistics* were used in the power generation facilities, while those under the rest of the sectors were used in the heat utilization facilities.

➢ ***Coke production***

As the activity data of CH_4 emissions from coke production, the coke production amount was given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

Table 3-26 Coke production amount

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Coke production	kt	47,338	42,279	38,511	38,009	37,036	35,082	32,439	29,287	30,219	28,709	27,252	25,621

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

➢ ***Furnaces (including biomass boilers)***

In case of using the default emission factor of the *2006 IPCC Guidelines*, the default uncertainties were applied. In case of using country specific emission factor, country specific uncertainties were established.

Since the uncertainty by fuel and sector of energy consumption in the *General Energy Statistics* were not available, upper value and lower value of uncertainty were established from standard deviation of the rate of statistics error of "Coal, Coal Products", "Oil, Oil Products", "Natural Gas, City Gas" and "Biomass Energy" from FY1990 to FY2016.

The uncertainties at furnaces were estimated to be −33% to +46% for CH_4 emissions and −33% to +33% for N_2O emissions as a whole for the fuel combustion category.

➢ ***Coke production***

For the uncertainty of the emission factor for coke production, the uncertainty of fuel combustion

emissions from the coking furnace and coking furnace lids were estimated separately. The uncertainty of fuel combustion emissions from the coking furnace and coking furnace lids was estimated as 98.5% and 61.8%, respectively. For the uncertainty of activity data, the standard value of 5% given by MOE (2006a) was used.

➢ ***Incineration of waste for energy purposes and with energy recovery***

See section 7.4.3

- ***Time-series Consistency***

➢ ***Furnaces (including biomass boilers)***

The emissions were calculated in a consistent manner in all time-series.

The emission factors for CH_4 and N_2O have been calculated by a consistent estimation method since FY1990.

The activity data was used from data in the *General Energy Statistics* in all time-series, and the statistics were made by a consistent estimation method in all time-series. For the activity data of "Production, Transmission and Distribution of Electricity" under "Auto power generation" of the *General Energy Statistics*, see section 3.2.4. c) (1.A.1).

➢ ***Coke production***

The activity data for coke production are calculated using the data from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*, by a consistent method throughout the time-series from FY1990 to the most recent year. The emission factor is based on the information provided by JISF and estimated using a consistent methodology throughout the time-series. Therefore, CH_4 emissions from coke production have been estimated in a consistent manner throughout the time-series.

➢ ***Incineration of waste for energy purposes and with energy recovery***

See section 7.4.3

d) Category-specific QA/QC and Verification

- ***QA/QC***

Same as the CO_2 emissions from the Energy Industries (1.A.1). See section 3.2.4. d).

- ***Verification***

N_2O emission factors of fuel combustion currently used are established based on the actual measurements conducted in 1990s. Since then, the change of combustion conditions due to the progress of energy saving may change the emission factors, and the necessity of periodical review of the emission factors were pointed out by the Committee for the Greenhouse Gases Emissions Estimation Methods in FY2009.

In response to this, the actual measurement conducted in FY2009 is described here. The object of measurement was the N_2O emission factor of fluidized-bed boilers combusting solid fuels. As a result, the validity of measurements in 1990s is confirmed because the result of the measurement in FY2009 is almost the same level of the emission factor based on the measurements in the 1990s.

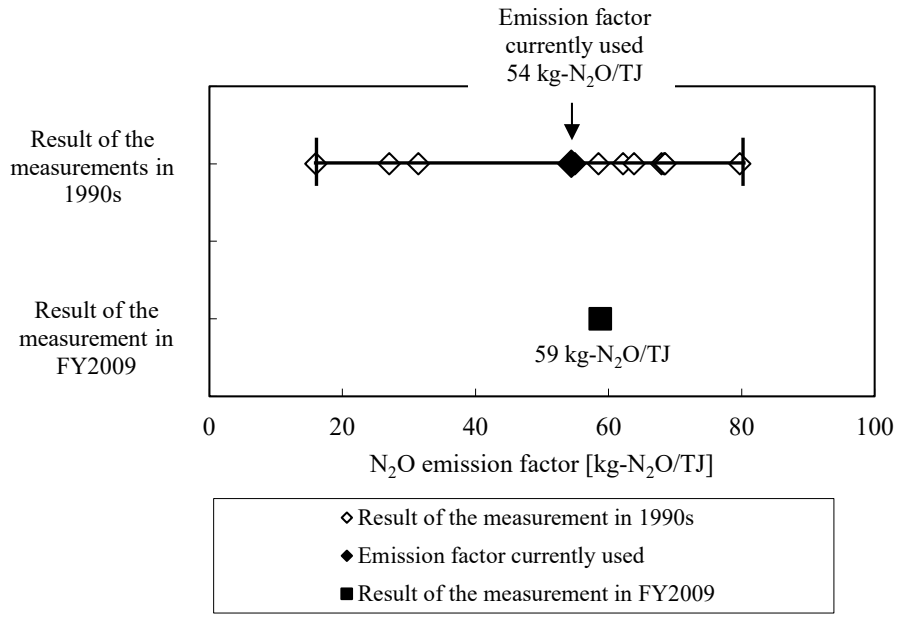

Figure 3-5 Comparison of the 1990s and FY2009 measurement results

Note: The result of the measurement in FY2009 in the figure is the average of three measurements in a boiler.

e) Category-specific Recalculations

Since the activity data in the *General Energy Statistics* were revised, the CH_4 emissions and the N_2O emissions for FY1990-2023 were recalculated. Since the emission factor of coking furnace lid and other facilities for FY2023 was provided by JISF, the CH_4 emissions in that year were recalculated.

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

3.2.6. CO_2 Emissions from Manufacturing Industries and Construction (1.A.2: CO_2)

a) Category Description

This section provides the estimation methods for determining CO_2 emissions from iron and steel (1.A.2.a); non-ferrous metals (1.A.2.b); chemicals (1.A.2.c); pulp, paper, and print (1.A.2.d); food processing, beverages, and tobacco (1.A.2.e); non-metallic minerals (1.A.2.f) and other (1.A.2.g).

In FY2024, CO_2 emissions from this category accounted for 218,206 kt-CO_2, and represented 20.9% of Japan's total GHG emissions (excluding LULUCF). The iron and steel (1.A.2.a) accounts for 49.8%, and is the largest source within the manufacturing industries and construction category.

b) Methodological Issues

- ***Estimation Method***

The Tier 2 Sectoral Approach has been used in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol.2, Page 1.9, Fig. 1.2) to calculate emissions, as was the case for the energy industries (1.A.1). See section 3.2.4. b) (1.A.1).

Please refer to section 3.2.12. for the emissions from waste incineration with energy recovery.

The CO_2 emissions from biomass are not included in the national totals but are reported in the CRTs as reference in accordance with the *2006 IPCC Guidelines*.

- ***Emission Factors***

The emission factors elaborated in the energy industries (1.A.1) are also used in this category. See section 3.2.4. b) (1.A.1).

- ***Activity Data***

The data presented in the *General Energy Statistics* were used for activity data, as was the case for the energy industries (1.A.1).

Table 3-27 Energy consumptions in Manufacturing Industries and Construction category (1.A.2) (unit: PJ)

Fuel	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Liquid fuels	1,964	2,119	1,914	1,549	1,053	1,024	896	748	795	771	739	716
Solid fuels	2,130	2,054	2,034	2,051	2,043	2,087	2,000	1,560	1,693	1,517	1,476	1,435
Gaseous fuels	227	344	408	599	629	611	595	578	598	585	580	579
Other fossil fuels	88	98	110	170	200	211	220	227	232	230	243	238
Biomass	227	226	240	273	298	309	300	259	276	267	279	277
Total	4,636	4,841	4,706	4,642	4,223	4,242	4,010	3,372	3,594	3,371	3,317	3,245

The activity data for the Manufacturing Industries and Construction category (1.A.2) were calculated by totaling the energy consumption from production activities in factories and offices (final energy consumption: #6xxxxx[11]), energy consumption related to non-utility power generation for use in one's own factories and offices (auto power generation: #25xxxx), and energy consumption related to steam production for use in own factories and offices (auto steam generation: #26xxxx) shown in the *General Energy Statistics*.

The energy consumption for production activities in factories and offices [#6xxxxx] contains a certain amount used as raw materials (non-energy and feedstock use: #95xxxx), which was considered not emitting CO_2 in the energy sector. Hence, this amount was subtracted. However, out of this amount deducted as feedstock and non-energy use, the emissions from what is used or collected as energy during waste incineration are separately estimated and reported.

The auto power generation and auto steam generation sectors are included in the energy transformation & own use sector in the *General Energy Statistics*. However, the *2006 IPCC Guidelines* allocates CO_2 emissions from energy consumption for power or steam generation to the sectors generating that power or steam. As such, these CO_2 emissions are added to those from each industry in the final energy consumption sector and are reported in 1.A.2.

Table 3-28 shows the correspondence between the sectors of Japan's Energy Balance Tables and those of the CRT (1.A.2).

[11] x indicates any number.

Table 3-28 Correspondence between sectors of Japan's Energy Balance Tables and of the CRT (1.A.2)

CRT		General Energy Statistics	
1.A.2	Manufacturing industries and construction		
1.A.2.a	Iron and steel	Auto power generation; Manufacture of iron and steel	#253220
		Auto steam generation; Manufacture of iron and steel	#263220
		Final energy consumption; Manufacture of iron and steel	#629100
		Non-energy and feedstock use; Manufacture of iron, steel and steel products	#951560
1.A.2.b	Non-ferrous metals	Auto power generation; Manufacture of non-ferrous metals and products	#253230
		Auto steam generation; Manufacture of non-ferrous metals and products	#263230
		Final energy consumption; Manufacture of non-ferrous metals and products	#629300
		Non-energy and feedstock use; Primary smelting and refining of copper, lead, zinc and aluminium	#951570
1.A.2.c	Chemicals	Auto power generation; Manufacture of chemical and allied products	#253160
		Auto steam generation; Manufacture of chemical and allied products	#263160
		Final energy consumption; Manufacture of chemical and allied products	#626100
		Non-energy and feedstock use; Manufacture of petrochemical, ammonia, soda products	#951530
1.A.2.d	Pulp, paper and print	Auto power generation; Manufacture of pulp, paper and paper products	#253140
		Auto power generation; Printing and allied industries	#253150
		Auto steam generation; Manufacture of pulp, paper and paper products	#263140
		Auto steam generation; Printing and allied industries	#263150
		Final energy consumption; Manufacture of pulp, paper and paper products	#624000
		Final energy consumption; Printing and allied industries	#625000
		Non-energy and feedstock use; Manufacture of pulp, paper and paper products, large scale	#951520
1.A.2.e	Food processing, beverages and tobacco	Auto power generation; Manufacture of food	#253090
		Auto power generation; Manufacture of beverages, tobacco and feed	#253100
		Auto steam generation; Manufacture of food	#263090
		Auto steam generation; Manufacture of beverages, tobacco and feed	#263100
		Final energy consumption; Manufacture of food, beverages, tobacco and feed	#621000
1.A.2.f	Non-metallic minerals	Auto power generation; Manufacture of ceramic, stone and clay products	#253210
		Auto steam generation; Manufacture of ceramic, stone and clay products	#263210
		Final energy consumption; Manufacture of ceramic, stone and clay products	#628100
		Non-energy and feedstock use; Manufacture of ceramic, stone and clay products	#951550
1.A.2.g	Other	Auto power generation; Agriculture, fishery, mining and construction (except for Agriculture, forestry and fishery [#251010-#251040])	#251000
		Auto power generation; Manufacturing (except for the industries listed in 1.A.1.b, 1.A.1.c, 1.A.2.a through 1.A.2.f)	#252000
		Auto steam generation; Agriculture, fishery, mining and construction (except for Agriculture, forestry and fishery [#261010-#261040])	#261000
		Auto steam generation; Manufacturing (except for the industries listed in 1.A.1.b, 1.A.1.c, 1.A.2.a through 1.A.2.f)	#262000
		Final energy consumption; Agriculture, fishery, mining and construction (except for Agriculture, forestry and fishery [#611000])	#610000
		Final energy consumption; Manufacturing (except for the industries listed in 1.A.1.b, 1.A.1.c, 1.A.2.a through 1.A.2.f)	#620000
		Non-energy and feedstock use; Agriculture, fishery, mining and construction (except for agriculture, forestry and fishery)	#951100
		Non-energy and feedstock use; Manufacturing industry, large scale (except for the industries listed in 1.A.1.b, 1.A.1.c, 1.A.2.a through 1.A.2.f)	#951500
		Non-energy and feedstock use; Manufacturing industry, small and medium scale	#951700

Note: #95xxxx items are subtracted as non-energy use activities.

- ***Captured Amount***

Among the CO_2 emitted from this category, some will be captured and emitted to the atmosphere after directly utilized as liquified carbonated gas, or another will be captured and fixed within environmentally friendly concrete and CO_2-origin carbonate materials. These captured amounts are reported as "CO_2 amount captured"[12] in "Iron and steel (1.A.2.a)" or "Non-metallic minerals (1.A.2.f)", and the amount is subtracted from the emissions. (Some of the captured amount is reported as emissions under the IPPU sector.) Please refer to section 4.9.1 of Chapter 4 for the details of direct utilization of CO_2, and refer to section 4.9.5. of Chapter 4 for details of CO_2 fixed inside the environmentally friendly concrete and CO_2-origin carbonate materials.

[12] As it is impossible to identify the origin of the captured CO_2, the captured amount is collectively reported under the solid fuels and the captured amounts of the other fuel categories are reported as "IE".

Table 3-29 CO_2 amount captured in Manufacturing Industries and Construction (1.A.2) and its usage

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Amount captured	kt	-70	-100	-85	-76	-9	-10	-31	-24	-25	-24	-25	-22
Liquefied carbonated gas	kt	-70	-100	-85	-76	-9	-10	-31	-24	-25	-24	-25	-22
Environmentally friendly concrete	kt	NO	NO	NO	NO	NO	NO	NO	NO	-0	NO	-0	-0
CO_2-origin carbonate material	kt	NO	NO	NO	NO	NO	NO	NO	-0	-0	-0	-0	-0

c) Uncertainty Assessment and Time-series Consistency

Same as 3.2.4 Energy Industries (1.A.1). See section 3.2.4. c).

See section 4.9.5 for the uncertainties of the CO_2 captured amount for manufacturing CO_2-origin carbonate materials.

d) Category-specific QA/QC and Verification

Same as the Energy Industries (1.A.1). See section 3.2.4. d).

e) Category-specific Recalculations

Due to the updates of the activity data based on the update of the *General Energy Statistics*, the emissions for the period of FY1990-FY2023were recalculated.

Due to an addition of another product of CO_2-origin carbonate materials and another specification of CO_2 fixing concrete during manufacturing, the captured amount and the emissions from "Non-metallic minerals (1.A.2.f)" in FY2022-FY2023 were recalculated. See section 4.9.5 for details.

Updating the statistical data and improving the estimation methodology in the waste sector, CO_2 emissions from other fossil fuels in FY1990-FY2023 were recalculated. See section 7.4.3 for details.

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

3.2.7. CH_4 and N_2O Emissions from Manufacturing Industries and Construction (1.A.2: CH_4, N_2O)

a) Category Description

This section provides the estimation methods for determining CH_4 and N_2O emissions from iron and steel (1.A.2.a); non-ferrous metals (1.A.2.b); chemicals (1.A.2.c); pulp, paper, and print (1.A.2.d); food processing, beverages, and tobacco (1.A.2.e); non-metallic minerals (1.A.2.f); and other (1.A.2.g).

This section also provides the estimation methods for determining CH_4 and N_2O emissions from off-road vehicles, work ships and other machinery.

b) Methodological Issues

- ***Estimation Method***

➢ ***Furnaces***

Same with Energy Industries (1.A.1), CH_4 and N_2O emissions from fuel combustion in this category are calculated by using Tier 3 method in accordance with the decision tree of the *2006 IPCC Guidelines*

(Vol.2, Page 1.9, Fig. 1.2). See section 3.2.5. b) (1.A.1).

➢ ***Biomass boilers***

The estimation method for biomass boilers is the same as Energy Industries (1.A.1). See section 3.2.5.b).

➢ ***Off-road vehicles and other machinery***

The emissions from off-road vehicles, work ships and other machinery of manufacturing industries and construction are estimated by Tier 1 in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol.2, Page 3.34, Fig. 3.3.1) to calculate emissions and reported in each sub-category of manufacturing industries and construction (1.A.2).

➢ ***Incineration of waste for energy purposes and with energy recovery***

See section 7.4.3.

● ***Emission Factors***

➢ ***Furnaces***

The emission factors which were established in Energy Industries (1.A.1) were used. See Table 3-22 and Table 3-23, See section 3.2.5. b) (1.A.1).

➢ ***Biomass boilers***

See section 3.2.5. b) (1.A.1).

➢ ***Off-road vehicles and other machinery***

The emission factors of fuel oil A of work ships were estimated using the default values of Ocean-going Ships which were provided in the *2006 IPCC Guidelines* (Vol.2, page 3.50, Table 3.5.3) after conversion to the gross calorific value by multiplying them by 0.95 (*2006 IPCC Guidelines*, Vol.2, page 1.16). The emission factors of gasoline, diesel oil and fuel oil A for other than work ships were estimated from the default emission factors of European Environment Agency (EEA, 2016) after conversion to the gross calorific value.

Table 3-30 Emission factors of CH_4 and N_2O for off-road vehicles and other machinery in manufacturing industries and construction (1.A.2)

Fuel	Unit	CH_4 emission factor	N_2O emission factor	Reference
Gasoline	g/t	665	59	EEA (2016), Non-road mobile sources and machinery, Table 3-1, 1.A.2.g.vii
Diesel oil (includes fuel oil A used for other than ships)	g/t	83	135	
Fuel oil A used for ships	kg/TJ(NCV)	7	2	*2006 IPCC Guidelines*, Vol.2, Table 3.5.3

● ***Activity Data***

➢ ***Furnaces***

The fuel consumption of mobile combustion and stationary combustion are estimated by multiplying the fuel consumption of each category and each fuel type in the *General Energy Statistics* by the ratios of mobile and stationary combustion on the Table 3-31, which are the survey results executed by MOE in FY2014 and FY2015.

In addition, the fuel consumption, which is estimated by multiplying the fuel consumption of stationary combustion obtained as described above by the fuel consumption ratio of each furnace type, is assumed as the activity data for the stationary combustion (namely combustion in furnaces). Same with Energy Industries (1.A.1), the ratio of fuel consumption of each furnace type was estimated from data on the

General Survey of the Emissions of Air Pollutants and data on each fuel consumption statistics (*Yearbook of the Current Survey of Energy Consumption in the Selected Industries*, *Structural Survey of Energy Consumption*, *Electric Power Statistics*, and *Current Survey of Production Concerning Gas Industry*). See section 3.2.5. b) (1.A.1).

- ***Biomass boilers***

As the activity data from the biomass boilers, the inventory used the fuel consumption for each sector, each fuel type in the *General Energy Statistics*. However, the consumption of non-specified biomass for each industry type before FY2001 under "Auto steam generation sector" in the *General Energy Statistics* was not available because it was not investigated. Therefore, for this period, it was estimated on the assumption that it is proportional to the amount of steam generation for each industry type before FY2001, based on the amount of steam generation in FY2002.

- ***Off-road vehicles and other machinery***

The fuel consumption, which is estimated by multiplying the fuel consumption of each category and each fuel type in the *General Energy Statistics* by the fuel consumption ratio in the Table 3-31, is assumed to be the activity data of the mobile combustion, namely the off-road vehicles and other machinery.

In relation to the Table 3-31, all fuel consumption of fuel oil A and diesel oil of construction in the *General Energy Statistics* were used for activity data of mobile combustion. According to Japan Federation of Construction Contractors, the fuel consumption of electric generator as stationary combustions is included in the value of fuel oil A and diesel oil of construction, however the emission factors of mobile combustion are applied for electric generator, because a combustion engine of electric generator is similar with diesel engine.

Table 3-31 Fuel consumption ratio of mobile combustion and stationary combustion in manufacturing industries and construction (1.A.2)

CRT code	Category in General Energy Statistics	Gasoline		Diesel oil		Fuel oil A		
		Mobile combustion	Stationary combustion	Mobile combustion	Stationary combustion	Mobile combustion (ships)	Mobile combustion	Stationary combustion
1.A.2.a	Manufacture of Iron and Steel	1%	99%	16%	84%			
1.A.2.b	Manufacture of Non-ferrous Metals and Products	24%	76%	1%	99%			
1.A.2.c	Manufacture of Chemical and Allied Products	100%	0%	1%	99%			
1.A.2.d	Manufacture of Pulp, Paper and Paper Products	74%	26%	10%	90%			
	Printing and Allied Industries			0%	100%			
1.A.2.e	Manufacture of Food, Beverages, Tobacco and Feed			1%	99%			
1.A.2.f	Manufacture of Ceramic, Stone and Clay Products	7%	93%	1%	99%			
1.A.2.g	Manufacture of Fabricated Metal Products			1%	99%			
	Manufacture of Machinery	2%	98%	1%	99%			
	Mining, Quarrying of Stone and Gravel			100%	0%	17%	25%	58%
	Manufacture of Lumber and Wood Products, except Furniture and Fixtures			2%	98%			
	Construction Work Industry			100%	0%	0%	100%	0%
	Manufacture of Textile Mill Products	100%	0%					
	Manufacture of Leather Tanning, Leather Products and Fur Skins			0%	100%			
	Manufacture of Furniture and Fixtures			0%	100%			
	Manufacture of Rubber Products			0%	100%			
	Manufacture of Plastic Products, except Otherwise Classified			0%	100%			
	Miscellaneous Manufacturing Industry			4%	96%			

Reference: Estimated based on MOE (2015b) and MOE (2016).

c) Uncertainty Assessment and Time-series Consistency

- ***Furnaces (including Biomass boilers)***

Same as Energy Industries (1.A.1). See section 3.2.5. c).

The consumption of non-specified biomass for each industry type before FY2001 was not available because it was not investigated. Therefore, time-series consistency is ensured by estimating the consumption on the assumption that it is proportional to the amount of steam generation for each industry type before FY2001, based on the amount of steam generation in FY2002.

- ***Off-road vehicles and other machinery***

The default values of the *2006 IPCC Guidelines* were substituted for the uncertainties of emission factors. The uncertainties of the activity data were established from the standard deviation of the rate of statistical discrepancy of liquid and gaseous fuels of the *General Energy Statistics*. For the activity data obtained from the fuel consumption ratio of mobile combustion, the uncertainties of the ratio were estimated from the survey conducted by MOE in FY2014 and FY2015 and they were combined by the error propagation formula. As a result, the uncertainties were determined to be −29% to +41% for CH_4 emissions and −23% to +91% for N_2O emissions from off-road vehicles and other machinery as a whole for the fuel combustion category.

- ***Incineration of waste for energy purposes and with energy recovery***

See section 7.4.3.

d) Category-specific QA/QC and Verification

Same as the Energy Industries (1.A.1). See section 3.2.4. d).

e) Category-specific Recalculations

Since the activity data for FY1990-2023 in the *General Energy Statistics* were revised, the CH_4 and N_2O emissions in those years were recalculated.

Updating the statistical data in the waste sector, CH_4 and N_2O emissions for FY2023 were recalculated. See section 7.4.3 for details.

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

Same as Energy Industries (1.A.1). See section 3.2.5. f).

3.2.8. CO_2 Emissions from Transport (1.A.3: CO_2)

a) Category Description

This section provides the methods used to estimate CO_2 emissions from domestic aviation (1.A.3.a), road transportation (1.A.3.b), railways (1.A.3.c), domestic navigation (1.A.3.d), and other transportation (1.A.3.e). The emissions from mobile sources that the main purpose is other than transport of passenger or freight (e.g. off-road vehicles, work ships and fishing boats) are included in manufacturing industries and construction (1.A.2) and other sectors (1.A.4).

In FY2024, CO_2 emissions from this category accounted for 180,630 kt-CO_2, and represented 17.3% of Japan's total GHG emissions (excluding LULUCF). The road transportation (1.A.3.b) accounts for 88.7% and is the largest within the Transport category.

b) Methodological Issues

- ***Estimation Method***

  - ***Fuels such as gasoline and diesel oil***

The Tier 2 Sectoral Approach has been used in accordance with the decision tree of the *2006 IPCC Guidelines* to calculate emissions (Vol.2, Page 1.9, Fig. 1.2), as was the case for the energy industries (1.A.1). See section 3.2.4. b)). In the CRTs, the CO_2 emissions from biofuels are estimated from domestic supply [#190000] of biofuels from the *General Energy Statistics* and reported in Road transportation (1.A.3.b) as reference values. (The CO_2 emissions from biomass are not included in the national totals in accordance with the *2006 IPCC Guidelines*.)

  - ***Lubricants***

CO_2 is emitted by oxidation of lubricants in engines during use. According to the *2006 IPCC Guidelines* (Vol.3, page 5.6), in the case of 2-stroke (2-cycle) engines, where the lubricant is mixed with another fuel and thus on purpose co-combusted in the engine, the emissions should be estimated and reported as part of the combustion emissions in the energy sector. 2-stroke engine oil for automobile and marine diesel engine oil correspond to be reported in the energy sector. The emissions are estimated by the following equation. The emissions from 2-stroke engine oil are reported in 1.A.3.b and those from marine diesel oil are reported in 1.A.3.d.

$$E = \sum_i (LC_i \times CC_i \times ODU_i \times 44/12)$$

E : CO_2 emissions from lubricants oxidized during use [kt-CO_2]
LC_i : Consumption of lubricant [TJ]
CC_i : Carbon content of lubricant [kt-C/TJ]
ODU_i : Oxidized During Use (ODU) factor
i : Lubricant type (2-stroke engine oil for automobile and marine diesel engine oil)

- ***Emission Factors***

➢ ***Fuels such as gasoline and diesel oil***

The emission factors elaborated in the energy industries (1.A.1) are also used in this category. See section 3.2.4. b).

Please refer to Annex 3 (Section A3.3) for the reasons for the carbon emission factor for diesel oil in 1.A.3.b (Road transportation) is at the level of lower confidence interval of the default value of the *2006 IPCC Guidelines*.

➢ ***Lubricants***

The carbon content *CC* is the carbon emission factor of lubricants elaborated in the energy industries (1.A.1). The ODU factor is 1.0 assuming that all lubricants are oxidized.

- ***Activity Data***

Table 3-32 Energy consumptions in Transport (1.A.3.) (unit: PJ)

Fuel	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Liquid fuels	2,982	3,581	3,735	3,514	3,281	3,135	3,049	2,581	2,601	2,698	2,686	2,645
Solid fuels	0	0	0	0	0	0	0	0	0	0	0	0
Gaseous fuels	0	0	1	4	5	4	3	1	1	1	1	1
Other fossil fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biomass	NO	NO	NO	0	9	10	15	20	20	20	20	20
Total	2,983	3,581	3,736	3,518	3,295	3,149	3,067	2,602	2,622	2,719	2,707	2,666

➢ ***Fuels such as gasoline and diesel oil***

The data given in the *General Energy Statistics* were used for activity data.

The energy consumption reported in each subsector under “Transportation” [#800000] in the *General Energy Statistics* are used for activity data. Because these values include the amount used for purposes other than combustion, the amount reported under ‘non-energy and feedstock use; Transport’ [#953000] was subtracted. (see Table 3-33)

Table 3-33 Correspondence between sectors of Japan's Energy Balance Tables and those of the CRT (1.A.3)

CRT			General Energy Statistics	
1.A.3	Transport			
1.A.3.a	Domestic aviation		Final energy consumption; Passenger; Air passenger transport	#815000
			Final energy consumption; Freight; Air freight transport	#854000
			Non-energy and feedstock use; Transportation (air)	#953000
1.A.3.b	Road transportation			
		i Cars	Final energy consumption; Passenger; Passenger vehicle	#811000
			Non-energy and feedstock use; Transportation (passenger vehicle)	#953000
		ii Light duty trucks	IE (1.A.3.b.iii)	-
		iii Heavy duty trucks and buses	Final energy consumption; Passenger; Bus	#811500
			Final energy consumption; Freight; Truck and lorry	#851000
			Non-energy and feedstock use; Transportation (bus, truck and lorry)	#953000
		iv Motorcycles	Final energy consumption; Passenger; Motorcycles	#812000
			Non-energy and feedstock use; Transportation (Motorcycles)	#953000
		v Other	IE (1.A.3.b.iii)	-
1.A.3.c	Railways		Final energy consumption; Passenger; Railway passenger transport	#813000
			Final energy consumption; Freight; Railway freight transport	#852000
			Non-energy and feedstock use; Transportation (railways)	#953000
1.A.3.d	Domestic navigation		Final energy consumption; Passenger; Water passenger transport	#814000
			Final energy consumption; Freight; Water freight transport	#853000
			Non-energy and feedstock use; Transportation (water)	#953000
1.A.3.e	Other transportation		NO	-

Note: #95xxxx items are subtracted as non-energy use activities.

➢ *Lubricants*

The sales of engine oils for automobiles and navigation are estimated from the total sales of lubricants, and then they are used to estimate the consumptions of total loss type engine oils.

The sales of engine oils for automobile (gasoline engine oil and diesel engine oil) and marine diesel engine oil in cubic volume basis are estimated by multiplying DS[13], or the domestic sales of all lubricants shown in *Yearbook of Mineral Resources and Petroleum Products Statistics* and *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, by R_i, or the proportion of each of engine oil to all lubricants sold to consumers, wholesalers and retailers[14] estimated from these yearbooks. They are multiplied by R_{TLi}, or the proportions of total loss type lubricants to each of engine oil, to obtain the consumptions of total loss type engine oils. R_{TLi} is derived by dividing the productions and imports of 2-stroke engine oils and marine cylinder oil in fiscal year 2011 shown in Japan Lubricating Oil Society (2013) by the domestic sales of engine oils for automobiles and marine diesel engine oil estimated above, respectively (0.65% for engine oils for automobiles and 59% for marine diesel engine oil).

LC_i, or the consumptions of total loss type engine oils in quantity of heat basis, are obtained by converting the consumptions in cubic volume basis by using the gross calorific values of lubricants shown in the *General Energy Statistics*, and they are set as activity data.

$$LC_i = DS \times R_i \times R_{TLi} \times GCV$$

LC_i : Consumption of each of engine oil [TJ]
DS : Domestic sales of all lubricants [1,000 kL]
R_i : Proportion of each of engine oil to all lubricants sold to consumers, wholesalers and retailers
R_{TLi} : Proportions of total loss type lubricants to each of engine oil
i : Lubricant type (engine oils for automobile and marine diesel engine oil)
GCV : Gross calorific values of lubricants [GJ/kL]

[13] Because the data collection process of the domestic sales of lubricants has been changed since FY2022, the domestic sales in and before FY2021 are multiplied by the overlap factor (1.41) given by METI to ensure time-series consistency.
[14] Lubricants sold to consumers, for FY1990-2001.

Table 3-34 Consumption of total loss type engine oils

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Two stroke engine oil for automobiles	TJ	207	215	210	194	183	158	142	144	142	133	125	113
Cylinder oil for navigation	TJ	5,318	5,503	7,144	6,250	4,627	3,502	3,124	2,831	2,602	2,318	2,271	2,234
Total sales of lubricants	1000 kL	3,439	3,292	3,090	2,886	2,485	2,159	2,058	2,017	2,036	1,885	1,835	1,695
Proportion of sales of engine oils for automobiles	-	23%	25%	26%	26%	28%	28%	26%	27%	27%	27%	26%	26%
Proportion of sales of marine diesel engine oils	-	6.5%	7.1%	9.8%	9.1%	7.9%	6.8%	6.4%	5.9%	5.4%	5.2%	5.2%	5.6%
Gross calorific value of lubricants	GJ/kL	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2	40.2

c) Uncertainty Assessment and Time-series Consistency

Same as 3.2.4 Energy Industries (1.A.1). See section 3.2.4. c).

d) Category-specific QA/QC and Verification

Same as the Energy Industries (1.A.1). See section 3.2.4. d).

e) Category-specific Recalculations

Due to the updates of the activity data based on the update of the *General Energy Statistics*, the emissions for the period of FY2009-FY2010, FY2014, FY2016-FY2019, and FY2021-FY2023 were recalculated. Due to the updates of the *Yearbook of Mineral Resources and Petroleum Products Statistics*, the emissions from oxidation of lubricants for FY2023 were recalculated.

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

3.2.9. CH_4 and N_2O Emissions from Transport (1.A.3: CH_4, N_2O)

This section provides the estimation methods for CH_4 and N_2O emissions from domestic aviation (1.A.3.a), road transportation (1.A.3.b), railways (1.A.3.c), domestic navigation (1.A.3.d), and other transportation (1.A.3.e). The emissions from mobile sources that the main purpose is other than transport of passenger or freight (e.g. off-road vehicles, work ships and fishing boats) are included in manufacturing industries and construction (1.A.2) and other sectors (1.A.4).

3.2.9.1. Domestic Aviation (1.A.3.a)

a) Category Description

This section provides the estimation methods for CH_4 and N_2O emissions from energy consumption in domestic aviation. Greenhouse gases associated with the domestic operation of Japanese airliners are mainly emitted from jet fuels. In addition, a small amount of aviation gasoline used by light aircraft and helicopters is also a source of CH_4 and N_2O emissions.

b) Methodological Issues

- ***Estimation Method***

In accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 3.60, Fig. 3.6.1), the emissions from jet fuel for jet aircraft are estimated using the Tier 2 method by each operation phase: Landing/Take-Off (LTO) cycle and cruise. For LTO phase, the emissions by aircraft type are estimated

by multiplying the emission factor per LTO 1 cycle by the number of LTO cycles for each aircraft type on domestic routes, and then they are aggregated. However, the emissions prior to FY2000 are estimated by multiplying the weighted average emission factor for all type of aircraft in FY2001 by the total activity data due to lack of activity data by aircraft type prior to FY2000. For cruise phase, the emissions are estimated from the total jet fuel consumption during cruising on domestic routes.

The emissions from aviation gasoline, which is used for light aircraft and helicopters, are estimated by the Tier 1 method from the total domestic fuel consumption.

$$E_{jet} = \sum_i (EF_{LTO,i} \times AD_{LTO,i}) + EF_{cruise} \times AD_{cruise}$$

E_{jet} : CH_4 and N_2O emissions from domestic airliners using jet fuel
$EF_{LTO,i}$: Emission factor per LTO 1 cycle by aircraft type of domestic airliner
$AD_{LTO,i}$: Number of LTO cycles by aircraft type on domestic routes
EF_{cruise} : Emission factor associated with jet fuel consumption
AD_{cruise} : Jet fuel consumption during cruising on domestic routes
i : Aircraft type

$$E_{gasoline} = EF_{gasoline} \times AD_{gasoline}$$

$E_{gasoline}$: CH_4 and N_2O emissions associated with flight of gasoline-powered domestic aircraft
$EF_{gasoline}$: Emission factor associated with the consumption of aviation gasoline
$AD_{gasoline}$: Consumption of aviation gasoline by aircraft on domestic routes

- ***Emission Factors***

➢ ***Jet fuel***

The default values given in the *2006 IPCC Guidelines* are used for the emission factors of CH_4 and N_2O during LTO as well as cruising (See Table 3-35).

➢ ***Aviation gasoline***

The default values given in the *2006 IPCC Guidelines* are used for emission factors of CH_4 and N_2O (See Table 3-35).

Table 3-35 CH_4 and N_2O emission factors for aircraft

Type of aircraft (fuel)	Flight phase	CH_4	N_2O
Jet aircraft (Jet fuel)	LTO	Varies per aircraft type (see Table 3-36)	
	Cruise	- [1)]	2 [kg-N_2O/TJ(NCV)]
Other than jet aircraft (Aviation gasoline)	-	0.5 [kg-CH_4/TJ(NCV)]	2 [kg-N_2O/TJ(NCV)]

Reference: *2006 IPCC Guidelines*, Volume 2, page 3.64, Table 3.6.5
Note:
LTO: Landing and take-off
1) Excluded from calculations, as the emissions are assumed as negligible in the guidelines.

Table 3-36 CH_4 and N_2O emission factors and fuel consumption for major types of jet aircraft

Aircraft type	CH_4 emission factor [kg/CH_4/LTO] 1)	N_2O emission factor [kg/N_2O/LTO] 1)	Fuel consumption [kg/LTO] 1)
B737-300/400/500	0.08	0.1	780
B737-800	0.07	0.1	880
B747SR (B747-100, -200, -300)	4.84 2)	0.4 2)	3,440 3)
B747-400	0.22	0.3	3,240
B767-300	0.12	0.2	1,780
B777-200/300	0.07	0.3	2,560
A320	0.06	0.1	770
Average of emission factors of all aircraft types in FY 2001 (adopted for the emission factor of all types of aircraft before 2001)	0.34	0.15	—

Reference: *2006 IPCC Guideline*s, Vol. 2, page 3.70, Table 3.6.9
Note:
1) LTO: Landing and take-off
2) Maximum value of B747-100, -200, and -300 is used
3) Average value of B747-100, -200, and -300 is used

- ***Activity Data***

➢ ***Jet fuel***

The number of LTO (landing and take-off) by aircraft type given in the *PRTR Outside Notification Emissions Estimated Data* (MOE) is used as activity data for LTO. However, these data involve the international flights LTO, thus the number of international flights LTO is subtracted for each aircraft type used for both domestic and international flights in same ratio of domestic and international flights from total LTO, so as to keep the total number of domestic LTO in the *Airport Management Status Study Report* (MLIT).

The fuel consumption during LTO is calculated by multiplying the fuel amount consumed per one LTO, which is given in the 2006 *IPCC Guidelines* for each aircraft type, by the number of LTO given above.

The fuel consumption for cruising is estimated by subtracting the amount of jet fuel consumed during LTO from the total jet fuel consumption in the *Statistical Yearbook of Air Transport* (MLIT).

➢ ***Aviation gasoline***

The consumption of gasoline in the domestic aviation, which is taken from the *General Energy Statistics*, is used for activity data.

Table 3-37 Activity data used for emission estimates of aircraft

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Number of LTO cycle	1000 LTO	669	783	865	895	882	993	997	627	793	1,006	1,002	993
Jet fuel consumption during cruise	1000 kL	1,621	2,425	2,742	3,031	2,629	2,933	3,005	1,553	2,045	3,010	3,174	3,227
Aviation gasoline consumption	1000 kL	5.3	6.0	4.3	7.7	1.9	1.9	1.7	2.4	2.4	2.5	2.5	2.2

Table 3-38 Number of LTO cycle of major types of jet aircraft since FY2001

Aircraft type	Unit	2001	2005	2010	2013	2015	2020	2021	2022	2023	2024
B737-300/400/500	1000 LTO	123	103	84	131	80	7	3	NO	17	16
B737-800		NO	NO	97	118	166	134	168	219	198	195
B747SR		43	30	3	1	1	NO	2	2	0	0
B747-400		56	54	22	14	5	2	NO	NO	2	2
B767-300		146	103	101	87	75	26	33	52	57	56
B777-200/300		69	76	89	93	78	19	19	18	32	31
A320		59	47	48	95	103	71	90	99	75	73

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

As for the uncertainty of emission factors, the default values by each aircraft type per one LTO given in the *2006 IPCC Guidelines* (Tier 2) are applied for the emission factors, and the estimation is considered to be more accurate than Tier 1. Therefore, the values of the Tier 1 default uncertainty in the guideline (CH_4: -57% to +100%, N_2O: -70% to +150%) are considered to be the upper limit, and are adopted. As for the uncertainty of activity data, because the *Airport Management Status Study Report* is a complete survey executed by MLIT, the values in the *2006 IPCC Guidelines* (-5% to +5%) are used. As a result, the uncertainty of the emissions from domestic aviation is evaluated as -57% to +100% for CH_4, and -70% to +150% for N_2O.

- ***Time-series Consistency***

For the emission factors per LTO, the same value is used for every fiscal year since FY2001 by each aircraft type. For the emission factors prior to FY2000, because the activity data by each aircraft type are not available, the average emission factor for all aircraft type is established from the FY2001 data, and it is used for the fiscal years back to FY1990. In addition, the jet fuel consumption in the *Statistical Yearbook of Air Transport* and the aviation gasoline consumption in the *General Energy Statistics* are used as activity data consistently from FY1990 to the nearest year.

d) Category-specific QA/QC and Verification

Same as the Energy Industries (1.A.1). See section 3.2.4. d).

e) Category-specific Recalculations

Due to update of the number of LTO by aircraft type in FY2023 in the *PRTR Outside Notification Emissions Estimated Data*, the CH_4 and N_2O emissions from jet fuel in FY2023 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

3.2.9.2. Road Transportation (1.A.3.b)

This section provides the estimation methods for CH_4 and N_2O emissions from the following vehicle categories:

Table 3-39 Reporting categories and definitions of emissions from automobiles

Vehicle type	Definition	Fuel type for emission reporting			
		Gasoline	Diesel	LPG	Natural gas
Light passenger vehicles	Light vehicles used for transportation of people	Yes	-	-	-
Passenger vehicles	Regular vehicles or small vehicles used for transportation of people, with a capacity of 10 persons or less	Yes	Yes	Yes	Yes
Buses	Regular vehicles or small vehicles used for transportation of people, with a capacity of 11 persons or more	Yes	Yes	Yes [1)]	Yes
Light cargo trucks	Light vehicles used for transportation of cargo	Yes	-	-	-
Small cargo trucks	Small vehicles used for transportation of cargo	Yes	Yes	Yes [1)]	Yes [2)]
Regular cargo trucks	Regular vehicles used for transportation of cargo	Yes	Yes		
Special-purpose vehicles	Regular, small or light vehicles used for special purposes, including flushers, advertising vans, hearses, and others	Yes	Yes		Yes
Motorcycles	Two-wheeled vehicles	Yes	-	-	-

1) The vehicle type is grouped as “Others”.
2) The vehicle type is grouped as cargo trucks.

Table 3-40 Correspondence between vehicle type and sectors of the CRT (1.A.3.b)

CRT	Vehicle type, or notation key
1.A.3.b.i. Cars	Light passenger vehicles and passenger vehicles
1.A.3.b.ii. Light duty trucks	IE (included in 1.A.3.b.iii. Heavy duty trucks and buses)
1.A.3.b.iii. Heavy duty trucks and buses	Buses, light cargo trucks, small cargo trucks, regular cargo trucks, and special-purpose vehicles
1.A.3.b.iv. Motorcycles	Motorcycles
1.A.3.b.v. Other	IE (included in 1.A.3.b.iii. Heavy duty trucks and buses)

Different estimation methods are used between motorcycles and other road transportation vehicles. Road transportation vehicles other than motorcycles (section 3.2.9.2.a) and Motorcycles (section 3.2.9.2.b) are separately described in the following sections.

3.2.9.2.a. Road Transportation: Vehicles Other Than Motorcycles

a) Category Description

This section provides the estimation methods for CH_4 and N_2O emissions from road transportation vehicles other than motorcycles, namely light passenger vehicles, light cargo trucks, passenger vehicles, buses, small cargo trucks, regular cargo trucks, and special-purpose vehicles.

b) Methodological Issues

- ***Estimation Method***

The emissions are calculated by using the Tier 3 method, in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 3.14, Fig. 3.2.3).

$$E = \sum_i (EF_i \times AD_i)$$

E : CH_4 and N_2O emissions from road transportation (vehicles other than motorcycles)
EF_i : Emission factor per distance traveled by vehicle type
AD_i : Distance traveled by vehicle type
i : Vehicle type

- ***Emission Factors***

The emission factors for CH_4 and N_2O are established for each fuel type for each vehicle type, using the data shown in Table 3-41.

For "JAMA etc. data", the emission factors are established on the basis of the raw emission factors data provided by Japan Automobile Manufacturers Association (hereinafter referred to as JAMA) and other organizations[15]. For "JAMA data", the emission factors are established on the basis of the raw emission factors data provided by JAMA only. The raw emission factors are arranged[16] as combined mode emission factors[17] by vehicle exhaust gas regulation[18] year. The emission factors are estimated by averaging the arranged emission factors weighted by the number of vehicles of each regulation year of each car type. The main reference of the number of vehicles is *Statistics of AIRIA/ Number of Motor Vehicles* compiled by the Automobile Inspection and Registration Information Association (AIRIA). (See Table 3-42, Table 3-43.)

For "Measured data", the emission factors are established on the basis of actual Japanese data. The emission factors are developed as weighted averages calculated from emission factors estimated by each class of running speed and proportion of distance traveled for each class of running speed given in *Road Transport Census* (MLIT). The emission factors reflect the actual operation of vehicles in Japan because the proportion of distance traveled by each class of running speed during rush hour was applied.

The N_2O emission factors for natural gas trucks are established from actual measurement data. The emission factors are developed as weighted averages calculated from emission factors of each class of running speed based on actual measurements taken in Japan and the proportion of distance traveled for each class of running speed reported in the *Road Transport Census*. However, N_2O emission factors for passenger vehicles, buses, and special-purpose vehicles, and CH_4 emission factors for special-purpose vehicles are established by the method indicated in Table 3-41, because of the absence of actual measurement data in Japan.

The detailed method for establishing the emission factors is described in MOE (2006b).

[15] MOE, Bureau of Environment of Tokyo Metropolitan Government, NIES, National Traffic Safety and Environment Laboratory (NTSEL), and Japan Petroleum Energy Center (JPEC)

[16] The emission factors of regular cargo trucks take into account penetration status of selective catalytic reduction (SCR) technologies.

[17] The data were provided by test mode. The emission factors were calculated using "combined driving mode". "Combined JC08 driving mode" = "hot start driving mode" ×0.75 + "cold start driving mode" ×0.25

[18] The regulated gases are air pollutants such as CO, non-methane hydrocarbons (NMHC), NOx and particulate matter (PM). The history of the regulation limits is available at https://www.mlit.go.jp/jidosha/jidosha_tk10_000002.html (in Japanese).

Table 3-41 Data source of the emission factors of vehicle

Fuel / Vehicle type	Gasoline		Diesel		Natural gas	
	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O
Light passenger vehicles	JAMA etc. data	JAMA etc. data				
Passenger vehicles	JAMA etc. data	JAMA etc. data	JAMA etc. data	JAMA etc. data	JAMA data	The EF of small cargo trucks is used considering the standard of vehicle type.
Buses	2006GL	2006GL	Measured data	2006GL	JAMA data	Established by correcting the EF of regular cargo trucks by the equivalent inertial weight ratio considering vehicle weight.
Light cargo trucks	JAMA etc. data	JAMA etc. data				
Small cargo trucks	JAMA etc. data	JAMA etc. data	JAMA etc. data	JAMA etc. data		Established based on the actual measured data (grouped as cargo trucks).
Regular cargo trucks	2006GL	2006GL	JAMA etc. data	JAMA etc. data	JAMA data	
Special-purpose vehicles	2006GL	2006GL	Measured data	2006GL	Established using the corrected travel distance ratio by each running speed, considering the EFs by each speed of regular cargo trucks and running pattern of special-purpose vehicles.	

Note:
1) JAMA etc. data: Calculated by using driving mode test data provided by Japan Automobile Manufacturers Association (JAMA) and other organizations
2) JAMA data: Calculated by using driving mode test data provided by JAMA
3) Measured data: Using actual Japanese data other than the above JAMA data
4) 2006GL: Using the default values in the *2006 IPCC Guidelines*.
5) EFs of LPG passenger vehicles for business use (taxis) are the same as those of gasoline passenger vehicles. EFs of the other LPG vehicles are the same as those of gasoline regular cargo trucks.

Table 3-42 CH_4 emission factors for road transportation

Fuel	Vehicle type	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Gasoline	Light passenger vehicle	mg-CH_4/km	8.3	8.3	8.2	6.9	5.0	4.2	3.8	3.3	3.3	3.3	3.3	3.3
	Passenger vehicle (non-hybrid)		14.5	14.5	14.3	11.3	8.0	6.6	6.0	5.0	4.9	4.8	4.8	4.7
	Passenger vehicle (hybrid)		NO	NO	NO	1.8	1.8	1.8	1.8	2.0	2.0	2.1	2.2	2.2
	Bus		14											
	Light cargo truck		18.7	18.7	18.0	11.7	7.2	5.8	5.2	4.2	4.0	3.9	3.8	3.8
	Small cargo truck		21.2	21.2	21.2	14.5	8.8	6.8	5.9	4.5	4.3	4.2	4.2	4.1
	Regular cargo truck		14											
	Special-purpose vehicle		14											
Diesel	Passenger vehicle		11.3	12.2	12.6	12.8	12.8	12.9	12.4	10.5	10.1	9.8	9.5	9.2
	Bus		19.0	18.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0	17.0
	Small cargo truck		9.6	10.7	10.1	8.7	8.3	7.9	7.7	7.2	7.1	7.0	7.0	6.9
	Regular cargo truck		17.0	16.0	15.0	13.9	11.1	9.6	8.5	5.9	5.6	5.2	4.9	4.6
	Special-purpose vehicle		17.0	15.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0	13.0
LPG	Passenger vehicle		14.5	14.5	14.3	11.3	8.0	6.6	6.0	5.0	4.9	4.8	4.8	4.7
	Others		14											
Natural gas	Passenger vehicle		13											
	Bus		50											
	Cargo truck		93											
	Special-purpose vehicle		105											

Table 3-43 N_2O emission factors for road transportation

Fuel	Vehicle type	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Gasoline	Light passenger vehicles	mg-N_2O/km	14.2	14.2	13.9	9.3	5.2	3.6	2.9	2.0	2.0	1.9	1.9	1.9
	Passenger vehicles (non-hybrid)		23.7	23.7	20.3	12.2	6.3	4.4	3.7	2.8	2.7	2.7	2.6	2.6
	Passenger vehicles (hybrid)		NO	NO	NO	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.2	1.2
	Buses		25											
	Light cargo trucks		23.7	23.7	21.7	12.8	7.3	5.7	5.0	3.8	3.7	3.6	3.4	3.4
	Small cargo trucks		21.1	21.6	21.8	13.1	8.0	6.3	5.5	4.1	3.8	3.7	3.5	3.3
	Regular cargo trucks		25											
	Special-purpose vehicles		25											
Diesel	Passenger vehicles		5.7	4.7	4.4	4.4	4.9	5.4	5.1	4.3	4.2	4.0	4.0	3.9
	Buses		3.0											
	Small cargo trucks		9.3	10.3	11.1	11.7	12.2	12.5	12.7	13.0	13.1	13.1	13.1	13.2
	Regular cargo trucks		15.0	15.0	14.9	16.9	31.8	35.2	37.6	40.2	40.2	40.2	40.2	40.1
	Special-purpose vehicles		3.0											
LPG	Taxis		23.7	23.7	20.3	12.2	6.3	4.4	3.7	2.8	2.7	2.7	2.6	2.6
	Others		25											
Natural gas	Passenger vehicles		0.2											
	Buses		38											
	Cargo trucks		13											
	Special-purpose vehicles		15											

- ***Activity Data***

The estimates of annual distance traveled by each vehicle type and by each fuel type are used as activity data.

As for gasoline, diesel and LPG vehicles, the method of estimating the distance traveled by each vehicle type and by each fuel type up to FY2009 is to multiply the proportion of distance traveled for each fuel type, which is calculated from fuel consumption and fuel efficiency, by the distance traveled for each vehicle type given in *Statistical Yearbook of Motor Vehicle Transport* (MLIT). To separate out hybrid passenger vehicles (PV) from gasoline PV, the distance traveled by hybrid PV is estimated by multiplying the number of the vehicles by the annual distance traveled per vehicle. Before estimating the distance traveled, the values of *Statistical Yearbook of Motor Vehicle Transport* are converted to be consistent with the activity data since FY2010, using the overlap factors given by MLIT.

The annual distance traveled by vehicle type and by fuel type since FY2010 for gasoline, diesel and LPG vehicles is given in *Statistical Yearbook of Motor Vehicle Fuel Consumption* (MLIT). *Monthly Report of Motor Vehicle Transport Statistics* (MLIT) are also used supplementarily to estimate the annual distance for some vehicle types.

As for the natural gas vehicles, the annual distance traveled per vehicle type is determined by multiplying the number of natural gas-powered vehicles by the annual distance traveled per vehicle. From FY1990 to FY1996, the number of these vehicles is taken from the number of introduced natural gas-powered vehicles per type in the data compiled by the Japan Gas Association, and from FY1997, the number of registered natural gas-powered vehicles reported in the *Statistics of AIRIA/ Number of Motor Vehicles*. For the annual distance traveled per vehicle, the activity data are calculated using the annual total distance traveled by natural gas-powered vehicles, reported in the *Statistical Yearbook of Motor Vehicle Fuel Consumption*, the annual distance traveled by each vehicle type reported in the *Statistical Yearbook of Motor Vehicle Transport*, and the number of registered vehicles by each vehicle type reported in the *Statistics of AIRIA/ Number of Motor Vehicles*.

Table 3-44 Distance traveled of automobiles

Fuel	Vehicle type	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Gasoline	Light passenger vehicle	Billion vehicle-km	16	41	72	106	137	150	161	163	159	165	164	165
	Passenger vehicle (non-hybrid)		273	304	343	349	319	303	273	209	193	204	190	184
	Passenger vehicle (hybrid)		NO	NO	NO	3	14	38	58	91	95	111	120	129
	Bus		0.09	0.03	0.02	0.04	0.31	0.19	0.21	0.17	0.19	0.20	0.23	0.23
	Light cargo truck		91	90	80	78	75	77	76	66	62	65	65	63
	Small cargo truck		29	20	20	21	22	23	23	20	18	20	21	20
	Regular cargo truck		0	0	0	1	1	1	1	1	1	1	1	1
	Special-purpose vehicle		1	1	1	1	3	3	2	2	3	3	3	3
Diesel	Passenger vehicle		40	63	55	29	10	8	9	13	14	16	17	18
	Bus		7	7	6	7	6	6	6	4	4	4	5	5
	Small cargo truck		44	49	45	33	23	23	22	18	18	19	19	19
	Regular cargo truck		58	68	72	69	63	59	59	56	58	59	58	57
	Special-purpose vehicle		9	14	17	17	21	21	21	19	20	21	21	21
LPG	Taxi		18	17	15	14	11	10	9	4	4	4	4	4
	Others		IE	IE	IE	IE	0.70	0.53	0.42	0.21	0.18	0.17	0.15	0.14
Natural gas	Passenger vehicle	Million vehicle-km	0.05	0.10	1.93	5.91	6.00	3.01	1.57	0.09	0.06	0.06	0.07	0.07
	Bus		NO	1.9	15	48	52	39	28	5	3	3	2	2
	Cargo truck		0.22	10	79	254	303	265	230	85	68	57	51	47
	Special-purpose vehicle		0.05	2.2	18	57	67	62	49	17	13	12	10	8

- ***N_2O emissions from gasoline passenger vehicles in Japan***

With the enhancement of the regulation of exhaust emissions of air pollutants on gasoline passenger vehicles in 1978, the under-floor type three-way catalyst started to be installed in Japan, leading to an increase in N_2O emissions per distance traveled until around 1986 when the three-way catalyst became widely used. New emission regulations on gasoline passenger vehicles were not stipulated for the time being. Therefore, N_2O emissions per distance traveled were stable from 1986 to 1997. From 1997, low emission vehicles were introduced. From 2000, with the stipulation of the "2000 Emission Regulation", N_2O emissions per distance traveled started to decrease in response to the introduction of the close-coupled catalytic converter (or directly exhaust manifold type catalyst). Since 1997, the trend of N_2O emissions per distance traveled is on the decrease.

The purification of toxic gas by catalyst does not start if the catalyst temperature has not exceeded a certain threshold level. Therefore, the early activation (or quick temperature raise) of catalyst at cold start has been projected, and the catalyst was relocated directly under the exhaust manifold, and this structure is introduced to close-coupled catalytic converter. N_2O is produced at medium temperature range, however the temperature of close-coupled catalytic converter reaches over this range in a short time period, thus the N_2O emissions can be reduced. (Goto et al., 2003; Yoda et al., 2010)

The figure below shows the N_2O emissions from a vehicle with the under-floor type catalyst and a vehicle with the directly exhaust manifold type catalyst on the condition of the same test mode.

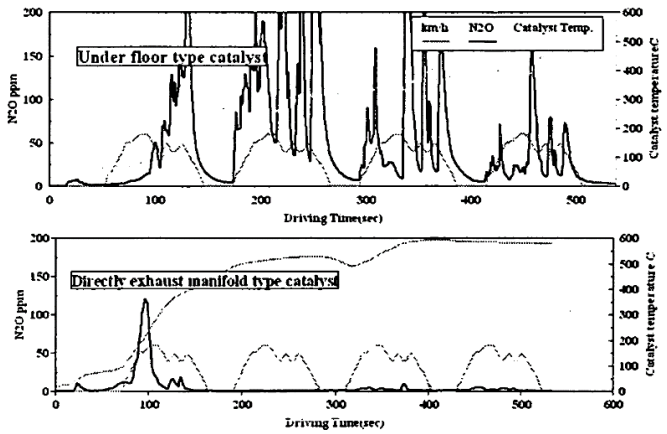

Figure 3-6 Difference of N_2O emissions by catalyst fitting position
Note: Test mode is 11 mode. Reference: Goto et al. (2003)

- ***Completeness***

➢ ***Biofuels***

Biofuels have been used in recent years, however the CH_4 and N_2O emissions are estimated from activity data, which are not fuel consumption but mileage by vehicle type, and it is impossible to extract mileage only for biofuels. Therefore, CH_4 and N_2O emissions from biofuels are reported as "IE", assuming those emissions are already included in the existing emissions from gasoline or diesel oil.

➢ ***Methanol***

The number of methanol vehicles owned in Japan was only 9 at the end of March 2016 (data surveyed by AIRIA). Therefore, activity data is negligible, and is not reported, as it is assumed that the emissions are also negligible.

➢ ***Lubricants***

Since CH_4 and N_2O emissions from use of lubricants are very small in comparison to CO_2, these can be neglected for the greenhouse gas calculation according to the *2006 IPCC Guidelines* (Vol.3, page 5.7). Therefore, the emissions are reported as "NE".

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

The emission factors of road transportation vehicles are established from the data provided by JAMA and other organizations. For the emission factors established from the samples more than five, the uncertainty is calculated from 95% confidence interval with the assumption of logarithmic standard deviation. For the emission factors established from the samples less than five, the default values of uncertainty in the *2006 IPCC Guidelines* are adopted. As for the uncertainty of activity data, because the *Statistical Yearbook of Motor Vehicle Fuel Consumption* is used for the activity data, the target accuracy of the Motor Vehicle Fuel Consumption Survey (Statistics Commission, 2010) is used for the uncertainty. As a result, the uncertainty of emissions from road transportation vehicles including motorcycles is evaluated as -36% to +104% for CH_4, and -37% to +107% for N_2O.

- ***Time-series Consistency***

The emission factors are developed by using the same method throughout the time-series. The activity data of gasoline, diesel and LPG vehicles by FY2009 are estimated using the overlap factors given by MLIT, to be consistent with the activity data since FY2010. The activity data of natural gas vehicles are estimated based on the number of registered vehicles reported in the *Statistics of AIRIA/ Number of Motor Vehicles* after the accurate data has become available in 1997, and using the Japan Gas Association data for the total number of vehicles introduced before 1996 when the natural gas-powered vehicles was not popular. As for other activity data of natural vehicle, the data are estimated based on the *Statistical Yearbook of Motor Vehicle Transport* and the *Statistics of AIRIA/ Number of Motor Vehicles* by a consistent method throughout the time-series from FY1990 to the nearest year.

d) Category-specific QA/QC and Verification

- ***QA/QC***

Same as the Energy Industries (1.A.1). See section 3.2.4. d).

- ***Verification***

It is *good practice* to compare fuel consumption with distance traveled according to the *2006 IPCC Guidelines* (Vol.2, Section 3.2.1.3).

The following tables show the annual number of vehicles by type, the annual mileage per vehicle and the fuel efficiency per vehicle type. Please note that not all these data are used for the estimation of the activity data as stated in the previous section.

Table 3-45 Annual number of vehicles by type

Fuel	Vehicle type	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Gasoline	Light passenger vehicle	1000 vehicles	2,715	5,966	10,084	14,350	18,004	20,230	21,477	22,736	22,850	23,071	23,226	23,376
	Passenger vehicle (non-hybrid)		29,140	33,891	37,794	40,104	37,594	35,023	32,685	27,469	26,416	25,334	24,074	22,854
	Passenger vehicle (hybrid)		NO	NO	NO	253	1,404	3,823	5,559	10,014	10,805	11,655	12,697	13,786
	Bus		8	3	2	5	9	13	15	18	19	19	19	19
	Light cargo truck		12,312	11,377	9,958	9,548	8,923	8,708	8,520	8,284	8,299	8,365	8,370	8,378
	Small cargo truck		2,820	2,144	1,901	1,988	1,826	1,772	1,750	1,709	1,692	1,666	1,633	1,593
	Regular cargo truck		41	38	39	90	128	140	150	162	163	164	163	162
	Special-purpose vehicle		141	198	393	330	287	291	297	313	317	322	326	330
Diesel	Passenger vehicle		2,994	4,924	4,254	2,126	905	730	855	1,437	1,528	1,609	1,679	1,726
	Bus		238	240	233	225	216	212	214	202	196	191	189	187
	Small cargo truck		3,711	4,002	3,480	2,545	1,954	1,824	1,780	1,748	1,749	1,759	1,759	1,752
	Regular cargo truck		2,164	2,544	2,534	2,350	2,105	2,100	2,130	2,243	2,258	2,266	2,272	2,275
	Special-purpose vehicle		628	804	994	903	820	818	829	869	873	877	880	886
LPG	Passenger vehicle		302	288	265	262	225	204	191	130	120	112	101	89
	Others		16	16	21	32	32	28	25	15	13	12	10	9
Natural gas	Passenger vehicle		0.01	0.01	0.2	0.6	0.7	0.3	0.2	0.01	0.01	0.01	0.01	0.01
	Bus		NO	0.04	0.3	1.1	1.2	0.9	0.7	0.2	0.1	0.1	0.1	0.1
	Cargo truck		0.01	0.5	3.9	12.8	15.0	12.9	11.0	4.9	3.9	3.5	3.1	2.8
	Special-purpose vehicle		0.004	0.2	1.5	4.8	5.6	4.9	3.9	1.5	1.3	1.1	0.9	0.7

Reference: *Statistics of AIRIA/ Number of Motor Vehicles* and Japan Gas Association

Table 3-46 Annual mileage per vehicle

Fuel	Vehicle type	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Gasoline	Light passenger vehicle	1000 km /vehicle	5.8	6.8	7.2	7.4	7.6	7.4	7.5	7.1	7.0	7.2	7.0	7.1
	Passenger vehicle (non-hybrid)		9.4	9.0	9.1	8.7	8.5	8.6	8.3	7.6	7.3	8.1	7.9	8.0
	Passenger vehicle (hybrid)[1)]		NO	NO	NO	10.1	10.2	10.0	10.5	9.0	8.8	9.5	9.5	9.4
	Bus		11.9	9.3	9.0	8.6	34.7	14.9	14.5	9.3	10.1	11.0	12.2	12.4
	Light cargo truck		7.4	7.9	8.0	8.2	8.4	8.9	8.9	8.0	7.5	7.7	7.7	7.5
	Small cargo truck		10.3	9.5	10.3	10.5	12.2	13.1	13.1	11.7	10.9	12.3	12.8	12.4
	Regular cargo truck		8.8	7.7	6.9	6.7	11.0	9.9	9.4	7.4	7.5	7.0	6.7	7.2
	Special-purpose vehicle		4.7	3.5	3.3	3.9	9.9	8.9	8.3	7.4	8.0	8.0	8.3	8.0
Diesel	Passenger vehicle		13.3	12.8	13.0	13.7	11.4	11.1	10.1	9.2	9.3	9.7	10.2	10.6
	Bus		28.9	27.6	27.9	28.9	28.6	28.2	27.4	18.7	18.7	22.3	24.2	25.1
	Small cargo truck		11.8	12.2	12.9	12.9	11.8	12.4	12.1	10.2	10.1	10.8	11.0	11.1
	Regular cargo truck		26.7	26.8	28.6	29.5	29.9	28.1	27.9	24.9	25.9	25.9	25.6	25.1
	Special-purpose vehicle		14.6	16.9	17.2	18.9	25.3	25.9	25.9	22.4	23.3	23.9	23.8	23.3
LPG	Passenger vehicle		59.6	58.6	56.8	52.2	50.9	47.8	46.1	27.5	29.5	36.6	37.9	40.2
	Others		IE	IE	IE	IE	21.9	19.0	17.3	14.0	13.6	14.6	14.7	15.0
Natural gas	Passenger vehicle		10.2	9.8	9.8	9.2	8.9	9.0	8.9	8.1	7.8	8.6	8.6	8.7
	Bus		NO	47.6	45.9	44.9	43.3	41.9	39.9	26.8	26.0	31.2	33.3	34.5
	Cargo truck		18.7	18.9	20.2	19.9	20.2	20.6	20.9	17.5	17.2	16.5	16.2	16.6
	Special-purpose vehicle		11.1	11.2	12.0	11.8	12.0	12.7	12.6	10.8	10.3	11.3	11.5	11.2

Note: Estimated by dividing the distance traveled on Table 3-44 by number of vehicles on Table 3-45.
1) Due to absence of mileage statistical data, the values until FY2009 are assumed to be the mean value of FY2010-2014.

Table 3-47 Fuel efficiency per vehicle type

Fuel	Vehicle type	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Gasoline	Light passenger vehicle	km/L	14.2	12.9	12.0	12.6	12.6	13.3	13.7	15.1	15.0	15.1	15.3	15.1
	Passenger vehicle (non-hybrid)[1)]	km/L	10.0	9.2	9.0	9.8	9.8	10.0	10.2	10.6	10.6	10.8	10.8	10.8
	Passenger vehicle (hybrid)	km/L	NO	NO	NO	IE	16.3	15.7	16.0	17.1	16.8	16.8	17.0	16.5
	Bus[2)]	km/L	4.1	3.9	4.1	4.3	5.8	6.5	6.8	7.7	7.5	7.8	7.9	7.8
	Light cargo truck	km/L	12.3	11.4	11.1	11.7	12.1	12.0	12.1	13.0	12.9	13.2	13.1	13.1
	Small cargo truck[3)]	km/L	8.2	7.7	8.2	8.5	9.3	9.1	9.0	9.9	9.8	9.9	10.0	9.6
	Regular cargo truck	km/L	4.4	4.2	4.4	4.6	IE	IE	IE	IE	IE	IE	IE	IE
	Special-purpose vehicle	km/L	5.1	4.8	5.2	6.4	IE	IE	IE	IE	IE	IE	IE	IE
Diesel	Passenger vehicle	km/L	9.7	7.8	7.0	6.9	9.0	9.0	9.3	12.3	12.7	12.7	12.7	12.8
	Bus	km/L	3.6	3.4	3.4	3.6	3.6	3.5	3.6	3.4	3.4	3.4	3.3	3.3
	Small cargo truck	km/L	9.7	10.0	9.7	10.1	9.1	8.7	8.6	8.6	8.6	8.8	8.7	8.6
	Regular cargo truck	km/L	3.3	3.2	3.4	3.7	3.7	3.9	3.9	3.9	3.8	4.0	3.9	4.0
	Special-purpose vehicle	km/L	3.0	3.0	3.2	3.8	4.0	4.1	4.0	4.0	4.0	4.0	4.1	4.1
LPG	Taxi	km/L	6.0	5.6	5.3	5.4	5.5	5.4	5.5	5.9	6.0	6.6	6.8	7.1
	Others	km/L	IE	IE	IE	IE	4.4	4.3	4.2	4.2	4.1	4.4	4.4	4.6
Natural gas	All types[4)]	km/m^3	4.1	4.1	4.1	4.1	4.1	4.2	4.2	4.0	3.9	3.9	4.1	4.2

Note: Mileage in *Statistical Yearbook of Motor Vehicle Fuel Consumption* and *Statistical Yearbook of Motor Vehicle Transport* are divided by fuel consumption in each statistics.

1) Hybrid passenger vehicles are included until FY2009.
2) Passenger vehicles for business-non-cargo-use and special-purpose vehicles for private-non-cargo-use are included since FY2010.
3) Regular cargo trucks and special-purpose vehicles for business cargo are included since FY2010.
4) Due to absence of fuel consumption statistical data, the values until FY2009 are assumed to be the same as the value of FY2010.

In regard to the relation between mileage and fuel consumption used for emission estimation, *Statistical Yearbook of Motor Vehicle Transport* and *Statistical Yearbook of Motor Vehicle Fuel Consumption* provide the annual total mileage, the fuel consumption (and the fuel efficiency derived from them). The annual total mileage from these statistics are used as a basis of the activity data to estimate CH_4 and N_2O emissions. The CO_2 emissions are estimated by using *General Energy Statistics* (Japan's energy balance tables). *General Energy Statistics* uses the fuel consumption given in the above mentioned MLIT's statistics as primary statistics. Therefore, the same statistics are used as a basis in estimating both CO_2, CH_4 and N_2O emissions.

e) Category-specific Recalculations

New measurements of raw emission factors for vehicles were provided by JAMA and the Bureau of Environment of the Tokyo Metropolitan Government. Therefore, the emission factors were revised for light passenger vehicles since FY2018, gasoline and LPG passenger vehicles since FY2018, gasoline hybrid passenger vehicles since FY2003, gasoline small cargo trucks since FY2018, and diesel passenger vehicles since FY2018. In response to these revisions, the CH_4 and N_2O emissions for the period of FY2003-FY2023 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

The emission factors will be reviewed, as appropriate, in order to represent Japan's circumstances more suitably.

3.2.9.2.b. Motorcycles

a) Category Description

This section provides the estimation methods for CH_4 and N_2O emissions from motorcycles.

b) Methodological Issues

- ***Estimation Method***

The CH_4 and N_2O emissions from motorcycles are established by using Tier 3 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 3.14, Fig. 3.2.3). According to the Tier 3 method (Vol. 2, page 3.15, Equation 3.2.5), the equation indicates the aggregation of two types of emissions in different condition, one is the emissions in "hot" (running) condition when the engine is warm, and the other is "cold start" condition when the engine is cold at starting.

In Japan, the emission control regulation[19] for motorcycle has been established in 1999, and JAMA has collected the CH_4 and N_2O emission data measured by test from "hot" and "cold start" condition engines of each type of emission-controlled motorcycles. For these motorcycles, the emission factors are established from these measured data, and for emission uncontrolled motorcycles the default values in the *2006 IPCC Guidelines* are used. The CH_4 and N_2O emissions are estimated and aggregated by using the equations below.

$$E = \sum_{i,j} (EF_{hot,i,j} \times AD_{hot,i,j} + EF_{cold,i,j} \times AD_{cold,i,j})$$

E : CH_4 and N_2O emissions from motorcycles
$EF_{hot,i,j}$: Emission factor for vehicle-km by type of motorcycle and by emission control status
$AD_{hot,i,j}$: Total annual distance traveled by motorcycles by type and by emission control status
$EF_{cold,i,j}$: Emission factor per startup by type and by emission control status
$AD_{cold,i,j}$: Number of engine startups per year by each type of motorcycle and by emission control status
i : Vehicle type
j : Emission control status

- ***Emission Factors***

➢ ***"Hot" condition***

The CH_4 and N_2O emission factors established by JAMA are used for the emission-controlled motorcycles, and for uncontrolled motorcycles the default values in the *2006 IPCC Guidelines* are used.

Table 3-48 CH_4 and N_2O emission factors of motorcycle in "hot" condition [mg/km]

Vehicle type (displacement)	3rd and 4th Regulation[1)]		1st and 2nd Regulation[1)]		Uncontrolled [2)]	
	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O
Motor-driven cycles class 1 (50cc and under)[3)]	2.1	0.18	13.3	2.64	53	4
Motor-driven cycles class 2 (51cc-125cc)	3.2	0.94	16.7	0.23		
Mini-sized motorcycles (126cc-250cc)	6.2	0.61	12.5	0.85		
Small-sized motorcycles (Over 250cc)	2.2	0.36	22.2	1.09		

Note:
1) Data provided by JAMA
2) *2006 IPCC Guidelines*, Vol. 2, page 3.22, Table 3.2.3 Motorcycles/Uncontrolled/Running(hot)
3) Motor-driven cycles with displacement of 125cc or less and maximum output of 4.0 kW or less (so-called new standard motor-driven cycles) will be included as class 1 since FY2025.

➢ ***"Cold start" condition***

The CH_4 and N_2O emission factors established by JAMA are used for the emission-controlled motorcycles, and for uncontrolled motorcycles the default values in the *2006 IPCC Guidelines* are used.

[19] Primarily, the regulated gases were CO, hydrocarbons (HC) and NOx. Non-methane hydrocarbons (NMHC) and particulate matter (PM) were added from the 4th regulation.

Table 3-49 CH_4 and N_2O emission factors for motorcycles in "cold start" condition [mg/start]

Vehicle type	3rd and 4th Regulation 1)		1st and 2nd Regulation 1)		Uncontrolled 2)	
	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O
Motor-driven cycles class 1	32.3	5.6	15.8	11.2	33	15
Motor-driven cycles class 2	30.0	17.3	18.3	4.2		
Mini-sized motorcycles	51.3	14.7	30.2	13.7		
Small-sized motorcycles	56.5	15.2	26.1	6.9		

Note:
1) Data provided by JAMA
2) *2006 IPCC Guidelines*, Vol. 2, page 3.22, Table 3.2.3 Motorcycles/Uncontrolled/cold start

- ***Activity Data***

➢ ***"Hot" condition***

For the estimation of annual distance traveled by each vehicle type and by each emission control status, firstly and based on the number of owned vehicles by each vehicle type (*Monthly Report Statistics of Vehicle*s (JAMA), *Survey of Levy Status of City, Town and Village Taxes* (Ministry of Internal Affairs and Communications), or *Monthly Report of Number of Motor Vehicles* (AIRIA)), the number of sold vehicles by each sales year and by each vehicle type (JAMA and Japan Light Motor Vehicle and Motorcycle Association) is multiplied by the survival ratio by each past year (Japan Automobile Research Institute, 2008), and then the ratio of number of owned vehicles of each year by each past year is obtained, and the number of owned vehicles by each sales year and by each vehicle type is calculated. Secondary, this number is multiplied by annual travel distance by each vehicle type per one vehicle (calculated from *Survey of Motorcycle Market Trends* (JAMA)) and multiplied by use factor by each vehicle type and by each past year (Japan Automobile Research Institute, 2007), then the annual travel distance by each sales year and by each vehicle type is obtained. The emission control status is judged by the sales year.

➢ ***"Cold start" condition***

For the estimation of annual number of startup by each vehicle type and by emission control status, the number of owned vehicles by each vehicle type and by each emission control status, which is obtained through the calculation of "hot" condition activity data, is multiplied by annual number of startup by each vehicle type per one vehicle (calculated from *Survey of Motorcycle Market Trends*) and multiplied by use factor by each vehicle type and by each past year (Japan Automobile Research Institute, 2007), and then the annual number of startup by each sales year and by each vehicle type is obtained. The emission control status is judged by the sales year.

Table 3-50 Activity data of motorcycles

Activity data	Vehicle type	Emission control by regulation	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Distance traveled	Motor-driven cycles class 1	3rd & 4th regulation	Million vehicle-km	NO	NO	NO	NO	NO	NO	NO	1,108	1,309	1,451	1,390	1,448
		1st & 2nd regulation		NO	NO	1,773	4,165	3,643	3,325	2,829	693	531	384	264	185
		Uncontrolled		10,623	6,268	3,153	753	112	29	10	0	0	0	0	0
	Motor-driven cycles class 2	3rd & 4th regulation		NO	NO	NO	NO	NO	NO	NO	1,577	1,881	2,104	2,367	2,522
		1st & 2nd regulation		NO	NO	243	1,237	2,192	2,877	2,909	1,008	755	589	421	314
		Uncontrolled		2,060	1,853	1,568	686	172	61	23	1	1	0	0	0
	Mini-sized motorcycles	3rd & 4th regulation		NO	NO	NO	NO	NO	NO	NO	1,674	2,003	2,315	2,661	2,802
		1st & 2nd regulation		NO	NO	565	2,664	3,127	3,141	3,268	1,352	1,052	857	711	571
		Uncontrolled		6,111	3,577	2,209	1,055	330	147	79	9	5	3	1	1
	Small-sized motorcycles	3rd & 4th regulation		NO	NO	NO	NO	NO	NO	NO	1,634	1,991	2,498	2,692	2,964
		1st & 2nd regulation		NO	NO	317	1,662	2,751	2,883	3,471	1,761	1,418	1,184	916	746
		Uncontrolled		3,568	3,083	2,505	1,292	559	271	179	31	20	13	7	4
Number of startup	Motor-driven cycles class 1	3rd & 4th regulation	Million	NO	NO	NO	NO	NO	NO	NO	257	283	319	326	339
		1st & 2nd regulation		NO	NO	349	739	626	577	550	161	115	84	62	43
		Uncontrolled		1,838	1,131	621	134	19	5	2	0	0	0	0	0
	Motor-driven cycles class 2	3rd & 4th regulation		NO	NO	NO	NO	NO	NO	NO	207	229	399	447	475
		1st & 2nd regulation		NO	NO	31	140	228	274	325	132	92	112	80	59
		Uncontrolled		285	255	203	78	18	6	3	0	0	0	0	0
	Mini-sized motorcycles	3rd & 4th regulation		NO	NO	NO	NO	NO	NO	NO	107	117	204	227	239
		1st & 2nd regulation		NO	NO	41	177	193	179	204	86	62	75	61	49
		Uncontrolled		361	223	159	70	20	8	5	1	0	0	0	0
	Small-sized motorcycles	3rd & 4th regulation		NO	NO	NO	NO	NO	NO	NO	50	63	123	124	136
		1st & 2nd regulation		NO	NO	19	78	111	95	111	54	45	58	42	34
		Uncontrolled		187	177	154	60	23	9	6	1	1	1	0	0

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainty of the emissions from motorcycle is included and reported in "3.2.9.2.a Road transportation: vehicles other than motorcycles". Therefore, please refer to the description in the uncertainties of the section.

- ***Time-series Consistency***

The same estimation factors are used throughout the time-series. As for the activity data, the number of owned vehicles, travel distance per one vehicle, and number of startup per one vehicle are estimated using the data provided by JAMA, Japan Light Motor Vehicle and Motorcycle Association, and MOE by a consistent method throughout the time-series from FY1990 to the nearest year.

d) Category-specific QA/QC and Verification

Same as the Energy Industries (1.A.1). See section 3.2.4. d).

e) Category-specific Recalculations

The number of motor-driven cycles owned for FY2023 was obtained. Actual values of emission factors for Small-sized motorcycles which comply with the 4th regulation were provided by JAMA. Therefore, CH_4 and N_2O emissions since FY2017 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

3.2.9.3. Railways (1.A.3.c)

a) Category Description

This section provides the estimation methods for CH_4 and N_2O emissions from railways. Emissions

from railways come mainly from diesel-engine railway cars. In addition, there are small amounts of emissions from coal-fired steam locomotives.

b) Methodological Issues

- ***Estimation Method***

The emissions are calculated by using Tier 1 method in accordance with the *2006 IPCC Guidelines* (Vol. 2, page 3.41, Fig. 3.4.2).

$$E = \sum_i (EF_i \times AD_i)$$

E : CH_4 and N_2O emissions from railways
EF_i : Emission factor of fuel consumption in railways by fuel type
AD_i : Annual consumptions by fuel type
i : Fuel type (diesel oil and coal)

- ***Emission Factors***

For emission factors for diesel-powered railway cars, the default values of "Diesel" shown in the *2006 IPCC Guidelines* are used after conversion to a per-liter value using the calorific value of diesel oil.

For the emission factors for steam locomotives, the default values of "sub-bituminous coal" shown in the *2006 IPCC Guidelines* are used after conversion to a per-weight value using the calorific value of imported steam coal.

Table 3-51 Default values for railway emission factors

Gas	Unit	Diesel engines	Steam locomotives
CH_4	kg-CH_4/TJ(NCV)	4.15	2
N_2O	kg-N_2O/TJ(NCV)	28.6	1.5

Reference: *2006 IPCC Guidelines*, Vol. 2, p. 3.43, Table 3.4.1

- ***Activity Data***

For the consumption of diesel oil by diesel engines in railways and coal consumption by steam locomotives, the diesel oil and coal consumption in the railway shown in the *General Energy Statistics* is used as activity data, respectively.

Table 3-52 Activity data used for estimation of emissions from railways

Fuel type	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Diesel oil	1000 kL	356	313	270	248	218	205	198	178	171	173	171	171
Coal	kt	1.3	1.2	1.7	1.4	1.7	1.5	1.5	0.6	1.0	1.0	1.1	1.1

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

Since the default values in the *2006 IPCC Guidelines* are adopted for the emission factors of railways, the uncertainties indicated in the *2006 IPCC Guidelines* (-60% to +151% for CH_4 and -50% to +200% for N_2O) are adopted. Also, since the values in the *General Energy Statistics* are used for the activity data, the default values in the *2006 IPCC Guidelines* (-5% to +5%) are adopted for the uncertainty of activity data. As a result, the uncertainty of the emissions from railways is evaluated as -60% to +151% for CH_4 and -50% to +200% for N_2O.

- ***Time-series Consistency***

The same emission factors are used throughout the time-series. The data given in the *General Energy*

Statistics are used as activity data consistently throughout the time-series.

d) Category-specific QA/QC and Verification

Same as the Energy Industries (1.A.1). See section 3.2.4. d).

e) Category-specific Recalculations

The emissions for FY2021-FY2023 were recalculated due to a revision of the consumptions of coal and diesel oil in the *General Energy Statistics*. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

3.2.9.4. Domestic Navigation (1.A.3.d)

a) Category Description

This section provides the estimation methods for CH_4 and N_2O emissions from domestic navigation of ships for passenger and freight transport.

b) Methodological Issues

- ***Estimation Method***

The emissions were calculated by using Tier 1 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 3.49, Fig. 3.5.1).

$$E = \sum_i (EF_i \times AD_i)$$

E : CH_4 and N_2O emissions associated with the navigation of domestic vessels
EF_i : Emission factor of fuel consumption in domestic vessels
AD_i : Consumption of each type fuel by domestic vessels
i : Fuel type (diesel oil, fuel oil A, B and C)

- ***Emission Factors***

The default values for Ocean-Going Ships (diesel engines) given in the *2006 IPCC Guidelines* (see the following table) are equivalent to the emission factors introduced in *IMO (2009)*. *IMO (2014)* developed the emission factors based on the survey results that excluded vintage ships. The CH_4 emission factor in *IMO (2014)* is 0.2 times as high as that in *IMO (2009)*, and the N_2O emission factor is twice as high. Because it is judged that the emission factors in *IMO (2014)* better reflect the emissions from domestic navigation in Japan, the emission factors are established by multiplying the default values given in the *2006 IPCC Guidelines* by the correction factors, which are the ratio of *IMO (2014)* to *IMO (2009)*. The emission factors are converted to emission factors per liter using the calorific value for each type of fuel (diesel oil, fuel oil A, B and C) for estimation.

Table 3-53 Emission factors for navigation

Gas	Default values in the *2006 IPCC Guidelines*	Correction factors (Ratio of *IMO (2014)* to *IMO (2009)*)	Emission factors
CH_4	7 [kg-CH_4/TJ(NCV)]	0.2	1.4 [kg-CH_4/TJ(NCV)]
N_2O	2 [kg-N_2O/TJ(NCV)]	2.0	4.0 [kg-N_2O/TJ(NCV)]

Reference: *2006 IPCC Guidelines* Vol. 2, page 3.50, *IMO (2014)* page 119

- ***Activity Data***

The consumption of each fuel type in the domestic navigation taken from the *General Energy Statistics* is used for activity data.

Table 3-54 Activity data used for estimation of emissions from ships

Fuel type	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Diesel oil	1000 kL	133	208	204	195	154	142	148	109	113	125	125	125
Fuel oil A	1000 kL	1,602	1,625	1,728	1,324	1,007	994	980	1,039	1,220	1,334	1,248	1,309
Fuel oil B	1000 kL	526	215	152	63	18	14	9	0	0	0	0	0
Fuel oil C	1000 kL	2,446	3,002	3,055	2,873	2,482	2,487	2,386	2,175	2,168	2,107	1,995	1,879

- ***Completeness***

According to the *2006 IPCC Guidelines* (Vol. 3, page 5.7), CH_4 and N_2O emissions from use of lubricants are very small in comparison to CO_2, and these can be neglected for the greenhouse gas calculation. Therefore, the estimation is not done.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

Since the emission factors of domestic navigation are the default values in the *2006 IPCC Guidelines* multiplied by the correction factors, the uncertainties of the default values are combined with the uncertainties of the correction factors using error propagation equation. The uncertainties of the default values are indicated in the *2006 IPCC Guidelines* (-50% to +50% for CH_4 and -40% to +140% for N_2O). Since the uncertainties of the emission factors of *IMO* are not found, the uncertainties of the correction factors are estimated as follows. As the emission factors of *IMO* are shown as per weight of fuel, the emissions were estimated for trial on the basis of the activity data in unit of fuel weight, and compared with the emissions estimated on the basis of the activity data in unit of heat amount. The difference was about 1% for the CH_4 emissions and about 7% for the N_2O emissions, depending on values of density of fuels. Therefore, that difference was regarded as the uncertainties of the correction factors. Also, since the values in the *General Energy Statistics* are used for the activity data, the default values in the *2006 IPCC Guidelines* (-13% to +13%) are adopted for the uncertainty of activity data. As a result, the uncertainty of the emissions from domestic navigation is evaluated as -52% to +52% for CH_4 and -43% to +141% for N_2O.

- ***Time-series Consistency***

The same values for emission factors are throughout the time-series. The values given in the *General Energy Statistics* are used as activity data for domestic navigation consistently throughout the time-series from FY1990 to the nearest year.

d) Category-specific QA/QC and Verification

Same as the Energy Industries (1.A.1). See section 3.2.4. d).

e) Category-specific Recalculations

There have been no recalculations of emissions from this category.

f) Category-specific Planned Improvements

No improvements are planned.

3.2.9.5. Other Transportation (1.A.3.e)

This subcategory is reported as "NO", since fossil fuels are not combusted to transport materials by pipelines and no other activities to be reported are found.

3.2.10. CO_2 Emissions from Other Sectors and Other (1.A.4, 1.A.5: CO_2)

a) Category Description

This section provides the estimation methods for CO_2 emissions from the commercial/institutional (1.A.4.a), residential (1.A.4.b), agriculture/forestry/fishing (1.A.4.c) and other (1.A.5) sectors. The emissions from fuel combustion for the national defense purpose are included in commercial/institutional (1.A.4.a).

In FY2024, CO_2 emissions from this category accounted for 119,026 kt-CO_2, and represented 11.4% of Japan's total GHG emissions (excluding LULUCF). The commercial/institutional (1.A.4.a) accounts for 49.6%, and is the largest subcategory within the "Other sectors" category.

b) Methodological Issues

- ***Estimation Method***

The Tier 2 Sectoral Approach has been used in accordance with the decision tree of the *2006 IPCC Guidelines* to calculate emissions (Vol.2, Page 1.9, Fig. 1.2), as was the case for the energy industries (1.A.1). See section 3.2.4. b).

Please refer to section 3.2.12. for the emissions from waste incineration with energy recovery.

The CO_2 emissions from biomass are not included in the national totals but are reported in the CRTs as reference in accordance with the *2006 IPCC Guidelines*.

- ***Emission Factors***

The emission factors elaborated in the energy industries (1.A.1) were also used in this category. See section 3.2.4. b).

- ***Activity Data***

The data given in the *General Energy Statistics* were used for activity data, as was the case for the energy industries (1.A.1).

The activity data for each sub-category were calculated by totaling the final energy consumption in the "Commerce, public services and Not elsewhere specified" (#650000), "Residential" (#700000), and "Agriculture, forestry and fishery" (#611000) sectors, energy consumption related to non-utility power generation for use in one's own offices (auto power generation: #25xxxx), and energy consumption related to steam production for use in own offices (auto steam generation: #26xxxx) shown in the *General Energy Statistics*. Because the final energy consumption above includes the amount of non-energy use which was used for purposes other than combustion (non-energy and feedstock use: #951100, #951800 and #952000), these values were deducted from the energy consumption in each category.

The energy consumption of each fuel in the "agriculture, forestry and fishery" (#611000) sector in the *General Energy Statistics* is classified to mobile combustion and stationary combustion according to the ratio in the Table 3-57, which is the survey results by MOE in FY2014 and FY2015. Please refer to

the Table 3-56 for which category the emissions from mobile or stationary combustion to be allocated in the CRT.

The auto power generation and auto steam generation sectors are included in the "energy transformation & own use" sector in *General Energy Statistics*. However, the *2006 IPCC Guidelines* allocates CO_2 emissions from energy consumption for power or steam generation to the sectors generating that power or steam. As such, these CO_2 emissions are added to those from each office in the final energy consumption sector and are reported in 1.A.4.

Table 3-55 Energy consumptions in Other Sectors (1.A.4) (unit: PJ)

Fuel	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Liquid fuels	1,916	2,075	2,184	2,218	1,573	1,437	1,286	1,238	1,123	1,049	982	935
Solid fuels	3	2	1	1	19	15	12	70	70	68	66	61
Gaseous fuels	418	537	649	731	835	836	846	815	860	824	801	820
Other fossil fuels	196	219	257	278	243	248	239	258	250	248	244	242
Biomass	15	18	22	44	59	65	84	54	68	56	58	59
Total	2,548	2,850	3,113	3,272	2,729	2,602	2,466	2,434	2,371	2,245	2,151	2,117

Table 3-56 Correspondence between sectors of Japan's Energy Balance Tables and those of the CRT (1.A.4 and 1.A.5)

CRT			General Energy Statistics	
1.A.4	Other sectors			
	1.A.4.a	Commercial/ institutional	Auto power generation (Production, transmission and distribution of electricity [#255330] (since FY2016), Production and distribution of gas [#255340] through Government [#259000] (all years), and Unable to classify [#259991] (all years))	
			Auto steam generation (Production, transmission and distribution of electricity [#265330] through Government [#269000], and Unable to classify [#269991])	
			Final energy consumption; Commerce, public services and Not elsewhere specified	#650000
			Non-energy and feedstock use; Commerce, public services and Not elsewhere specified	#951800
	1.A.4.b	Residential	Final energy consumption; Residential	#700000
			Non-energy and feedstock use; Residential	#952000
	1.A.4.c	Agriculture/forestry/fishing		
		i Stationary	Auto power generation; Agriculture, fishery, mining and construction (agriculture, forestry and fishery [#251010-#251040])	
			Auto steam generation; Agriculture, fishery, mining and construction (agriculture, forestry and fishery [#261010-#261040])	
			Final energy consumption; Agriculture, forestry and fishery [#610000]; stationary sources (estimates)	
			Non-energy and feedstock use; Agriculture, fishery, mining and construction (agriculture, forestry and fishery)	#951100
		ii Off-road vehicles and other machinery	Final energy consumption; Agriculture [#611100]; mobile sources (estimates)	
			Final energy consumption; Forestry [#611200]; mobile sources (estimates)	
		iii Fishing	Final energy consumption; Fishery, except aquaculture [#611300]; mobile sources (estimates)	
			Final energy consumption; Aquaculture [#611400]; mobile sources (estimates)	
1.A.5	Other		NO	-

Note: #95xxxx items are subtracted as non-energy use activities.

Table 3-57 Ratio of mobile and stationary combustion by fuel in the agriculture/forestry/fishing (1.A.4.c)

Fuel	Agriculture		Forestry		Aquaculture			Fishery, except Aquaculture		
	Mobile com-bustion	Station-ary com-bustion	Mobile com-bustion	Station-ary com-bustion	Mobile com-bustion (ships)	Mobile com-bustion	Station-ary com-bustion	Mobile com-bustion (ships)	Mobile com-bustion	Station-ary com-bustion
Diesel oil	99%	1%	100%	0%	0%	100%	0%	0%	100%	0%
Fuel oil A	5%	95%	0%	100%	100%	0%	0%	100%	0%	0%
Kerosene	2%	98%	0%	100%	0%	0%	100%	0%	0%	100%
LPG and city gas	5%	95%	0%	100%	0%	0%	100%	0%	0%	100%

Reference: MOE (2015a)

c) Uncertainty Assessment and Time-series Consistency

Same as 3.2.4 Energy Industries (1. A. 1). See section 3.2.4. c).

d) Category-specific QA/QC and Verification

Same as the Energy Industries (1.A.1). See section 3.2.4. d).

e) Category-specific Recalculations

Due to the updates of the activity data based on the update of the *General Energy Statistics*, the emissions for the period of FY1990-FY2023were recalculated.

Updating the statistical data and improving the estimation methodology in the waste sector, CO_2 emissions from other fossil fuels for the period of FY2023 were recalculated. See section 7.4.3 for details. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

3.2.11. CH_4 and N_2O Emissions from Other Sectors and Other (1.A.4, 1.A.5: CH_4 and N_2O)

a) Category Description

This section provides the estimation methods for CH_4 and N_2O emissions from the Commercial/institutional (1.A.4.a), Residential (1.A.4.b), Agriculture/forestry/fishing (1.A.4.c), and Other (1.A.5) sectors.

This section also provides the estimation methods for determining CH_4 and N_2O emissions from mobile combustion such as off-road vehicles, fishing boats and other machinery. The emissions from fuel combustion for the national defense purpose are included in Commercial/institutional (1.A.4.a).

b) Methodological Issues

- ***Estimation Method***

➢ ***Furnaces***

For Commercial/institutional (1.A.4.a) and the stationary combustion in Agriculture/forestry/fishing (1.A.4.c), same with Energy Industries (1.A.1), CH_4 and N_2O emissions from fuel combustion in this category are calculated by using Tier 3 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol.2, Page 1.9, Fig. 1.2). See section 3.2.5. b) (1.A.1).

➢ ***Biomass boilers***

See section 3.2.5. b) (1.A.1).

➢ ***Residential***

For Residential (1.A.4.b), CH_4 and N_2O emissions from fuel combustion in this category are calculated by using Tier 1 method, since furnace-specific activity data is not available.

➢ ***Off-road vehicles and other machinery***

The emissions from mobile combustion in Agriculture/forestry/fishing (1.A.4.c) are estimated by Tier 1 in accordance with the decision tree of the *2006 IPCC Guidelines* to calculate emissions (Vol.2, Page

3.34, Fig. 3.3.1).

- ***Emission Factors***

➢ ***Furnaces***

For Commercial/institutional (1.A.4.a) and the stationary combustion in Agriculture/forestry/fishing (1.A.4.c), the emission factors which were established in Energy Industries (1.A.1) were used. See Table 3-22 and Table 3-23 (1.A.1).

➢ ***Biomass boilers***

See section 3.2.5. b) (1.A.1).

➢ ***Residential***

For Residential (1.A.4.b), the emission factors which were provided in the *2006 IPCC Guidelines* (Vol. 2, pages 2.22-2.23, Table 2.5) were used.

Table 3-58 CH_4 and N_2O emission factors for residential (1.A.4.b)

Furnace type	Fuel type	CH_4 Emission factor [kg-CH_4/TJ(GCV)]	N_2O Emission factor [kg-N_2O/TJ(GCV)]
Household equipment	Liquid fuels	9.5	0.57
	Solid fuels	290	1.4
	Gaseous fuels	4.5	0.090

Note: Conversion to the GCV basis by multiplying the default emission factors by the default conversion factors (0.95 for liquid and solid fuels and 0.9 for gaseous fuels from the *2006 IPCC Guidelines*, Vol.2, page 1.16).

➢ ***Off-road vehicles and other machinery***

The emission factors of diesel oil used for the mobile combustion in agriculture, fishing and aquaculture were estimated from the values of "1.A.4.c.ii-Agriculture/ Diesel" in the Table 3-1 of EEA (2016). The emission factors of fuel oil A and kerosene used for agriculture were not shown in the guidebook but were applied the same value of diesel oil since most of the fuel oil A and kerosene are also used for tractors. The emission factors of LPG and city gas were estimated from the value of "LPG" in the same Table, and the emission factors of diesel oil for forestry were estimated from the values of "1.A.4.c.ii-Forestry/ Diesel" in the same Table.

The emission factors of fuel oil A used for fishing and aquaculture were estimated from the default values in the *2006 IPCC Guidelines*.

Table 3-59 Emission factors of CH_4 and N_2O for off-road vehicles and other machinery in Agriculture/forestry/fishing (1.A.4.c)

Fuel	Unit	CH_4 emission factor	N_2O emission factor	Reference
Diesel oil, kerosene, fuel oil A used for other than ships	g/t	87	136	EEA (2016), Non-road mobile sources and machinery, Table 3-1
Diesel oil for forestry	g/t	49	138	
LPG, city gas	g/t	354	161	
Fuel oil A for ships	kg/TJ(NCV)	7	2	*2006 IPCC Guidelines*, Vol.2, Table 3.5.3

- ***Activity Data***

➢ ***Furnaces***

The fuel consumption, obtained by multiplying the fuel consumption of each sector and each fuel type in the *General Energy Statistics* by the ratio of stationary combustion in the Table 3-57 and the fuel consumption ratio by furnace type, is assumed to be the activity data for the stationary combustion

namely combustion in furnaces. Same with Energy Industries (1.A.1), the fuel consumption ratios by furnace were estimated from data by furnace on the *General Survey of the Emissions of Air Pollutants* and data on each fuel consumption statistics (*Yearbook of the Current Survey of Energy Consumption in the Selected Industries, Structural Survey of Energy Consumption, Electric Power Statistics*, and *Current Survey of Production Concerning Gas Industry*). See section 3.2.5. b) (1.A.1).

- ***Biomass boilers***

The method to establish the activity data for biomass boilers is the same as Manufacturing Industries and Construction (1.A.2). See section 3.2.7. b).

- ***Residential***

The fuel consumption by fuel type in the *General Energy Statistics* was used for the activity data of residential (1.A.4.b).

- ***Off-road vehicles and other machinery***

The fuel consumption, estimated by multiplying the fuel consumption of each fuel type in Agriculture, Forestry and Fishery in the *General Energy Statistics* by the ratios of fuel consumption of mobile combustion (Table 3-57), were used for the activity data of mobile combustion namely off-road vehicles and other machinery.

c) Uncertainty Assessment and Time-series Consistency

- ***Furnaces (including biomass boilers)***

See section 3.2.7. c).

- ***Residential***

The uncertainties of the emission factors are set by the default values. The uncertainties of the activity data are set by the values established in section 3.2.4. c).

- ***Off-road vehicles and other machinery***

See section 3.2.7. c).

d) Category-specific QA/QC and Verification

Same as the Energy Industries (1.A.1). See section 3.2.4. d).

e) Category-specific Recalculations

Since the activity data for FY1990-2023 in the *General Energy Statistics* were revised, the CH_4 and N_2O emissions in those years were recalculated.

Updating the statistical data in the waste sector, CH_4 and N_2O emissions in FY2023 were recalculated. See section 7.4.3 for details. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

See section 3.2.5. f).

3.2.12. Emissions from Waste Incineration with Energy Recovery

The three cases below in which waste is utilized as raw material or fuel meet the definition of emissions

from waste incineration with energy recovery.

- Waste incineration with energy recovery
- Direct use of waste as alternative fuel
- Incineration of waste processed as fuel

The estimation method for emissions from waste incineration (5.C.1.) is applied to these sources above in accordance with the *2006 IPCC Guidelines*. The emissions are included in fuel combustion (1.A.) in accordance with the *2006 IPCC Guidelines.* Please refer to Chapter 7 for the details of the estimation methods.

The reporting category of the emissions for each type of waste is either "energy industries (category 1.A.1)", "manufacturing industries and construction (1.A.2)" or "other sectors (1.A.4)" according to the use of waste as raw material or fuel. The fuel type is classified as "other fossil fuels" and "biomass".

Greenhouse gas emissions during the direct use of waste as a raw material, such as plastics used as reducing agents in blast furnaces or as a chemical material in coking furnaces, or the use of intermediate products manufactured using the waste as a raw material, are also subject to the estimation of emissions.

Refuse-derived solid fuels (RDF: Refuse-Derived Fuel, RPF: Refuse Paper and Plastic Fuel) are also subject to the estimation of emissions as fuels produced from waste.

Table 3-60 GHG emissions from waste incineration and energy use (reported in the energy sector) (1.A.)

Category		Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
1.A.1. Energy industries		kt-CO_2	IE	IE	16	252	253	5	47	34	34	31	98	96
1.A.2. Manufacturing industries and construction	a. Iron and steel	kt-CO_2	NO	NO	267	515	444	391	451	323	372	334	249	136
	b. Non-ferrous metals	kt-CO_2	119	63	51	17	2	NO	NO	NO	NO	NO	NO	NO
	c. Chemicals	kt-CO_2	10	61	86	65	72	81	68	25	16	6	4	3
	d. Pulp, paper and print	kt-CO_2	NO	56	112	996	1,790	1,919	2,032	2,043	2,142	2,100	2,156	2,198
	e. Food processing, beverages and tobacco	kt-CO_2	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	f. Non-metallic minerals	kt-CO_2	197	485	800	854	979	1,052	1,145	1,468	1,511	1,546	1,552	1,592
	g. Other	kt-CO_2	3,134	3,249	3,060	3,970	3,797	3,776	3,802	3,692	3,730	3,696	3,974	3,844
1.A.4	a. Commercial/institutional	kt-CO_2	6,523	7,149	9,012	8,304	6,575	7,354	6,963	8,301	8,388	8,544	8,519	8,553
Total		kt-CO_2	9,983	11,063	13,404	14,973	13,911	14,579	14,507	15,885	16,193	16,256	16,554	16,422
1.A.1. Energy industries		kt-CH_4	IE	IE	1.7.E-06	1.8.E-05	1.6.E-05	1.3.E-05	1.7.E-05	1.6.E-06	IE	IE	IE	IE
1.A.2. Manufacturing industries and construction	a. Iron and steel	kt-CH_4	NO	NO	NO	7.7.E-04	1.4.E-03	1.2.E-03	1.4.E-03	2.8.E-04	2.8.E-05	5.7.E-05	2.8.E-05	8.5.E-05
	b. Non-ferrous metals	kt-CH_4	3.2.E-04	1.8.E-04	1.4.E-04	7.7.E-05	7.7.E-06	NO	NO	NO	NO	NO	NO	NO
	c. Chemicals	kt-CH_4	2.0.E-05	1.0.E-04	1.5.E-04	1.7.E-04	1.9.E-04	2.2.E-04	1.9.E-04	6.4.E-05	3.9.E-05	1.7.E-05	1.3.E-05	8.5.E-06
	d. Pulp, paper and print	kt-CH_4	NO	1.0.E-04	2.2.E-04	2.7.E-03	4.8.E-03	5.2.E-03	5.6.E-03	5.7.E-03	6.0.E-03	5.9.E-03	6.1.E-03	6.1.E-03
	e. Food processing, beverages and tobacco	kt-CH_4	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	f. Non-metallic minerals	kt-CH_4	0.03	0.08	0.14	0.20	0.22	0.23	0.25	0.32	0.33	0.34	0.33	0.34
	g. Other	kt-CH_4	1.8	1.8	2.2	2.9	4.2	4.8	5.0	5.4	5.4	5.3	5.8	5.7
1.A.4	a. Commercial/institutional	kt-CH_4	0.54	0.54	0.60	0.15	0.14	0.15	0.14	0.14	0.13	0.13	0.15	0.14
Total		kt-CH_4	2.3	2.4	3.0	3.3	4.6	5.2	5.4	5.9	5.9	5.8	6.3	6.2
		kt-CO_2 eq.	66	67	83	91	128	145	151	164	164	163	176	173
1.A.1. Energy industries		kt-N_2O	IE	IE	1.1.E-05	1.2.E-04	1.0.E-04	8.1.E-05	1.1.E-04	1.0.E-05	IE	IE	IE	IE
1.A.2. Manufacturing industries and construction	a. Iron and steel	kt-N_2O	NO	NO	NO	9.1.E-04	1.6.E-03	1.5.E-03	1.6.E-03	3.4.E-04	3.4.E-05	6.7.E-05	3.4.E-05	1.0.E-04
	b. Non-ferrous metals	kt-N_2O	2.4.E-04	1.3.E-04	1.1.E-04	5.6.E-05	5.6.E-06	NO	NO	NO	NO	NO	NO	NO
	c. Chemicals	kt-N_2O	8.5.E-03	6.8.E-03	8.5.E-03	4.5.E-03	3.3.E-03	2.4.E-03	1.9.E-03	8.2.E-03	7.8.E-03	2.7.E-04	8.3.E-05	5.5.E-05
	d. Pulp, paper and print	kt-N_2O	NO	6.6.E-04	5.9.E-03	2.2.E-02	5.9.E-02	5.6.E-02	6.1.E-02	6.3.E-02	6.8.E-02	6.7.E-02	6.5.E-02	6.5.E-02
	e. Food processing, beverages and tobacco	kt-N_2O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	f. Non-metallic minerals	kt-N_2O	2.7.E-03	6.9.E-03	1.2.E-02	1.7.E-02	1.9.E-02	2.0.E-02	2.2.E-02	2.8.E-02	2.9.E-02	3.0.E-02	2.9.E-02	3.0.E-02
	g. Other	kt-N_2O	5.9.E-02	5.1.E-02	5.2.E-02	6.0.E-02	6.7.E-02	7.3.E-02	7.6.E-02	8.0.E-02	8.0.E-02	7.9.E-02	8.5.E-02	8.3.E-02
1.A.4	a. Commercial/institutional	kt-N_2O	1.2	1.3	1.6	1.1	0.9	1.0	0.9	0.9	0.9	0.9	0.9	0.9
Total		kt-N_2O	1.3	1.4	1.6	1.2	1.1	1.1	1.1	1.1	1.1	1.1	1.0	1.0
		kt-CO_2 eq.	337	369	434	331	291	297	284	297	288	281	278	276

Note:
1) Include fossil-fuel derived component only.
CO_2 emissions from the incineration of biomass-derived waste (including biomass-based plastics and waste animal and vegetable oil) is not included in the total emissions in accordance with the *2006 IPCC Guidelines*; instead it is estimated as a reference value and reported under "Biomass" in CRT table 1.A(a).
2) Include both fossil-fuel derived component and biogenic component.

3.3. Fugitive Emissions from Fuels (1.B)

The Fugitive Emissions subsector consists of intentional and unintentional GHG emissions from unburned fossil fuels during their mining, production, processing, refining, transportation, storage, and distribution, and from geothermal power plants.

There are two main source categories in this sector: solid fuels (1.B.1): fugitive emissions from coal mining and handling, and oil, natural gas and other emissions from energy production (1.B.2): fugitive emissions mainly from the oil and natural gas industries. The main source of emissions from solid fuels is CH_4 contained in coal bed, whereas fugitive emissions, venting, flaring, volatilization, and accidents are the main emission sources in the oil and natural gas industries. The emissions from geothermal power generation are also reported in 1.B.2.d.

In FY2024, GHG emissions from fugitive emissions from fuels were 1,202 kt-CO_2 eq. and accounted for 0.1% of Japan's total GHG emissions (excluding LULUCF). The emissions have decreased by 80.3% compared to 1990.

The contribution of the GHG emissions from this category relative to the national total is small in Japan. Japan mostly depends on fossil fuel imports. The domestic production of fossil fuels has comprised less than 3% of domestic supply since FY1990.

Table 3-61 Emission trends of the fugitive emissions subsector (1.B)

Gas	Category		Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
CO_2	1.B.1 Solid Fuels	a. Coal Mining	kt-CO_2	5.4	2.5	1.7	0.6	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4
		b. Fuel Transformation		0.5	1.0	1.6	1.6	1.7	2.1	2.2	2.8	3.0	IE	IE	IE
		c. Other (Uncontrolled Combustion and Burning Coal Dump)		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	1.B.2 Oil and Natural Gas	a. Oil		3.E-03	3.E-03	4.E-03	5.E-03	5.E-03	4.E-03	3.E-03	2.E-03	2.E-03	2.E-03	2.E-03	2.E-03
		b. Natural Gas		0.7	0.8	0.9	1.2	1.3	1.2	1.1	0.9	0.9	0.9	0.8	0.8
		c. Venting and Flaring		91.7	112.9	136.5	186.7	245.1	242.6	241.8	212.3	177.4	155.9	142.7	127.6
		d. Other (Geothermal Generation)		104.4	409.2	386.6	341.9	251.2	215.2	200.1	191.9	191.9	191.9	191.9	191.9
	Total		kt-CO_2	203	526	527	532	500	462	446	408	374	349	336	321
CH_4	1.B.1 Solid Fuels	a. Coal Mining	kt-CH_4	192.4	97.5	63.3	26.3	22.6	21.4	20.9	18.0	18.1	17.5	17.4	16.7
		b. Fuel Transformation		3.4	3.3	2.7	1.8	1.4	1.2	1.0	0.8	0.7	0.7	0.7	0.7
		c. Other (Uncontrolled Combustion and Burning Coal Dump)		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	1.B.2 Oil and Natural Gas	a. Oil		0.7	0.9	0.8	0.8	0.7	0.7	0.6	0.5	0.5	0.5	0.5	0.4
		b. Natural Gas		7.7	8.6	9.8	12.0	12.7	11.2	10.6	9.0	9.1	8.5	8.0	7.7
		c. Venting and Flaring		6.6	7.5	7.7	9.4	9.7	8.6	7.9	6.8	6.6	6.1	5.8	5.5
		d. Other (Geothermal Generation)		0.2	0.8	0.7	0.7	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	Total		kt-CH_4	211.0	118.5	85.0	51.1	47.7	43.5	41.5	35.4	35.4	33.8	32.8	31.5
			kt-CO_2 eq.	5,909	3,319	2,380	1,430	1,334	1,217	1,161	992	992	946	917	881
N_2O	1.B.1 Solid Fuels	a. Coal Mining	kt-N_2O	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		b. Fuel Transformation		7.E-03	7.E-03	5.E-03	4.E-03	3.E-03	2.E-03	2.E-03	2.E-03	1.E-03	1.E-03	1.E-03	1.E-03
		c. Other (Uncontrolled Combustion and Burning Coal Dump)		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	1.B.2 Oil and Natural Gas	a. Oil		NA,IE	NA,IE	NA,IE	NA,IE	NA,IE	NA,IE	NA,IE	NO,IE	NA,IE	NA,IE	NA,IE	NA,IE
		b. Natural Gas													
		c. Venting and Flaring		5.E-04	5.E-04	5.E-04	7.E-04	6.E-04	6.E-04	5.E-04	4.E-04	4.E-04	4.E-04	4.E-04	4.E-04
		d. Other (Geothermal Generation)		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Total		kt-N_2O	7.E-03	7.E-03	6.E-03	4.E-03	3.E-03	3.E-03	3.E-03	2.E-03	2.E-03	2.E-03	2.E-03	2.E-03
			kt-CO_2 eq.	1.89	1.88	1.57	1.13	0.89	0.78	0.68	0.54	0.48	0.46	0.47	0.44
	Total of all gases		kt-CO_2 eq.	6,113	3,847	2,909	1,963	1,835	1,679	1,607	1,401	1,366	1,295	1,253	1,202
(Reference) Biomass-origin CO_2 emissions															
CO_2	1.B.1 Solid Fuels	b. Fuel Transformation	kt-CO_2	130.7	129.2	105.9	70.5	53.5	46.5	40.6	31.0	26.9	26.8	27.3	25.6

3.3.1. Solid Fuels (1.B.1)

3.3.1.1. Coal Mining and Handling (1.B.1.a)

3.3.1.1.a. Underground Mines (1.B.1.a.i)

a) Category Description

This category deals with CH_4 and CO_2 emissions from coal mining, post-mining process, and abandoned mines.

Coal contains CH_4 which was formed during the coalification process. Most will have been naturally released from the ground surface before mine development, but mining releases the CH_4 remaining in coal beds into the atmosphere. Also, CH_4 may be released during post-mining activities, i.e. subsequent handling, processing and transportation of coal. In addition, some of the coal mines still emit CH_4 after they have been abandoned. Also, relatively low-density CO_2 is included in coal in comparison with CH_4, and is emitted to the air through the similar process with the CH_4.

The number of operational coal mines in Japan has decreased and coal production has decreased greatly as well. As a result, the amount of CH_4 emissions from coal mining has decreased year by year.

Furthermore, the coal mining practices have changed recently, resulting in the decreasing trend of CH_4 IEF. Specifically, coal is now mined in more shallow areas. Therefore, emitting less CH_4. This is because deep areas are costly to mine compared to coal in shallow areas. Additionally, areas which have been previously mined, thus already releasing CH_4, are re-mined for coal, using the latest technology. This contributes to low CH_4 emissions per amount of coal mined, even if compared with other countries.

The mining activities in Japan are elaborated in Matsumoto (2006) and Matsumoto *et al.* (2018).

The N_2O emissions are reported as "NE," because the existence of such activities in underground mines and surface mines has not been confirmed and no methodology is provided by the *2006 IPCC Guidelines*.

Emissions from "flaring of drained methane or conversion of methane to CO_2" (1.B.1.a.i.4) are reported as "NE". As discussed below, methane flaring does not occur during mining or in abandoned underground mines, but the existence of activities in post-mining in Japan has not been confirmed.

b) Methodological Issues

- ***Estimation Method***

➢ ***CH_4***

- ***Mining Activities***

CH_4 emissions from mining activities are drawn from actual measurements obtained from individual coal mines using the Tier 3 method, in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 4.11, Fig. 4.1.1).

- ***Post-Mining Activities***

CH_4 emissions from post-mining activities are estimated using the Tier 1 method, which uses default emission factors in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 4.11, Fig. 4.1.1). The emissions are estimated by multiplying the amount of coal mined from underground mines by the emission factor.

- ***Abandoned Underground Mines***

In accordance with the decision tree in the *2006 IPCC Guidelines* (Vol 2, page 4.22, Fig4.1.3), the Tier 2 method is used. The CH_4 emissions from abandoned underground mines are estimated by multiplying the number of abandoned mines which are not submerged by emission factors which are established with consideration of types of coal and period of being abandoned as shown in the following equation.

$$E = \sum_T E_T, \qquad E_T = N_T \times F_T \times ER \times EF_T \times CF, \qquad EF_T = (1 + a \times T)^b$$

E : Amount of CH_4 fugitive emissions from abandoned coal mines [kt/year]
E_T : Amount of CH_4 fugitive emissions from coal mines abandoned T years ago [kt/year]
N_T : Number of unflooded mines abandoned T years ago [sites]
F_T : Fraction of gassy mines abandoned T years ago
ER : Emission rate from mines before mine closure [m^3/year]
EF_T : Emission reduction factor for mines abandoned T years ago
a,b : Parameters determining emission decline curve
T : Time period of mine closure [year]
CF : CH_4 density (0.67×10^{-6} [kt/m^3])

➢ ***CO_2***

The method applied is reported as "CS" (country-specific) in CRT Summary 3, since the *2006 IPCC Guidelines* do not provide a method to estimate CO_2 emissions, but a country-specific CO_2 emission factor is available.

- ***Mining Activities***

CO_2 emissions are estimated by multiplying the production amount of coal by CO_2 emission factor.

- ***Post-Mining Activities***

CO_2 emissions are estimated by multiplying the production amount of coal by CO_2 emission factor.

- ***Abandoned Underground Mines***

The estimation method of CO_2 emissions is similar to that of CH_4 described above, and the CO_2 emission factor is established based on CH_4 emission factor.

● ***Emission Factors***

➢ ***CH_4***

- ***Mining Activities***

CH_4 emission factor for mining activities is established by converting the total emissions of CH_4 gas (in volume unit) identified in a survey by J-COAL (Japan Carbon Frontier Organization; former Japan Coal Energy Center) into weight basis using the density of CH_4 (0.67 [kg/m^3]) at 20°C and 1 atmosphere, and then dividing it by the production amount of coal from underground mines. From FY1991 to 1994, since actual measurement data cannot be obtained, the emission factors for those years are interpolated using FY1990 and 1995 values.

Table 3-62 Emission factors for mining activities: underground mines

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024	Remarks
Coal production of underground mines (A)	kt	9,471	8,118	4,016	1,635	1,225	1,103	980	565	799	616	729	475	Survey by J-COAL
CH_4 total emissions (B)	10^6m^3	262	92	57	4.2	2.0	1.9	2.4	1.2	1.3	1.3	1.3	1.3	Survey by J-COAL
CH_4 total emissions (C)	kt-CH_4	176	62	38	2.8	1.3	1.2	1.6	0.8	0.9	0.9	0.8	0.8	=(B)*0.67
Emission factor	kg-CH_4/t	19	8	9	1.7	1.1	1.1	1.6	1.4	1.1	1.4	1.2	1.8	=(C)/(A)*1000

- ***Post-Mining Activities***

Due to the lack of data for emissions from post-mining activities in Japan, the emission factors are calculated as 1.675 [kg-CH_4/t] by converting the average value (2.5 [m^3/t]) of the default values given in the *2006 IPCC Guidelines* with the density of CH_4 (0.67 [kg/m^3]) at 20°C and 1 atmosphere.

- ***Abandoned Underground Mines***

To establish emission factor for abandoned underground mines, following values are used for the formula on the previous page;
The median of default values which is indicated in Table 4.1.5 in page 4.24 in the *2006 IPCC Guidelines* Vol.2 (1990-1925: 5%, 1926-1950: 26.5%, 1951-1975: 40%, 1976-2000: 54%, 2001-: 54.5%) are used for the fraction of gassy mines (*F*).
The lower default value (1.3 [$10^6 m^3$/year/site]) indicated in Table 4.1.8 in page 4.27 in the *2006 IPCC Guidelines* Vol.2 is used for the emission rate from mines before mine closure (*ER*), taking scale of mines into consideration.
The coefficients for sub-bituminous coal (a = 0.27, b = -1.00) indicated in Table 4.1.9 in page 4.27 in the *2006 IPCC Guidelines* Vol.2 are used for parameters to determine declining curve for emissions.

➢ ***CO_2***

- ***Mining Activities***

CO_2 emission factor for mining activities is established by multiplying CH_4 emission factor (volume basis) by proportion of volume fraction of CO_2 in coalbed gas to that of CH_4 (0.0088), which is estimated by using Hokkaido Development Agency (1965), and by CO_2 density (1.84 [kg/m^3]).

- ***Post-Mining Activities***

In the same way as calculated for mining activities, the emissions factors for post-mining activities are established by multiplying CH_4 emission factor (volume basis) by 0.0088.

- ***Abandoned Underground Mines***

In the same way as calculated for mining activities, the emissions factors for post-mining activities are established by multiplying CH_4 emission factor (volume basis) by 0.0088.

● ***Activity Data***

- ***Mining Activities, Post-Mining Activities***

The values used for activity data for underground mining and post-mining activities during the period of FY1990 through FY2000 are derived by subtracting the surface mining production from the total raw coal production as given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke.* The data for FY2001 onward are provided by J-COAL.

Table 3-63 Trends in coal production

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Total coal production	kt	10,676	8,814	4,625	2,146	1,782	1,824	1,774	1,042	1,192	1,035	1,095	793
Surface mines		1,205	695	610	511	557	721	795	477	393	419	366	318
Underground mines		9,471	8,118	4,016	1,635	1,225	1,103	980	565	799	616	729	475

- ***Abandoned Underground Mines***

For activity data, the number of abandoned mines which were not submerged, estimated from the list of abandoned mines in J-COAL (2002). The cumulative number of mines that were not submerged is reported in the activity column in the CRT.

Table 3-64 The number of abandoned mines which were not submerged

Fiscal year of abandonment	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970
Number of abandoned coal mine without submergence	39	34	28	48	12	32	91	103	61	46	33	42	21	42	29
Fiscal year of abandonment	1971	1972	1973	1974	1975	1976	1977	1978	1980	1987	1989	1992	1994	1995	Total
Number of abandoned coal mine without submergence	13	20	12	1	2	3	1	2	2	2	3	1	1	1	725

- ***Recovery and Flaring***

  - ***Mining Activities***

There is no flaring activity of CH_4 which has been emitted from the coal bed during mining in Japan, however there are activities of recovering CH_4 and using it as fuel. Therefore, the net amount of the emissions is estimated by subtracting the recovered value from the total CH_4 emissions. The values of recovery were provided by the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* (FY1990-FY1997) and the data provided by J-COAL (since FY1998).

Table 3-65 Trends in CH_4 recovery from mining activities

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Recovery	1000 m^3	50,139	11,112	9,810	2,044	941	826	844	303	303	303	294	297

  - ***Post-Mining Activities***

The CH_4 recovery/flaring are reported as “NE,” because the existence of such activities has not been confirmed.

  - ***Abandoned Underground Mines***

Reported as “NO” since any activities for CH_4 recovery or flaring has not been implemented.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainties of CH_4 emissions during mining activities, the actual measurement values provided by J-COAL are used for reporting. However, it is difficult to evaluate the uncertainties of these data; therefore, for evaluating the uncertainties, the figures (combined the uncertainty due to measurement error and the uncertainty of error due to the change of flow rate, by using error propagation equation) given in the *2006 IPCC Guidelines* are used, and the uncertainties are established at -5% to +5%. For the uncertainties of CO_2 emissions during mining activity, the uncertainty of CH_4 emissions and the uncertainty of proportion of volume fraction of CO_2 in coalbed gas to that of CH_4 (-18% to +18%), which was calculated using data provided by Hokkaido Development Agency, are combined by error propagation equation, and the uncertainties are established at -19% to +19%.

For the uncertainties in CH_4 emission factors during post-mining activities, since the default values given in the *2006 IPCC Guidelines* are used for the estimation factors, the uncertainty values given in the *2006 IPCC Guidelines* (-33% to +300%) are used. For the uncertainties in CO_2 emission factors during post-mining activities, the uncertainty in CH_4 emission factors and the uncertainty in proportion of volume fraction of CO_2 in coalbed gas to that of CH_4, which is calculated using data provided by Hokkaido Development Agency are combined by error propagation equation, and the uncertainties are evaluated at -38% to +301%. For the uncertainties in activity data of CH_4 and CO_2, during post-mining activities, the actual measurement values provided by J-COAL are used for reporting. However, it is difficult to evaluate the uncertainties of these data; therefore, for evaluating the uncertainties, the figures given in the *2006 IPCC Guidelines* (-2% to +2%) are used, as a result, the uncertainties in emissions

during post-mining activities are evaluated at -33% to +300% for CH_4 emissions and -38% to +301% for CO_2 emissions.

The uncertainties in CH_4 emissions from abandoned mines are established at -50% to +100% based on the description on the uncertainty in Tier 2 given in the *2006 IPCC Guidelines*. For the uncertainties in CO_2 emissions from abandoned mines, the uncertainties in CH_4 emissions and the uncertainties in proportion of volume fraction of CO_2 in coalbed gas to that of CH_4, which is calculated using data provided by Hokkaido Development Agency, are combined by error propagation equation, and the uncertainties are evaluated at -53% to +102%.

- ***Time-series Consistency***

The CH_4 total emissions data for mining activities in underground mines are consistently derived from J-COAL statistics for FY1990 and since FY1995. From FY1991 to FY1994, time-series consistency is ensured by interpolating the emission factors.

The total coal production and coal production in surface mines are provided by the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* prepared from FY1990 to FY2000. Thereafter, they are provided by J-COAL, because the categories of surface mining production and total coal production in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* are no longer provided. The data from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* prepared until 2000 are provided by J-COAL. Therefore, the total coal production data from both of these sources are the same and are used in a consistent manner since FY1990.

The CH_4 recovery data for mining activities are consistent, as were the case for the total coal production and coal production in surface mines.

The numbers of abandoned coal mines, which are the activity data for the abandoned coal mines, are derived from the J-COAL (2002). The default values in the *2006 IPCC Guidelines* are used for the ratio of gas emitting coal mines, the amount of CH_4 emissions from the coal mine before the closure, and the parameters to determine the decreasing curve of the emissions. Also, the CO_2 emissions from the coal mine before closure are estimated from the CH_4 emissions by assuming the ratio of volume is constant, so that the time-series consistency is ensured.

d) Category-specific QA/QC and Verification

Same as the Energy Industries (1.A.1). See section 3.2.4. d).

In order to ensure the safety of coal mine workers in Japan, monitoring the concentration of CH_4 and CO in coal mines is ordained by law. Under the law, mining companies must set rules on monitoring management. Mining companies monitor accurately under strict management and checks, and compile relevant reports. Furthermore, national authorities regularly check the monitoring measurements and safety reports.

e) Category-specific Recalculations

There have been no recalculations of emissions from this category.

f) Category-specific Planned Improvements

No improvements are planned.

3.3.1.1.b. Surface Mines (1.B.1.a.ii)

a) Category Description

This category deals with fugitive emissions of CH_4 and CO_2 occurring during coal mining and post-mining activities in surface mines. The emissions of CH_4 recovered/flared during coal mining in surface mines are reported as "NE," because the existence of such activities has not been confirmed.

b) Methodological Issues

- ***Estimation Method***

➢ ***CH_4***

- ***Mining Activities***

The CH_4 emissions from mining activities are calculated using the Tier 1 method and the default emission factor in accordance with the decision tree in the *2006 IPCC Guidelines* (Vol.2, page 4.18, Fig.4.1.2).

- ***Post-Mining Activities***

The CH_4 emissions from post-mining activities are calculated using the Tier 1 method and the default emission factor in accordance with the decision tree in the *2006 IPCC Guidelines* (Vol.2, page 4.18, Fig.4.1.2).

Both are calculated by multiplying the amount of coal mined from surface mines by the relevant emission factor.

➢ ***CO_2***

The method applied is reported as "CS" (country-specific) in CRT Summary 3, since the *2006 IPCC Guidelines* do not provide a method to estimate CO_2 emissions, but a country-specific CO_2 emission factor is available.

- ***Mining Activities***

CO_2 emissions are estimated by multiplying the production amount of coal by CO_2 emission factor.

- ***Post-Mining Activities***

CO_2 emissions are estimated by multiplying the production amount of coal by CO_2 emission factor.

- ***Emission Factors***

➢ ***CH_4***

- ***Mining Activities***

The value of 0.804 [kg-CH_4/t] is used as emission factor for mining activities. It was derived by converting the average (1.2 [m^3/t]) of the default values given in the *2006 IPCC Guidelines*, using the CH_4 density at one atmospheric pressure and 20°C (0.67 [kg/m^3]).

- ***Post-Mining Activities***

The value of 0.067 [kg-CH_4/t] is used as emission factor for post-mining activities. It was derived by converting the average (0.1 [m^3/t]) of the default values given in the *2006 IPCC Guidelines*, using the CH_4 density at one atmospheric pressure and 20°C (0.67 [kg/m^3]).

➢ ***CO_2***

- ***Mining Activities***

CO_2 emission factor for mining activities is established by multiplying CH_4 emission factor (volume basis) by proportion of volume fraction of CO_2 in coalbed gas to that of CH_4 (0.0088), which is obtained by using Hokkaido Development Agency (1965), and by CO_2 density (1.84 [kg/m^3]).

- ***Post-Mining Activities***

In the same way as calculated for mining activities, the CO_2 emissions factors for post-mining activities are established by multiplying CH_4 emission factor (volume basis) by 0.0088.

● ***Activity Data***

The figure for the surface production given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* and the data provided by the J-COAL were used as activity data for mining and post-mining activities (see Table 3-63).

c) Uncertainty Assessment and Time-series Consistency

● ***Uncertainty Assessment***

For the uncertainty in CH_4 emission factor during mining activities, since the default value given in the *2006 IPCC Guidelines* is used for emission factor, the uncertainty values given in the *2006 IPCC Guidelines* (-50% to +200%) are used. For the uncertainty in CO_2 emission factor during mining activities, the uncertainty in CH_4 emission factor and the uncertainty in proportion of volume fraction of CO_2 in coalbed gas to that of CH_4, which is calculated using data provided by Hokkaido Development Agency, are combined by error propagation equation, and the uncertainty is calculated as -53% to +201%. For the activity data of CH_4 and CO_2 during mining activities, the actually measured data provided by J-COAL are reported, however it is difficult to evaluate the uncertainty of the data. Therefore, the uncertainty values of -2% to +2% in the *2006 IPCC Guidelines* are used. As a result, the uncertainties in emissions during mining were evaluated at -50% to +200% for CH_4 and -53% to +201% for CO_2.

For the uncertainty in CH_4 emission factor during post-mining activities, since the default value given in the *2006 IPCC Guidelines* is used for emission factor, the values given in the *2006 IPCC Guidelines* (-33% to +300%) are used. For the uncertainty in CO_2 emission factor during post-mining activities, the uncertainty in CH_4 emission factor and the uncertainty in proportion of volume fraction of CO_2 in coalbed gas to that of CH_4, which is calculated using data provided by Hokkaido Development Agency, are combined by error propagation equation, and the uncertainties are evaluated at -38% to +301%. For activity data for CH_4 and CO_2 during post-mining activities, the actual measurement data provided by J-COAL are reported. However, it is difficult to evaluate the uncertainties in these data, the figures (-2% to +2%) given by the *2006 IPCC Guidelines* are used. As a result, the uncertainties in emissions during post-mining activities are evaluated at -33% to +300% for CH_4 and -38% to +301% for CO_2.

● ***Time-series Consistency***

The total coal production and coal production in surface mines were provided by the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* prepared from FY1990 to FY2000. Thereafter, they have been provided by J-COAL, because the categories of surface mining production and total coal production in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* are no longer provided. The data from the *Yearbook of Production, Supply and Demand of*

Petroleum, Coal and Coke prepared by METI until 2000 are provided by J-COAL. Therefore, the total coal production data from both of these sources are the same and have been used in a consistent manner since FY1990.

d) Category-specific QA/QC and Verification

Same as the Energy Industries (1.A.1). See section 3.2.4. d).

e) Category-specific Recalculations

There have been no recalculations of emissions from this category.

f) Category-specific Planned Improvements

No improvements are planned.

3.3.1.2. Fuel Transformation (1.B.1.b)

a) Category Description

This category deals with the GHG emissions in the process of manufacturing charcoal and coke. Although the *2006 IPCC Guidelines* do not specify emission sources to be included in this category, fugitive emissions from charcoal and coke production may be included in this category according to the CRT. Because the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (hereinafter, *2019 Refinement*) provides estimation methods of fugitive emissions from charcoal and coke production, these emissions are estimated.

CH_4 emissions are released in the process of manufacturing charcoal due to imperfect combustion of carbon contained wood material which is raw material of charcoal.

Coke oven gas (COG) is a by-product of coke production by coal pyrolysis. COG contains H_2, CH_4, CO and other gases. Most of COG is used as fuel and the emissions are included in "Fuel Combustion (1.A)". The *2019 Refinement* provides estimation methods for flaring of COG for operational safety reasons and equipment maintenance purposes.

According to the interview with the Japan Iron and Steel Federation (JISF), flaring is not conducted during the usual operation, but it is conducted rarely during the suspension or construction of consumption process. Nevertheless, most of the factories report productions and consumptions of COG, including the amount of flaring, to the *Current Survey of Energy Consumption*, which is one of the primary statistics of the *General Energy Statistics* (Japan's energy balance tables). Therefore, the amount already reported is included in "Fuel Combustion (1.A)". Because the amount of flaring from unreported factories was provided by JISF, the emissions prior to FY2021 are estimated and reported in this category. The reporting instructions of the *Current Survey of Energy Consumption* in and after FY2022 have clarified that the amount of production and consumption of COG should include flaring. Therefore, the emissions from flaring of COG, including factories that have not reported flaring amount so far, have been included in "Fuel Combustion (1.A)", and CO_2 emissions in this category have been reported as "IE" from FY2022.

b) Methodological Issues

- ***Estimation Method***

  - ***Charcoal Production***

The emissions from manufacturing charcoal are estimated by using the Tier 1 method in accordance with the decision tree of the *2019 Refinement* (Vol.2, Page 4.101, Fig. 4.3.1), multiplying production amount of charcoal by the default emission factor.

CO_2 are also emitted by charcoal production, but the emissions are not included in the national totals but are reported in the NID as reference because they are of biomass origin.

The CH_4 recovery/flaring in the CRT are reported as "NE" because the existence of such activities during charcoal production has not been confirmed.

  - ***Flaring of Coke Oven Gas***

The CO_2 emissions from flaring of COG are estimated using the Tier 2 method in accordance with the decision tree of the *2019 Refinement* (Vol.2, Page 4.114, Fig. 4.3.4) because flaring amount and country-specific emission factors are available.

$$E=AD\times EF\times 44/12$$

E : CO_2 emissions from flaring of COG [t-CO_2]
AD : Flaring amount of COG not reported to the *Current Survey of Energy Consumption* [TJ]
EF : Carbon emission factor of COG [t-C/TJ]

The CH_4 recovery/flaring in the CRT Table 1.B.1 are reported as "NE". It is assumed that this cell is used for reporting the reduced amount of CH_4 through flaring of fugitive gas from coke oven. The reduced amount of fugitive CH_4 is not estimated since the CH_4 leaking from coking furnace lids are reported in "Manufacture of solid fuels and other energy industries (1.A.1.c)" and CH_4 content of coke oven gas is not established.

- ***Emission Factors***

  - ***Charcoal Production***

The default values of the charcoal production given in the *2019 Refinement* are used. Although the *2019 Refinement* provides the default values for the production of biochar (charcoal for amendment in cropland), the default values of charcoal production are also applied for the emission estimation of biochar production, considering the national circumstances. The default values of biochar are for products by flame curtain biochar kilns, but charcoal kilns, mechanical kilns, and open-hearth furnaces are mainly used for biochar manufacturing in Japan. It is appropriate to apply the default values of charcoal for biochar manufacturing.

Table 3-66 Emission factors for charcoal production

Item	Unit	CO_2	CH_4	N_2O
Charcoal production	g/kg	1,570	40.3	0.08

Reference: *2019 Refinement,* Vol. 2, page 4.103, Table 4.3.3

  - ***Flaring of Coke Oven Gas***

The emission factor is the same as the carbon emission factor of COG used in "Fuel Combustion (1.A.)" (see Table 3-11).

- ***Activity Data***

  - ***Charcoal Production***

The activity data are the production amount of charcoal (hard charcoal, soft charcoal, bamboo charcoal, fine charcoal and sawdust charcoal), which is obtained from *Basic Data for Special Forest Product* (Forestry Agency) and *Data for Charcoal* (Forestry Agency).

Table 3-67 Production Amount of Charcoal

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Charcoal Production	kt	83.2	82.3	67.4	44.9	34.1	29.6	25.9	19.8	17.2	17.1	17.4	16.3

  - ***Flaring of Coke Oven Gas***

The amount of flaring not reported to the *Current Survey of Energy Consumption* is used as activity data. Since JISF only has data on the unreported flaring amount for FY2020 and all flaring amount for FY1990, 2000, 2010 and 2020, the other years are estimated using the formula below.

$$AD = P \times R \times U \times GCV$$

AD : Unreported flaring amount of COG [TJ]
P : Production amount of COG [million m^3]
R : Flaring rate
U : Unreported rate
GCV : Gross calorific value (GCV) of COG [MJ/m^3]

The production amount of COG *P* is obtained from the values shown in Metallurgical Coke (#212100) and Coke Oven Gas ($0221) of the *General Energy Statistics*. The flaring rate *R* for FY1990, 2000, 2010 and 2020 is obtained from dividing the flaring amount of each year (provided by JISF) by *P* of the same year. *R* for the other years is estimated by interpolation or extrapolation. The unreported rate *U* for FY2020 is obtained from dividing the unreported flaring amount of the year (provided by JISF) by all the flaring amount of the same year. *U* for the other years is the same as *U* for FY2020. *GCV* is the same as the GCV of COG used in "Fuel Combustion (1.A)" (see Table 3-17).

The gas volume is shown in normal condition (273.15 K, 101.325 kPa) for the values of the *General Energy Statistics* (FY1990-2012) and the values provided by JISF, and it is shown in SATP condition (298.15 K, 100 kPa) for the values of the *General Energy Statistics* (FY2013 onward). The values are converted from normal condition to SATP condition by multiplying 1.0773, as appropriate.

Table 3-68 Flaring Amount of Coke Oven Gas
not Reported to the *Current Survey of Energy Consumption*

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Unreported flaring amount of COG	TJ	11.6	25.5	38.8	38.5	41.2	52.9	55.9	70.6	75.6	IE	IE	IE

- ***Completeness***

The emissions from charcoal use as fuel are included in "Fuel Combustion (1.A)", however the CO_2 emissions are not included in the national totals but are reported in the CRTs as reference in accordance with the *2006 IPCC Guidelines*. The carbon stock changes in mineral soils by charcoal amendments in cropland are estimated in "Cropland Remaining Cropland" (4.B.1) (See Chapter 6).

The flaring amount of COG already reported to the *Current Survey of Energy Consumption* is included in "Fuel Combustion (1.A)". For the sources of coke production other than flaring of COG presented in the *2019 Refinement*, the emissions are taken into account through the activity data (fuel consumption

of the *General Energy Statistics*) or the CH_4 emission factor of coking furnace lid.

In Japan, the production of coal briquettes is considered to meet the description of the activity of fuel transformation. The process of coal briquette production includes introducing water to coal, and squeeze-drying it. Therefore, the process is not thought to involve any chemical reactions, but the emissions of CO_2, CH_4 or N_2O cannot be denied. However, the emissions are not estimated as no actual measurement has been taken and no default value is provided.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

  - ***Charcoal Production***

As for emission factors, the uncertainties for the default emission factors for charcoal production provided in the *2019 Refinement* are adopted. (-68% to +121% for CH_4 and -75% to +163% for N_2O) As for activity data, the uncertainties are substituted by the uncertainties for coal mining and handling (1.B.1.a) given in the *2006 IPCC Guidelines* (-2% to +2%), because the uncertainties for charcoal production are not available in the *Basic Data for Special Forest Product*. As a result, uncertainties for emissions from charcoal production are evaluated as -68% to +121% for CH_4 and -75% to +163% for N_2O.

  - ***Flaring of coke oven gas***

The uncertainties of emission factors are set by the upper and lower limits of 95% confidence intervals derived from the original data of carbon emission factors of COG (-0.46% to +0.46%). For the uncertainties of activity data, the uncertainties in flaring amount and the uncertainties in the GCV are combined by error propagation equation. As for the uncertainties in flaring amount, the values shown in the *2006 IPCC Guidelines* (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes) from fugitive emissions from oil and natural gas systems) are used since neither JISF nor the *2019 Refinement* provide the uncertainties in flaring amount. The uncertainties of the GCV are set by the upper and lower limits of 95% confidence intervals derived from the original data of the GCV of COG (-1.2% to +1.2%). As a result, the uncertainty for the CO_2 emissions from flaring of COG are evaluated to be -15% to +15%.

- ***Time-series Consistency***

  - ***Charcoal Production***

The reference of the charcoal production amount in FY1990, which is the *Data for Charcoal*, is different from the reference in and after FY1991, which is the *Basic Data for Special Forest Product*. However, both data are provided by the Forestry Agency and the data capturing ranges are set to be the same. The default values in the *2019 Refinement* are used for the emission factors throughout the time-series so that the consistency is ensured.

  - ***Flaring of coke oven gas***

As for the activity data, the production amount of COG from the *General Energy Statistics* is used as a surrogate parameter to ensure time-series consistency. The emission factors are the same as “Energy Industries (1.A.1)”. See 3.2.4. c).

d) Category-specific QA/QC and Verification

Same as the Energy Industries (1.A.1). See section 3.2.4. d).

e) Category-specific Recalculations

Since the production amount of charcoal for FY2023 in *Basic Data for Special Forest Product* were revised, the CO_2, CH_4 and N_2O emissions for FY2023 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

3.3.1.3. Others (Uncontrolled Combustion and Burning Coal Dumps) (1.B.1.c)

This category deals with CO_2 emissions generated by unintentional coal combustion due to mine fire. The *2006 IPCC Guidelines* recognize uncontrolled combustion and burning coal dumps as a potential emission source, but do not provide an emission estimation method.

As for FY1999, coal combustion was occurred by the fire in Ikejima Coal Mine. However, since the amount of combusted coal is not available, it is reported as "NE". As for other fiscal years, any fire resulted in coal combustion was not occurred; therefore, it is reported as "NO".

It is impossible to specify from the official statistics whether fires occur at coal dumps as well as the amount of combusted coal there.

3.3.2. Oil, Natural Gas and Other Emissions from Energy Production (1.B.2)

3.3.2.1. Oil (1.B.2.a)

3.3.2.1.a. Oil Exploration (1.B.2.a.i)

This category deals with fugitive emissions of CO_2, CH_4 and N_2O from the explorative drilling of oil.

According to the Japan Natural Gas Association, GHG emissions by the explorative drilling of oil and natural gas fields in Japan are only from flaring as long as they are properly managed. Therefore, it is reported as "NA" in the "Oil Exploration (1.B.2.a.i)" for oil in the CRT, and the emissions from the venting during explorative drilling for oil are not estimated.

For flaring during explorative drilling, the number of explorative wells is chosen as the activity data. Although it is not possible to separate oil wells and gas wells in all time-series, it can be assumed that most of them are gas wells. Therefore, emissions from flaring during oil exploration are included in "Flaring (Gas) (1.B.2.c.ii.2)". See Section "3.3.2.2.a Natural Gas Exploration (1.B.2.b.i)" for details on how to estimate emissions from flaring during natural gas explorative drilling.

3.3.2.1.b. Oil Production and Upgrading (1.B.2.a.ii)

a) Category Description

This category deals with fugitive emissions of CO_2 and CH_4 occurring at production of crude oil for each offshore and onshore oil fields.

Among the emissions associated with fugitive emissions during oil production, the emissions are

reported from venting in "Venting (Oil) (1.B.2.c.i.1)", from flaring in "Flaring (Oil) (1.B.2.c.ii.1)" and from other fugitive emissions in this category (1.B.2.a.ii), respectively.

b) Methodological Issues

- ***Estimation Method***

The default emission factors in the *2019 Refinement* are considered to better reflect the actual situation in Japan than the default emission factors in the *2006 IPCC Guidelines*, therefore, the emissions are estimated using the Tier 1 method, in accordance with the decision tree in the *2019 Refinement* (Vol. 2, page 4.42, Fig.4.2.12).

- ***Emission Factors***

The default values for fugitive emissions per unit of oil production from offshore and offshore oil fields, which are indicated in the *2019 Refinement*, are used. As for emission factors for onshore fields, since the installation of flaring and vapor recovery equipment has increased significantly in the past and most wells are expected to have such equipment installed after FY1990, the default values for lower-emitting technologies are used.

Table 3-69 Emission factors for fugitive emissions from oil production

Category/ Sub-category	Emission source	Unit	CH_4	CO_2	N_2O
Onshore Production/ Lower-emitting technologies	Leaks	$t/10^3m^3$	0.26 (2.91*9%)	0	0
	Vents[1)]		2.27 (2.91*78%)	0.45 (44.99*1%)	0
	Flares[2)]		0.38 (2.91*13%)	44.54 (44.99*99%)	6.7×10^{-4} (100%)
Offshore Oil Production	Leaks		0.49 (2.46*20%)	0	0
	Vents[1)]		1.97 (2.46*80%)	0.12 (4.08*3%)	0
	Flare[2)]		0	3.96 (4.08*97%)	1.6×10^{-5} (100%)

Reference: *2019 Refinement* Vol. 2, page 4.54, Table 4.2.4A, and page 4.129, Table 4A.2.2
Note:
1) Emissions from venting are reported in "Venting (Oil) (1.B.2.c.i.1)" of CRT.
2) Emissions from flaring are reported in "Flaring (Oil) (1.B.2.c.ii.1)" of CRT.

- ***Activity Data***

The amount of crude oil production by offshore and onshore oil field (excluding condensate[20]) is used for activity data.

The amount of condensate production in offshore gas field is estimated by multiplying the production amount of condensate by the percentage of production volume in offshore in total production volume of natural gas.

The estimated value above is deducted from total volume of domestic crude production in offshore oil field to obtain the production amount of crude oil from offshore oil field (excluding condensate).
The production amount of crude oil in onshore oil field (excluding condensate) is estimated by deducting crude oil production in offshore (excluding condensate) from total amount of crude oil production (excluding condensate).

Total production volume of natural gas, crude oil, and condensate is obtained from the data given in the

[20] Light, liquid hydrocarbon that is produced from natural gas wells associated with natural gas production

Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke, the *Yearbook of Mineral Resources and Petroleum Products* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*. The production amount of natural gas and crude oil from offshore is obtained from *Natural Gas Data Yearbook* (Japan Natural Gas Association).

Table 3-70 Amount of oil production excluding condensate from offshore and onshore oil fields

Item		Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Oil production excluding condensate	Offshore	1000 kL	175	391	167	76	78	70	76	89	84	65	63	63
	Onshore	1000 kL	245	232	218	295	215	195	164	165	138	116	119	120

- ***Completeness***

In this category, the amount of crude oil production excluding condensate is used as activity data. The GHG emissions associated with condensate production are included in "Natural Gas Production and Gathering (1.B.2.b.ii)" and "Natural Gas Processing (1.B.2.b.iii)", because emission factors of these categories include emission from condensate production.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainties for emission factors given in the *2019 Refinement* (CO_2 and CH_4: -30% to +30%, N_2O: -10% to +1000%) are used for emission factors for oil production, since the default values in the *2019 Refinement* are used exclusively. For activity data, because the uncertainties of statistical data used as reference are not available, the values given in the *2019 Refinement* (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) are used. As a result, the uncertainties for emissions of CO_2 and CH_4 from oil production are evaluated as -34% to +34% for each, and the uncertainties for emissions of N_2O are evaluated as -18% to +1000%. Although the disaggregation rates for leaks, venting, and flaring may also have uncertainties, they were not evaluated because they are not indicated in the *2019 Refinement*.

- ***Time-series Consistency***

Consistent values are used for emission factors from FY1990 to the nearest year, using the above-described method. The activity data are calculated by using the annual data from the *Yearbook of Mineral Resources and Petroleum Products*, the *Natural Gas Data Yearbook* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* by the consistent estimation method throughout the time-series from FY1990 to the nearest year.

d) Category-specific QA/QC and Verification

Same as the Energy Industries (1.A.1). See section 3.2.4. d).

e) Category-specific Recalculations

Since the activity data for FY2023 in the *Natural Gas Data Yearbook* were revised, the CH_4 emissions for all years were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

3.3.2.1.c. Oil Transport (1.B.2.a.iii)

a) Category Description

This category deals with fugitive emissions of CO_2 and CH_4 occurring during the transportation of crude oil and condensate through pipelines, tank trucks, and tank cars to refineries.

b) Methodological Issues

- ***Estimation Method***

The fugitive emissions from transport of crude oil and condensate are estimated using the Tier 1 method in accordance with the decision tree in the *2006 IPCC Guidelines* (Vol.2, page 4.40, Fig.4.2.3) by multiplying the amount of crude oil and condensate production by the emission factors.

In this category, fugitive emissions from ocean transportation of crude oil which are produced at domestic offshore oil fields and are shipped from ocean to land, and the fugitive emissions from land transportation are estimated. Crude oil is transported on sea entirely by pipeline, and is not expected to generate any fugitive emissions from other transportation modes. Land transport includes a number of methods, including pipeline, tank trucks, and tank cars, but it is difficult to differentiate them statistically. For that reason, the emissions were estimated under the assumption that all of the produced oil is transported by tank trucks and rail cars[21].

- ***Emission Factors***

The default values given in the *2006 IPCC Guidelines* were used as emission factors. (The default values have not changed in the *2019 Refinement*.)

Table 3-71 Emission factors for transportation of crude oil and condensate

Item	Unit	CH_4	CO_2	N_2O
Oil Transport/ Tanker Trucks and Rail Cars	$kt/10^3m^3$	2.5×10^{-5}	2.3×10^{-6}	NA
Natural Gas Liquids Transport/ Condensate	$kt/10^3m^3$	1.1×10^{-4}	7.2×10^{-6}	ND

Reference: *2006 IPCC Guidelines* Vol. 2, page 4.50 and 4.53, Table 4.2.4
Note: N_2O is excluded from calculations, as the default value is "NA" or "ND".

- ***Activity Data***

The amount of oil and condensate production in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* are used as activity data for fugitive emissions from transport.

Table 3-72 Production of crude oil and condensate in Japan

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Oil production excluding condensate	1000 kL	420	623	386	370	293	265	240	254	222	182	181	183
Condensate production		234	243	375	541	560	403	339	259	252	229	210	198
Oil production (total)		655	866	761	911	853	668	578	513	473	410	392	381

[21] As the default values of tanker trucks and rail cars are higher than those of pipelines, this assumption does not lead to underestimation.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainty of emission factors for CO_2 and CH_4 fugitive emissions from transportation of crude oil and condensate, the values given in the *2006 IPCC Guidelines* (-100% to +100%) are applied since the default values given in the guidelines are used exclusively. As for the uncertainty for activity data, the values given in the *2006 IPCC Guidelines* (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) are used since the uncertainties of statistical data used as reference are not available. As a result, the uncertainties for the CO_2 and CH_4 emissions from oil and condensate transport are evaluated to be -101% to +101% for each.

- ***Time-series Consistency***

For the emission factors, consistent values are used from FY1990 to the nearest year with the above-mentioned method. The activity data are calculated based on the annual data from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke,* the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* by a consistent method throughout the time-series from FY1990 to the nearest year.

d) Category-specific QA/QC and Verification

Same as the Energy Industries (1.A.1). See section 3.2.4. d).

e) Category-specific Recalculations

There have been no recalculations of emissions from this category.

f) Category-specific Planned Improvements

No improvements are planned.

3.3.2.1.d. Oil Refining / Storage (1.B.2.a.iv)

a) Category Description

This category deals with fugitive emissions of CH_4 occurring when crude oil is refined or stored at oil refineries.

The CO_2 emissions from this source are reported as “NE”. Refining/storage activities exist in Japan and an extremely small amount of CO_2 is considered to be released into the atmosphere from these activities if CO_2 is included in crude oil. Because there are neither actual measurements of the CO_2 content of crude oil nor any default values for emission factors, CO_2 emissions from this source are not estimated.

The N_2O emissions from this source are reported as “IE”. The *2019 Refinement* provides a default emission factor for N_2O, which is considered to be for N_2O generated during petroleum coke calcination. Such emissions are included in “Fuel Combustion (1.A.)”.

b) Methodological Issues

- ***Estimation Method***

Although the *Revised 1996 IPCC Guidelines* provided the default emission factors for refining and

storage tanks separately, the *2006 IPCC Guidelines* provide the default emission factor for refining only. As a country-specific emission factor for storage is available, the emissions from storage as well as refining are estimated.

- ***Oil Refining***

The fugitive emissions from oil refining are estimated using the Tier 1 method in accordance with the decision tree in the *2006 IPCC Guidelines* (Vol. 2, page 4.40, Fig. 4.2.3).

- ***Oil Storage***

The fugitive emissions from oil storage are estimated using a country-specific emission factor. This method is equivalent to Tier 2 if the decision tree in the *2006 IPCC Guidelines* (Vol. 2, page 4.40, Fig. 4.2.3) is applied.

- ***Emission Factors***

- ***Oil Refining***

The amount of CH_4 emitted during the crude oil refining process is considered to be negligible because no fugitive emission of CH_4 is likely to occur in Japan during crude oil refining at normal operation. For that reason, the lower limit of the default values shown in the *2006 IPCC Guidelines* is adopted for the emission factors for fugitive emissions during the refining process.

Table 3-73 Emission factor during crude oil refining

	Emission factor [kg-CH_4/10^3m^3]
Oil refining	2.6×10^{-6}

Reference : *2006 IPCC Guidelines* Vol. 2, page 4.53, Table 4.2.4
Note: The default value is 2.6×10^{-6} - 41.0×10^{-6}

- ***Oil Storage***

Oil is stored in either corn-roof tanks or floating-roof tanks. All oil storage in Japan adopts floating-roof tanks, which means that the fugitive CH_4 emissions are considered to be very small. If fugitive CH_4 emissions were to occur, they could only occur by vaporization of oil left on the exposed wall wet with oil when the floating roof descends as the stored oil is removed; thus, the amount of fugitive CH_4 emissions would be small.

The Petroleum Association of Japan conducted experiments relating to the evaporation of CH_4 from tank walls by making the model of floating-roof tank, and based on the result the CH_4 emissions are estimated.

The emission factor associated with the storage of crude oil is obtained by dividing the emissions estimated by the Petroleum Association (0.007 kt-CH_4/year as of 1998) by the amount of the crude oil put into the oil refining industry (from *General Energy Statistics*).

Table 3-74 Calculation process of emission factor during oil storage

CH_4 emissions [kt-CH_4/year]	Input of crude oil to oil refining industry [10^3kL]	Emission factor [kt-CH_4/10^3kL]
7×10^{-3}	242,861	2.9×10^{-8}

- ***Activity Data***

The values used for activity data during refining and storing are the values (in volume) of refined NGL (Natural Gas Liquids) and crude oil in the petroleum refining industry taken from the *General Energy Statistics*.

Table 3-75 Amount of crude oil and NGL refined in Japan

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Oil and NGL refined	10^6m^3	204	241	242	241	209	200	188	139	147	156	145	135

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainties of emission factors for fugitive emissions of CH_4 from refining crude oil and NGL, the values shown in the *2006 IPCC Guidelines* (-100% to +100%) are applied since the default values in the guidelines are used exclusively. The uncertainties for activity data for the fugitive emissions from refining crude oil and NGL are evaluated to be -21% to +21% respectively by error propagation method using the uncertainties of the standard calorific value and statistics used for estimating consumption. However, since the uncertainties of statistical data used for estimating consumption (*Yearbook of Mineral Resources and Petroleum Products* and *Yearbook of the Current Survey of Energy Consumption*) are not available, the default values provided in the *2006 IPCC Guidelines* (the uncertainties associated with measurement of flow rate (excluding sales volumes)) are substituted. As a result, the uncertainties for CH_4 fugitive emissions associated with refining of crude oil and NGL are evaluated at -102% to +102% for each.

As for the uncertainties of emission factors for fugitive emissions of CH_4 during storage of crude oil and NGL, the country-specific values were used. However, it is difficult to evaluate uncertainties; therefore, the values evaluated in the *2006 IPCC Guidelines* (-100% to +100%) are applied. The uncertainties for activity data for the fugitive emissions during storage of crude oil and NGL are evaluated to be -21% to +21% respectively by error propagation method using the uncertainties of standard calorific value and statistics used for estimating consumption. However, since the uncertainties of statistical data used for estimating consumption (*Yearbook of Mineral Resources and Petroleum Products* and Y*earbook of the Current Survey of Energy Consumption*) are not available, the default values provided in the *2006 IPCC Guidelines* (the uncertainties associated with measurement of flow rate (excluding sales volumes)) are substituted. As a result, the uncertainties for CH_4 fugitive emissions associated with storage of crude oil and NGL are evaluated at -102% to +102% for each.

- ***Time-series Consistency***

Consistent values are used for emission factors from FY1990 to the nearest year by using above–mentioned method. The activity data for refining and storage are calculated using the data from the *General Energy Statistics,* by a consistent method throughout the time-series from FY1990 to the nearest year.

d) Category-specific QA/QC and Verification

- ***QA/QC***

Same as the Energy Industries (1.A.1). See section 3.2.4. d).

- ***Verification***

The reasons and history for the selection of the lowest value of the default emission factors (EFs) shown in the *2006 IPCC Guidelines* for fugitive emissions during the refining process are explained below.

In the 1999 submission, Japan used to use the median of the default EFs in the *Revised 1996 IPCC Guidelines* (745 kg-CH_4/PJ for oil refining and 135 kg-CH_4/PJ for oil storage). Then, a country-specific emission factor (CSEF) of storage was obtained (0.7 kg-CH_4/PJ). The EF for refining (745 kg/PJ) was

about 1,000 times higher than the new CSEF for storage. The Breakout group on Energy and Industrial Processes of the Committee for the Greenhouse Gas Emission Estimation Methods held in 1999 was unable to justify the large gap of two EFs between refining and storage. Therefore, the lowest value of the default EFs for refining shown in the *Revised 1996 IPCC Guidelines* and the CSEF of storage had been applied since the 2000 submission.

In the 2015 submission, the EF for refining was replaced with the default value of the *2006 IPCC Guidelines*, but the notion of using the lowest value was unchanged. Although the *2006 IPCC Guidelines* do not provide the default emission factor for storage, the CSEF for storage is still used. It is unknown if the default EF of refining in the *2006 IPCC Guidelines* takes storage into consideration.

According to the interview with the Petroleum Association of Japan (PAJ) held in 2022, the PAJ said CH_4 generated in the oil refineries in Japan is recovered and utilized by gas recovery facilities and the emissions are limited. The CO_2 emissions from utilization of the recovered CH_4 are estimated under "Fuel Combustion (1.A.)" as refinery gas. This is the additional rationale of using the lowest value of the default EFs.

The default EF provided in the *2019 Refinement* is not applied because it is unclear how the EF is established.

Table 3-76 Comparison of emission factors during refining and storage process

Item	Emission factor of refining	Emission factor of storage	Remarks
Value used in the calculation	2.6 [kg/10^3 m^3]	0.029 [kg/10^3 m^3]	Refining: the lowest value of the *2006 IPCC Guidelines* Storage: CSEF
Revised 1996 IPCC Guidelines	90 – 1400 [kg/PJ] (3 – 51 [kg/10^3 m^3]) 1)	20 – 250 [kg/PJ] (0.7 – 9.2 [kg/10^3 m^3]) 1)	Survey by the United States Environmental Protection Agency
2006 IPCC Guidelines	2.6 – 41.0 [kg/10^3 m^3]	Not provided	
2019 Refinement	30 [kg/10^3 m^3]	Not provided	

Note:
1) Converted value using the net calorific value of the United States (42.71 [TJ/kt] from Vol.3, Table 1-2) and the density of crude oil (860 [kg/m^3] from Vol.2, page 1.72) in the *Revised 1996 IPCC Guidelines*.

e) Category-specific Recalculations

There have been no recalculations of emissions from this category.

f) Category-specific Planned Improvements

No improvements are planned.

3.3.2.1.e. Distribution of Oil Products (1.B.2.a.v)

Oil products are distributed in Japan, and where CO_2 and CH_4 are dissolved, it is conceivable that either or both will be emitted as a result of the relevant activity. However, the level of CO_2 or CH_4 emitted by the activity is in principle unlikely in light of the composition of the oil products. In addition, the *2006 IPCC Guidelines* and the *2019 Refinement* also provide an emission factor of "NA", therefore, the emissions by this activity are reported as "NA".

3.3.2.1.f. Other (Abandoned Oil Wells, etc.) (1.B.2.a.vi)

This category deals with fugitive emissions from abandoned oil wells, accidents, etc.

Fugitive emissions from abandoned wells are reported as "NA". The estimation method for greenhouse gas emissions from abandoned oil wells was not provided in the *2006 IPCC Guidelines* but was provided in the *2019 Refinement*.

In accordance with the Enforcement Ordinance of the Mine Safety Act, systems are in place to prevent gas leakage from abandoned mines, as examples of measures to be taken by holders of mining rights, the following are listed: "Method of sealing wells", "Method of installing cement plugs", "Filling with muddy water, etc.", "Examination after measures and confirmation of sealing condition" and "Method of restoration around the mine entrance area" (Ministry of Economy, Trade and Industry, 2012). Also, in the event of gas outburst or outflow of hazardous gas, this Enforcement Ordinance imposes an obligation to report the status of the disaster to the METI immediately after the occurrence of the disaster, and management systems have been established to enable immediate identification of any leakage in this activity.

In addition, according to the Japan Natural Gas Association, the abandoned petroleum mines[22] in Japan have been taking measures to prevent gas leakage in accordance with the Mine Safety Act, and there have been no leaks from the wells. Also, each operator reportedly conducts regular inspections (about once a year) even after waiving the mining rights.

Judging from the above-mentioned measures regime in the abandoned mines, there are no emissions from the abandoned oil wells in Japan. Therefore, it is reported as "NA" in this category, which means that "the activity does occur, but do not result in emissions or removals of a specific gas".

Fugitive emissions due to accident is reported as "NE". For example, the Great East Japan Earthquake that occurred in March 2011 caused fires at oil complexes, but emissions could not be reported because of the difficulty in estimating emissions. Similarly, greenhouse gas emissions may have occurred in past accidents, but it was difficult to quantify the emissions in each case.

3.3.2.2. Natural Gas (1.B.2.b)

The natural gas supply network and the inventory categorization of GHG fugitive emissions from each process of the network are shown in Figure 3-7.

[22] In Enforcement Ordinance of the Mine Safety Act, "petroleum" includes combustible natural gas (excluding those collected in connection with the mining of coal or lignite in mines intended for the mining of coal or lignite).

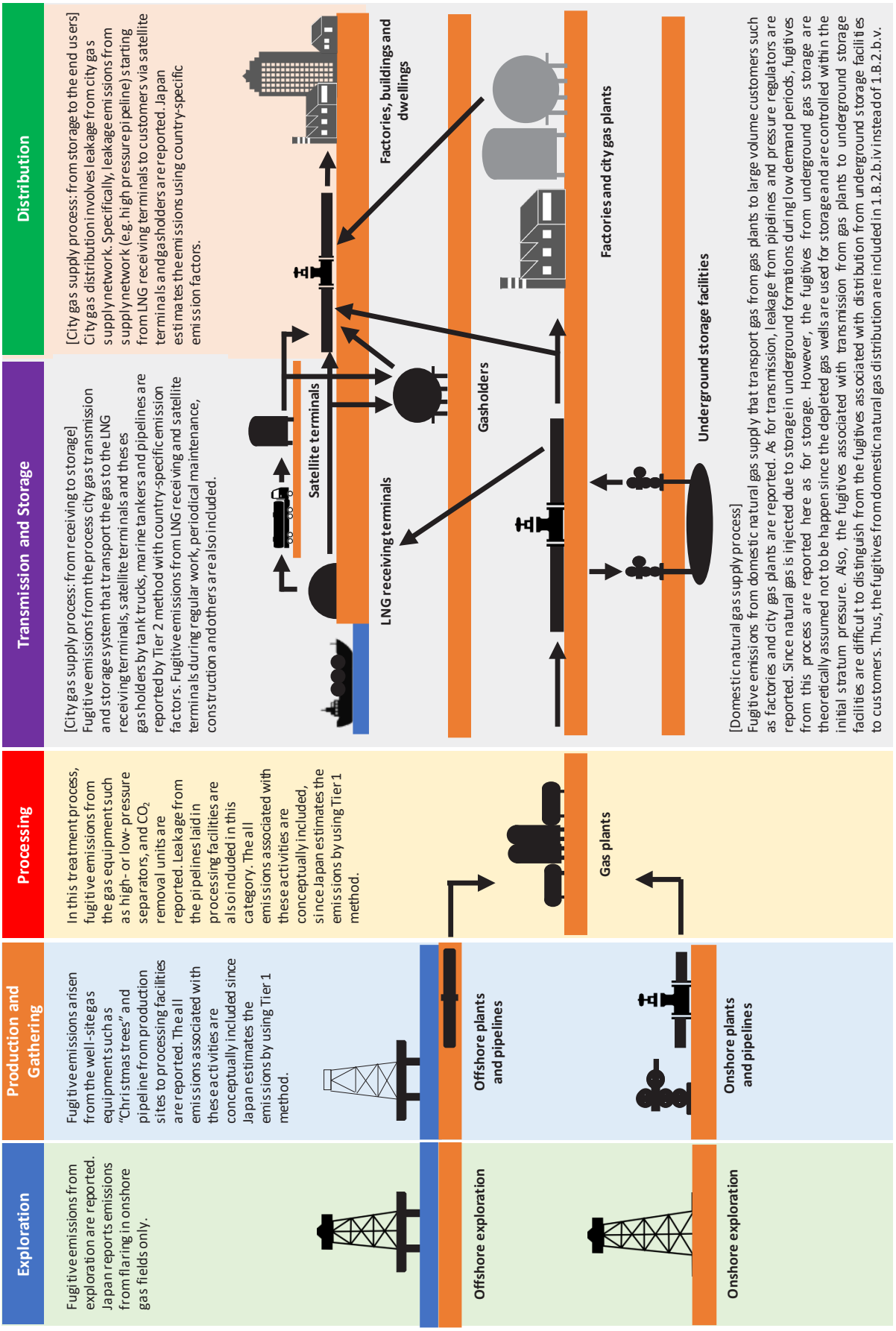

Figure 3-7 Supply network and inventory categorization of natural gas

3.3.2.2.a. Natural Gas Exploration (1.B.2.b.i)

a) Category Description

This category deals with fugitive emissions of CO_2, CH_4, and N_2O from the explorative drilling of natural gas fields. According to the Japan Natural Gas Association, GHG emissions by the explorative drilling of natural gas wells in Japan are only from flaring as long as they are properly managed. Therefore, in the "Natural Gas Exploration (1.B.2.b.i)" for natural gas in the CRT, it is reported as "NA" and the emissions from venting during explorative drilling for natural gas are not estimated, only the emissions from "Flaring (Gas) (1.B.2.c.ii.2)" are estimated.

b) Methodological Issues

- ***Estimation Method***

Because the default emission factors of the *2019 Refinement* are considered to better reflect the actual situation in Japan than the default emission factors of the *2006 IPCC Guidelines*, the emissions are estimated using Tier 1 method, in accordance with the *2019 Refinement* (Vol. 2, page 4.42, Fig. 4.2.1). Also, according to the *2019 Refinement*, the emissions from exploration in offshore gas wells can be negligible, and therefore only the emissions from onshore field are estimated.

- ***Emission Factors***

The default values for flaring provided in the *2019 Refinement* are used. Since hydraulic fracturing is hardly practiced in Japan, the emission factors per explorative well under "conventional technologies" in the *2019 Refinement* are used.

Table 3-77 Emission factors of fugitive emissions for natural gas exploration

Sub-category	Emission source	Unit	CH_4	CO_2	N_2O
Onshore conventional Gas exploration	Flares	t/number of wells drilled	0.0578 (5.78*1%)	4.72 (100%)	3.4×10^{-5} (100%)

Reference: *2019 Refinement* Vol. 2, page 4.67, Table 4.2.4F and page 4.131, Table 4A.2.4

- ***Activity Data***

The number of onshore explorative wells in the *Natural Gas Data Yearbook* are used for activity data.

Table 3-78 Number of onshore explorative wells drilled

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Number of onshore wells drilled	wells	7	6	6	7	2	3	2	0	1	1	1	1

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For emission factors, the values of the *2019 Refinement* were used (CO_2, CH_4: -20% to +20%, N_2O: -10% to +1000%). For activity data, the values in the *2019 Refinement* (uncertainty in the number of production facilities: -25% to +25%) were used because the uncertainty in the source statistics could not be ascertained. As a result, the uncertainties of CO_2 and CH_4 emissions during explorative drilling of natural gas fields were evaluated to be -32% to +32% respectively and the uncertainties of N_2O emissions were evaluated to be -27% to +1000%, respectively.

- ***Time-series Consistency***

The emission factors are constant from FY1990 to the most recent year. The activity data are estimated using the same method for all time-series from FY1990 to the most recent year, based on the *Natural Gas Data Yearbook*.

d) Category-specific QA/QC and Verification

Same as the Energy Industries (1.A.1). See section 3.2.4. d).

e) Category-specific Recalculations

There have been no recalculations of emissions from this category.

f) Category-specific Planned Improvements

No improvements are planned.

3.3.2.2.b. Natural Gas Production and Gathering (1.B.2.b.ii)

a) Category Description

This category deals with fugitive emissions of CO_2, CH_4 and N_2O from natural gas production. Specifically, it deals with emissions from facilities and pipelines from onshore or offshore gas wells to gas processing plants in the natural gas supply network.

CO_2 emissions from venting associated with the production of natural gas are estimated in the other category using the country-specific emission factors which reflect the actual status of the emissions in Japan. See Section "3.3.2.3.b Venting (Gas) (1.B.2.c.i.2)". Emissions from venting associated with natural gas production are reported in "Venting (Gas) (1.B.2.c.i.2)", emissions from flaring associated with natural gas production are reported in "Flaring (Gas) (1.B.2.c.ii.2)" and other fugitive emissions are reported in this category (1.B.2.b.ii), respectively.

b) Methodological Issues

- ***Estimation Method***

The emissions are estimated using Tier 1 method in accordance with the *2019 Refinement* (Vol. 2, page 4.42, Fig. 4.2.1), because the default emission factors of the *2019 Refinement* are considered to better reflect the actual situation in Japan than the default emission factors of the *2006 IPCC Guidelines*.

- ***Emission Factors***

As indicated in the *2019 Refinement,* separate emission factors per production of natural gas are used for the emissions from onshore gas wells, gathering gas wells and offshore gas wells. In Japan, gas compressors and pipes are equipped with leak detection devices, and if any abnormality is found, the leak is immediately repaired, and emissions from such activities are considered to be limited. Therefore, for onshore gas wells, emission factors for "lower-emitting technologies" in the *2019 Refinement* are used.

Table 3-79 Emission factors of fugitive emissions for natural gas production

Sub-category	Emission source	Unit	CH_4	CO_2	N_2O
Onshore/ lower-emitting technologies	Leaks	t/10^6m^3	0.38 (2.54*15.5%)	0.07 (3.60*2%)	0
	Vent [2)]		2.15 (2.54*84.5%)	CS[4)]	0
	Flare [3)]		0	3.31 (3.60*92%)	6.1×10^{-5} (100%)
Gathering [1)] (onshore)	Leaks		3.20	0.35	
	Flare [3)]				6.0×10^{-6}
Offshore	Leaks		0.68 (2.94*23%)	0	0
	Vent [2)]		2.26 (2.94*77%)	CS[4)]	0
	Flare [3)]		0	4.75 (4.80*99%)	8.2×10^{-5} (100%)

Reference: *2019 Refinement* Vol. 2, page 4.70, Table 4.2.4G and page 4.132, Table 4A.2.5

Note:

1) As the 2019 *Refinement* does not indicate the disaggregation rate of leaks, venting and flaring for gas gathering, all CH_4 and CO_2 are regarded as leaks and all N_2O are regarded as flaring.
2) Emissions from venting are reported in "Venting (Gas) (1.B.2.c.ii.1)" of the CRT.
3) Emissions from flaring are reported in "Flaring (Gas) (1.B.2.c.ii.2)" of the CRT.
4) Country-specific. See "3.3.2.3.b3.3.2.3.b Venting (Gas) (1.B.2.c.i.2)"

- ***Activity Data***

The production volume of natural gas from offshore in the *Natural Gas Data Yearbook* is used for the production volume of natural gas from offshore gas field. The production volume of natural gas from onshore gas field is estimated by subtracting the production volume of natural gas from offshore gas field above from the total production volume of natural gas in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

Table 3-80 Natural gas production

Item		Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Natural gas production	Offshore	10^6m^3	342	374	350	361	188	196	190	87	83	65	70	70
	Onshore		1,724	1,863	2,149	2,779	3,155	2,744	2,525	2,202	2,179	2,044	1,908	1,818
	Total		2,066	2,237	2,499	3,140	3,343	2,940	2,715	2,290	2,262	2,108	1,978	1,888

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainties of emission factors, the values provided in the *2019 Refinement* (CO_2 and CH_4 in onshore and offshore gas fields: -20% to +20%, CO_2 and CH_4 in gathering: -10% to +10%, N_2O in onshore, offshore and gathering: -10% to +1000%) are applied, since the default values in the *2019 Refinement* are used exclusively. For the activity data, the values provided in the *2019 Refinement* (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) are applied, since the uncertainties for statistical data used as reference are not available. As a result, the uncertainties of emissions of CO_2 and CH_4 from production in onshore and offshore gas fields are each evaluated to be -25% to +25%, the uncertainties of emissions of CO_2 and CH_4 from the gathering are evaluated to be -18% to +18%, and the uncertainties of N_2O emissions are evaluated to be -18% to +1000%. Although there may be some uncertainty in the disaggregation rate, since it is not indicated in the *2019 Refinement*, the uncertainty in the disaggregation rate is not evaluated.

- ***Time-series Consistency***

Consistent values are used for emission factors from FY1990 to the nearest year by using the above-mentioned method. The activity data are calculated by using the data on the production volume of natural gas from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* and on the number of oil/natural gas wells from the *Natural Gas Data Yearbook.* A consistent method is used throughout the time-series from FY1990 to the nearest year.

d) Category-specific QA/QC and Verification

Same as the Energy Industries (1.A.1). See section 3.2.4. d).

e) Category-specific Recalculations

Since the activity data for FY2023 in the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* and *Natural Gas Data Yearbook* were revised, the CO_2 and CH_4 emissions in that year were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

3.3.2.2.c. Natural Gas Processing (1.B.2.b.iii)

a) Category Description

This category deals with fugitive CO_2, CH_4 and N_2O emissions from the processing of natural gas including adjustment of its constituent elements.

b) Methodological Issues

- ***Estimation Method***

Because the default emission factors of the *2019 Refinement* are considered to better reflect the actual situation in Japan than the default emission factors of the *2006 IPCC Guidelines*, the fugitive emissions associated with processing natural gas are estimated using Tier 1 method in accordance with the decision tree in the *2019 Refinement* (Vol.2, page 4.42, Fig.4.2.1).

- ***Emission Factors***

Since dry seals are used in Japan for compressors and other equipment, the default values per gas production with the use of dry seals are applied to the emission factors as indicated in the *2019 Refinement*.

In addition, since the gas produced in Japan is sweet gas (natural gas without hydrogen sulfide), the emission factors for processing of sour gas (natural gas with high hydrogen sulfide content) in the *2019 Refinement* are not applied.

Table 3-81 Emission factors for natural gas processing

Sub-category	Emission source	Unit	CH_4	CO_2	N_2O
Natural gas processing (Extensive LDAR, and around 50% or more of centrifugal compressors have dry seals)	Leaks	$t/10^6m^3$	0.02 (0.57*4%)	0	0
	Vents[1)]		0.52 (0.57*91%)	0.07 (7.21*1%)	0
	Flare[2)]		0.03 (0.57*5%)	7.14 (7.21*99%)	7.9×10^{-5} (100%)

Reference: *2019 Refinement* Vol. 2, page 4.73, Table 4.2.4H and page 4.133, Table 4A.2.6
Note:
1) The emissions from Vents are reported in "Venting (gas) (1.B.2.c.i.2)" of CRT.
2) The emissions from Flare are reported in "Flaring (gas) (1.B.2.c.ii.2)" of CRT.

- ***Activity Data***

The production volume of natural gas in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* is used as activity data during processing. (Refer to Table 3-80).

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainties of emission factors, the values provided in the *2019 Refinement* (CO_2, CH_4: -10% to +10%, N_2O: -10% to +1000%) are applied since the default values in the *2019 Refinement* are used exclusively. As for the activity data, the values provided in the *2019 Refinement* (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) are used, since the uncertainties of the statistical data used are not available. As a result, the uncertainties of emissions of CO_2 and CH_4 are each evaluated to be -18% to +18%, and the uncertainties of emissions of N_2O are evaluated to be -18% to +1000%. Although there may be some uncertainties of the disaggregation rates as well, since they are not indicated in the *2019 Refinement*, the uncertainties of the disaggregation rates are not evaluated.

- ***Time-series Consistency***

The default values are consistently used for emission factors from FY1990 to the nearest year. The activity data during natural gas processing are calculated by using the data from the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*. A consistent method is used throughout the time-series from FY1990 to the nearest year.

d) Category-specific QA/QC and Verification

Same as the Energy Industries (1.A.1). See section 3.2.4. d).

e) Category-specific Recalculations

There have been no recalculations of emissions from this category.

f) Category-specific Planned Improvements

No improvements are planned.

3.3.2.2.d. Natural Gas Transmission and Storage (1.B.2.b.iv)

a) Category Description

This category deals with CH_4 emissions from transmission of domestically produced natural gas, such as the release of gas when relocating and building pipelines, and the release of gas used to operate pressure regulators. This category also includes CH_4 emissions from storage facilities of natural gas, such as the emissions occurring by normal operation, regular maintenance, and construction works in receiving domestic LNG (liquefied natural gas) facilities, city gas production facilities, and satellite facilities.

The CO_2 emissions in this source are reported as insignificant "NE". Approximately 90% of city gas is based on LNG and is free of CO_2. This is because the liquefaction process requires the removal of all CO_2 prior to the cooling process to prevent CO_2 ice from forming within the liquefaction equipment. However, domestically produced natural gas from some of Japan's natural gas strata contains CO_2. Nearly all of this CO_2 is removed at the natural gas production plants, and the CO_2 are included in "Venting (Gas) (1.B.2.c.i.2)". Because domestically produced natural gas is sent to pipelines after CO_2 removal, almost no CO_2 in natural gas is emitted from natural gas pipelines, and the natural gas provided by city gas suppliers most likely contains no CO_2. The four major gas providers in Japan (Tokyo Gas, Osaka Gas, Toho Gas and Saibu Gas) demonstrated through composition analysis that their gas contains no CO_2 as of 2022. The approximate results of emissions estimated are less than 3 kt-CO_2, which is a criterion to include the emissions in the national totals established by the Committee for the Greenhouse Gases Emissions Estimation Methods in FY2012. Therefore, the CO_2 emissions are reported as insignificant "NE". The treatment of insignificant "NE" is described in Annex 6.

b) Methodological Issues

- ***Estimation Method***

CH_4 emissions from transmission of natural gas are estimated using Tier 2 method in accordance with the decision tree in the *2006 IPCC Guidelines* (Vol.2, page 4.38, Fig.4.2.1). The emissions are estimated by multiplying the sales volume of natural gas by the country-specific emission factors.

CH_4 emissions from storage facilities of natural gas are estimated by multiplying the amount of LNG and indigenous natural gas, which are utilized as raw material for city gas, by the country-specific emission factors. Since city gas is not recognized in the *2006 IPCC Guidelines*, the method applied is reported as "CS" (country-specific) in CRT Summary 3.

- ***Emission Factors***

  - ***Transmission***

CH_4 emissions associated with the release of gas from the facilities of Japan Natural Gas Association member companies in relocating and building of pipelines have been surveyed in FY2004, FY2008 and onward; and CH_4 emissions associated with the release of gas used to operate pressure regulators have been surveyed in FY2004, FY2011 and onward by Japan Natural Gas Association. To establish country-specific emission factors for Japan, the results of the surveys are used.

The emission factors for emissions from relocating and building of pipelines, and for emissions from the release of gas used to operate pressure regulators are estimated respectively as shown in the following Table 3-82 and the total values are applied to the emission factors. For the sales volume of indigenous natural gas which is used for establishing emission factors, the data are sourced from the

member companies of Japan Natural Gas Association and provided by the association.

Table 3-82 The method of estimating emission factors of natural gas transmission

Fiscal year	Relocation and building work of pipeline	Release of gas used to operate pressure regulators
1990 - 2003	The same value as FY2004 is consistently used.	
2004	Estimated by dividing the actual CH_4 emissions in FY2004 by the sales volume of natural gas in the same fiscal year.	
2005 - 2007	Estimated by interpolating the emission factor in FY2004 and that in FY2008 which is estimated by the same method as FY2004.	Estimated by interpolating the emission factor in FY2004 and that in FY2011 which is estimated by the same method as FY2004.
2008 - 2010	Estimated by dividing the actual CH_4 emissions in each fiscal year by the sales volume of natural gas in the same fiscal year.	
2011 -	Estimated by dividing the actual CH_4 emissions in each fiscal year by the sales volume of natural gas in the same fiscal year.	

As a result of the above estimation, the emission factors in each fiscal year are estimated as shown on the Table 3-83.

Table 3-83 Estimation result of emission factors of natural gas transmission

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Pipeline relocation & installation	t-CH_4/10^6m^3	0.220	0.220	0.220	0.190	0.071	0.062	0.115	0.029	0.073	0.063	0.061	0.082
Gas for operating pressure regulators	t-CH_4/10^6m^3	0.087	0.087	0.087	0.077	0.028	0.009	0.001	0.003	0.003	0.002	0.002	0.000
Total	t-CH_4/10^6m^3	0.306	0.306	0.306	0.267	0.099	0.071	0.116	0.032	0.075	0.065	0.063	0.083

- ***Storage***

The emission factor is calculated by dividing the CH_4 emissions actually measured during regular maintenance or construction in the major LNG receiving terminals, city gas production facilities, and satellite terminals in Japan, by the calorific value of the raw material input (LNG and indigenous natural gas). The emission factor calculated using the FY1998 data is 905.41 [kg-CH_4/PJ], while that calculated using the FY2007 data is 264.07 [kg-CH_4/PJ]. The main reason of such change in emission factor is the reduction in CH_4 emissions, which is due to the progress in reduction measures such as the installation of new sampling and recovery lines used for gas analyses (changes to gas recovery lines from atmospheric dispersion) in LNG receiving terminals and city gas production facilities. Because the measures to reduce CH_4 emissions have been implemented gradually, the emission factors for the period from FY1999 to FY2006 are set by linear interpolation. At present, measures to reduce CH_4 emissions have been generally implemented, thereby affording little expectation of any major change in the emission factor for the time being. Therefore, the FY2007 emission factor value is kept for FY2008 and subsequent years.

- ***Activity Data***

- ***Transmission***

The sales volume of indigenous natural gas provided in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* is used for activity data.

Table 3-84 Sales amount of natural gas

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Natural gas sales amount	10^6m^3	2,067	2,339	2,617	3,329	4,020	3,790	3,709	3,768	3,902	3,664	3,619	3,594

- ***Storage***

The amount of LNG and indigenous natural gas used as raw material for city gas, provided in the *General Energy Statistics*, is used for activity data

Table 3-85 LNG and domestically produced natural gas used for the feedstock of city gas

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
LNG consumption with city gas production	PJ	464	676	864	1,230	1,531	1,555	1,567	1,532	1,593	1,532	1,472	1,470
Natural gas consumption with city gas production	PJ	40	48	61	86	115	107	103	71	68	61	61	59

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

A country-specific emission factor is used for CH_4 emissions from transmission of natural gas, however, since it is difficult to assess the uncertainties, the values given in the *2006 IPCC Guidelines* (-100% to +100%) are applied. As for activity data, because the uncertainties of statistical data used as reference are not available, the values given in the *2006 IPCC Guidelines* (-2% to +2% of the uncertainties associated with measurement of flow rate (sales volumes)) are applied. As a result, the uncertainties of fugitive emissions of CO_2 and CH_4 from natural gas transmission are assessed to be -100% to +100%.

For the emission factors for fugitive CH_4 emissions associated with storage of natural gas, a country-specific emission factor is used; however, since it is difficult to assess the uncertainties, the values given in the *2006 IPCC Guidelines* (-20% to +500%) are applied. As for the activity data, the values given in the *2006 IPCC Guidelines* (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) are used, since the uncertainties for statistical data used as reference are not available. As a result, the uncertainties of CH_4 fugitive emissions from natural gas storage are assessed to be -25% to +500%.

- ***Time-series Consistency***

Regarding emission factors for transmission of natural gas in and after FY2004, the values are established by dividing the measured emissions by corresponding natural gas production amount for the fiscal years when emission measurement was implemented. For fiscal years when emission measurement was not implemented, emission factors are established by interpolating. For emissions before FY2003, the established values for FY2004 are used for all fiscal years. In addition, the natural gas sales volume used for activity data is provided in the *Yearbook of Production Supply and Demand of Petroleum, Cool and Coke*, in the *Yearbook of Mineral Resources and Petroleum Products Statistics* and in the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

For emission factors for storage of natural gas, as described above and based on the emission factors established from the survey in FY1998 and FY2007, the emission factor for FY1998 is used for before FY1997, the emission factor for FY2007 is used for FY2008 and onward, and the emission factors for FY1999-2006 are established by interpolation using the FY1998 and FY2007 factors.

To ensure the consistency, the figures provided in the *General Energy Statistics* are adopted consistently for activity data of LNG and indigenous natural gas which are used as raw material of city gas.

d) Category-specific QA/QC and Verification

Same as the Energy Industries (1.A.1). See section 3.2.4. d).

e) Category-specific Recalculations

Since the activity data for FY2023 in the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* were revised, the CH_4 emissions for FY2023 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

3.3.2.2.e. Natural Gas Distribution (1.B.2.b.v)

a) Category Description

This category deals with CH_4 emissions from city gas supply networks.

In Japan, liquefied petroleum gas, coal, coke, naphtha, crude oil, and natural gas are refined and blended at gas plants into gas, which, after being conditioned to produce a certain calorific value, is supplied to urban areas through gas lines. Such gas fuel is called “city gas”, of which more than 90% is LNG-based. As for detail of city gas, please refer to the explanation of city gas emission factor in 3.2.4. b) Methodological issues (Figure 3-4 , Table 3-14, etc.).

The CO_2 emissions in this source are reported as insignificant “NE”. Although CO_2 is basically not included in the city gas constituents, it is impossible to say no CO_2 is included at all. (See “section 3.3.2.2.d.a) Category Description (of Transmission and Storage)” for details.) The treatment of insignificant “NE” is described in Annex 6.

b) Methodological Issues

- ***Estimation Method***

CH_4 emissions from high-pressure pipelines, from medium- and low-pressure pipelines and holders, and from service pipes are calculated by multiplying the sales volume of city gas by the country-specific emission factors. Since city gas is not recognized in the *2006 IPCC Guidelines*, the method applied is reported as “CS” (country-specific) in CRT Summary 3.

- ***Emission Factors***

The emission sources in the supply of domestically produced city gas are (i) high-pressure pipelines, (ii) medium- and low-pressure pipelines and holders, and (iii) service pipes. Table 3-86 shows the CH_4 emissions from the city gas pipelines of former general gas companies calculated by Japan Gas Association from the actual data by each emission source. The emissions are estimated by CH_4 contents in the city gas, pipeline length of construction, number of inspections, etc. The value of 9.5×10^{-6} kt-$CH_4/10^6m^3N$, which is obtained by dividing the CH_4 emissions (292 t-CH_4) in FY2004 by the city gas amount sold by former general gas companies in the same fiscal year of $30{,}696\times10^6m^3N$ (Derived from *Current Survey of Production Concerning Gas Industry*), is used for the emission factor per sales amount.

Table 3-86 CH_4 emissions from city gas pipelines (FY2004 actual data)

Emission sources		CH_4 emissions [t/year]
High-pressure pipelines	New pipeline installation, and pipeline relocation	180
Medium- and low-pressure pipelines and holders	Construction, demolition, fugitive emissions, inspection of governor and others, holder construction, and overhauling	93
Service pipes	Installation of service pipes, post-installation purging, removal, change of meters, fugitive emissions, go around for opening valves and regular maintenance, and equipment repairs (mainly the emissions occur when the work is done at user sites (homes))	19

- ***Activity Data***

The city gas sales amount in calorific value in the *Current Survey of Production Concerning Gas Industry* is divided by the calorific value per volume in the *General Energy Statistics* to get the amount in volume, and the result is used for the activity data. (Emission factors are set in NTP, but the calorific values in the *General Energy Statistics* are shown in SATP after FY2013, so the calorific values after FY2013 are converted to NTP for the calculation in this category.) The city gas sales amount is classified as industrial use, commercial use, residential use and other use. As the activity data include all of them, the emissions from city gas supplied to industrial plants are included in the estimation.

Table 3-87 Sales amount of city gas

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Sales amount of city gas	PJ	643	877	1,064	1,419	1,644	1,667	1,671	1,654	1,723	1,684	1,591	1,600
Calorific value per volume	MJ/m^3N	41.9	41.9	41.1	44.8	44.8	36.9	36.8	36.1	36.2	36.5	36.2	36.1
Sales amount of city gas in volume	10^6m^3N	15,367	20,952	25,899	31,684	36,705	45,228	45,426	45,829	47,568	46,165	43,968	44,296

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For emission factor in CH_4 fugitive emissions accompanied by city gas distribution, country-specific figure is used. However, it is difficult to evaluate the uncertainties in this figure; therefore, values (-20% to +500%) provided in the *2006 IPCC Guidelines* are adopted. As for activity data, since it is unable to evaluate the uncertainties in statistical data used as reference, the setting values (-2% to +2% of the uncertainties associated with measurement of flow rate (sales volumes)) given in the *2006 IPCC Guidelines* are adopted. As a result, the uncertainties in CH_4 fugitive emissions accompanied by city gas distribution are evaluated at -20% to +500%.

- ***Time-series Consistency***

For the emission factor, the consistent value is used from FY1990 to the nearest year, by using the above-mentioned method. The activity data are calculated using the data from the *Current Survey of Production Concerning Gas Industry* with a consistent method throughout the time-series from FY1990 to the nearest year.

d) Category-specific QA/QC and Verification

- ***QA/QC***

Same as the Energy Industries (1.A.1). See section 3.2.4. d).

- ***Verification***

The national circumstances relating to natural gas distribution, and the reason for using a CH_4 EF that is significantly lower than the default value of the *2006 IPCC Guidelines* (1.1×10^{-3} kt-$CH_4/10^6m^3$) are described below.

The default value is an emission factor per utility sales. However, at the moment, such an emission factor per utility sales is not found in the original references of the default value. Therefore, it is difficult to compare the default value with the country-specific emission factor (CSEF). According to the *2006 IPCC Guidelines* (Vol.2, page 4.37), a Tier 1 approach should only be used as a last resort option for the estimation of the fugitive emissions from oil and gas. Since the CSEF specifies emission sources as described above, it is regarded that the CSEF reflects Japan's circumstances better than the default value.

e) Category-specific Recalculations

Since the city gas sales amounts in the *Current Survey of Production Concerning Gas Industry* for FY2023 were revised, the CH_4 emissions in that year were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

3.3.2.2.f. Other (Post-Meter Leakage and Abandoned Gas Wells) (1.B.2.b.vi)

This category deals with the fugitive emissions of greenhouse gases from post-meter and abandoned gas wells.

The conceivable sources of emissions from post-meter include leakage of city gas from gas pipe work in buildings, but because these emissions are included in those of "Natural Gas Distribution (1.B.2.b.v)", emissions from this source are reported as "IE."

In the *2019 Refinement*, the CH_4 emission factor from LNG power plant was newly provided. However, as a result of our study, it became clear that there is a high possibility of discrepancy between the facility situations of Japan and the former Soviet Union on points such as the maintenance status and the pipeline damages caused by melting permafrost. In addition, according to our domestic survey, regarding the actual status of safety securement of electric companies, the possibility of regular leakage of CH_4 in a certain scale is very low during normal operations, and the separation of leakage amount from the error in measurement instruments is considered to be difficult even if limited leaks occur. Based on the above, the emissions from this source are reported as "NE", according to the Decision Tree for Application of Notation Keys (see Annex 6).

The *2019 Refinement* provides the estimation method for abandoned gas wells that was not provided in the *2006 IPCC Guidelines*. As mentioned in Section "3.3.2.1.f Other (abandoned oil wells, etc.) (1.B.2.a.vi)", for abandoned gas wells as well as for abandoned oil wells, systems to prevent gas leakage has been established in Japan based on the Mine Safety Act and the Enforcement Ordinance of the Mine Safety Act. Therefore, the emissions from abandoned gas wells are reported as "NA".

3.3.2.3. Venting and Flaring (1.B.2.c)

This category deals with fugitive emissions of CO_2 and CH_4 occurring from venting in the oil and natural gas industries.

It also deals with CO_2, CH_4 and N_2O emissions from flaring in the oil and natural gas industries.

3.3.2.3.a. Venting (Oil) (1.B.2.c.i.1)

This category deals with CO_2 and CH_4 emissions from venting in the oil industry. The emissions from venting in the oil industry in Japan are considered to occur during the oil production stage. See "3.3.2.1.b Oil Production and Upgrading (1.B.2.a.ii)" for details including the estimation method. In the CRT, these emissions are reported in this category (1.B.2.c.i.1).

If the CO_2 injected under enhanced oil recovery (EOR) projects is captured along with associated gas and released to the atmosphere, the CO_2 emissions are reported not under "CO_2 transport and storage (1.C)" but under "Oil, Natural Gas and Other Emissions from Energy Production (1.B.2)" in accordance with the *2006 IPCC Guidelines* (Vol.2, page 4.33). The approximate results of the emissions from the past EOR projects in Japan are less than 3 kt-CO_2, which is a criterion to include the emissions in the national totals established by the Committee for the Greenhouse Gases Emissions Estimation Methods in FY2012. Therefore, the emissions are regarded as insignificant and are not estimated.

3.3.2.3.b. Venting (Gas) (1.B.2.c.i.2)

This category deals with CO_2 and CH_4 emissions from venting in the natural gas industry. For details including estimation methods of emissions from venting associated with natural gas production and processing, please refer to "3.3.2.2.b Natural Gas Production and Gathering (1.B.2.b.ii)" and "3.3.2.2.c Natural Gas Processing (1.B.2.b.iii)", respectively. These emissions are reported in this category (1.B.2.c.i.2) in the CRT.

CH_4 emissions from venting associated with natural gas transmission are reported together in "Natural Gas Transmission and Storage (1.B.2.b.iv)". See "3.3.2.2.d Natural Gas Transmission and Storage (1.B.2.b.iv)" for details including the estimation method. CO_2 emissions from transmission are not estimated because CO_2 emissions are reported as insignificant "NE" in "Natural Gas Transmission and Storage (1.B.2.b.iv)".

CO_2 emissions from natural gas production are reported in this category (1.B.2.c.i.2) and are described in detail below.

a) Category Description

This category deals with CO_2 emissions accompanied by separation and diffusion of CO_2 which is contained in natural gas produced in natural gas production facilities when CO_2 contents does not meet the standard of non-combustion gas content provided by users.

b) Methodological Issues

- ***Estimation Method***

Tier 3 method is used for the years when the actual measurement data are available and Tier 2 method is used for the other years, in accordance with the decision tree in the *2006 IPCC Guidelines* (Vol.2, page 4.38, Fig.4.2.1).

For the emissions from this category in FY1990, FY1995 and onward, actual measurement data of CO_2 emission provided by Japan Energy Resources Development Association (JERDA; former Japan Petroleum Development Association) is used for reporting.

For FY1991-1994, the natural gas amount produced from gas field, where separation of CO_2 from

natural gas has been implemented (Minami-Nagaoka and Katagai gas fields), is used for the activity data, and the emissions are estimated by multiplying the activity data by emissions factors. As for the emission factors, nominal emission factors are estimated by dividing the emissions in FY1990 and FY1995 provided by JERDA by activity data in the same fiscal years, and the emission factors for FY1991-1994 are estimated by interpolation using the values for FY1990 and FY1995.

- ***Emission Factors***

For FY1990, FY1995 and onward, the values are estimated by dividing emissions data provided by JERDA by activity data. As for FY1991 – FY1994, the values are estimated by interpolation using the values for FY1990 and FY1995. (The emission factors are used only for FY1991-1994 for emission estimation.)

Table 3-88 Emission factors of natural gas field venting

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Emission factor	kg-CO_2/m^3	0.133	0.117	0.126	0.114	0.120	0.122	0.128	0.122	0.101	0.096	0.095	0.083

- ***Activity Data***

The total production amount of Minami-Nagaoka gas field and Katagai gas field indicated in *Natural Gas Data Yearbook* are used for activity data. (The activity data are used only for FY1991-1994 for emission estimation.)

Table 3-89 Production amount of natural gas from Minami-Nagaoka and Katagai gas fields

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Natural gas production from Minami-nagaoka and Katagai gas field	10^6 m^3	432	657	789	1,229	1,660	1,664	1,598	1,474	1,457	1,334	1,229	1,229

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

As for emissions from venting (natural gas), actual measurement emission data provided by JERDA is used for reporting for FY1990, FY1995 and onward. However, it is difficult to evaluate the uncertainty for the data. Therefore, the standard value of uncertainty associated with measurement of flow rate (-15% to +15%) provided in the *2006 IPCC Guidelines* is adopted.

- ***Time-series Consistency***

For the emissions from this source, the emission data provided by JERDA are consistently used for FY1990, FY1995 and onward. As for FY1991-1994, the emissions are estimated from the FY1990 and FY1995 emission data provided by JERDA.

d) Category-specific QA/QC and Verification

Same as the Energy Industries (1.A.1). See section 3.2.4. d).

e) Category-specific Recalculations

There have been no recalculations of emissions from this category.

f) Category-specific Planned Improvements

No improvements are planned.

3.3.2.3.c. Venting (Combined) (1.B.2.c.i.3)

Statistical data are reported for two categories of oil and natural gas in Japan. As a result, fugitive emissions from venting in the combined oil and natural gas industries were reported as "IE" since they were accounted for in the emissions from Venting (Oil) (1.B.2.c.i.1) and Venting (Gas) (1.B.2.c.i.2).

3.3.2.3.d. Flaring (Oil) (1.B.2.c.ii.1)

This category deals with CO_2, CH_4, and N_2O from flaring in the oil industry. The emissions from flaring in the oil industry in Japan are considered to occur during the stages of oil exploration, production and refining. Of these, emissions associated with exploratory drilling are collectively reported in "Flaring (Gas) (1.B.2.ii.2)". See "3.3.2.2.a Natural Gas Exploration (1.B.2.b.i)" for details including estimation method. The flaring emissions from oil production are reported in this category (1.B.2.c.ii.1). See "3.3.2.2.b Natural Gas Production and Gathering (1.B.2.b.ii)" for details including estimation method. The CH_4 emissions from flaring during oil refining are collectively reported in "Oil Refining / Storage (1.B.2.a.iv)", because emissions related to flaring are likely to be included in the default emission factors of the *2006 IPCC Guidelines*. See "3.3.2.1.d Oil Refining / Storage (1.B.2.a.iv)" for details including the estimation method.

3.3.2.3.e. Flaring (Gas) (1.B.2.c.ii.2)

This category deals with CO_2, CH_4, and N_2O emissions from flaring in the natural gas industry. The emissions from flaring in the natural gas industry in Japan are considered to occur during the stages of natural gas exploration, production and processing. Of these, the emissions from flaring during gas exploration are reported in this category (1.B.2.c.ii.2). See "3.3.2.2.a Natural Gas Exploration (1.B.2.b.i)" for details including estimation methods. The emissions from flaring during gas production are also reported in this category (1.B.2.c.ii.2). See "3.3.2.2.b Natural Gas Production and Gathering (1.B.2.b.ii)" for details including estimation methods. The emissions from flaring during gas processing are also reported in this category (1.B.2.c.ii.2). See "3.3.2.2.c Natural Gas Processing (1.B.2.b.iii)" for details including estimation methods. According to the *2019 Refinement* (Volume 2, Table 4A.2.7), CO_2 emissions from flaring can occur during natural gas transmission and storage. Japan Natural Gas Association said that flaring may occur in long distance pipelines of natural gas transmission, however, the members of the association operated to avoid flaring as much as possible, due to environmental and economic reasons. Additionally, since the likely level of the CO_2 emissions from this source which were calculated with the default emission factor from the *2006 IPCC Guidelines* were less than 3 kt CO_2, the emissions from this source are regarded as insignificant NE according to the Decision Tree for Application of Notation Keys (see Annex 6).

3.3.2.3.f. Flaring (Combined) (1.B.2.c.ii.3)

The emissions from this category are reported as "IE". In Japan, the statistical data are reported for two categories of oil and natural gas. The fugitive emissions from flaring in the combined oil and natural gas industries are included in "Flaring (Oil) (1.B.2.c.ii.1)" or "Flaring (Gas) (1.B.2.c.ii.2)".

The emissions from flaring associated with exploratory drilling and testing of oil and natural gas, which

was reported in this category for the inventories submitted until 2023, is reported together in "Flaring (Gas) (1.B.2.c.ii.2)", because exploration surveys since FY1990 have often been conducted at depths of 3,000 m or more, and many of these wells can be assumed to be gas wells based on their pressures. See "3.3.2.2.a Natural Gas Exploration (1.B.2.b.i)" for details including estimation methods.

3.3.2.4. Other (Fugitive Emissions Associated with the Geothermal Power Generation) (1.B.2.d)

a) Category Description

This category deals with the CO_2 and CH_4 emissions in geothermal power plants, where the CO_2 and CH_4 from steam production wells are emitted from cooling towers into the atmosphere.

b) Methodological Issues

- ***Estimation Method***

The emissions from this category are estimated by multiplying the amount of steam production (weight base) in each geothermal power plant by mass concentration rate of CO_2 and CH_4, since any descriptions for estimation methods for this category are not provided in the *2006 IPCC Guidelines*. However, as for CO_2 and CH_4 in the steam produced in production well, even though there is a possibility that the steam dissolves in water during transmitting in condenser, it is difficult to estimate the dissolved amount. Therefore, the emissions are estimated assuming that the total amount of CO_2 and CH_4 in the produced steam is emitted into the air. Binary geothermal power plants are excluded from emission estimation, because non-condensable gas in the steam is not emitted into the air. In a binary geothermal power plant, a thermal circulating cycle with hot water is independent from that with working liquid of low boiling point.

Since this source is not recognized in the *2006 IPCC Guidelines*, the method applied is reported as "CS" (country-specific) in CRT Summary 3.

- ***Emission Factors***

Mass concentration rate of CO_2 in steam is estimated by using volume concentration of non-condensable gas in steam and volume concentration of CO_2 in non-condensable gas in each geothermal power plant (Japan Geothermal Energy Association, 2000).

Mass concentration rate of CH_4 is estimated by using volume concentration of non-condensable gas in steam in each geothermal power plant (Japan Geothermal Energy Association, 2000) and concentration of CH_4 in non-condensable gas (Geothermal Energy Association, 2012).

- ***Activity Data***

The amount of steam production in each geothermal power plant is basically estimated by multiplying an amount of steam production per hour in each plant provided in *Trend of Geothermal Power in Japan* (JGEA) and *Current Status and Trend of Geothermal Power* (Thermal and Nuclear Power Engineering Society), by operating time of production well. The operating time of production well is assumed as the same as the power generating time of each power plant in *Current Status and Trend of Geothermal Power*.

Each emission factor for CO_2 and CH_4 for geothermal power plants in Japan and the trend of the produced amount of steam are indicated in the Table 3-90.

Table 3-90 Emission factor and produced amount of steam of geothermal power plants

Power plant name	Emission factor		Production amount of steam [kt]											
	CO_2 [t-CO_2/kt]	CH_4 [t-CH_4/kt]	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Matsukawa	12.2	0.025	1,884	1,493	1,708	1,115	813	872	666	683	683	683	683	683
Ohtake	3.1	0.006	1,173	995	995	774	789	937	867	468	468	468	468	468
Ohnuma	0.6	0.002	694	682	535	651	600	537	489	506	506	506	506	506
Onikobe	2.6	0.008	1,018	1,015	1,035	982	1,185	357	334	NO	NO	NO	NO	NO
Hatchobaru 1	6.5	0.013	2,883	2,366	2,598	2,602	2,287	2,347	1,963	2,417	2,417	2,417	2,417	2,417
Hatchobaru 2	5.8	0.011	2,514	2,686	2,532	2,452	2,291	2,342	2,209	2,532	2,532	2,532	2,532	2,532
Kakkonda 1	0.3	0.001	3,498	3,126	1,966	2,021	1,535	1,374	1,362	1,248	1,248	1,248	1,248	1,248
Kakkonda 2	0.4	0.001	NO	209	1,823	2,004	1,440	1,269	1,142	884	884	884	884	884
Suginoi	8.5	0.019	220	284	203	144	129	147	140	122	122	122	122	122
Mori	28.1	0.053	1,367	1,990	1,981	1,501	1,068	1,001	934	711	711	711	711	711
Kirishima International Hotel	1.1	0.003	48	97	70	NO	30	68	NO	NO	NO	NO	NO	NO
Uenotai	6.5	0.014	NO	1,882	2,070	1,601	482	1,784	1,512	1,443	1,443	1,443	1,443	1,443
Yamakawa	5.8	0.012	NO	1,451	1,336	639	1,026	989	744	1,191	1,191	1,191	1,191	1,191
Sumikawa	1.4	0.004	NO	3,234	2,846	2,908	2,611	2,038	2,903	2,372	2,372	2,372	2,372	2,372
Yanaizu-Nishiyama	68.8	0.130	NO	3,912	3,425	3,197	2,229	1,626	1,537	1,230	1,230	1,230	1,230	1,230
Ohgiri	0.4	0.001	NO	219	2,373	2,306	2,286	1,969	1,928	1,777	1,777	1,777	1,777	1,777
Takigami	1.9	0.004	NO	NO	2,111	2,075	2,239	2,374	2,422	2,184	2,184	2,184	2,184	2,184
Hachijo-jima	18.1	0.041	NO	NO	187	156	152	149	147	NO	NO	NO	NO	NO
Kuju	8.5	0.019	NO	NO	10	136	124	120	108	108	108	108	108	108
Waita	8.5	0.019	NO	NO	NO	NO	NO	NO	148	195	195	195	195	195
Wasabizawa	8.5	0.019	NO	NO	NO	NO	NO	NO	NO	2,096	2,096	2,096	2,096	2,096

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

As for the emission factors, because the emissions were estimated from the concentration of non-condensable gas in the steam and the concentration of GHG in the non-condensable gas, the uncertainty was estimated at -7% to +7% based on the uncertainty of measurement of gas concentration given in the *2006 IPCC Guidelines*. As for the activity data, because the uncertainty of the referred statistics was not available, the values given in the *2006 IPCC Guidelines* (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) were used. As a result, the uncertainty of CO_2 and CH_4 emissions from the steam generated in production well in geothermal production was evaluated as -17% to +17%.

- ***Time-series Consistency***

For the emission factors, consistent values are used from FY1990 to the nearest year, by using the above-mentioned method. The activity data are calculated by a consistent method throughout the time-series from FY1990 to the nearest year, based on the *Current Status and Trend of Geothermal Power*.

d) Category-specific QA/QC and Verification

Same as the Energy Industries (1.A.1). See section 3.2.4. d).

e) Category-specific Recalculations

There have been no recalculations of emissions from this category.

f) Category-specific Planned Improvements

Activity data have been cited in *Current Status and Trends of Geothermal Power*, but the annual power generation hours and steam production per unit hour for each geothermal power plant will no longer be released starting with the 2023 edition. Therefore, it is necessary to consider a new method of obtaining activity data, taking into account the possibility of changing the estimation method in the future.

3.4. CO_2 Transport and Storage (1.C)

CO_2 transport and storage sector includes CO_2 emissions associated with the carbon dioxide capture and storage (CCS). CCS is the technology or methodology that captures the CO_2 which would be emitted to the atmosphere and stores it underground or under seabed.

This sector consists of three categories; Transport of CO_2 (1.C.1): emissions in the stage of CO_2 transport, Injection and storage (1.C.2): emissions in the stage of CO_2 injection and storage, and Other (1.C.3). Five projects are recognized as CO_2 injected underground in the past in Japan (Table 3-91). CO_2 emissions in the stage of transport and injection can occur during the period of injection, and CO_2 emissions in the stage of storage can have occurred continuously since CO_2 is injected. Table 3-92 shows the emissions from CO_2 transport and storage (1.C).

Table 3-91 Past projects of CO_2 underground injection in Japan

Injection site	Period of injection	Purpose
Kubiki	March 1991 – June 1993	Enhanced oil recovery
Sarukawa	September 1997 – September 1999	Enhanced oil recovery
Nagaoka	July 2003 – January 2005	Demonstration of geological storage of CO_2
Yubari	November 2004 – October 2007	Enhanced coal bed methane recovery
Tomakomai	April 2016 – November 2019	Demonstration of geological storage of CO_2

Table 3-92 CO_2 emissions from CO_2 transport and storage (1.C)

CRT Category		1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
1.C.1 Transport of CO_2	a. Pipelines	NE	NO	NO	NE	NO	NO	NO	NO	NO	NO	NO	NO
	b. Ships	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	c. Other	NE	NO	NO	NE	NO	NO	NO	NO	NO	NO	NO	NO
1.C.2 Injection and storage	a. Injection	NE	NO	NO	NE	NO	NO	NO	NO	NO	NO	NO	NO
	b. Storage	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
1.C.3 Other		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

3.4.1. Transport of CO_2 (1.C.1)

3.4.1.1. Pipelines (1.C.1.a)

This category deals with fugitive emissions of CO_2 in the stage of CO_2 transport by pipelines.

According to the interview to the entities of the projects shown in Table 3-91, the fugitive emissions in the stage of CO_2 transport by pipelines do not occur basically or the amount is quite small even if the fugitive emissions occur. Especially in the case of Tomakomai injection site, the pipeline is structurally designed to allow no gas leaks, and the assurance of airtightness is confirmed by execution of airtightness test. In addition, the approximate results of emissions estimated using the default emission factor of the *2006 IPCC Guidelines* (vol. 2, page 5.10, Table 5.2) are less than 3 kt-CO_2, which is a criterion to include the emissions in the national totals established by the Committee for the Greenhouse Gases Emissions Estimation Methods in FY2012. Therefore, the emissions from this category are reported as insignificant NE in the year CO_2 injection was conducted (but reported as NA in the year CO_2 injection was conducted only in Tomakomai site where the airtightness is assured) and reported as NO in the other years. The treatment of insignificant NE is described in Annex 6.

3.4.1.2. Ships (1.C.1.b)

This category deals with fugitive emissions of CO_2 in the stage of CO_2 transport by ships. The emissions are reported as NO, because ships were not used in the past projects in Japan.

3.4.1.3. Other (1.C.1.c)

This category deals with fugitive emissions of CO_2 in the stage of liquefied CO_2 transport by a lorry from a plant to an injection site or from a storage tank of liquefied CO_2. It is hard to consider the annual fugitive emissions become larger than 3 kt-CO_2 for following reasons: First, according to the interview to the entities of the projects shown in Table 3-91 (excluding the Tomakomai project), the fugitive emissions shown above do not occur basically or the amount is quite small even if the fugitive emissions occur. Second, the maximum amount of annual injection is about 6 kt-CO_2. Therefore, the emissions from this category are reported as insignificant NE in the years CO_2 injection were conducted in the projects other than Tomakomai. The treatment of insignificant NE is described in Annex 6. The emissions from this category are reported as NO in the years CO_2 injection were conducted only in Tomakomai site because there were no related activities. The emissions are reported as NO in the years CO_2 injection was not conducted in any of the projects.

3.4.2. Injection and Storage (1.C.2)

3.4.2.1. Injection (1.C.2.a)

This category deals with fugitive emissions of CO_2 in the stage of a compressor or an injection well at an injection site. According to the interview to the entities of the projects shown in Table 3-91, the fugitive emissions in the stage of injection do not occur basically or the amount is quite small even if the fugitive emissions occur. In addition, the approximate results of emissions estimated using the emission factors shown in Koornneef *et al*. (2008) are less than 3 kt-CO_2, which is a criterion to include the emissions in the national total established by the Committee for the Greenhouse Gases Emissions Estimation Methods in FY2012. Therefore, the emissions from this category are reported as insignificant NE in the year CO_2 injection was conducted (but reported as NA in the year CO_2 injection was conducted only in Tomakomai site where the airtightness is assured) and reported as NO in the other years. The treatment of insignificant NE is described in Annex 6.

3.4.2.2. Storage (1.C.2.b)

This category deals with fugitive emissions from a storage site. According to the interview to the entities of the projects shown in Table 3-91, the fugitive emissions from a storage site do not occur basically or the amount is quite small even if the fugitive emissions occur. In addition, the approximate results of emissions estimated using the fraction of the injected CO_2 amount that is retained shown in the IPCC (2005) are less than 3 kt-CO_2, which is a criterion to include the emissions in the national total established by the Committee for the Greenhouse Gases Emissions Estimation Methods in FY2012. Therefore, the emissions from this category are reported as insignificant NE through all reporting years. The treatment of insignificant NE is described in Annex 6.

3.4.3. Other (1.C.3)

This category deals with any other emissions from CCS not reported in Transport of CO_2 (1.C.1) and Injection and storage (1.C.2). The emissions are reported as NO, because there are no emissions to be reported in this subcategory.

3.4.4. Information Item

This section describes the amount of CO_2 captured for geological storage. CRT Table 1.C contains the column 'Information item' for checking if the amount of CO_2 from capture to storage process is accurately reported. It should be noted that reporting values under 'Total amount captured for storage' in 'Information item' does not mean that the amount of CO_2 captured is subtracted from CO_2 transport and storage (1.C.) category. The amount of CO_2 captured is subtracted from CO_2 emissions from categories where capture takes place. (See the *2006 IPCC Guidelines*, Volume 2, Chapter 2, Equation 2.7.)

The amount of CO_2 captured is considered to be nearly equal to that of CO_2 injected in the past projects of geological injection of CO_2 conducted in Japan. Thus, the amount of CO_2 injected that was provided by the entities of the projects is reported as the amount of CO_2 captured in the fiscal years when the injections were conducted. The captured amount is reported in Petroleum refining (1.A.1.b) or Ammonia production (2.B.1) in accordance with the source of CO_2 used in each project.

Table 3-93 Amount of CO_2 injected

Injection site	Unit	1990	1991	1992	1993	1997	1998	1999	2003	2004	2005	2006	2007	2016	2017	2018	2019	Reported under
Kubiki (EOR)	kt	0.23	3.93	4.46	1.17	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	2.B.1 Ammonia production
Sarukawa (EOR)	kt	NO	NO	NO	NO	2.37	4.87	2.71	NO	NO	NO	NO	NO	NO	NO	NO	NO	2.B.1 Ammonia production
Nagaoka	kt	NO	NO	NO	NO	NO	NO	NO	3.98	6.43	NO	NO	NO	NO	NO	NO	NO	2.B.1 Ammonia production
Yubari (EGR)	kt	NO	NO	NO	NO	NO	NO	NO	NO	0.04	0.12	0.36	0.37	NO	NO	NO	NO	1.A.1.b Petroleum refining
Tomakomai	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	29.22	126.80	79.58	64.51	1.A.1.b Petroleum refining

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Chapter 4. Industrial Processes and Product Use (CRT sector 2)

4.1. Overview of Sector

Chemical and physical transformations in industrial processes release GHGs into the atmosphere. This chapter describes the methodologies used to estimate industrial process and product use (IPPU) emissions shown in Table 4-1. The estimation methods, emission factors, activity data, etc. of each source are reviewed and approved by the breakout groups on Energy and Industrial Processes, F-gases, and Carbon Capture and Utilization (CCU) of the Committee for Greenhouse Gas Emissions Estimation Methods, consisting of experts from various fields (see Chapter 1).

Emissions have been estimated for all years, with zero emissions for some years and sources. To the extent that space and confidentiality concerns allow, relative indices are shown in the tables under each sub-category. Emissions by each sub-category and by gas are shown in the first table of each category.

Table 4-1 Categories in the Industrial Processes and Product Use Sector

Source categories					CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NF_3
2.A Mineral industry	2.A.1	Cement Production			○						
	2.A.2	Lime Production			○						
	2.A.3	Glass Production			○						
	2.A.4	Other Process Uses of Carbonates	Ceramics		○						
			Other Uses of Soda Ash		○						
			Non-metallurgical Magnesium Production		IE						
			Other	Desulfurization of Exhaust Gas and Chemical Products	○						
2.B Chemical Industry	2.B.1	Ammonia Production			○	NE	NA				
	2.B.2	Nitric Acid Production					○				
	2.B.3	Adipic Acid Production			NA		○				
	2.B.4	Caprolactam, Glyoxal and Glyoxylic Acid Production	Caprolactam				○				
			Glyoxal				○				
			Glyoxylic Acid				○				
	2.B.5	Carbide Production	Silicon Carbide		○	○					
			Calcium Carbide		○	NA					
	2.B.6	Titanium Dioxide Production			○						
	2.B.7	Soda Ash Production			IE						
	2.B.8	Petrochemical and Carbon Black Production	Methanol		NO	NO					
			Ethylene		○	○					
			1,2-Dichloroethane and Chloroethylene		○	○					
			Ethylene Oxide		○	○					
			Acrylonitrile		○	NA					
			Carbon Black		○	○					
			Other	Styrene		○					
				Phthalic Anhydride	○						
				Maleic Anhydride	○						
	2.B.9	Fluorochemical Production	By-product Emissions - Production of HCFC-22					○			
			Fugitive emissions					○	○	○	○
	2.B.10	Other	Hydrogen Production		○						
			Other	Utilization of Carbonated Gas	○						
2.C Metal Industry	2.C.1	Iron and Steel Production	Steel		IE	NA					
			Use of Electric Arc Furnaces in Steel Production		○	○					
			Pig Iron		IE	NA					
			Limestone and dolomite use in Iron and Steel Production		○						
			By-product Gas Flaring in Iron and Steel Production		○						
			Direct Reduced Iron		NO	NO					
			Sinter		IE	IE					
			Pellet		IE	IE					
			Other	Utilization of Carbonated Gas	○						
	2.C.2	Ferroalloys Production			IE	○					
	2.C.3	Aluminium Production	By-product Emissions		○				○		
			F-gases Used in Foundries							NO	
	2.C.4	Magnesium Production						○		○	
	2.C.5	Lead Production			IE						
	2.C.6	Zinc Production			IE						
	2.C.7	Other	Rare Earths Production		NE				NE		
2.D Non-energy Products from Fuels and Solvent Use	2.D.1	Lubricant Use			○	NE	NE				
	2.D.2	Paraffin Wax Use			○	NE	NE				
	2.D.3	Other	Road Paving with Asphalt								
			Asphalt Roofing								
			Urea used as a catalyst		○						
			NMVOC Incineration		○						
2.E Electronics Industry	2.E.1	Semiconductor					○	○	○	○	○
	2.E.2	Liquid Crystals					IE	○	○	○	○
	2.E.3	Photovoltaics							IE		
	2.E.4	Heat Transfer Fluid							IE		
	2.E.5	Other	Microelectromechanical systems					IE	IE		

Table 4-1 Categories in the Industrial Processes and Product Use Sector (Continued)

Source categories						CO_2	CH_4	N_2O	HFCs	PFCs	SF_6	NF_3
2.F Product Uses as Substitutes for ODS	2.F.1	Refrigeration and Air-Conditioning	Commercial Refrigeration	Commercial Refrigeration	manufacturing				○	NO	NO	NO
					stocks				○	NO	NO	NO
					disposal				○	NO	NO	NO
				Automatic Vending Machines	manufacturing				○	NO	NO	NO
					stocks				IE	NO	NO	NO
					disposal				IE	NO	NO	NO
			Domestic Refrigeration		manufacturing				○	NO	NO	NO
					stocks				○	NO	NO	NO
					disposal				○	NO	NO	NO
			Industrial Refrigeration		manufacturing				IE	NO	NO	NO
					stocks				IE	NO	NO	NO
					disposal				IE	NO	NO	NO
			Transport Refrigeration		manufacturing				○	NO	NO	NO
					stocks				○	NO	NO	NO
					disposal				○	NO	NO	NO
			Mobile Air-Conditioning		manufacturing				○	NO	NO	NO
					stocks				○	NO	NO	NO
					disposal				○	NO	NO	NO
			Stationary Air-Conditioning (Household)		manufacturing				○	NO	NO	NO
					stocks				○	NO	NO	NO
					disposal				○	NO	NO	NO
	2.F.2	Foam Blowing Agents	Closed Cells	Urethane Foam	manufacturing				○	NO	NO	NO
					stocks				○	NO	NO	NO
					disposal				IE	NO	NO	NO
				Extruded Polystyrene Foam	manufacturing				○	NO	NO	NO
					stocks				○	NO	NO	NO
					disposal				IE	NO	NO	NO
			Open Cells	High Expanded Polyethylene Foam	manufacturing				○	NO	NO	NO
					stocks				NO	NO	NO	NO
	2.F.3	Fire Protection			manufacturing				NO	NO	NO	NO
					stocks				○	NO	NO	NO
					disposal				○	NO	NO	NO
	2.F.4	Aerosols	Metered Dose Inhalers		manufacturing				○	NO	NO	NO
					stocks				○	NO	NO	NO
			Other	Aerosols	manufacturing				○	NO	NO	NO
					stocks				○	NO	NO	NO
	2.F.5	Solvents			manufacturing				NO	NO	NO	NO
					stocks				○	○	NO	NO
					disposal				IE	IE	NO	NO
	2.F.6	Other Applications										
2.G Other Product Manufacture and Use	2.G.1	Electrical Equipment			manufacturing						○	
					stocks						○	
					disposal						IE	
	2.G.2	SF_6 and PFCs from Other Product Use	Military Applications		manufacturing					NE	NE	
					stocks					NE	○	
					disposal					NE	NE	
			Accelerators		manufacturing					NE	NE	
					stocks					NO	○	
					disposal					NE	NE	
			Soundproof Windows		manufacturing					NE	NE	
					stocks					NE	NE	
					disposal					NE	NE	
			Adiabatic Properties: Shoes and Tyres		manufacturing					NE	NE	
					stocks					NO	NO	
					disposal					NE	NE	
			Other	Railway Silicon Rectifiers	manufacturing					NA	NA	
					stocks					NA	NA	
					disposal					○	NA	
	2.G.3	N_2O from Product Uses	Medical Applications					○				
	2.G.4	Other	PFCs and HFCs from Waterproofing electronic circuits						○	○		
2.H Other	2.H.2	Food and Beverages Industry				○						
	2.H.3	Emissions from Imported Carbonated Gas				○						
		Utilization of Carbonated Gas				○						

Note: ODS: ozone depleting substances

In FY2024, total GHG emissions from this sector amounted to approximately 69,891 kt-CO_2 eq., and accounting for 6.7% of national total emissions (excluding LULUCF) in Japan. The emissions of CO_2, CH_4, and N_2O from this sector decreased by 49.1% compared to FY1990. The emissions of HFCs, PFCs, SF_6, and NF_3 from this sector decreased by 3.4% compared to 1990.

The main driving factors for the decrease in emissions for this sector since FY1990 are the decrease in emissions of HFC-23 produced as a by-product of HCFC-22 production due to regulation under the Act on the Protection of the Ozone Layer Through the Control of Specified Substances and Other Measures (chemical industry), the decrease in CO_2 emissions from cement production (mineral industry) as the

clinker production declined, the decrease in N_2O emissions from adipic acid production (chemical industry) as the N_2O abatement equipment came on stream. However, HFC emissions from the product uses as ODS substitutes have largely increased.

For FY2019 to 2020, the decreases in CO_2 emissions observed for Other uses of soda ash (2.A.4.b), Ammonia production (2.B.1), Carbon black production (2.B.8.f), and Use of electric arc furnaces in steel production (2.C.1.a), and the decrease in N_2O emissions observed for Nitric acid production (2.B.2) are due to the decrease in production owing to the coronavirus disease 2019 pandemic, etc.

The methodological tiers used in the IPPU sector are as shown in the below Table 4-2.

Table 4-2 Methodological Tiers Used in the IPPU Sector

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2		CH_4		N_2O			
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor		
2.A. Mineral industry	CS,T2	CS						
2.B. Chemical industry	CS,T1,T2,T3	CS,D	CS,T1	CS	CS,T1,T2,T3	CS,PS		
2.C. Metal industry	CS,T1	CS,D	CS	CS				
2.D. Non-energy products from fuels and solvent use	D,T1,T2	CS,D						
2.E. Electronics industry					T2	D,CS		
2.F. Product uses as substitutes for ODS								
2.G. Other product manufacture and use					CS	OTH		
2.H. Other	CS	OTH						
GREENHOUSE GAS SOURCE AND SINK CATEGORIES	**HFCs**		**PFCs**		**SF_6**		**NF_3**	
	Method applied	**Emission factor**	**Method applied**	**Emission factor**	**Method applied**	**Emission factor**	**Method applied**	**Emission factor**
2.A. Mineral industry								
2.B. Chemical industry	T2,T3	CS,OTH	T3	OTH	T3	OTH	T3	OTH
2.C. Metal industry	CS	CS	T2	D,CS	T2	OTH		
2.D. Non-energy products from fuels and solvent use								
2.E. Electronics industry	T2	D,CS	T2	D,CS	T2	D,CS	T2	D,CS
2.F. Product uses as substitutes for ODS	CS	D,CS	CS	CS				
2.G. Other product manufacture and use	T1	T1	T1,CS	T1,CS	CS,T1,T2	CS,D		
2.H. Other								

Note: D: IPCC default, T1-T3: IPCC Tier 1-3, CS: country-specific, PS: plant specific, OTH: other

4.2. Mineral Industry (2.A.)

This category covers CO_2 emissions from the calcination of mineral raw material such as $CaCO_3$, $MgCO_3$, Na_2CO_3, etc. This section deals with the following sources: Cement production (2.A.1.), Lime production (2.A.2.), Glass production (2.A.3.), and Other process uses of carbonates (2.A.4.).

In FY2024, emissions from this category were 26,167 kt-CO_2 and represented 2.5% of total GHG emissions (excluding LULUCF). The emissions decreased by 46.3% compared to FY1990.

Table 4-3 CO_2 Emissions from Mineral Industry (2.A.)

Gas				Units	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
CO_2	2.A.1	Cement production		kt-CO_2	38,701	42,142	35,086	32,280	24,321	26,805	25,936	24,490	24,396	22,479	20,756	20,175
	2.A.2	Lime production		kt-CO_2	6,674	5,795	5,900	6,646	6,285	5,767	5,477	4,504	4,892	4,608	4,454	4,372
	2.A.3	Glass production		kt-CO_2	313	283	233	244	188	212	211	164	168	152	162	156
	2.A.4	Other process uses of carbonates	Ceramics	kt-CO_2	928	1,065	980	771	880	966	825	616	657	679	545	547
			Other uses of soda ash	kt-CO_2	119	118	102	79	62	46	46	34	35	35	31	29
			Other - Desulfurization of Exhaust Gas and Chemical Products	kt-CO_2	1,978	1,285	1,187	1,093	940	1,135	1,034	897	939	973	869	887
	Total			kt-CO_2	48,714	50,689	43,487	41,112	32,676	34,930	33,528	30,705	31,086	28,927	26,816	26,167

4.2.1. Cement Production (2.A.1.)

a) Category Description

CO_2 is emitted by the calcination of limestone, the main component of which is calcium carbonate, during the production of clinker[1)], an intermediate product of cement and the main component of which is calcium oxide. Although to a lesser extent than calcium carbonate, limestone also contains magnesium carbonate, which by calcination emits CO_2.

CO_2 emission mechanism of the cement production process

$CaCO_3 \rightarrow CaO + CO_2$
$MgCO_3 \rightarrow MgO + CO_2$

Note: 1) Cement clinker, a black nodule like a volcanic rock with a diameter of 1 cm or so is formed, by introducing a mixture of raw materials such as clay, silica stone, or iron materials, in addition to the main material limestone, into a large rotating kiln after pre-heating, and calcining them under high temperatures, and then rapidly cooling by air. This is ground up, and with the addition of gypsum, is transformed into cement. (from Japan Cement Association's website, partially edited)

b) Methodological Issues

- ***Estimation Method***

Following the Tier 2 method in the *2006 IPCC Guidelines*, the CO_2 emissions from this source was estimated by multiplying the amount of clinker produced by a country-specific emission factor.

$$E = EF_{cl} \times M_{cl} \times CF_{ckd}$$

E	: CO_2 emissions from cement production [t-CO_2]
EF_{cl}	: Emission factor [t-CO_2/t]
M_{cl}	: Clinker production [t]
CF_{ckd}	: Cement kiln dust correction coefficient

- ***Emission Factors***

Since Japan's cement industry takes in large amounts of waste and byproducts from other industries and recycles them as substitute raw materials for cement production, clinker contains CaO and MgO from sources other than carbonates. This CaO and MgO do not go through the limestone calcination stage, and therefore do not emit CO_2 during the clinker production process. For that reason, emission factors were determined by estimating the CaO and MgO content of clinker from carbonates, by subtracting CaO and MgO originating from waste and other sources from the total CaO and MgO content of clinker. Japan applies 1.00 for the cement kiln dust (CKD) correction coefficient, because normally almost all CKD is recovered and used again in the production process, as confirmed by the Cement Association. The emission factors for CO_2 emitted from cement production were established as follows.

$$EF = EF_{CaO} + EF_{MgO}$$

EF_{CaO}	: $CaCO_3$-origin CO_2 emission factor [t-CO_2/t] (established by the following equation)
EF_{MgO}	: $MgCO_3$-origin CO_2 emission factor [t-CO_2/t] (established by the following equation)

where,

$$EF_{CaO} = (CaO_{cl} - CaO_{Cl\text{-}Waste}) \times 0.785$$

$$CaO_{Cl\text{-}Waste} = W_{dry} \times CaO_{waste} / M$$

CaO_{Cl}	: CaO content of clinker
$CaO_{Cl\text{-}waste}$	: CaO content of clinker (waste-origin)
0.785	: Molecular weight ratio of CO_2 to CaO
W_{dry}	: Weight of inputs of waste and other materials (dry) [t]
CaO_{Waste}	: CaO content of waste and other materials
M	: Production amount of clinker [t]

$$EF_{MgO} = (MgO_{Cl} - MgO_{Cl\text{-}Waste}) \times 1.092$$

$$MgO_{Cl\text{-}Waste} = W_{dry} \times MgO_{waste} / M$$

MgO_{Cl}	: MgO content of clinker
$MgO_{Cl\text{-}Waste}$	: MgO content of clinker (waste-origin)
1.092	: Molecular weight ratio of CO_2 to MgO
W_{dry}	: Weight of inputs of waste and other materials (dry) [t]
MgO_{Waste}	: MgO content of waste and other materials
M	: Production amount of clinker [t]

- ***Dry weight of waste and other materials input in raw material processing***

The following 13 types of waste and other materials were chosen for this calculation: coal ash (incineration residue), sewage sludge incineration ash, municipal solid waste incineration ash, glass refuse/ceramics refuse, concrete refuse, blast furnace slag (water granulated), blast furnace slag (slow-cooled), steelmaking slag, nonferrous slag, casting sand, particulates/dust, coal ash (fluidized bed furnace ash), and coal ash (from dust collectors) (these waste account for over 90% of the CaO and 80% of the MgO from waste and other materials). Waste amounts (emission-based) and the water content of each waste and other material were determined from studies by Japan Cement Association (only for FY2000 and thereafter).

- ***Content of CaO and MgO from waste and other materials in clinker***

The dry weights of each type of waste and other materials are multiplied by the respective CaO and MgO content for each type as found by Japan Cement Association, thereby yielding the respective total CaO and MgO amounts in clinker derived from waste and other materials. This is divided by clinker production amount to find the CaO and MgO content from waste and other materials in clinker.

- ***CaO and MgO content of clinker, excluding the CaO and MgO from waste and other materials***

CaO and MgO content in waste and other materials is subtracted from the respective average CaO and MgO content of clinker as determined by Japan Cement Association, which yields the respective proportion of CaO and MgO in clinker that is used to set emission factors.

Table 4-4 Composition of Waste-origin Materials[2)]

Group	Types of waste	Water content	CaO content	MgO content
Incineration residue	Coal ash	7.2 - 19.5%	5.0 - 5.8%	1.0 - 1.1%
	Sewage sludge incineration ash [1)]	7.2 - 17.8%	7.4 - 12.5%	3.5 - 3.8%
	Municipal solid waste incineration ash [1)]	15.6 - 24.6%	10.0 - 26.5%	2.6 - 2.8%
Glass refuse, Concrete refuse, and Ceramics refuse	Glass refuse, Ceramics refuse [1)]	12.1 - 32.7%	17.5 - 31.1%	1.0 - 2.5%
	Concrete refuse [1)]	0 - 37.5%	6.4 - 43.9%	1.0 - 1.1%
Slag	Blast furnace slag (water granulated)	1.9 - 16.9%	40.0 - 42.4%	4.7 - 5.8%
	Blast furnace slag (slow-cooled)	5.5 - 16.7%	40.8 - 41.5%	6.1 - 6.5%
	Steelmaking slag	7.7 - 14.7%	34.8 - 40.5%	2.0 - 3.0%
	Nonferrous slag	2.6 - 8.4%	6.4 - 10.0%	1.1 - 1.5%
	Casting sand [1)]	9.6 - 14.0%	6.5%	1.3 - 1.6%
Particulates (dust collector dust)	Particulates/dust	8.9 -15.7%	9.0 - 13.4%	1.2 - 1.5%
	Coal ash (fluidized bed furnace ash) [1)]	0.1 - 3.2%	14.5 - 20.7%	0.7 - 0.9%
	Coal ash	1.0 - 3.9%	4.1 - 5.0%	1.0 - 1.1%

Note: 1) Newly added from FY2009.

2) CO_2 emissions from unburned carbon contained in coal ash and particulates, etc. will be accounted for under Fuel combustion (1.A.) and Waste incineration (5.C.1.) categories since an oxidation factor of 1.0 is used for emission estimation of these sources in Japan. The CO_2 emissions from unburned carbon contained in sewage sludge incineration ash are not included in the total emissions because sewage sludge is of biogenic origin.

Table 4-5 CO_2 Emission Factors for Cement Production

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Average CaO content in clinker	%	65.9	65.9	66.0	65.9	65.8	65.8	65.8	65.8	65.8	65.8	65.8	65.8
Waste origin CaO content in clinker	%	2.6	2.6	2.9	2.0	1.7	1.7	1.6	1.6	1.6	1.6	1.7	1.7
CaO content in clinker excluding waste origin CaO	%	63.3	63.3	63.0	63.9	64.1	64.1	64.2	64.2	64.2	64.2	64.1	64.1
CO_2/CaO		0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785
Emission factor	t-CO_2/t	0.497	0.497	0.495	0.501	0.503	0.503	0.504	0.504	0.504	0.503	0.503	0.503
Average MgO content in clinker	%	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
Waste origin MgO content in clinker	%	0.3	0.3	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
MgO content in clinker excluding waste origin MgO	%	1.0	1.0	0.9	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1
CO_2/MgO		1.092	1.092	1.092	1.092	1.092	1.092	1.092	1.092	1.092	1.092	1.092	1.092
Emission factor	t-CO_2/t	0.010	0.010	0.010	0.011	0.011	0.012	0.012	0.012	0.012	0.012	0.012	0.012
Combined emission factor	t-CO_2/t	0.508	0.508	0.505	0.512	0.514	0.514	0.516	0.515	0.515	0.515	0.515	0.515

- ***Activity Data***

Cement Association provides the data on the amount of clinker produced. Because there is no statistics on clinker production from FY1990 to FY1999, an estimation is made for past (FY1990 - FY1999) clinker production using the average values of the FY2000 - FY2003 ratios of clinker production (Cement Association data) to limestone consumption (*Yearbook of Ceramics and Building Materials Statistics* (Ministry of Economy, Trade and Industry, hereafter METI)).

Table 4-6 Clinker Production

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Consumption of limestone (actual)	kt (dry)	89,366	97,311	81,376	-	-	-	-	-	-	-	-	-
Clinker production (actual)	kt	-	-	69,528	63,003	47,279	52,105	50,307	47,522	47,338	43,650	40,316	39,193
Ratio of actual clinker production to actual consumption of limestone		0.853	0.853										
Estimated clinker production after correction	kt	76,253	83,032										

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainty of the CO_2 emission factor and activity data for cement production, the default value given specified in the *2006 IPCC Guidelines* was applied. As a result, the uncertainty of emissions was estimated to be 4%.

- ***Time-series Consistency***

CO_2 emissions from cement production from FY1990 to FY1999 is estimated using estimated activity data and emission factors based on values provided by Japan Cement Association. For years from FY2000 and onward, the methodology described in the sections above is consistently applied using the data provided by Japan Cement Association.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Annex 4.

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.2.2. Lime Production (2.A.2.)

a) Category Description

CO_2 is emitted during the calcination of $CaCO_3$, $MgCO_3$ in limestone used as raw material to produce quicklime.

CO_2 generation mechanism of quicklime production process

$CaCO_3 \rightarrow CaO + CO_2$
$MgCO_3 \rightarrow MgO + CO_2$

b) Methodological Issues

- ***Estimation Method***

CO_2 emissions are calculated by multiplying limestone consumption by the country-specific emission factor.

$E = EF \times M$

E	: CO_2 emissions generated by use of raw materials in quicklime production [t-CO_2]
EF	: Emission factor [t-CO_2/t-raw material]
M	: Amount of limestone consumed [t-raw material]

- ***Emission Factors***

An emission factor per unit raw material (limestone) (0.428 t-CO_2/t-raw material)[1] provided by Japan Lime Association was used.

The Emission factor per unit raw material was calculated by finding the CO_2 emissions per unit raw material estimated from the amounts of carbon and other substances in raw material constituents and quicklime products, and then finding the weighted average using production amounts of each district. The emission factor for lime production is the same for all years because annual change is thought to be small. This emission factor is country-specific, as described above.

- ***Activity Data***

Limestone consumption data for quicklime and slaked lime use, categorized under 'Ceramic and quarry products - other ceramics and quarry products' in the *Adjusted Price Transaction Table* is used. It is converted to dry weight using the water content from limestone used for cement.

[1] The emission factor per lime produced can be derived as follows: 0.428 [t-CO_2/t-material] / (1-0.428) [t-lime/t-material] = 0.748 [t-CO_2/t-lime]

The *Adjusted Price Transaction Table*:

The *Adjusted Price Transaction Table* is a table created by integrating supply/demand information on limestone, dolomite and related derivatives obtained from the input table in the Input-Output Table/ industrial statistics, etc., and is an application of similar estimation methods which were used in the *General Energy Statistics* (the Energy Balance Table) (Agency for Natural Resources and Energy). The items for which supply/demand information are not available are supplemented by estimation.

In the existing transaction table on quantity attached to the Input-Output Table, although expressing the domestic supply and demand of products without any omission/duplication, there exists the possibility of over/under evaluation of transaction depending on the sector if the actual price differs, since transaction in each sector is based on the input from the average price across all industries. In contrast, the *Adjusted Price Transaction Table* attempts to eliminate differences between sectors, by taking into consideration the uneven transaction prices based on the differences in product quality/form in each sector, and through using statistical values in industrial statistics, etc. to the extent which possible.

By using consumption data in the *Adjusted Price Transaction Table* as activity data, it is considered possible to capture activity data for all industries without omission/duplication, and to achieve a correct categorization of emission/non-emission related use, based on its detailed breakdown of sectors. See Kainou (2010) for more details on the *Adjusted Price Transaction Table.*

In the inventory, limestone/dolomite consumption data by sector in the *Adjusted Price Transaction Table* will be used as activity data for each limestone related source, excluding that for Cement production (2.A.1.).

As for the dolomite consumed in dolomitic lime production, it is accounted for under Other process uses of carbonates (2.A.4.), and therefore will not be included under Lime production (2.A.2.). The re-absorption of CO_2 by the production of light calcium carbonate is already subtracted in the *Adjusted Price Transaction Table*.

As regards lime production in sugar mills, according to an interview conducted with three domestic producers documented in the *Report on the Development of the Foundation for the Mandatory GHG Accounting and Reporting System (2010)* by Ministry of the Environment (MOE), as regards cane sugar, slaked lime is acquired from outside to make the lime milk at all domestic producers, and as for beet sugar, in cases when limestone is calcined, the CO_2 emitted is reabsorbed into the lime cake. On the basis of this information, CO_2 emissions from sugar manufacturing are not estimated.

As regards aluminium production in Japan, it was confirmed that lime has never been produced from FY1990 onward according to information from Japan Aluminum Association. (Aluminium production ended in 2014.) Therefore, the CO_2 emissions are not estimated.

Table 4-7 Limestone Consumption

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Limestone consumption (dry)	kt	15,595	13,540	13,785	15,527	14,684	13,474	12,797	10,524	11,430	10,767	10,406	10,216

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainty of the emission factor, the default value of 2% in the *2006 IPCC Guidelines* was used. For the uncertainty of activity data, the default value of 3% in the *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated to be 4%.

- ***Time-series consistency***

Limestone consumption data provided in the *Adjusted Price Transaction Table* is used as lime production activity data for all years from FY1990. The emission factors are constant for all years from FY1990. Therefore, CO_2 emission from lime production has been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

Recalculations occurred due to updates in the *Adjusted Price Transaction Table* for FY2023. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.2.3. Glass Production (2.A.3.)

a) Category Description

Limestone contains $CaCO_3$ and minute amounts of $MgCO_3$, and dolomite contains $CaCO_3$ and $MgCO_3$. The heating of limestone and dolomite releases CO_2 derived from $CaCO_3$ and $MgCO_3$. Similarly, CO_2 is emitted from soda ash, barium carbonate, potassium carbonate, strontium carbonate, and lithium carbonate. There is still no detailed information available regarding the use of bone ash in glass production in Japan.

CO_2 generating mechanism of limestone and dolomite use

$CaCO_3 \rightarrow CaO + CO_2$
$MgCO_3 \rightarrow MgO + CO_2$

b) Methodological Issues

- ***Estimation Method***

The amounts of limestone, dolomite, soda ash, barium carbonate, potassium carbonate, strontium carbonate, and lithium carbonate used in glass production are multiplied by the emission factors to calculate emissions.

- ***Emission Factors***

➢ ***Limestone***

The emission factor is calculated by adding the value obtained when multiplying the molecular weight ratio of CO_2 and $CaCO_3$ by the $CaCO_3$ content, calculated from the percentage of CaO that can be extracted from limestone (55.4%, the median value of the "54.8% to 56.0%" given in *The Story of Lime* (Japan Lime Association)), and the value obtained when multiplying the molecular weight ratio of CO_2 and $MgCO_3$ by the $MgCO_3$ content, calculated from the percentage of MgO that can be extracted from limestone (0.5%, the median value of the "0.0% to 1.0%" given in *The Story of Lime*). The emission factor is country-specific, as shown below. A review of this EF was conducted in 2009, and it was confirmed that it remains valid.

・Proportion of CaO extractable from limestone : 55.4 % (Median of 54.8% to 56.0% [b])
・Proportion of MgO extractable from limestone : 0.5 % [b] (Median of 0.0% to 1.0% [b])
・Molecular weight of $CaCO_3$ (primary constituent of limestone) : 100.0869 [a]
・Molecular weight of $MgCO_3$: 84.3139 [a]
・Molecular weight of CaO : 56.0774 [a]
・Molecular weight of MgO : 40.3044 [a]
・Molecular weight of CO_2 : 44.0095 [a]

・$CaCO_3$ content = proportion of CaO extractable from limestone × molecular weight of $CaCO_3$ / molecular weight of CaO
・$MgCO_3$ content = proportion of MgO extractable from limestone × molecular weight of $MgCO_3$ / molecular weight of MgO

○Emission factor = (molecular weight of CO_2 / molecular weight of $CaCO_3$ × $CaCO_3$ content) + (molecular weight of CO_2 / molecular weight of $MgCO_3$ × $MgCO_3$ content)
= 440 [kg-CO_2/t]

Reference:
a) *Atomic Weights of the Elements 1999* [http://www.ciaaw.org/pubs/TSAW-1999.pdf] (IUPAC)
b) *The Story of Lime*

➢ *Dolomite*

The emission factor is calculated by adding the value obtained when multiplying the molecular weight ratio of CO_2 and $CaCO_3$ by the $CaCO_3$ content, calculated from the percentage of CaO that can be extracted from dolomite (34.5%, the median value of the 33.1% to 35.85% range given in *The Story of Lime*), and the value obtained when multiplying the molecular weight ratio of CO_2 and $MgCO_3$ by the $MgCO_3$ content, calculated from the percentage of MgO that can be extracted from dolomite (18.3%, the median value of the 17.2% to 19.5% range given in *The Story of Lime*). The emission factor is country-specific, as shown below. A review of this EF was conducted in 2009, and it was confirmed that it remains valid.

・Proportion of CaO extractable from dolomite : 34.5% (Median value of the 33.1% to 35.85% [a])
・Proportion of MgO extractable from dolomite : 18.3% (Median value of the 17.2% to 19.5% [a])
・Molecular weight of $CaCO_3$ (major constituent of dolomite) : 100.0869
・Molecular weight of $MgCO_3$ (major constituent of dolomite) : 84.3139
・Molecular weight of CaO : 56.0774
・Molecular weight of MgO : 40.3044
・Molecular weight of CO_2 : 44.0098

・$CaCO_3$ content = proportion of CaO extractable from dolomite × molecular weight of $CaCO_3$/ molecular weight of CaO

・$MgCO_3$ content = proportion of MgO extractable from dolomite × molecular weight of $MgCO_3$/ molecular weight of MgO
○Emission factor = molecular weight of CO_2 / molecular weight of $CaCO_3$ × $CaCO_3$ content + molecular weight of CO_2 / molecular weight of $MgCO_3$ × $MgCO_3$ content
= 471 [kg-CO_2/t]

Reference:
a) *The Story of Lime*

➢ *Soda ash*

Same as Other uses of soda ash (2.A.4.b.). See section 4.2.4.2. b).

➢ *Other materials*

For barium carbonate ($BaCO_3$), 0.22 t-CO_2/t, based on molecular weight ratio of CO_2 to $BaCO_3$, is used.

For potassium carbonate (K_2CO_3), 0.32 t-CO_2/t, based on molecular weight ratio of CO_2 to K_2CO_3, is used. For strontium carbonate ($SrCO_3$), 0.30 t-CO_2/t, based on molecular weight ratio of CO_2 to $SrCO_3$, is used. For lithium carbonate (Li_2CO_3), 0.60 t-CO_2/t, based on molecular weight ratio of CO_2 to Li_2CO_3, is used.

- ***Activity Data***

➢ ***Limestone, Dolomite, and Soda ash***

Of the limestone, dolomite, and soda ash consumption data in the *Adjusted Price Transaction Table*, all limestone, dolomite, soda ash consumption categorized under 'emissive use' that are under the Glass products related sectors will be accounted for under this subcategory. Activity data is in dry weight, converted using the water content from limestone used for cement.

The corresponding sectors in the *Adjusted Price Transaction Table* are as follows:

Table 4-8 Main Uses and Corresponding Sectors in the *Adjusted Price Transaction Table*

Use	Limestone	Dolomite	Soda ash
Glass products	251 Ceramic and quarry products - glass/glass products	251 Ceramic and quarry products - glass/glass products	251 Ceramic and quarry products -glass/glass products

Note: The numbers before the sector names are categorization numbers in the *Adjusted Price Transaction Table*.

Table 4-9 Amounts of Limestone, Dolomite, and Soda Ash Consumption

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Limestone consumption (dry)	kt	66	42	26	31	17	23	23	12	13	9	11	10
Dolomite consumption (dry)	kt	264	250	203	221	184	203	202	166	169	155	163	159
Soda ash consumption (dry)	kt	358	320	257	279	217	249	247	187	192	171	184	176

➢ ***Other materials***

For barium carbonate, shipment amounts for cathode-ray tube optical glass given in the *Mineral Resources Material Flow* (Japan Oil, Gas and Metals National Corporation) converted to pure substance mass (69%) are used for years FY2000 to FY2010. For other years, extrapolation using production amounts of glass bulbs for lights and electron tubes (including tubes and rods) given in the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials* (METI) are applied.

For potassium carbonate, domestic demand obtained by subtracting export quantities from import quantities given in the *Trade Statistics of Japan* (Ministry of Finance) converted to pure substance mass (57%) are used for years FY1991 and onward.

For strontium carbonate, demand amounts of tube glass (including flat panel glass and other glass) converted to pure substance mass (59%) are used for years FY2000 to FY2006, FY2008, and FY2010. For FY2007 and FY2009, interpolation was applied. For years FY1990 to FY1999, extrapolation using production amounts of glass bulbs for lights and electron tubes (including tubes and rods) given in the *Yearbook of Ceramics and Building Materials Statistics* was applied, and for years from FY2011 and onward extrapolation using demand amounts of $SrCO_3$ given in the *Mineral Resources Material Flow* are applied.

For lithium carbonate, demand amounts of ceramic additives (19%) given in the *Mineral Resources Material Flow* are used for years FY2002 and onward. For years FY1998 to FY2001, extrapolation using demand amounts for glass additives given in the *Mineral Resources Material Flow* are applied. For years FY1990 to FY1997, extrapolation using production amounts of plate glass given in the *Yearbook of Ceramics and Building Materials Statistics* are applied.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainty of the emission factor, the default value of 5% in the *2006 IPCC Guidelines* was used. For the uncertainty of activity data, the default value of 3% in the *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated to be 6%.

- ***Time-series consistency***

For activity data, the same source-data is used as much as possible throughout the time-series with the method described in the section above to supplement for the lack of data. The emission factors are constant for all years from FY1990. Therefore, CO_2 emission has been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

For FY2023, recalculations occurred due to updates made to limestone, dolomite, and soda ash consumption in the *Adjusted Price Transaction Table*. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.2.4. Other Process Uses of Carbonates (2.A.4.)

4.2.4.1. Ceramics (2.A.4.a.)

a) Category Description

Limestone contains $CaCO_3$ and minute amounts of $MgCO_3$, and dolomite contains $CaCO_3$ and $MgCO_3$. The heating of limestone and dolomite releases CO_2 derived from $CaCO_3$ and $MgCO_3$.

b) Methodological Issues

- ***Estimation Method***

The amounts of limestone and dolomite used in ceramics production are multiplied by the emission factors to calculate emissions.

- ***Emission Factors***

➢ ***Limestone***

Same as Glass Production (2.A.3.) See section 4.2.3. b).

➢ ***Dolomite***

Same as Glass Production (2.A.3.) See section 4.2.3. b).

- ***Activity Data***

Of the limestone and dolomite consumption data in the *Adjusted Price Transaction Table*, all limestone and dolomite consumption categorized under 'emissive use' that are under the Ceramics products related sectors will be accounted for under this subcategory. Activity data is in dry weight, converted using the

water content from limestone used for cement.

The corresponding sectors in the *Adjusted Price Transaction Table* are as follows:

Table 4-10 Corresponding Sectors in the *Adjusted Price Transaction Table*

Uses	Limestone		Dolomite	
Ceramics products			063	Mining industry - non-metallic minerals
	2531-01	Ceramic and quarry products-ceramics	2531-01	Ceramic and quarry products - ceramics
	2591-01	Ceramic and quarry products - clay refractories	2591-01	Ceramic and quarry products - clay refractories
			2599-01	Ceramic and quarry products - carbon graphite products
			2599-09	Ceramic and quarry products - other ceramic and quarry products
			2811-01 to 2899-09	Metal Products - metal products for construction use Metal Products - other metal products
			6741-09	Private services - other amusement

Note: The numbers before the sector names are categorization numbers in the *Adjusted Price Transaction Table*.

Table 4-11 Amounts of Limestone and Dolomite Consumption for Ceramic Products

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Limestone consumption (dry)	kt	438	1,107	1,135	463	365	630	722	686	744	890	692	741
Dolomite consumption (dry)	kt	1,561	1,227	1,020	1,204	1,527	1,462	1,077	668	700	609	510	470

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

Same as Glass Production (2.A.3.). See section 4.2.3.c).

- ***Time-series consistency***

Limestone and dolomite consumption data provided in the *Adjusted Price Transaction Table* is used as limestone and dolomite use activity data for all years from FY1990. The emission factors are constant for all years from FY1990. Therefore, CO_2 emission from limestone and dolomite use has been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

Recalculations occurred due to updates made to limestone and dolomite consumption in the *Adjusted Price Transaction Table* for FY2023. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.2.4.2. Other uses of soda ash (2.A.4.b.)

a) Category Description

CO_2 is released during the use of soda ash (Na_2CO_3).

b) Methodological Issues

- ***Estimation Method***

CO_2 emissions from soda ash use are calculated by multiplying soda ash consumption by the country-specific emission factor.

- ***Emission Factors***

Soda ash consumption data categorized under 'for emission purpose' in the *Adjusted Price Transaction Table* does not differentiate between domestic products and imported products, and therefore the emission factor is established by taking a weighted average of the below emission factors for domestic soda ash and imports, by total domestic shipment and total import amounts.

For domestic soda ash, the emission factor is set as follows using data on the purity of soda ash. (The inter-annual fluctuation in the purity of soda ash is small, and therefore the emission factor will be set constant over the time-series.)

$$EF = P \times MW_{CO2} / MW_{Na2CO3}$$
$$= 0.995 \times 44.01 / 105.99$$
$$= 0.413 \text{ [t-CO}_2\text{/t]}$$

EF	: Emission factor for domestic soda ash
P	: Purity of soda ash (arithmetic mean between the 2 domestic companies)
MW_{CO2}	: Molecular weight of CO_2
MW_{Na2CO3}	: Molecular weight of Na_2CO_3

For soda ash imported, and other disodium carbonate imported, there is not enough information to set representative emission factors. Therefore, the default value (0.415 [t-CO_2/t-Na_2CO_3]) specified in the *2006 IPCC Guidelines* (Vol. 3 p. 2.7) is used.

- ***Activity Data***

Soda ash consumption data categorized under 'for emission purpose' in the *Adjusted Price Transaction Table* is used. (excluding consumption for glass production)

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainty of the emission factor, the default value of 5% in the *2006 IPCC Guidelines* was used. For the uncertainty of activity data, the default value of 3% in the *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated to be 6%.

- ***Time-series consistency***

Soda ash consumption data provided in the *Adjusted Price Transaction Table* is used as soda ash use activity data for all years from FY1990. The emission factor is constant for all years from FY1990. Therefore, CO_2 emission from soda ash use has been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

For FY2023, recalculations occurred due to updates made to soda ash consumption in the *Adjusted Price Transaction Table*. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.2.4.3. Non-metallurgical Magnesium Production (2.A.4.c.)

Emissions are included under Other – Desulfurization of Exhaust Gas and Chemical Products (2.A.4.d.-), and are therefore reported as "IE".

4.2.4.4. Other – Desulfurization of Exhaust Gas and Chemical Products (2.A.4.d.-)

a) Category Description

Limestone contains $CaCO_3$ and minute amounts of $MgCO_3$, and dolomite contains $CaCO_3$ and $MgCO_3$. The heating of limestone and dolomite releases CO_2 derived from $CaCO_3$ and $MgCO_3$.

CO_2 generating mechanism of limestone and dolomite use

$CaCO_3 \rightarrow CaO + CO_2$
$MgCO_3 \rightarrow MgO + CO_2$

b) Methodological Issues

- ***Estimation Method***

The amounts of limestone and dolomite used in desulfurization of exhaust gas and production of chemical products are multiplied by the emission factors to calculate emissions.

- ***Emission Factors***

➢ ***Limestone***

Same as Glass Production (2.A.3.). See section 4.2.3. b).

➢ ***Dolomite***

Same as Glass Production (2.A.3.). See section 4.2.3. b).

- ***Activity Data***

Of the limestone and dolomite consumption data in the *Adjusted Price Transaction Table*, all limestone and dolomite consumption categorized under 'emissive use,' that are under related sectors for desulfurization of exhaust gas, and production of chemical products excluding chemical fertilizers will be accounted for under this subcategory. Activity data is in dry weight, converted using the water content from limestone used for cement.

The corresponding sectors in the *Adjusted Price Transaction Table* are as follows:

Table 4-12 Uses and Corresponding Sectors in the *Adjusted Price Transaction Table*

Uses	Limestone		Dolomite	
Desulfurization of exhaust gas	063	Mining industry – non-metallic minerals		
Chemical products	2029-09	Chemical Products – other inorganic chemical industry products	2029-09	Chemical Products – other inorganic chemical industry products
			2081-011	Chemical Products – processed oil and fat products
	2049-09	Chemical Products – other organic chemical industry products	2049-09	Chemical Products – other organic chemical industry products
			2071-01	Chemical Products – medicaments
			2089-09	Chemical Products – catalytic and other chemical end products

Note: The numbers before the sector names are categorization numbers in the *Adjusted Price Transaction Table*.

Table 4-13 Amounts of Limestone and Dolomite Consumption

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Limestone consumption													
For desulfurization of exhaust gas (dry)	kt	1,950	2,163	1,842	2,077	1,840	2,124	1,853	1,490	1,528	1,487	1,398	1,398
For chemical products (dry)	kt	2,458	713	812	367	260	421	468	516	569	689	543	587
Dolomite consumption													
For chemical products (dry)	kt	82	43	42	37	34	33	26	29	35	34	31	30

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

Same as Glass Production (2.A.3.). See section 4.2.3. c).

- ***Time-series consistency***

Limestone and dolomite consumption data provided in the *Adjusted Price Transaction Table* is used as limestone and dolomite use activity data for all years from FY1990. The emission factors are constant for all years from FY1990. Therefore, CO_2 emission from limestone and dolomite use has been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

For FY2023, recalculations occurred due to the updates of limestone consumption for desulfurization of exhaust gas and for chemical products, as well as dolomite consumption for chemical products. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.3. Chemical Industry (2.B.)

This category covers CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, and NF_3 emissions from the processes of chemical productions.

This section deals with the following sources: Ammonia production (2.B.1.), Nitric acid production (2.B.2.), Adipic acid production (2.B.3.), Caprolactam, glyoxal and glyoxylic acid production (2.B.4),

Carbide production (2.B.5.), Titanium dioxide production (2.B.6.), Soda Ash Production (2.B.7.), Petrochemical and carbon black production (2.B.8.), Fluorochemical production (2.B.9.), and Other (2.B.10.).

In FY2024, emissions from this category were 3,183 kt-CO_2 eq. and represented 0.3% of Japan's total GHG emissions (excluding LULUCF). The total emissions of CO_2, CH_4, and N_2O from this category decreased by 79.3% compared to FY1990. The total of HFCs, PFCs, SF_6, and NF_3 decreased by 99.1% compared to 1990.

Table 4-14 Emissions from Chemical Industry (2.B.)

Gas				Units	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
CO_2	2.B.1	Ammonia production		kt-CO_2	2,445	2,471	2,312	1,498	1,435	1,236	1,271	752	1,070	887	865	649
	2.B.5	Carbide production	Silicon carbide	kt-CO_2	C	C	C	C	C	C	C	C	C	C	C	C
			Calcium carbide	kt-CO_2	C	C	C	C	C	C	C	C	C	C	C	C
	2.B.6	Titanium dioxide production		kt-CO_2	102	39	53	59	62	60	53	49	60	57	59	58
	2.B.8	Petrochemical and carbon black production	Methanol	kt-CO_2	56	51	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
			Ethylene	kt-CO_2	C	C	C	C	C	C	C	C	C	C	C	C
			Ethylene dichloride and vinyl chloride monomer	kt-CO_2	150	171	193	200	184	148	169	174	177	169	168	159
			Ethylene oxide	kt-CO_2	170	203	272	278	244	264	231	205	219	163	159	149
			Acrylonitrile	kt-CO_2	440	476	536	509	524	364	315	306	325	293	245	203
			Carbon black	kt-CO_2	1,633	1,563	1,590	1,659	1,505	1,294	1,161	980	1,198	1,153	1,117	1,056
			Phthalic anhydride	kt-CO_2	109	116	95	84	62	62	62	54	59	56	54	48
			Maleic anhydride	kt-CO_2	71	80	88	78	70	70	71	59	69	61	57	51
	2.B.10	Other	Hydrogen production	kt-CO_2	6	21	39	34	34	28	27	20	17	17	15	16
			Utilization of carbonated gas	kt-CO_2	40	45	42	39	67	58	59	64	66	76	75	62
	Total			kt-CO_2	6,047	6,019	5,924	5,170	4,819	4,177	3,967	3,075	3,753	3,421	3,183	2,856
CH_4	2.B.5	Carbide production	Silicon carbide	kt-CH_4	C	C	C	C	C	C	C	C	C	C	C	C
	2.B.8	Petrochemical and carbon black production	Methanol	kt-CH_4	0.19	0.17	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
			Ethylene	kt-CH_4	C	C	C	C	C	C	C	C	C	C	C	C
			Ethylene dichloride and vinyl chloride monomer	kt-CH_4	0.01	0.02	0.02	NO	NO	NO	NO	NO	NO	NO	NO	NO
			Ethylene oxide	kt-CH_4	C	C	C	C	C	C	C	C	C	C	C	C
			Carbon black	kt-CH_4	C	C	C	C	C	C	C	C	C	C	C	C
			Styrene	kt-CH_4	C	C	C	C	C	C	C	C	C	C	C	C
	Total			kt-CH_4	1.50	1.48	1.37	1.35	1.45	1.13	1.27	0.95	1.08	0.94	0.69	0.46
	Total			kt-CO_2 eq.	42	42	38	38	41	32	36	27	30	26	19	13
N_2O	2.B.2	Nitric acid production		kt-N_2O	2.47	2.46	2.57	2.52	1.81	1.54	1.40	0.68	0.86	0.70	0.59	0.49
	2.B.3	Adipic acid production		kt-N_2O	24.20	24.03	12.56	1.68	1.66	0.77	0.38	1.14	0.16	0.07	0.28	0.07
	2.B.4	Caprolactam, glyoxal and glyoxylic acid production	Caprolactam	kt-N_2O	4.66	4.93	5.20	3.36	2.56	1.92	0.90	0.40	0.47	0.37	0.08	0.06
			Glyoxal	kt-N_2O	C	C	C	C	C	C	C	C	C	C	C	C
			Glyoxylic acid	kt-N_2O	C	C	C	C	C	C	C	C	C	C	C	C
	Total			kt-N_2O	32.28	32.43	21.30	8.58	6.08	4.22	2.68	2.22	1.50	1.14	0.96	0.62
	Total			kt-CO_2 eq.	8,555	8,595	5,645	2,275	1,612	1,120	709	589	397	301	254	164
Total of CO_2, CH_4, and N_2O				kt-CO_2 eq.	14,643	14,655	11,608	7,483	6,472	5,328	4,712	3,691	4,179	3,748	3,456	3,033
Gas				Units	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
HFCs	2.B.9	Fluorochemical production	By-product emissions: Production of HCFC-22	kt-CO_2 eq.	13,346	17,980	13,144	491	45	14	25	118	110	4	2	4
			Fugitive emissions	kt-CO_2 eq.	1	503	264	407	115	119	75	69	109	63	85	60
	Total			kt-CO_2 eq.	13,347	18,483	13,408	898	160	132	100	187	220	66	88	64
PFCs	2.B.9	Fluorochemical production	Fugitive emissions	kt-CO_2 eq.	304	840	1,499	955	227	100	104	67	72	67	37	32
SF_6			Fugitive emissions	t	152.23	197.00	36.00	40.80	8.30	4.07	2.30	2.28	2.00	1.44	1.00	1.76
				kt-CO_2 eq.	3,577	4,630	846	959	195	96	54	54	47	34	24	41
NF_3			Fugitive emissions	t	0.16	1.00	7.00	72.10	76.90	86.40	23.50	0.88	1.39	1.19	0.84	0.76
				kt-CO_2 eq.	3	16	113	1,161	1,238	1,391	378	14	22	19	14	12
Total of F-gases				kt-CO_2 eq.	17,231	23,968	15,866	3,972	1,820	1,719	636	322	361	186	161	149

4.3.1. Ammonia Production (2.B.1.)

a) Category Description

1) CO_2

In ammonia production, CO_2 is emitted when hydrocarbon feedstock is broken down to make H_2.

CO_2 generating mechanism of ammonia production

$0.88CH_4 + 1.26air + 1.24H_2O \rightarrow 0.88CO_2 + N_2 + 3H_2$

Ammonia synthesis

$N_2 + 3H_2 \rightarrow 2NH_3$

2) CH_4

Emissions of CH_4 from ammonia production have been confirmed by actual measurements. As there are not enough examples to enable the establishment of an emission factor, it is currently not possible to calculate emissions. The *2006 IPCC Guidelines* also do not give a default emission factor. Therefore, CH_4 was reported as "NE".

3) N_2O

Emissions of N_2O from ammonia production is theoretically impossible and given that even in actual measurements the emission factor for N_2O is below the limits of measurement, N_2O was reported as "NA".

b) Methodological Issues

- **Estimation Method**

Following the Tier 2 method in the *2006 IPCC Guidelines*, CO_2 emissions are calculated by multiplying the amount of fuel consumed as ammonia feedstock by country-specific emission factors. Since carbonated gas, mainly provided from Ammonia production plants, was injected and geologically stored in years 1990 to 1993, 1997 to 1999, 2003, and 2004, this amount is subtracted from emissions (see section 3.4.4 (1.C.) for details). CO_2 recoveries for urea production are subtracted from CO_2 emissions for ammonia production. CO_2 emissions from urea use are accounted for under the categories of Urea used as a catalyst (2.D.3.-) and Urea application (3.H.). Additionally, the amount of CO_2 recoveries for liquefied CO_2 and for dry ice are subtracted from the CO_2 emissions from ammonia production. See section 4.9.1. for details of the allocation of CO_2 emissions from the utilization of CO_2 recovered.

$$E = \Sigma_i \left(AD_i \times GCV_i \times 10^{-3} \times EF_i \times 44/12\right) - R_{ccs} - R_{urea} - R_u$$

E	: CO_2 emissions from ammonia production [t-CO_2]
AD_i	: Consumption amount of feedstock i [t, kL, 10^3m^3]
GCV_i	: Gross calorific value (higher heating value) for feedstock i [MJ/kg, MJ/L, MJ/m^3]
EF_i	: Carbon content of feedstock i [t-C/TJ]
R_{ccs}	: Amount of CO_2 recoveries due to CCS [t-CO_2]
R_{urea}	: Amount of CO_2 recoveries for urea production [t-CO_2]
R_u	: Amount of CO_2 recoveries for liquefied CO_2 /dry ice [t-CO_2]

where,

$$R_{urea} = AD_{urea} \times 44/60$$

AD_{urea}	: Production amount of urea [t]
44/60	: Molecular weight ratio of CO_2 to urea

- **Emission Factors**

The same carbon emission factors and gross calorific values that are used to calculate CO_2 emissions from the Fuel combustion category (Chapter 3, 1.A.) are used for each feedstock listed in Table 4-15. It should be noted that the implied emission factor changes every year, since the composition of the feedstocks consumed for ammonia production varies annually.

Table 4-15 Emission Factors and Calorific Values of Feedstocks Used in Ammonia Production

Item		Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Naphtha	GCV	MJ/L	33.63	33.63	33.57	33.55	33.53	33.31	33.31	33.31	33.31	33.31	33.32	33.32
	CEF	t-C/TJ	18.17	18.17	18.17	18.17	18.17	18.63	18.63	18.63	18.63	18.63	18.63	18.63
LPG	GCV	MJ/kg	50.53	50.63	50.70	50.75	50.77	50.07	50.10	50.12	50.13	50.12	50.12	50.14
	CEF	t-C/TJ	16.54	16.51	16.49	16.48	16.47	16.38	16.36	16.34	16.34	16.34	16.35	16.34
Off gas	GCV	MJ/m^3	39.35	39.35	44.90	44.90	44.90	46.12	46.12	46.12	46.12	46.12	42.41	42.41
	CEF	t-C/TJ	14.15	14.15	14.15	14.15	14.15	14.44	14.44	14.44	14.44	14.44	14.44	14.44
Natural gas	GCV	MJ/m^3	42.09	42.39	42.55	42.87	44.67	39.62	39.62	38.38	38.38	38.38	38.36	38.36
	CEF	t-C/TJ	13.90	13.90	13.90	13.90	13.90	13.97	13.97	13.91	13.91	13.91	13.90	13.90
Coal	GCV	MJ/kg	25.95	25.95	26.60	25.70	25.70	25.97	25.97	26.08	26.08	26.08	25.88	25.88
	CEF	t-C/TJ	24.71	24.71	24.71	24.71	24.71	24.42	24.42	24.29	24.29	24.29	24.76	24.76
Oil coke	GCV	MJ/kg	35.58	35.58	35.60	29.90	29.90	33.29	33.29	33.29	34.11	34.11	34.11	34.11
	CEF	t-C/TJ	25.35	25.35	25.35	25.35	25.35	24.50	24.50	24.50	24.80	24.80	24.80	24.80
LNG	GCV	MJ/kg	54.54	54.53	54.52	54.51	54.49	54.46	54.46	54.73	54.73	54.71	54.69	54.59
	CEF	t-C/TJ	13.94	13.95	13.94	13.94	13.95	13.96	13.96	13.86	13.86	13.87	13.84	13.84
COG	GCV	MJ/m^3	21.51	21.57	21.27	21.42	21.32	18.87	18.87	18.38	18.38	18.38	18.19	18.19
	CEF	t-C/TJ	10.99	10.99	10.99	10.99	10.99	10.93	10.93	10.88	10.88	10.88	10.79	10.79

Reference: *General Energy Statistics*

- ***Activity Data***

For consumption of feedstock for ammonia production, the original units (including weight and volume) for the fuel types in Table 4-16 below, which are from the *Yearbook of the Current Survey of Energy Consumption* (METI), were converted using the calorific values in the *General Energy Statistics*, and results were used as activity data. Consumption data for some fuel types are confidential. For production amount of urea (calendar year basis), the values provided by the *Yearbook of Fertilizer Statistics (Pocket Edition)* (Ministry of Agriculture, Forestry and Fisheries) were used.

Table 4-16 Amount of Feedstocks Used for Ammonia Production

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Naphtha	kL	189,714	477,539	406,958	92,453	70,067	71,494	73,612	NO	NO	NO	NO	NO
LPG	t	226,593	45,932	5,991	NO	NO	NO	NO	NO	NO	NO	NO	NO
Off gas	10^3m^3	C	230,972	240,200	147,502	143,634	NO	NO	NO	NO	NO	NO	NO
Natural gas	10^3m^3	C	100,468	86,873	77,299	41,640	47,956	17,498	941	278	947	439	541
Coal	t	C	209,839	726	1,239	629	919	362	845	499	934	424	684
Oil coke	t	C	273,125	420,862	353,983	394,116	401,721	468,684	347,107	450,097	367,225	384,046	296,217
LNG	t	C	46,501	23,395	165,606	157,918	168,155	122,453	132,158	131,465	148,381	121,351	137,099
COG	10^3m^3	C	35,860	55,333	NO	NO	NO	NO	NO	NO	NO	NO	NO

Note: C: Confidential

- ***Point to Note***

Fuel consumption in this category has been subtracted from energy sector activity data (see Chapter 3).

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainty of each fuel was estimated. For the uncertainty of emission factors, the upper limit and lower limit values of the 95% confidence interval for the carbon emission factors were applied. For the uncertainty of the activity data, the same values were applied as in Fuel combustion category (1.A). As

a result, the uncertainty of emissions is the following: naphtha -3 to +1%; LPG -3 to +1%; hydrocarbon gas -4 to +3%; natural gas -1 to +1%; coal (steam coal, imported coal) -4 to +3%; oil coke -3 to +1%; LNG -1 to +1%; and COG -4 to +3%.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time-series, from the *Current Survey of Energy Consumption*. The emission factor is constantly based on the *General Energy Statistics* throughout the time-series. Therefore, CO_2 emission from ammonia production has been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.2. Nitric Acid Production (2.B.2.)

a) Category Description

N_2O is emitted when nitric acid (HNO_3) is produced from ammonia.

N_2O generating mechanism in nitric acid production

$$4NH_3 + 5O_2 \rightarrow 4NO + 6H_2O$$
$$2NO + H_2O \rightarrow 2NO_2$$
$$3NO_2 + H_2O \rightarrow 2HNO_3 + NO \quad (\rightarrow N_2O)$$

In Japan, the main processes used in nitric acid production are the New Fauser Process (medium pressure) and Chemico Process (high pressure), both based on the Ostwald chemical process. With regard to N_2O decomposition, there are catalytic decomposition units in operation.

b) Methodological Issues

- ***Estimation Method***

N_2O emissions were estimated by multiplying the amount of nitric acid produced by an emission factor, based on the Tier 2 method given in the *2006 IPCC Guidelines*. Emission data for individual factories are confidential, and therefore the nitric acid production amount and the emission factor were set for all of Japan. The amount of N_2O destroyed is currently unavailable but is reflected in the emission factor.

$$E = EF \times NAP$$

E : N_2O emissions from nitric acid production [kg-N_2O]
EF : Emission factor [kg-N_2O/t]
NAP : Nitric acid production amount [t]

- ***Emission Factors***

Data for individual factories are confidential, and therefore the emission factor was set by using each factory's nitric acid production amount to find the weighted average of Japan's 10 nitric acid producing factories' emission factors (measurement data). These emission factors take N_2O recovery and destruction into account.

Table 4-17 N_2O Emission Factors for Nitric Acid Production

Item	Unit	1990	1995	2000	2005	2010	2013	2020	2021	2022	2023	2024
EFs for nitric acid production	kg-N_2O/t	3.50	3.51	3.92	4.18	3.58	3.55	3.00	3.47	3.21	2.98	2.41

- ***Activity Data***

Production amounts of nitric acid are directly provided by METI.

Table 4-18 Amount of Nitric Acid Production

Item	Unit	1990	1995	2000	2005	2010	2013	2020	2021	2022	2023	2024
Nitric acid production	kt	706	701	656	602	506	434	227	248	218	198	203

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

The standard deviation was calculated for the emission factors and production amounts of each plant, and the uncertainty of the emission factor was assessed to be 112%. For the uncertainty of activity data, the default value of 2% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty of emissions was estimated to be 112%.

- ***Time-series Consistency***

Emissions throughout the time-series are consistently estimated using the activity data and emission factors provided by METI.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.3. Adipic Acid Production (2.B.3.)

a) Category Description

N_2O is emitted in the adipic acid ($C_6H_{10}O_4$) production process through the reaction of cyclohexanone, cyclohexanol, and nitric acid.

b) Methodological Issues

- ***Estimation Method***

Emissions were estimated using the N_2O generation rates, N_2O decomposition amount, and adipic acid production amount of the relevant operating sites.

- ***Emission Factors***

Country specific emission factors were established using the following parameters. Relevant emission factor/parameter data are confidential.

➢ ***Nitrous oxide generation rate***

Actual measurement data provided from the sole producer of adipic acid as an end product in Japan is used.

➢ ***Nitrous oxide decomposition rate***

The figure used is the result of measurement of the rate of decomposition of nitrous oxide in the operating site.

➢ ***Decomposition unit operation rate***

A full-scale survey on the number of operation hours is conducted annually for N_2O decomposition units and adipic acid production plants. The operating rate is based on this survey.

- ***Activity Data***

The activity data for nitrous oxide emissions associated with the manufacturing of adipic acid is the amount of adipic acid produced provided to METI by the manufacturer. Relevant data used in estimation is confidential.

- ***Point to Note***

From 1990 to 1997, N_2O emissions from adipic acid production increased gradually. However, N_2O decomposition units were installed in adipic acid production plants in March 1999, and emissions since then have decreased dramatically. There was a temporary growth in the emissions in 2000 and 2020 due to the low operating rate of N_2O decomposition units caused by mechanical and instrumental failures of the decomposition units.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainty of the emission factor for adipic acid was estimated by combining the uncertainty of the N_2O generation rate, N_2O decomposition rate, and the operating rate of the decomposition unit. As a result, the uncertainty of the emission factor was estimated to be 9%. A 2% uncertainty given by the *2006 IPCC Guidelines* was applied for activity data. As a result, the uncertainty for adipic acid was estimated to be 9%.

- ***Time-series Consistency***

Activity data and emission factors consistently provided by the producer of adipic acid are used to estimate emissions throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.4. Caprolactam, Glyoxal and Glyoxylic Acid Production (2.B.4.)

4.3.4.1. Caprolactam (2.B.4.a.)

a) Category Description

Caprolactam is a monomer for nylon-6 which transforms into Nylon 6 by ring-opening polymerization. Nylon 6 is used as fibers for carpets, etc., or resin material. N_2O is emitted from ammonia oxidation during the manufacturing process.

b) Methodological Issues

- ***Estimation Method***

Emissions are calculated by multiplying the amount of caprolactam produced by a weighted average emission factor, based on plant-specific emission factors established in accordance with Tier 1 - 3 methods in the *2006 IPCC Guidelines*.

- ***Emission Factors***

A country-specific emission factor per production amount was established by dividing total emissions by total production amounts. This was based on data provided from Japan Chemical Industry Association, including production amounts, emission factors, and emissions for all plants producing caprolactam in Japan. Each plant's emission factor fluctuates by year. Emission factors for FY2022 and onward are confidential since activity data are confidential due to the fact that the number of manufacturers has become equal or less than two.

- ***Activity Data***

For 1990 to 2021, caprolactam production amounts from the *Yearbook of Current Production Statistics - Chemical Industry* (METI) were used as activity data. For FY2022 and onward, caprolactam production (confidential) provided by Japan Chemical Industry Association was used.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

As for the uncertainty of the emission factor, the standard deviation was calculated from the emission factors and production amounts of each plant and was assessed to be 162%. For the uncertainty of activity data, the default value of 2% in the *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated to be 162%.

- ***Time-series Consistency***

For the activity data, data from the *Yearbook of Current Production Statistics – Chemical Industry*, etc. are consistently used throughout the time-series. The emission factors are constant throughout the time-series. Therefore, emissions have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

The emission factor for FY2023 was revised, resulting in recalculations. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.4.2. Glyoxal (2.B.4.b.)

a) Category Description

Glyoxal is mainly used as a crosslinking agent for acrylic resins, disinfectant, gelatin hardening agent, and textile finishing agent, etc. It's produced from oxidation of acetaldehyde with concentrated nitric acid, or from the catalytic oxidation of ethylene glycol, and N_2O is emitted in the process of oxidation of acetaldehyde (see below).

$$2C_2H_4O + 2HNO_3 \rightarrow 2C_2H_2O_2 + N_2O + H_2O$$

b) Methodological Issues

- ***Estimation Method***

Emissions are calculated in accordance with the Tier 3 method in the *2006 IPCC Guidelines*, by multiplying the amount of glyoxal produced by an emission factor. There is no production from FY2010 onward, but emissions for FY1990 to FY2011 are reported as "C" due to confidentiality reasons of Glyoxylic acid for FY2010 and FY2011.

- ***Emission Factors***

A country-specific emission factor per production amount based on information provided by the manufacturer was used. This was established based on the amounts of gas emitted in the manufacturing process of each product, and measurements of N_2O concentrations, and will be applied to all years.

- ***Activity Data***

No statistics are available on glyoxal production amounts, and therefore the production amounts at one manufacturer that had been producing until recent were used as activity data. There is no production from FY2010 onward.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainty of the emission factor, the default value of 10% in the *2006 IPCC Guidelines* was used. For the uncertainty of activity data, the default value of 2% in the *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated to be 10%.

- ***Time-series Consistency***

For the activity data, data from the one manufacturer that had been producing until recent are consistently used throughout the time-series. The emission factors are constant throughout the time-series. Therefore, emissions have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.4.3. Glyoxylic acid (2.B.4.c.)

a) Category Description

Glyoxylic acid is used for the production of synthetic aromas, agrochemicals, and pharmaceutical intermediates. It is produced by nitric acid oxidation of glyoxal, and N_2O is emitted in the process of reduction of nitric acid.

b) Methodological Issues

- ***Estimation Method***

Emissions are calculated in accordance with the Tier 3 method in the *2006 IPCC Guidelines*, by multiplying the amount of glyoxylic acid produced by an emission factor. There is no production from FY2012 onward.

- ***Emission Factors***

A country-specific emission factor per production amount based on information provided by the manufacturer was used. This was established based on the amounts of gas emitted in the manufacturing process of each product, and measurements of N_2O concentrations, and will be applied to all years.

- ***Activity Data***

No statistics are available on glyoxylic acid production amounts, and therefore the production amounts at one manufacturer that had been producing until recently were used as activity data. There is no production from FY2012 onward.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainty of the emission factor, the default value of 10% in the *2006 IPCC Guidelines* was used. For the uncertainty of activity data, the default value of 2% in the *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated to be 10%.

- ***Time-series Consistency***

For the activity data, data from the one manufacturer that had been producing until recent are consistently used throughout the time-series. The emission factors are constant throughout the time-series. Therefore, emissions have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.5. Carbide Production (2.B.5.)

4.3.5.1. Silicon Carbide (2.B.5.a.)

a) Category Description

1) CO_2

CO_2 is emitted by the reaction of petroleum coke with silica as raw materials in the production of silicon carbide.

CO_2 generating mechanism in the silicon carbide production process

$SiO_2 + 3C \rightarrow SiC + 2CO \quad (\rightarrow CO_2)$

2) CH_4

In Japan, silicon carbide is produced in electric arc furnaces, and it is believed that CH_4 is generated from the oxidation of coke, which is used as a reducing agent in silicon carbide production.

b) Methodological Issues

1) CO_2

- ***Estimation Method***

Emissions are calculated by multiplying the amount of petroleum coke used as silicon carbide feedstock by an emission factor.

- ***Emission Factors***

Because Japan does not have measurement data or emission factor data, the default value 2.3 [t-CO_2/t] for silicon carbide production in the *2006 IPCC Guidelines* is used.

- ***Activity Data***

The activity data for CO_2 emissions from silicon carbide production is the amount of petroleum coke consumed, provided by Japan's only silicon carbide production facility. The data is confidential.

2) CH_4

- ***Estimation Method***

Emissions were calculated by multiplying an emission factor based on actual measurements obtained from electric arc furnace facilities in Japan by the energy consumption of electric arc furnaces.

- ***Emission Factors***

The emission factor of energy consumption in electric arc furnaces (12.8 kg-CH_4/TJ) was determined from CH_4 concentrations in the flue gas, measured dry flue gas amounts per hour, and measured quantity of heat generated per hour. See section 4.4.2.b) for the process of deriving the emission factor.

- ***Activity Data***

The activity data for CH_4 emissions from silicon carbide production is the amount of energy consumed, provided by Japan's only silicon carbide production facility. The data is confidential.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

1) CO_2

For the uncertainty of the emission factor, the default value of 10% was applied as provided by the *2006 IPCC Guidelines*. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated to be 11%.

2) CH_4

The uncertainty of the emission factor, the default value of 10% was applied as provided by the *2006 IPCC Guidelines*. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated to be 11%.

- ***Time-series Consistency***

For both CO_2 and CH_4 activity data, the same sources are consistently used throughout the time-series-from the manufacturing facility. The emission factors for both gases are constant throughout the time-series. Therefore, CO_2 and CH_4 emissions from silicon carbide have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.5.2. Calcium Carbide (2.B.5.b.)

a) Category Description

1) CO_2

CO_2 is generated in the process of making the quicklime and is also emitted by the combustion of CO occurring from calcium carbide production. However, the former is included in emissions from Other process uses of carbonates (2.A.4.), and therefore only reducing agent-origin emissions are accounted for here. Further, CO_2 is generated by the combustion of acetylene, which is generated by reacting calcium carbide with water, and these emissions are reported here.

CO_2 generator mechanism in the calcium carbide production process

(Production)

$$CaCO_3 \rightarrow CaO + CO_2$$
$$CaO + 3C \rightarrow CaC_2 + CO\ (\rightarrow CO_2)$$

(Use)

$$CaC_2 + 2H_2O \rightarrow Ca(OH)_2 + C_2H_2\ (\rightarrow CO_2)$$

2) CH_4

Byproduct gases (mainly CO) generated in carbide production include a small amount of CH_4, all of which is recovered and burned as fuel, with none being emitted outside the system. Therefore, emissions from this source are reported as "NA".

b) Methodological Issues

- **Estimation Method**

CO_2 emissions are calculated by multiplying calcium carbide production by the following emission factor, based on the Tier 2 method in the *2006 IPCC Guidelines*.

- **Emission Factors**

For years FY1990 to FY2007, because Japan does not have measurement data or emission factor data, the below default values in the *2006 IPCC Guidelines* is used.

Table 4-19 CO_2 Emission Factors for Calcium Carbide Production and Consumption (FY1990- FY2007)

Unit	From reducing agent in production	From use
t-CO_2/t	1.09	1.10

For years after FY2008, country-specific emission factors from reducing agents during production (changes annually) are used, which are based on measurement data from the two calcium carbide producing companies in Japan. These emission factors are confidential.

The default emission factor (1.10 t-CO_2/t) for calcium carbide use is also used for FY2008 and onwards.

The calcium carbide production amount used for calculating the CO_2 EF includes not only CaC_2, but also unreactive CaO used as raw material. This is the reason for the EF being lower than the stoichiometric value derived from a reaction only involving CaC_2. In Japan, CaC_2 is produced under conditions with excessive CaO. With CaC_2, the higher the purity, the higher is the melting point. Therefore, to avoid the rise in viscosity and hardening in the cooler parts of the plant which impairs production, the melting point is suppressed through intentionally maintaining a lower purity. Purity is also kept low to reduce reactivity from the viewpoint of safety.

- **Activity Data**

Calcium carbide production data provided by Carbide Industry Association are used as the calcium carbide production amount. It includes not only CaC_2 but also unreactive CaO used as raw material. The data are confidential.

c) Uncertainty Assessment and Time-series Consistency

- **Uncertainty Assessment**

For the uncertainty of the CO_2 emission factor, the 10% default value was applied as provided by the *2006 IPCC Guidelines* for both reducing agent origin and from use. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* for both reducing agent origin and from use. As a result, the uncertainty for emissions for both reducing agent origin and from use was estimated to be 11%.

- **Time-series Consistency**

For activity data, the same sources are used throughout the time-series. The emission factor is constant

from FY1990 to FY2007, and for years from FY2008 and onward, country-specific emission factors are used. This is because there is no data available on the scale of production or improvements in manufacturing technology to establish country-specific emission factors for earlier years, and therefore default emission factors are used for FY1990 to FY2007.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.6. Titanium Dioxide Production (2.B.6.)

a) Category Description

Titanium dioxide (TiO_2) is a kind of white pigment, generally used in paper, plastics, rubber, ceramics, fabrics, floor covering, printing ink, and paint, etc. The two forms of TiO_2, anatase TiO_2 and rutile TiO_2 (both tetragonal), differ in terms of the crystalline structure, and the anatase TiO_2 is produced by hydrolyzing titanium sulfate and calcination (the sulfate process), or from titanium slag. Rutile TiO_2 is produced through the carbothermal chlorination of synthetic rutile to produce titanium tetrachloride ($TiCl_4$) and oxidation of the $TiCl_4$ vapors to TiO_2. (the chloride route)

CO_2 is emitted from the oxidization of carbon electrodes in the production of titanium slag in electric furnaces, from the oxidization of black coal during the production of synthetic rutile, and from the oxidization of oil coke in the chloride route. The following reactions occur in the chloride route.

$$2TiO_2 + 4Cl_2 + 3C \rightarrow 2TiCl_4 + 2CO + CO_2$$

$$TiCl_4 + O_2 \rightarrow TiO_2 + 2Cl_2$$

b) Methodological Issues

- ***Estimation Method***

For rutile titanium dioxide (the chloride route), emissions are calculated by multiplying titanium dioxide production amounts (rutile TiO_2) produced through the chloride route which entails CO_2 emissions, by an emission factor provided by the manufacturer, based on the Tier 1 method in the *2006 IPCC Guidelines*.

For rutile titanium dioxide (from synthetic rutile), emissions are calculated by multiplying synthetic rutile production amounts by the default emission factor, based on the Tier 1 method in the *2006 IPCC Guidelines*.

- ***Emission Factors***

For rutile TiO_2 (the chloride route), an emission factor calculated as follows, based on coke input, etc. into the process at the manufacturer, is used.

$$E = (CI - CO) \times CC \times 44/12$$
$$EF = E / AD$$

E : CO_2 emissions [t-CO_2]
CI : Coke input amount [t]
CO : Carry-over amount (Raw material left over without reacting) [t]
CC : Carbon content of coke
EF : CO_2 emission factor [t-CO_2/t]
AD : Titanium dioxide production amounts [t]

Emission factors that can be drawn from the above equation, are only for FY2011 to FY2013, and therefore for years FY1990 – FY2010, the average for FY2011- FY2013 are used. (For years from FY2011 and onward, country-specific emission factors provided by Japan Titanium Dioxide Industry Association are used)

CO_2 EF for rutile TiO_2 is lower than the IPCC default because in the case of Japanese manufacturers, reactions take place under high temperatures such as 1,000 degrees Celsius, and therefore a second reaction ($TiO_2 + 2Cl_2 + 2CO \rightarrow TiCl_4 + 2CO_2$) is simultaneously taking place, in addition to the above-mentioned reactions described in the *2006 IPCC Guidelines* (yielding 3 mol of CO_2 from 2 mol of TiO_2), and uses CO. Because of this, and assuming that this CO is used completely in the first-mentioned reaction, 1 mol of TiO_2 only yields 1 mol of CO_2. (There does not exist any excess carbon. CO_2 occurs only from input coke.) These emission factors are confidential.

For rutile titanium dioxide (from synthetic rutile), the default value of 1.43 t-CO_2/t from the *2006 IPCC Guidelines* is used.

- ***Activity Data***

For rutile titanium dioxide production amounts (the chloride route), the titanium dioxide amounts produced in the chloride route process (provided by Japan Titanium Dioxide Industry Association) which entails CO_2 emissions is used.

For rutile titanium dioxide production amounts (from synthetic rutile), synthetic rutile production amounts (provided by METI) are used. The data is confidential.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainty of emission factors for rutile titanium dioxide and synthetic rutile, the default values from the *2006 IPCC Guidelines* of 15% and 10%, were respectively used. For the uncertainty of activity data, the default value of 5% from the *2006 IPCC Guidelines* was used for both rutile titanium dioxide and synthetic rutile. As a result, the uncertainty of emissions was estimated to be 16% and 11%, respectively.

- ***Time-series Consistency***

For the activity data, data from Japan Titanium Dioxide Industry Association and METI are consistently used throughout the time-series. The emission factors are constant throughout the time-series. Therefore, emissions have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.7. Soda Ash Production (2.B.7.)

In Japan, the ammonium chloride soda process is used to produce soda ash (Na_2CO_3). The soda ash production process involves calcinating limestone and coke in a lime kiln, which emits CO_2. Almost all lime-derived CO_2 is stored in the product.

In the soda ash production process, purchased CO_2 is sometimes input through a pipeline, but because these CO_2 emissions are from the ammonia industry, they are already included in Ammonia production (2.B.1.). Also, the coke consumed is listed as that for heating in the *Yearbook of the Current Survey of Energy Consumption*, and thus CO_2 emissions from coke are already counted under Fuel combustion (1.A.). Therefore, all emissions from this source are already included in other categories and are reported as "IE". Coke is input as a heat-source and CO_2 source. The thinking on where to account for CO_2 emissions from coke is the same as that for Iron and steel production.

The *2006 IPCC Guidelines* offer a method to calculate CO_2 emissions from calcinating trona (Na_2CO_3-$NaHCO_3$-$2H_2O$), but these emissions are not estimated because in Japan soda ash has never been manufactured by trona calcination.

4.3.8. Petrochemical and Carbon Black Production (2.B.8.)

4.3.8.1. Methanol (2.B.8.a.)

a) Category Description

CO_2 and CH_4 are emitted during the production of methanol.

b) Methodological Issues

- ***Estimation Method***

CO_2 and CH_4 emissions from methanol production are calculated using the Tier 1 method given in the *2006 IPCC Guidelines*.

According to industry organizations, the production (synthesis) of methanol stopped in Japan in 1995 due to the price difference with overseas methanol. Since then all methanol has been imported, and methanol production plants disappeared from Japan in about 1995.

Accordingly, from FY1990 to FY1995, emissions are reported using the production amounts from industry organization statistics. For FY1996 and thereafter, emissions are reported as "NO" because it is assumed that methanol has not been produced (synthesized) since 1995.

- ***Emission Factors***

The default value for CO_2 from methanol given in the *2006 IPCC Guidelines* which corresponds to Japan's country-specific production method was used. The emission factor is 0.67 [t-CO_2/t] (Refer to

the *2006 IPCC Guidelines* Vol. 3 p 3.73, Table 3.12).

The default value for CH_4 from methanol given in the *2006 IPCC Guidelines* was used. The emission factor is 2.3 [kg-CH_4/t] (Refer to the *2006 IPCC Guidelines* Vol. 3 p 3.74).

- ***Activity Data***

Production amounts of methanol (calendar year basis) provided by Methanol and Formalin Association were used as activity data for CO_2 and CH_4 emissions from methanol production.

Table 4-20 Methanol Production Amount

Item	Unit	1990	1995	1996 onward
Methanol production	kt	84	75	NO

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainty of the emission factor, the default values from the *2006 IPCC Guidelines* of -30 to +30% (CO_2) and -80 to +30% (CH_4) were used. For the uncertainty of activity data, the default values of similar chemical products from the *2006 IPCC Guidelines* of -5 to +5% were used. As a result, the uncertainty of CO_2 and CH_4 emissions were estimated to be -30 to +30% and -80 to +30%, respectively.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time-series. The emission factor is constant throughout the time-series. Therefore, CO_2 and CH_4 emissions from methanol production have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.8.2. Ethylene (2.B.8.b.)

a) Category Description

1) CO_2, CH_4

CO_2 is emitted in the ethylene production process. CH_4 is emitted by naphtha cracking through steam cracking in the ethylene production process.

Carbon losses in the ethylene production process are accounted for under petrochemicals in the Energy transformation & own use sector of the *General Energy Statistics* (Energy Balance Table). The petrochemicals sector represents the process of production of by-products such as refinery gas, fuels, and other oil products, from the factories that produce basic chemical feedstock from naphtha and reformed material oil, by regarding it as energy conversion.

2) N_2O

There is almost no nitrogen contained in naphtha, the raw material of ethylene, and the ethylene production process takes place under conditions that are almost completely devoid of oxygen. In accordance with expert judgment, there is theoretically no N_2O emissions.

b) Methodological Issues

- ***Estimation Method***

CH_4 and CO_2 emissions from ethylene production were calculated by multiplying ethylene production by Japan's country-specific emission factor, in accordance with the Tier 1 method in the *2006 IPCC Guidelines*. CO_2 emissions from the energy use of industrial process off gases obtained from the feedstocks in Japan's ethylene production (steam cracking process) are considered to be included in emissions from Refinery Gas under Petrochemical – Energy Use in the *General Energy Statistics*. These emissions are already accounted for in 'Manufacturing industries and construction – Chemicals (1.A.2.c.)'.

- ***Emission Factors***

➢ ***CO_2***

The country-specific emission factor was set, based on a survey conducted by Japan Petrochemical Industry Association (JPIA) in 2009 on the CO_2 emission factor from ethylene production. This CO_2 EF was established based on CO_2 emissions from decoking, etc. and ethylene production data from all ethylene manufacturers collected by JPIA. Based on confirmation of the coverage of this country-specific EF with JPIA, the emission processes investigated for establishing the country-specific EF includes decoking, and therefore processes that emit CO_2 from non-energy origins are covered in this survey.

Additionally, Japan considers that there is a difference between the IPCC default EF, which includes CO_2 emissions from the energy use of by-product gases obtained from feedstocks, and the country-specific EF, which does not, because CO_2 emissions from the energy use of by-product gases obtained from feedstocks are allocated under the category 1.A.2.c as described above. Japan also confirmed that the scale of and trend in CO_2 emissions accounted for under the category Manufacturing industries and construction – Chemicals (1.A.2.c) are roughly consistent with trial estimations obtained using the IPCC default value. This emission factor is confidential.

➢ ***CH_4***

Estimates of amount of exhaust gas from flare stacks at a normal operation and an unsteady operation at operating sites in Japan (assuming that 98% of the amount that enters is combusted[2]), and measured amount of exhaust gas from naphtha cracking furnaces and furnaces heated by re-cycled gas, were divided by the production amount to calculate emission factors for each company. The weighted average based on production from each company was then applied to establish the emission factor. (Surveyed by JPIA) This emission factor is confidential.

According to JPIA, fugitive emissions in plants are controlled to be below detectable levels (nearly zero) under the High Pressure Gas Safety Act. Therefore, it is considered that there are nearly no fugitive emissions from flanges, valves, and other process equipment during the steam cracking of naphtha.

[2] The assumption was originally set based on a flaring efficiency of 98% shown in the *GPG2000* (Table 2.16 note e). The same value is also adopted in the *2006 IPCC Guidelines* (Vol. 2, Table 4.2.4, note e).

- ***Activity Data***

Ethylene production amounts from the *Yearbook of Current Production Statistics – Chemical Industry* were used as activity data for emissions of CH_4 and CO_2 from ethylene production.

Table 4-21 Ethylene Production Amount

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Ethylene production	kt	5,966	6,951	7,566	7,549	6,999	6,764	6,780	6,043	6,102	5,482	5,276	4,976

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainty for both CO_2 and CH_4 emission factors for ethylene were calculated by finding the 95% confidence interval of emission factors. The estimated uncertainty for both CO_2 and CH_4 was 77%. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty for both CO_2 and CH_4 was estimated to be 77%.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time-series. The emission factor is constant throughout the time-series. Therefore, CO_2 and CH_4 emissions from ethylene production have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

Recalculations of CO_2 and CH_4 emissions occurred due to updates in the *Yearbook of Current Production Statistics – Chemical Industry* for FY2023. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.8.3. 1,2-Dichloroethane and Chloroethylene (2.B.8.c.)

a) Category Description

1) CO_2

1,2-dichloroethane (Ethylene Dichloride) is a precursor of polyvinyl chloride and is mainly used for chloroethylene (VCM) production. It is also used for cleaning agents, solvents, pesticides, and fumigants, etc. It is manufactured by the direct chlorination process or the oxychlorination process, or by a process combining the two. The direct chlorination process involves gas-phase reaction of ethylene with chlorine to produce ethylene dichloride, and the oxychlorination process involves gas-phase reaction of ethylene with hydrochloric acid and oxygen to produce ethylene dichloride. The oxychlorination process produces CO_2 from the oxidation of ethylene (see below).

$$C_2H_4 + 0.5O_2 + 2HCl \rightarrow C_2H_4Cl_2 + H_2O$$

$$[C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2\ H_2O]$$

The ethylene dichloride is cracked to produce chloroethylene monomers, a precursor of polyvinyl chloride, and hydrochloric acid. The ethylene dichloride is cracked to produce chloroethylene monomers, a precursor of polyvinyl chloride, and hydrochloric acid. Since hydrochloric acid can be utilized in the oxychlorination process, the combined process of the two spread widely. CO_2 is emitted through the same chemical reactions as the above in the combined process.

2) CH_4

1,2-dichloroethane passes through washing, refining, and thermolysis processes to become chloroethylene (C_2H_3Cl). A very small amount of CH_4 is contained in the exhaust gases of the reaction, and of the washing and refining processes.

b) Methodological Issues

- ***Estimation Method***

CO_2 emissions are calculated by multiplying the production amount by Japan's country-specific emission factor, based on plant-specific data, in accordance with the Tier 1 method in the *2006 IPCC Guidelines*.

For years FY1990 to FY2000, CH_4 emissions are calculated by multiplying the production amount by Japan's country-specific emission factor, based on plant-specific data, in accordance with the Tier 1 method in the *2006 IPCC Guidelines*. According to Vinyl Environmental Council, equipment installation for exhaust gas combustion was completed for all plants, and the CH_4 contained in the tail gas is below detectable levels. Therefore, emissions are reported as "NO" for years FY2001 and onward. (The amount combusted is reported as recovered)

- ***Emission Factors***

  - ***CO_2***

A CO_2 emission factor (0.0647 t-CO_2/tVCM) per chloroethylene production provided by the Vinyl Environmental Council was applied for all years.

This emission factor was established by dividing the total measured CO_2 emissions across all five plants producing 1,2-dichloroethane and chloroethylene in 2012, by the total chloroethylene production amounts in 2012.

The default value 0.294 t-CO_2/t-VCM also accounts for CO_2 emitted from combustion of auxiliary fuel, but for the above country-specific emission factor, this is removed in order to avoid double-counting with the energy sector, resulting in a lower value than the default.

  - ***CH_4***

The concentration of CH_4 in exhaust gas from three member companies of the Vinyl Environmental Council (representing approximately 70% of total 1,2-dichloroethane production in Japan) was measured, and a weighted average was calculated to establish the emission factor. (Years FY1990 to FY2000) The emission factor is 0.0050 [kg-CH_4/t]. Based on the information on the production processes in each Dichloroethane producing company, the representativeness of the EF has been confirmed. (Surveyed by the Vinyl Environmental Council) The installation of equipment for exhaust gas combustion has progressed, and due to this, the fraction of CH_4 in the tail gas is lower than the default value and is now below detectable levels. No emission factors are set for years FY2001 and onward.

- ***Activity Data***

VCM (Chloroethylene) production amounts from the *Yearbook of Current Production Statistics – Chemical Industry* were used as activity data for CO_2 emissions.

1,2-Dichloroethane production amounts from the *Yearbook of Current Production Statistics – Chemical Industry* were used as activity data for CH_4 emissions.

Table 4-22 VCM (Chloroethylene) Production Amount

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
VCM production amount	kt	2,316	2,648	2,976	3,098	2,850	2,286	2,616	2,690	2,735	2,615	2,594	2,459

Table 4-23 1,2-Dichloroethane Production Amount

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
1,2-Dichloroethane production	kt	2,683	3,014	3,346	3,639	3,155	2,733	3,003	3,263	3,451	3,279	3,297	3,067

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainty of the CO_2 and CH_4 emission factors for 1,2-dichloroethane production, the default values of -50 to +20% and -10 to +10% in the *2006 IPCC Guidelines* were respectively applied. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty of 1,2-dichloroethane production was estimated to be -50 to +21% and -11 to +11%, respectively.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time-series. The emission factor is constant throughout the time-series. Therefore, CH_4 emissions from 1,2-Dichloroethane production have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.8.4. Ethylene Oxide (2.B.8.d.)

a) Category Description

Ethylene oxide is produced by reacting ethylene with oxygen over a catalyst, with CO_2 released as a by-product (see below). There are two methods in providing oxygen; one through providing air, and the other through providing pure oxygen separated from air.

$$C_2H_4 + 0.5O_2 \rightarrow C_2H_4O$$

$$C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$$

The CO_2 emitted is partially vented into the atmosphere, and is partially recovered by a carbonate solution to be used in food and beverage production, etc.

Generally, ethylene oxide production is a process where gases are recycled, and therefore it is necessary to partially purge the gases out of the system so to suppress the rise in pressure due to the accumulation of non- reactive fine impurities (such as argon or nitrogen) contained in the raw material gas, which results in gas emissions. This contains gases such as ethylene, methane, oxygen, or argon, and are generally flared as they are, but CH_4 may be emitted through leakage or venting.

b) Methodological Issues

- ***Estimation Method***

  - ***CO_2***

Following the Tier 3 method in the *2006 IPCC Guidelines*, emissions are estimated by multiplying the total domestic production amount by a country-specific emission factor established based on factory-specific data. CO_2 recoveries for liquefied CO_2 are subtracted from the CO_2 emissions from ethylene oxide production. See section 4.9.1. for details of the allocation of CO_2 emissions from the utilization of CO_2 recovered.

$$E_{CO2} = EO \times EF - R$$

E_{CO2} : CO_2 emissions from ethylene oxide production [t-CO_2]
EO : Ethylene oxide production amount per year [t]
EF : CO_2 emissions per ethylene oxide production amount [t-CO_2/t]
R : CO_2 recoveries from ethylene oxide production [t]

  - ***CH_4***

Following the Tier 1 method in the *2006 IPCC Guidelines*, emissions are estimated by multiplying the total domestic production amount by a country-specific emission factor established based on factory-specific data.

- ***Emission Factors***

  - ***CO_2***

EFs per production amount (0.33 t-CO_2/t) are used. (provided by Japan Petrochemical Industry Association) The EFs are a simple average of factory-specific EFs for all factories in Japan, and are based on the carbon balance, etc. of the amounts of raw or secondary material input, and amounts of product or by-product output. The production amounts per factory are confidential, and therefore a weighted average cannot be taken. Additionally, since all ethylene oxide is produced by the same process (the Oxygen method), it is considered that a simple average would not divert far from the actual conditions. In the Oxygen method applied in Japan, the selectivity of the catalyst is higher than that of the default, and therefore the EF is lower than the default value of 0.663 t-CO_2/t.

  - ***CH_4***

An EF based on measured data and specific to the manufacturer is used. The CH_4 emission data used to establish the EF is estimated by the manufacturer based on an estimation of CH_4 emissions into the atmosphere, which is further based on the CH_4 amount in the gas introduced from outside when gases are purged from the process. Data are only available from FY2004, and therefore for the preceding years, a three-year average of data from FY2004 to FY2006 will be taken and applied. The data is confidential.

- ***Activity Data***

  - ***CO_2***

The ethylene oxide production amounts in the *Yearbook of Current Production Statistics – Chemical Industry* are used. (Table 4-24)

Table 4-24 Ethylene Oxide Production Amount

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Ethylene oxide production	kt	714	795	961	1,001	843	915	923	790	818	618	569	539

  - ***CH_4***

The ethylene oxide production amount at the one manufacturer is used. The data is confidential.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainty for the CO_2 emission factor, the default value of 10% specified in the *2006 IPCC Guidelines* was applied. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty of emissions was estimated at 11%.

For the uncertainty for the CH_4 emission factor, the default value of 60% specified in the *2006 IPCC Guidelines* was applied. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty of emissions was estimated at 60%.

- ***Time-series Consistency***

For activity data, the same source – the *Yearbook of Current Production Statistics – Chemical Industry* and data from one manufacturer are used throughout the time-series. The emission factor is set based on data from the same sources. Therefore, CO_2 and CH_4 emissions from ethylene oxide production have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.8.5. Acrylonitrile (2.B.8.e.)

a) Category Description

1) CO_2

Acrylonitrile (C_3H_3N) is used as raw material for acrylic fiber or synthetic resin and is mainly manufactured by way of direct ammoxidation of propylene with ammonia and oxygen over a metal catalyst. (SOHIO process) On the order of 85 percent of the propylene feedstock is converted to either the primary product acrylonitrile or secondary products acetonitrile or hydrogen cyanide (see below chemical equations 1 to 3). The remainder of the propylene feedstock is either converted to other hydrocarbons through side reactions in the ammoxidation process or converted directly to CO_2 by direct

oxidation of the feedstock in the ammoxidation process (see below chemical equation 4).

Equation 1: Acrylonitrile reaction

$$CH_2 = CHCH_3 + 1.5O_2 + NH_3 \rightarrow CH_2 = CHCN + 3H_2O$$

Equation 2: Hydrogen cyanide reaction

$$CH_2 = CHCH_3 + 3O_2 + 3NH_3 \rightarrow 3HCN + 6H_2O$$

Equation 3: Acetonitrile reaction

$$CH_2 = CHCH_3 + 1.5O_2 + 1.5NH_3 \rightarrow 1.5CH_3CN + 3H_2O$$

Equation 4: Feedstock oxidation

$$CH_2 = CHCH_3 + 4.5O_2 \rightarrow 3CO_2 + 3H_2O$$

2) CH_4

The CH_4 in off-gases are analyzed in the plants manufacturing acrylonitrile, but since no emissions are detected, they are reported as “NA”.

b) Methodological Issues

- ***Estimation Method***

Emissions are calculated by multiplying the acrylonitrile production amount by Japan’s country-specific emission factor, based on plant-specific data, in accordance with the Tier 3 method in the *2006 IPCC Guidelines*.

- ***Emission Factors***

A CO_2 emission factor per production (0.73 t-CO_2/t, provided by Japan Petrochemical Industry Association) is applied for all years. This emission factor is an arithmetic mean of plant-specific CO_2 emission factors for all plants, based on the carbon balance of raw material and secondary material input and product and by-product output for each plant. This is done due to the fact that production data for each plant are confidential, and this does not allow for taking a weighted average, and that acrylonitrile is manufactured by the same process throughout Japan (SOHIO process), which means that taking an arithmetic mean will not deviate far from actual conditions.

In the acrylonitrile manufacturing processes in Japan, acetonitrile and hydrogen cyanide are collected as products, and therefore the emission factor is close to the default value in the *2006 IPCC Guidelines* (0.79 t-CO_2/t). The reason for it being slightly lower is due to efforts made to improve the efficiency of production.

- ***Activity Data***

Acrylonitrile production amounts given in the *Yearbook of Current Production Statistics – Chemical Industry* were used for activity data.

Table 4-25 Acrylonitrile Production Amount

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Acrylonitrile production	kt	602	652	734	697	718	499	431	420	445	402	336	278

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainty of the emission factor, the default value of 60% in the *2006 IPCC Guidelines* was used. For the uncertainty of activity data, the default value of 5% in the *2006 IPCC Guidelines* was used. As a result, the uncertainty of emissions was estimated at 60%.

- ***Time-series Consistency***

For activity data, the same source, the *Yearbook of Current Production Statistics – Chemical Industry,* are used throughout the time-series. The emission factor is constant throughout the time-series. Therefore, CO_2 emissions from acrylonitrile production have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.8.6. Carbon Black (2.B.8.f.)

a) Category Description

Carbon black is mainly produced from the partial combustion of byproduct oil and gas from the petroleum refining and metallurgical refining processes in a high temperature atmosphere. (furnace black process) The CO_2 and CH_4 in the tail gas (off gas) emitted from the carbon black production process is released into the atmosphere.

b) Methodological Issues

- ***Estimation Method***

➢ ***CO_2***

CO_2 emissions from carbon black production are calculated by multiplying the carbon black production amount by Japan's country-specific emission factor, in accordance with the Tier 1 method in the *2006 IPCC Guidelines*.

➢ ***CH_4***

CH_4 emissions from carbon black production are calculated by multiplying the carbon black production amount by Japan's country-specific emission factor, established based on plant-specific data, in accordance with the Tier 1 method in the *2006 IPCC Guidelines*.

- ***Emission Factors***

➢ ***CO_2***

Since it is considered that the CO_2 from natural gas that is used to heat the furnace (secondary feedstock origin) is already accounted for under Fuel combustion (1.A.), only CO_2 from the oil and gas used

directly as raw material (primary feedstock origin) is accounted for here. A CO_2 emission factor per production (2.06 t-CO_2/t) provided by Carbon Black Association is used. This is established by taking a weighted average of total CO_2 measurements (subtracting out the carbon left over in the product from the carbon in the raw material, then dividing it by the weight of the product) for all five member companies' plants, with the production amounts of each company. Since these five companies cover over 95% of domestic production and sales, the emission factor is considered representative for Japan. All companies use the oil furnace process, and therefore emission factors do not differ much nor vary much annually.

➢ ***CH_4***

In carbon black manufacturing plants in Japan, CH_4 is only emitted into the atmosphere during non-steady operation, when venting is done at shutdowns and startups. According to the *Carbon Black Handbook* (Carbon Black Association), the concentrations of CH_4, and the concentrations of CO, CO_2, and CH_4 combined in the average tail gas are 0.6wt% and 21.5wt% respectively, and this is the same for during shutdowns and startups. Therefore, the CH_4 emission factor can be calculated from the CO_2 emission factor (2.06 t-CO_2/t) as below. The data is confidential.

$$EF_{CH4} = 2.06\ [\text{t-CO}_2/\text{t}] \times R \times 0.6\ [\text{wt\%}] / 21.5\ [\text{wt\%}] \times 16/44$$

EF_{CH4} : EF for carbon black production

R : The ratio of venting time at shutdowns and startups to the total operation time

No gas leakage occurs from the system, since inside the process the air pressure is negative, and therefore only emissions associated with venting is estimated.

● ***Activity Data***

Carbon black production amounts given in the *Yearbook of Current Production Statistics – Chemical Industry* were used for activity data for both CO_2 and CH_4 emissions associated with the manufacturing of carbon black.

Table 4-26 Carbon Black Production Amount

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Carbon black production	kt	793	759	772	805	730	628	563	476	582	560	542	513

c) Uncertainty Assessment and Time-series Consistency

● ***Uncertainty Assessment***

The uncertainty for the emission factor was calculated by finding the 95% confidence interval of emission factors. The estimated uncertainty was 55% for both CO_2 and CH_4. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used for both CO_2 and CH_4. As a result, the uncertainty of emissions was estimated at 55% for both CO_2 and CH_4.

● ***Time-series Consistency***

For activity data, the same source, the *Yearbook of Current Production Statistics – Chemical Industry*, are used throughout the time-series. The emission factor is constant throughout the time-series. Therefore, emissions have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.8.7. Other (2.b.8.g.)

4.3.8.7.a. Styrene (2.B.8.g.i.)

a) Category Description

CH_4 is emitted in the styrene production process.

b) Methodological Issues

- ***Estimation Method***

CH_4 emissions from styrene production were calculated by multiplying styrene production amount by Japan's country-specific emission factor, based on the method given in the *2006 IPCC Guidelines*.

- ***Emission Factors***

Estimates of amount of exhaust gas from flare stacks at a normal operation and an unsteady operation at operating sites in Japan (assuming that 98% of the amount that enters is combusted. See footnote 2) in section 4.3.8.2. b), and measured amount of waste gas from heating furnaces, were divided by the production amount to calculate emission factors for each company. The weighted average by production from each company was then applied to establish the emission factor. (Surveyed by Japan Petrochemical Industry Association) This emission factor is confidential.

- ***Activity Data***

Styrene monomer production amounts from the *Yearbook of Current Production Statistics – Chemical Industry* were used as activity data for CH_4 emissions from styrene production.

Table 4-27 Styrene Monomer Production Amount

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Styrene production	kt	2,227	2,952	3,020	3,375	3,019	2,539	2,260	1,874	1,898	1,496	1,420	1,255

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainty for the CH_4 emission factor for styrene production was estimated by finding the 95% confidence interval of emission factors. The estimated uncertainty was 113%. For the uncertainty of activity data, the standard value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty of emissions was estimated to be 113%.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time-series. The emission factor is constant throughout the time-series. Therefore, CH_4 emissions from styrene production have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.8.7.b. Phthalic Anhydride (2.B.8.g.ii.−)

a) Category Description

Phthalic anhydride is used as raw material for plasticizers, synthetic resins, paints, dyes, etc. CO and CO_2 are emitted during the oxidation of naphthalene and o-xylene in the production process of Phthalic anhydride. CO is also combusted and ultimately emitted as CO_2.

b) Methodological Issues

- ***Estimation Method***

The production amount of phthalic anhydride is multiplied by an emission factor per production amount to calculate emissions.

- ***Emission Factors***

The CO_2 generation rate (mol %) was calculated by assuming that carbon that did not become products or other by-products ultimately become CO_2, and by using the yield of products or other by-products (mol %) per production process of phthalic anhydride (*Petrochemical Processes* (The Japan Petroleum Institute)). The CO_2 generation rate also takes into account CO_2 generated during the production of phthalic anhydride and maleic anhydride. The EFs in each production process are calculated from the CO_2 emissions per production amount, based on the generation rate of CO_2 and products and the molecular weight of each substance. The yield is shown with an upper limit and lower limit in *Petrochemical Processes*, and therefore EFs are set using the median value.

Table 4-28 Generation Rate of Each Substance by Production Process of Phthalic Anhydride

Production process	Product yield	Maleic Anhydride	Other	CO_2 *	EF *
Oxidation of naphthalene	87-91 [mol %]	4-6 [mol %]	1 [mol %]	200-226 [mol %]	0.71 [t-CO_2/t]
Oxidation of o-xylene	80-82 [mol %]	3-5 [mol %]	1-2 [mol %]	22-36 [mol %]	0.11 [t-CO_2/t]

Reference: *Petrochemical Processes* (excluding*)

Following this, a weighted average is taken for each year to set the EF for all of Japan. This is based on the productive capacity by year and by production process in the *Chemicals Handbook* (The Heavy and Chemical Industries News Agency)

Table 4-29 Weighted Average EF Based on Productive Capacity of Phthalic Anhydride

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
EFs for phthalic anhydride production	t-CO_2/t	0.36	0.36	0.33	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39	0.39

Note: No information is available on the productive capacity per production process prior to FY1996, and therefore the FY1996 value is used for the preceding years.

- ***Activity Data***

The production amounts of phthalic anhydride in the *Yearbook of Current Production Statistics – Chemical Industry* are used.

Table 4-30 Phthalic Anhydride Production Amount

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Phthalic anhydride production	kt	300	319	288	216	160	158	159	137	151	142	138	123

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainty of the emission factor, a 197% value, derived from the upper/lower limits of the generation rate of CO_2 and products which were used to establish the emissions factor, was used. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty of emissions was estimated at 197%.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time-series. The emission factor is based on a consistent methodology throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.8.7.c. Maleic Anhydride (2.B.8.g.iii.-)

a) Category Description

Maleic anhydride is used as raw material for unsaturated polyester resins, or for resin improving agents, food additives, pharmaceutical ingredients, or synthetic raw material for organic acids such as malic acid and succinic acid. CO and CO_2 are emitted during the oxidation of benzene and n-butane in the production process of maleic anhydride. CO is also combusted and ultimately emitted as CO_2.

b) Methodological Issues

- ***Estimation Method***

The production amount of maleic anhydride is multiplied by an emission factor per production amount to calculate emissions.

- ***Emission Factors***

The CO_2 generation rate (mol %) was calculated by assuming that carbon that did not become products or other by-products ultimately become CO_2, and by using the yield of products or other by-products (mol %) per production process of maleic anhydride (*Petrochemical Processes*). The CO_2 generation rate also takes into account CO_2 generated during the production of maleic anhydride. The EFs in each

production process are calculated from the CO_2 emissions per production amount, based on the generation rate of CO_2 and products and the molecular weight of each substance. The yield is shown with an upper limit and lower limit in *Petrochemical Processes*, and therefore EFs are set using the median value.

Table 4-31 Generation Rate of Each Substance by Production Process of Maleic Anhydride

Production process	Product yield	CO_2 *	EF *
Oxidation of benzene	70-80 [mol %]	160-190 [mol %]	1.05 [t-CO_2/t]
Oxidation of n-butane	55-60 [mol %]	40-45 [mol %]	0.33 [t-CO_2/t]

Reference: *Petrochemical Processes* (excluding *)

Following this, a weighted average is taken for each year to set the EF for all of Japan. This is based on the productive capacity by year and by production process in the *Chemicals Handbook*

Table 4-32 Weighted Average EF Based on Productive Capacity of Maleic Anhydride

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
EFs for maleic anhydride production	t-CO_2/t	0.69	0.69	0.66	0.76	0.76	0.82	0.82	0.79	0.79	0.79	0.79	0.79

Note: No information is available on the productive capacity per production process prior to FY1996, and therefore the FY1996 value is used for the preceding years.

- ***Activity Data***

The production amounts of maleic anhydride in the *Yearbook of Current Production Statistics – Chemical Industry* are used.

Table 4-33 Maleic Anhydride Production Amount

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Maleic anhydride production	kt	103	116	132	103	93	86	87	74	87	77	72	64

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainty of the emission factor, a 213% value, derived from the upper/lower limits of the generation rate of CO_2 and products which was used to establish the emissions factor, was used. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty of emissions was estimated at 213%.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time-series. The emission factor is based on a consistent methodology throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.9. Fluorochemical Production (2.B.9.)

4.3.9.1. By-product Emissions - Production of HCFC-22 (2.B.9.a.i.)

a) Category Description

HFC-23 is generated as a by-product of HCFC-22 production.

b) Methodological Issues

- ***Estimation Method***

Emissions are estimated by subtracting the recovery and destruction amount of by-product HFC-23 (measured data) from the amount of by-product HFC-23 generated at HCFC-22 production plants in Japan. The amount of by-product HFC-23 was estimated by multiplying the production of HCFC-22 by the generation rate of HFC-23 (obtained from the results of composition analysis of the interior of a reactor). Emission factors are country-specific.

The recovery/destruction units are constantly running when the plants are in operation. If any trouble arises in the units, management practices are to stop the plant operation, and for any portion of emissions without recovery/destruction, this is reflected in the data.

$$E = P_{HCFC\text{-}22} \times EF - R$$

E : Emissions of by-product HFC-23 associated with the production of HCFC-22 [t]
$P_{HCFC\text{-}22}$: Production of HCFC-22 [t]
EF : Rate of generation of HFC-23 [%]
R : Amount of recovery and destruction [t]

Table 4-34 Indices Related to By-product Emissions of HFC-23: Production of HCFC-22

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Production of HCFC-22	t	60,122	81,000	95,271	65,715	46,149	47,546	49,116	44,733	53,326	55,255	50,900	49,783
Rate of generation of HFC-23	%	2.13%	2.13%	1.70%	1.90%	2.01%	1.41%	1.46%	2.06%	1.81%	2.04%	2.01%	1.61%
Emission rate to production of HCFC-22	%	1.79%	1.79%	1.11%	0.06%	0.01%	0.002%	0.004%	0.021%	0.017%	0.001%	0.0004%	0.0006%
Emissions	t	1,076.27	1,450.00	1,060.00	39.60	3.60	1.10	2.00	9.50	8.90	0.30	0.20	0.30
	kt-CO_2 eq.	13,346	17,980	13,144	491	45	14	25	118	110	4	2	4

Reference: *Documents of Fluorocarbons etc. Measures Working Group, Group for Chemical Substance Policy, Manufacturing Industries Sub-Group, Industrial Structure Council, Ministry of Economy, Trade and Industry* (hereafter, *Documents of Fluorocarbons etc. Measures Working Group*), *Documents of the first meeting of the Breakout Group on F-gases, FY2013 Committee for the Greenhouse Gas Emissions Estimation Methods* (hereafter, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*)

Note: Emissions decreased because all manufacturing facilities were equipped with recovery/destruction units in 2004. The low emission rate to production is due to efforts made to prevent the fall of the operating rates through the improvement in techniques of operation management of destruction facilities and maintenance. Emission reduction has further advanced since, with continuous efforts made in improvement of operation management techniques etc.

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using the combined HCFC-22 production amounts for the purpose of material for fluorocarbon polymers (estimated from the production amounts of fluorocarbon polymers and the ratio of HCFC-22 production amounts for the purpose of material for fluorocarbon polymers to the production amounts of fluorocarbon polymers (an average of 1995-2006 where data were available)) and HCFC-22 production amounts for the purpose of refrigerants (estimated from total HCFC-22 shipment amounts[3], and HCFC-22 shipment amounts for the purpose of refrigerants from 1995) as data for total HCFC-22

[3] *Documents of the first meeting of the Group for global warming chemicals, Risk Management Sub-Group, Chemicals Council* (MITI).

production amounts, and by using data on the emission rate to the production of HCFC-22 from 1995, and extrapolating for these years.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainty of the emissions, a 2% value from the *2006 IPCC Guidelines* was applied.

- ***Time-series Consistency***

For years after 1995, the Manufacturing Industries Sub-Group, Ministry of Economy, Trade and Industry annually collects and estimates F-gas emissions. For the years 1990 to 1994, estimates have been done by extrapolation, etc. of relevant data from 1995 onward, and therefore time-series consistency is taken into account to the extent possible.

d) Category-specific QA/QC and Verification

The data collected and estimated by the Manufacturing Industries Sub-Group, Ministry of Economy, Trade and Industry, is checked by the Committee for Greenhouse Gas Estimation Methods and is used in the inventory. Emissions are surveyed for all production plants in Japan. Composition analysis is carried out frequently, as in the case where one plant takes measurements every day. Concentration measurements are implemented at the vent of the plant.

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.9.2. Fugitive Emissions (2.B.9.b.)

a) Category Description

HFCs, PFCs, SF_6, and NF_3 are emitted as fugitive emissions during manufacturing. Regarding returned gas cylinders, when residual gas is decomposed and the containment shell is cleansed, or when there is release into the atmosphere, these emissions are reported under this subcategory.

b) Methodological Issues

- ***Estimation Method***

Emissions were reported based on measurement data at each of HFCs, PFCs, SF_6, and NF_3 manufacturing plant in Japan. Recovery, etc. is hereby taken into account. The recovery/destruction units are constantly running when the plants are in operation. If any trouble arises in the units, management practices are to stop the plant operation.

The associated indices are given in the table below.

Table 4-35 Fugitive Emissions from HFC Production

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
HFCs Emissions	kt-CO_2 eq.	1	503	264	407	115	119	75	69	109	63	85	60

Reference: *Documents of Fluorocarbons etc. Measures Working Group* (data from Japan Fluorocarbon Manufactures Association), and data provided by METI, *Documents of the first meeting of the Breakout Group on F-gases and FY2013 Committee for the Greenhouse Gas Emissions Estimation Methods*

Note: With emission reduction measures such as installation of destruction units subsidized by the government, and re-evaluation of the production processes, emission reduction has advanced.

Table 4-36 Fugitive Emissions from PFC Production

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
PFCs Emissions	kt-CO_2 eq.	304	840	1,499	955	227	100	104	67	72	67	37	32

Reference: *Documents of Fluorocarbons etc. Measures Working Group* (data from Japan Chemical Industry Association), *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Note: With emission reduction measures such as installation of destruction units subsidized by the government, and re-evaluation of the production processes, emission reduction has advanced. The installation of destruction units in 2011 for lean gas emitted further contributed to the achievement of emission reduction.

Table 4-37 Indices Related to Fugitive Emissions from SF_6 Production

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Production of SF_6	t	1,848.36	2,392.00	1,556.00	2,313.00	2,201.00	2,128.00	2,027.00	1,260.00	1,307.20	1,229.80	945.23	1,042.34
Emissions	t	152.23	197.00	36.00	40.80	8.30	4.07	2.30	2.28	2.00	1.44	1.00	1.76
	kt-CO_2 eq.	3,577	4,630	846	959	195	96	54	54	47	34	24	41

Reference: *Documents of Fluorocarbons etc. Measures Working Group* (data from Japan Chemical Industry Association), *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Note: Emissions decreased because all manufacturing facilities were equipped with recovery/destruction units in 2009. Re-evaluation of the production processes and handling at shipment has also advanced emission reduction.

Table 4-38 Indices Related to Fugitive Emissions from NF_3 Production

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Production of NF_3	t	6.00	37.00	208.00	1,663.00	3,642.00	4,148.00	4,963.00	4,037.00	4,191.00	4,172.00	3,006.46	3,537.00
Emissions	t	0.16	1.00	7.00	72.10	76.90	86.40	23.50	0.88	1.39	1.19	0.84	0.76
	kt-CO_2 eq.	3	16	113	1,161	1,238	1,391	378	14	22	19	14	12

Reference: *Documents of Fluorocarbons etc. Measures Working Group* (data from Japan Chemical Industry Association)

Note: Emission reduction has advanced through the expansion of destruction unit installation, etc. from mid-2014.

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using HFC, PFC, and SF_6 shipment amounts[4] which is thought to be proportional to HFC, PFC, and SF_6 production amounts, and the ratio of emissions to the HFC, PFC, SF_6, and NF_3 production amounts from 1995, and weighted average GWPs for HFCs and PFCs from 1995, and extrapolating for these years.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainties of the emissions for all HFCs, PFCs, SF_6, and NF_3, a 2% value from the *2006 IPCC Guidelines* was applied.

[4] *Documents of the first meeting of the Group for global warming chemicals, Risk Management Sub-Group, Chemicals Council, 1997* (MITI). All further reference to 'shipment amounts' used for emission estimates for years 1990 to 1994 are from the same source.

- ***Time-series Consistency***

Same as Fluorochemical Production –By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.10. Other (2.B.10.)

4.3.10.1. Hydrogen Production (2.B.10.a.)

a) Category Description

CO_2 is emitted from the steam reforming process of fossil fuels such as natural gas, petroleum, etc. during hydrogen production. Hydrogen is produced as a by-product during petroleum refining, ethylene production, etc., and is recovered and used, however relevant emissions are already captured under other categories. Therefore, CO_2 generated from hydrogen production from raw materials, where the sole purpose is to obtain hydrogen, is addressed here.

b) Methodological Issues

- ***Estimation Method***

The production amount of hydrogen is multiplied by an emission factor per production amount to calculate emissions.

- ***Emission Factors***

The aggregated CO_2 emissions from industrial gas producers was divided by the aggregated production amounts of hydrogen to establish a CO_2 EF per production. Both aggregated values are based on values reported by member companies of Japan Industrial and Medical Gases Association (JIMGA).

Table 4-39 Emission Factors for Hydrogen Production

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
EFs for hydrogen production	t-CO_2/10^3Nm^3	0.82	0.83	0.83	0.88	0.87	0.86	0.85	0.83	0.82	0.83	0.80	0.80

- ***Activity Data***

The production amounts of hydrogen are for those processes that entail CO_2 emissions and are based on values reported by member companies of JIMGA.

Table 4-40 Hydrogen Production Amount

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Hydrogen production	10^3Nm^3	7,431	25,116	46,562	37,911	38,889	32,170	32,257	23,567	20,348	21,019	18,368	19,632

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainty value of 77% for ethylene production was used for the EF uncertainty. Similarly, for the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used. As a result, the uncertainty for CO_2 emissions from hydrogen production was estimated to be 77%.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time-series. The emission factor is based on a consistent methodology throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.10.2. Other – Utilization of Carbonated Gas (2.B.10.b.-)

Of the amount of CO_2, which was recovered for liquefied CO_2 and subtracted from the emissions from Petroleum refining (1.A.1.b.), Iron and steel (1.A.2.a.), Ammonia production (2.B.1.), and Ethylene oxide production (2.B.8.d.) categories, utilized amounts in the chemical industry are allocated under this category. See section 4.9.1. for details.

4.4. Metal Industry (2.C.)

This category covers CO_2, CH_4, HFC, PFC and SF_6 emissions from the manufacturing processes of metal products.

This section deals with the following sources: Iron and steel production (2.C.1.), Ferroalloys production (2.C.2.), Aluminium production (2.C.3.), Magnesium production (2.C.4.), Lead production (2.C.5.), Zinc production (2.C.6.), and Rare Earths Production (2.C.7.a.).

In FY2024, emissions from this category were 4,938 kt-CO_2 eq. and represented 0.5% of Japan's total GHG emissions (excluding LULUCF). The total emissions of CO_2 and CH_4 from this category decreased by 34.6% compared to FY1990. The total of HFCs, PFCs and SF_6 decreased by 66.4% compared to 1990.

Table 4-41 Emissions from Metal Industry (2.C.)

Gas				Units	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
CO_2	2.C.1	Iron and steel production	Use of electric arc furnaces in steel production	kt-CO_2	298	328	190	231	152	140	132	91	189	194	150	143
			Limestone and dolomite use in iron and steel production	kt-CO_2	6,884	6,492	6,537	6,222	5,919	5,950	5,701	4,791	5,044	4,802	4,678	4,584
			By-product gas flaring in iron and steel production	kt-CO_2	25	56	102	174	243	256	223	133	149	IE	IE	IE
			Utilization of carbonated gas	kt-CO_2	26	30	28	42	46	45	43	37	42	41	46	44
	2.C.3	Aluminium production		kt-CO_2	58	29	11	11	8	5	NO	NO	NO	NO	NO	NO
	Total			kt-CO_2	7,292	6,935	6,869	6,680	6,368	6,397	6,099	5,051	5,425	5,037	4,874	4,771
CH_4	2.C.1	Iron and steel production	Use of electric arc furnaces in steel production	kt-CH_4	0.74	0.72	0.67	0.68	0.59	0.60	0.55	0.49	0.56	0.54	0.52	0.49
	2.C.2	Ferroalloys production		kt-CH_4	0.19	0.14	0.13	0.13	0.12	0.13	0.12	0.08	0.10	0.08	0.06	0.05
	Total			kt-CH_4	0.92	0.85	0.80	0.80	0.71	0.73	0.67	0.57	0.66	0.61	0.58	0.53
	Total			kt-CO_2 eq.	26	24	22	23	20	20	19	16	19	17	16	15
Total of CO_2 and CH_4				kt-CO_2 eq.	7,318	6,959	6,891	6,702	6,388	6,417	6,117	5,067	5,443	5,054	4,890	4,786
Gas				Units	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
HFCs	2.C.4	Magnesium production		kt-CO_2 eq.	NO	NO	NO	NO	NO	1	1	1	2	1	2	1
PFCs	2.C.3	Aluminium production		kt-CO_2 eq.	301	153	39	32	23	14	NO	NO	NO	NO	NO	NO
SF_6	2.C.4	Magnesium production		t	6.43	5.00	42.93	48.42	12.88	6.86	10.31	12.81	13.81	12.38	9.22	6.42
				kt-CO_2 eq.	151	118	1,009	1,138	303	161	242	301	324	291	217	151
Total of F-gases				kt-CO_2 eq.	453	271	1,048	1,170	325	176	244	302	326	292	218	152

4.4.1. Iron and Steel Production (2.C.1.)

The *General Energy Statistics* (Energy Balance Table) is a statistic that provides a comprehensive overview of domestic energy supply and demand. As mentioned in Vol.3 section 4.2.1 of the *2006 IPCC Guidelines*, carbon serves a dual purpose in the iron making process, primarily as a reducing agent to convert iron oxides to iron, but also as an energy source to provide heat when carbon and oxygen react exothermically. Coke, etc. used as a reducing agent are included in the fuel consumption amounts in the *General Energy Statistics* and related emissions are comprehensively captured in Energy sector – iron and steel (1.A.2.a) in Japan. Therefore, allocating emissions from the consumption of reducing agents to the energy sector does not make a difference in total emissions, but is rather more accurate, because it ensures completeness. The sum of energy sector – iron and steel (1.A.2.a) and IPPU sector – iron and steel production (2.C.1) are comparable to the emissions that are calculated in line with the *2006 IPCC Guidelines* (see the table below).

Table 4-42 CO_2 Emissions from Iron and Steel Production (for Energy and Reducing Agent Use)

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
1.A.2.a (Energy sector - iron and steel)	kt-CO_2	150,631	143,009	151,989	153,979	153,050	157,467	148,743	111,881	124,672	114,068	112,788	108,727
2.C.1 (IPPU sector - iron and steel production)	kt-CO_2	7,532	7,233	7,048	6,900	6,512	6,532	6,230	5,142	5,614	5,231	5,024	4,914
Total of CO_2	kt-CO_2	158,163	150,242	159,036	160,879	159,562	163,999	154,973	117,023	130,287	119,300	117,812	113,641

The 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (hereafter *2019 Refinement*, See Vol.3 section 4.2.2.5) recommends, to avoid double counting and to ensure completeness, to cross-check the proper allocation of the emissions between the Energy and IPPU sectors, and to document where and how they are reported. It is difficult for Japan to differentiate and allocate between energy use and reducing agents use completely, but we have confirmed that all emissions from reducing agent consumption have been allocated without double-counting or omissions, for certain. Explanation on the category where it is allocated is also provided in this NID appropriately. Japan would also like to note that the following was agreed at the 17th meeting of the Inventory Lead Reviewers (LR) meeting (para 8 (b)): “The LRs further concluded that, when the Party is using a different allocation of emissions from that recommended in the *2006 IPCC Guidelines* and is reporting the emissions as ”IE” under the energy or IPPU sectors, the ERT should check whether the Party has transparently reported where the emissions have been included and ensured the accuracy of the estimates. If this is not the case, the ERT should follow up with a relevant recommendation” This

indicates that there is possibility to report with a different allocation.

The main types of reducing agents (fuels) and the corresponding production processes are as follows: coke (steel production, pig iron production, sinter production, and pellet production), pulverized coal/waste plastics (pig iron production). See also Table 3-10 and Table 7-28.

4.4.1.1. Steel (2.C.1.a.)

Coke oxidizes when it is used as a reduction agent in steel production, and CO_2 is generated. The amount of coke used has been included under consumption of fuel in the Fuel combustion category (1.A.), and the CO_2 generated through the oxidization of coke used as a reducing agent has already been calculated under Fuel combustion category (1.A.).

4.4.1.2. Use of Electric Arc Furnaces in Steel Production (2.C.1.a.)

a) Category Description

CO_2 is emitted from carbon electrodes when using electric arc furnaces to make steel. CH_4 is also emitted from electric arc furnaces during iron and steel production.

b) Methodological Issues

1) CO_2

- ***Estimation Method***

CO_2 emissions from arc furnaces for steel production are estimated by amount of carbon calculated by weight of production and import of carbon electrodes minus weight of export of carbon electrodes. This difference of the carbon is assumed to be diffused to the atmosphere as CO_2. The carbon included in electric furnaces gas given in the *General Energy Statistics* are subtracted from the CO_2 emission in this source since these emissions are included in the category Fuel combustion (1.A.).

CO_2 emissions from carbon electrodes during aluminium production is accounted for under Aluminium Production (2.C.3.) (see section 4.4.3) and are subtracted from the emissions from this category.

- ***Activity Data***

Production of carbon electrodes given in *Yearbook of Current Production Statistics – Mineral Resources and Petroleum Products, Ceramics and Building Materials* and import and export of carbon electrodes given in *Trade Statistics of Japan* are used.

Table 4-43 CO_2 emissions accounted under the Use of Electric Arc Furnaces in Steel Production (2.C.1.a.)

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
#A Import of carbon electrodes	t-C	12,341	18,463	11,363	15,075	17,321	19,960	18,209	17,380	23,099	21,195	18,706	19,966
#B Domestic production of carbon electrodes	t-C	211,933	186,143	184,728	216,061	205,081	180,322	151,979	76,338	103,026	107,352	103,250	92,179
#C Export of carbon electrodes	t-C	87,108	92,812	107,998	138,409	139,757	128,435	103,834	44,578	46,239	50,859	56,135	48,374
#D Domestic consumptions of carbon electrodes (#A + #B − #C) / 10^3	kt-C	137	112	88	93	83	72	66	49	80	78	66	64
CO_2 emissions from carbon electrodes (#D*44/12)	kt-CO_2	503	410	323	340	303	263	243	180	293	285	241	234
CO_2 emissions from electric furnace gas under 1.A.Fuel Combustion	kt-CO_2	-146	-52	-122	-98	-143	-118	-112	-89	-103	-91	-91	-91
CO_2 emissions under 2.C.3. Aluminium Production	kt-CO_2	-58	-29	-11	-11	-8	-5	NO	NO	NO	NO	NO	NO
CO_2 emissions	kt-CO_2	298	328	190	231	152	140	132	91	189	194	150	143

2) CH_4

- ***Estimation Method***

Emissions were calculated by multiplying an emission factor based on actual measurements obtained from electric arc furnace facilities in Japan by the energy consumption of electric arc furnaces.

- ***Emission Factors***

The emission factor of energy consumption of electric arc furnaces (12.8 kg-CH_4/TJ) was used (see section 4.3.5.1.b)).

- ***Activity Data***

Energy consumption amounts included in the "electric furnace" category for the iron and steel industries of the *General Energy Statistics* were used.

Table 4-44 Energy Consumption in Electric Arc Furnaces

Electricity consumption	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Electric furnaces	TJ	57,564	55,986	52,457	52,747	45,793	46,786	42,919	38,160	43,848	42,015	40,589	37,965

c) Uncertainty Assessment and Time-series Consistency

1) CO_2

- ***Uncertainty Assessment***

Because all CO_2 from electric arc furnaces is assumed to escape into the atmosphere, no emission factor has been set. Therefore, by assessing the uncertainty for activity data the uncertainty for emissions is assessed. As a result of combining the uncertainties of the parameters for activity data, the uncertainty was estimated to be 5%.

- ***Time-series Consistency***

For activity data (emissions), the same sources are used throughout the time-series. Therefore, CO_2 emissions from electric arc furnaces have been estimated in a consistent manner throughout the time-series.

2) CH_4

- ***Uncertainty Assessment***

The uncertainty for the emission factor has been estimated to be 163% and the uncertainty for activity data has been estimated to be 5% (see chapter 3). As a result, the uncertainty for CH_4 emissions has been estimated to be 163%.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time-series. The emission factor is constant throughout the time-series. Therefore, CH_4 emissions from electric arc furnaces in steel production have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.4.1.3. Pig Iron (2.C.1.b.)

1) CO_2

CO_2 generated from pig iron production is emitted when coke, pulverized coal, and waste plastics, are used as a reduction agent. The amount of coke, etc. used has been included under consumption of fuel in the Fuel combustion category (1.A.), and the CO_2 generated through the oxidization of coke, etc. used as a reducing agent has already been calculated under Fuel combustion category (1.A.).

2) CH_4

It is theoretically impossible for CH_4 generation in association with pig iron production, and it has been confirmed that CH_4 is not emitted from actual measurements. Therefore, emissions have been reported as "NA".

4.4.1.4. Limestone and Dolomite Use in Iron and Steel Production (2.C.1.b.)

a) Category Description

Limestone contains $CaCO_3$ and minute amounts of $MgCO_3$, and dolomite contains $CaCO_3$ and $MgCO_3$. The heating of limestone and dolomite releases CO_2 derived from $CaCO_3$ and $MgCO_3$.

b) Methodological Issues

- ***Estimation Method***

The amounts of limestone and dolomite used in iron and steel production are multiplied by the emission factors to calculate emissions.

- ***Emission Factors***

➢ ***Limestone***

Same as Glass Production (2.A.3.). See section 4.2.3. b).

➢ ***Dolomite***

Same as Glass Production (2.A.3.). See section 4.2.3. b).

- ***Activity Data***

Of the limestone and dolomite consumption data in the *Adjusted Price Transaction Table*, all limestone and dolomite consumption categorized under 'emissive use' that are under the Iron and steel/Refining related sectors will be accounted for under this subcategory. Activity data is in dry weight, converted using the water content from limestone used for cement.

The corresponding sectors in the *Adjusted Price Transaction Table* are as follows:

Table 4-45 Corresponding Sectors in the *Adjusted Price Transaction Table*

Uses	Limestone		Dolomite	
Iron and Steel/ Refining	2611-01 to 2611-04	Steel – pig iron Steel – crude ore (electric furnace)	2611-01 to 2631-03	Steel – pig iron Steel – cast and forged materials (iron)
	2631-02 2631-03	Steel – cast pipe Steel – cast and forged materials (iron)		
	2711-01 2711-02	Non-ferrous metal – copper Non-ferrous metal lead and zinc	2711-02	Non-ferrous metal – lead and zinc
	2729-03	Non-ferrous metal – non-ferrous metal cast and forged products		

Note: The numbers before the sector names are categorization numbers in the *Adjusted Price Transaction Table*.

Table 4-46 Amounts of Limestone and Dolomite Consumption for Steelmaking and Refining

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Limestone consumption (dry)	kt	14,421	13,588	13,616	12,610	11,813	11,827	11,320	9,571	9,979	9,539	9,260	9,072
Dolomite consumption (dry)	kt	1,144	1,089	1,160	1,430	1,532	1,585	1,529	1,230	1,388	1,284	1,282	1,257

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainty of emission factors, a 3% default value in the *2006 IPCC Guidelines* was used for both limestone and dolomite. For the uncertainty for activity data, a 3% default value in the *2006 IPCC Guidelines* was used for both limestone and dolomite. As a result, the uncertainty for emissions was estimated to be 4% for both limestone and dolomite.

- ***Time-series consistency***

Limestone and dolomite consumption data provided in the *Adjusted Price Transaction Table* is used as limestone and dolomite use activity data for all years from FY1990. The emission factors are constant for all years from FY1990. Therefore, CO_2 emission from limestone and dolomite use has been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

Recalculations of CO_2 emissions occurred due to updates made to limestone and dolomite consumption data in the *Adjusted Price Transaction Table* for FY2023. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.4.1.5. By-product Gas Flaring in Iron and Steel Production (2.C.1.b.)

a) Category Description

CO_2 is emitted from the flaring of by-product gas (blast furnace gas and converter furnace gas) during emergencies or maintenance in iron and steel production.

b) Methodological Issues

- ***Estimation Method***

Emissions are estimated by multiplying the amount of the flaring of by-product gas by the gross calorific

value and carbon emission factor for each by-product gas based on Tier 1 methodology provided in the *2019 Refinement* (see below equation).

According to the survey by the Japan Iron and Steel Federation, part of the amounts of the flaring of the blast furnace gas and converter furnace gas are included in the *General Energy Statistics*, and associated emissions are already accounted for the Fuel combustion category (1.A.). Therefore, CO_2 emissions from flaring unaccounted in the *General Energy Statistics* are accounted for under this sub-category. As all amounts have been accounted for in the *General Energy Statistics* since FY2022, they are reported as "IE".

$$E = \Sigma_i (AD \times GCV \times EF \times 44/12)$$

E : CO_2 emissions from the flaring of by-product gas [kt-CO_2]
i : Type of by-product gas
AD : Amount of by-product gas unaccounted in the *General Energy Statistics* [MNm^3]
GCV : Gross calorific values [MJ/m^3]
EF : Carbon emission factor [t-C/GJ]

- ***Emission Factors***

The same carbon emission factors and gross calorific values as those used to calculate CO_2 emissions from the Fuel combustion category (1.A.) are used (see Table 3-11 and Table 3-17).

- ***Activity Data***

Of the total amount of the flaring of by-product gas surveyed by the Japan Iron and Steel Federation (hereafter, 'total flaring amount'), the amount unaccounted in the *General Energy Statistics* (hereafter, 'unaccounted amount') is used as activity data. Since 'unaccounted amount' is available only for FY2020, the other fiscal years are estimated by multiplying the 'total flaring amount' by the ratio of the 'unaccounted amount' for FY2020. Additionally, since 'total flaring amount' are available only for FY1990, FY2000, FY2010 and FY2020, the other fiscal years are estimated by multiplying the amount of by-product gas generated provided in the *General Energy Statistics* by the ratio of flaring. The flaring ratio for years other than FY1990, FY2000, FY2010 and FY2020 are estimated by interpolating between the flaring ratio for these years.

Table 4-47 Estimated Amounts of By-product Gas Flaring Unaccounted for in the *General Energy Statistics*

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022 onward
Blast furnace gas	Million Nm^3	23	22	22	29	36	37	31	16	19	0
Converter furnace gas	Million Nm^3	14	41	80	139	195	211	185	111	124	0

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainty of emission factors, the upper limit and lower limit values of the 95% confidence interval for the carbon emission factors of converter furnace gas were applied. Also, since the values in the *General Energy Statistics* are used for estimation of the activity data, the default values (-10% to +10%) in the *2019 Refinement* are adopted for the uncertainty of activity data. As a result, the uncertainty of the emissions is evaluated as 11%.

- ***Time-series consistency***

The activity data are estimated in a consistent manner based on the data provided by the Japan Iron and

Steel Federation, and the *General Energy Statistics* from FY1990. The emission factor is based on the *General Energy Statistics* from FY1990.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

Recalculations occurred due to updates in the *General Energy Statistics* for FY2022 to FY2023. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.4.1.6. Direct Reduced Iron (2.C.1.c.)

CO_2 and CH_4 are generated during the production of direct reduced iron, through the oxidation of natural gas or coal used as reductants. However, there has not been any production of direct reduced iron in Japan, and therefore, it has been reported as “NO”.

4.4.1.7. Sinter (2.C.1.d.)

CO_2 and CH_4 from the manufacturing of sinter are generated by the combustion of ore powder with coke fines; these emissions come under the Fuel combustion category (1.A.). As they are already calculated in this 1.A. category, they are reported as “IE”.

CO_2 emissions from limestone and dolomite used when making sinter are counted under “Limestone and Dolomite Use in Iron and Steel Production (2.C.1.b.)”.

4.4.1.8. Pellet (2.C.1.e.)

CO_2 and CH_4 from the manufacturing of pellets are generated by the combustion of fine ore powder with coke; these emissions come under the Fuel combustion category (1.A.). As they are already calculated in this 1.A. category, they are reported as “IE”.

CO_2 emissions from limestone and dolomite used when making pellets are counted under “Limestone and Dolomite Use in Iron and Steel Production (2.C.1.b.)”.

4.4.1.9. Other – Utilization of Carbonated Gas (2.C.1.f.-)

Of the amount of CO_2, which was recovered for liquefied CO_2 and subtracted from the emissions from Petroleum refining (1.A.1.b.), Iron and steel (1.A.2.a.), Ammonia production (2.B.1.), and Ethylene oxide production (2.B.8.d.) categories, utilized amounts in the iron and steel production are allocated under this category. See section 4.9.1. for details.

4.4.2. Ferroalloys Production (2.C.2.)

a) Category Description

1) CO_2

Ferroalloys are produced in Japan, and the CO_2 that is generated in association with the ferroalloys production is emitted as a result of the oxidization of coke used as a reducing agent. Consumption of coke is included in consumption of fuel under the Fuel combustion category (1.A.), and CO_2 generated as a consequence of the oxidization of coke used as a reduction agent has already been calculated under the Fuel combustion category (1.A.).The thinking on where to account for CO_2 emissions from coke is the same as that for Iron and steel production. Regarding reducing agents for ferroalloys production, see Table 3-10. Residual carbon in the ferroalloys is oxidized when the ferroalloys are used in the production of iron and steel, and are released into the atmosphere as CO_2.

CO_2 emissions from limestone and dolomite that are used as slag forming materials have already been accounted for under iron and steel production (2.C.1.) as CO_2 emissions occurring from limestone and dolomite used during production.

Therefore, CO_2 emissions have been reported as "IE".

Regarding carbon in the ore, it is thought that the primary raw materials for ferroalloys in Japan (currently, imported manganese ores, nickel ores, and chromium ores) are rarely imported as carbonate ores[5]. Public sources of information such as *Mineral Resources Material Flow* do not provide data on distribution amounts that can be used for estimation, and therefore these emissions are not estimated.

2) CH_4

Ferroalloys are manufactured in Japan in electric arc furnaces, small-scale blast furnaces, and Thermit furnaces. CH_4 generated in association with ferroalloy production is thought to be generated when the oxidization of coke, a reduction agent, takes place.

b) Methodological Issues

- ***Estimation Method***

CH_4 emissions from ferroalloy production were calculated by multiplying an emission factor based on actual measurements obtained from electric arc furnace facilities in Japan by the energy consumption of electric arc furnaces.

- ***Emission Factors***

The value for the emission factor of electric arc furnaces (12.8 kg-CH_4/TJ) was used because these furnaces produce ferroalloys.

The EF is established using measured CH_4 concentration, measured dry gas emissions per hour, calories per hour, calories per electricity, and therefore needs to be per electricity (in TJ). Additionally, electricity consumption is determined by the operation of the furnaces and type of ferroalloy produced, and therefore we have used the electricity consumption, not production, as more accurate and available activity data. This EF reflects the average operation of furnaces/type of ferroalloy at the

[5] Most of the manganese ores distributed in Japan are high grade manganese oxide ores (MnO_2) and it is thought that low grade manganese carbonates ores are rarely distributed.

time of measurement in Japan. The equation below shows the process of deriving the emission factor.

$$EF = C_{CH4} \times G \times MW / V_m / H$$

EF : Emission factor [kg-CH_4/TJ]
C_{CH4} : Measured CH_4 concentration in the emitted gas [ppm]
G : Measured dry gas emissions per hour [m^3_N/h]
MW : Molecular weight of CH_4 = 16 [g/mol]
V_m : Volume of 1 mole of ideal gas at standard pressure = 22.4 [$10^{-3}m^3$/mol]
H : Calories per hour [MJ/h]

Some of the parameters were established using measurements which were conducted generally in line with the guidance in the *2006 IPCC Guidelines*, for instance with making efforts to cover a representative sample.

- ***Activity Data***

Energy consumption amounts included in the "ferroalloy" category for the iron and steel industries of the *General Energy Statistics* were used.

Table 4-48 Energy Consumption for Ferroalloy Production

Electricity consumption	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Electric furnaces (for Ferroalloys)	TJ	14,456	10,699	10,181	10,072	9,510	9,956	9,228	6,404	8,017	5,909	4,522	3,692

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainty for the emission factor has been estimated to be 163% and the uncertainty for activity data has been estimated to be 5% (see chapter 3). As a result, the uncertainty for CH_4 emissions has been estimated to be 163%.

- ***Time-series Consistency***

For activity data, the same sources are used throughout the time-series. The emission factor is constant throughout the time-series. Therefore, CH_4 emissions from furnaces for ferroalloy have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.4.3. Aluminium Production (2.C.3.)

4.4.3.1. By-product emissions (2.C.3.a.)

a) Category Description

CO_2 generated in association with aluminium smelting is emitted in conjunction with the oxidization of the anode paste used as a reducing agent. The *2019 Refinement* provides estimation methodology for

CO_2 emissions from production of alumina, which is used as raw material for aluminium refining. However, estimation methodology for the conventional Bayer process used in Japan is not considered in the *2019 Refinement*.

PFCs are emitted during aluminium refining, due to the use of a fluoride melt consisting mainly of cryolite during electrolysis.

b) Methodological Issues

- ***Estimation Method***

CO_2 emissions were estimated by multiplying the production amount of primary aluminium refining by the CO_2 emission factor per production amount, based on the Tier 1 method in the *2006 IPCC Guidelines*.

PFC emissions were estimated by multiplying the production amount of primary aluminium refining by Japan's country-specific emission factors calculated using the equation prescribed in the *2019 Refinement*. According to the Japan Aluminium Association, there is no aluminium production with low voltage anode effects in Japan.

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by extrapolation, etc. of relevant data for these years.

- ***Emission Factors***

The default CO_2 EF (1.7 t-CO_2/t (Soderberg technology)) in the *2006 IPCC Guidelines* is used.

The equation prescribed in the Tier 2a method in the *2019 Refinement*, and its associated slope coefficients set by technology, together with the weight fraction of gases is used to determine PFC emission factors, as shown in the table below. For the years 1990 to 1994, the emission factor for 1995 is used.

Table 4-49 PFC Emission Factors and Aluminium Production Amounts

Item	Unit	1990	1995	2000	2005	2010	2013	2015 onward
PFC-14 (CF_4) EF	kg-PFC-14/t	1.181	1.181	0.804	0.663	0.647	0.643	NA
PFC-116 (C_2F_6) EF	kg-PFC-116/t	0.091	0.091	0.062	0.051	0.050	0.050	NA
Production of aluminium	t	34,100	17,338	6,500	6,490	4,670	2,950	0

Reference: *Yearbook of Minerals and Non-Ferrous Metals Statistics (METI), Documents of Fluorocarbons etc. Measures Working Group*

- ***Activity Data***

The aluminium production amounts given in the *Yearbook of Minerals and Non-Ferrous Metals Statistics* (1995 to 1997), and the *Documents of Fluorocarbons etc. Measures Working Group* (previously the Group for Prevention of Global Warming, Chemical and Bio Sub-Group, Industrial Structure Council, Ministry of Economy, Trade and Industry) (1998 and beyond), were used. (Production ended in 2014.)

For the years 1990 to 1994, aluminium production amounts given in the *Yearbook of Minerals and Non-Ferrous Metals Statistics* were used.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainty of the CO_2 emission factor and uncertainty of the activity data, the respective default

values of 10% and 2% in the *2006 IPCC Guidelines* were applied. As a result, the uncertainty of the emissions was determined to be 10%.

For the uncertainty of the PFC emission factor and uncertainty of the activity data, the respective default values of –47% to +28% in the *2019 Refinement* and 2% in the *2006 IPCC Guidelines* were applied. As a result, the uncertainty of the emissions was determined to be –47% to +28%.

- ***Time-series Consistency***

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. c)

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production –By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. d)

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.4.3.2. F-gases used in foundries (2.C.3.b.)

Emission from this source was reported as “NO” as it has been confirmed that Japan had no record of the use of SF_6 in aluminium forging processes.

4.4.4. Magnesium Production (2.C.4.)

a) Category Description

HFCs and SF_6 are emitted in magnesium foundries, due to its use as cover gas to prevent oxidation of molten magnesium.

b) Methodological Issues

Emissions are an aggregation of all HFCs and SF_6 used by magnesium foundries. The data that has been reported is given in documentation prepared by the Fluorocarbons etc. Measures Working Group, Group for Chemical Substance Policy, Manufacturing Industries Sub-Group of the Ministry of Economy, Trade and Industry’s Industrial Structure Council, for emissions of HFCs and SF_6 used in magnesium foundries. The associated indices are given in the table below.

Table 4-50 Indices Related to HFCs and SF_6 Emitted from Magnesium Foundries

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Consumption of HFC-134a	t	0	0	0	0	0	0.9	0.9	0.9	1.3	0.9	1.3	0.8
Consumption of SF_6	t	6.4	5.0	42.9	48.4	12.9	6.9	10.3	12.8	13.8	12.4	9.2	6.4

Reference: *Documents of Fluorocarbons etc. Measures Working Group*, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using other die cast production amounts (excluding aluminium and zinc) which is thought to

be proportional to molten magnesium amounts, and the consumption amount of SF_6 from 1995, and extrapolating for these years.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainty of emissions was set at the 5% value of the upper limit for the Tier 2 method in the *2006 IPCC Guidelines*.

- ***Time-series Consistency***

Same as Fluorochemical Production –By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.4.5. Lead Production (2.C.5.)

CO_2 generated from lead production are emitted by the oxidization of coke used as reductants. The amount of coke consumed as reductant used in lead production is included under "Direct heating purposes" (a fuel category under non-ferrous bare metal industry) in the *Yearbook of the Current Survey of Energy Consumption*. Since emissions are already accounted for under Manufacturing industries and construction (1.A.2.) in the Energy sector, emissions are reported as "IE". The thinking on where to account for CO_2 emissions from coke is the same as that for Iron and steel production.

4.4.6. Zinc Production (2.C.6.)

Similar to lead, CO_2 generated from zinc production are emitted by the oxidization of coke used as reductants. The amount of coke consumed as reductants used in zinc production is included under "Direct heating purposes" (a fuel category under non-ferrous bare metal industry) in the *Yearbook of the Current Survey of Energy Consumption*. Since emissions are already accounted for under Manufacturing industries and construction (1.A.2.) in the Energy sector, emissions are reported as "IE". The thinking on where to account for CO_2 emissions from coke is the same as that for Iron and steel production.

When Smithsonite ($ZnCO_3$) which includes carbon in the ore are used as raw material, there is the possibility of CO_2 arising from the ore in the reduction process. However, there are currently no cases of Smithsonite use in Japan.

4.4.7. Other – Rare Earths Production (2.C.7.a.)

CO_2 is emitted into the atmosphere from the consumption of carbon anodes in the electrolytic reaction which converts the raw material, rare earth oxides, to rare earth metals by molten salt electrolysis during rare earth metal and alloy smelting.

PFCs are also emitted from the reaction of the fluoride melt with the carbon in the anodes during the anode effects due to the use of a fluoride melt consisting of rare earth fluorides and lithium fluoride. CO_2 and PFCs emissions are estimated based on information provided by the Japan Society of Newer Metals regarding the rare earths smelting in Japan, and the Tier 1 methodology provided in the *2019 Refinement.* These emissions do not exceed 3,000 t-CO_2 eq, which is the threshold to estimate in this GHG inventory decided by the Committee for GHG Emissions Estimation Methods. Therefore, it was reported as "NE" (considered insignificant) (see Annex 6).

4.5. Non-energy Products from Fuels and Solvent Use (2.D.)

This category covers CO_2 emissions from the use of non-energy products from fuels and solvents. This section deals with the following sources: Lubricant use (2.D.1.), Paraffin wax use (2.D.2.), and Other (2.D.3.).

In FY2024, emissions from this category were 2,589 kt-CO_2 and represented 0.2% of Japan's total GHG emissions (excluding LULUCF). The emissions increased by 16.1% compared to FY1990.

Table 4-51 Emissions from Non-energy Products from Fuels and Solvent Use (2.D.)

Gas				Units	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
CO_2	2.D.1	Lubricant use		kt-CO_2	510	527	532	491	451	397	358	358	351	327	310	282
	2.D.2	Paraffin wax use		kt-CO_2	50	37	36	36	35	28	25	23	29	24	23	17
	2.D.3	Other	Urea-based catalysts	kt-CO_2	NO	NO	NO	0.3	3	8	12	25	29	32	36	38
			NMVOC incineration	kt-CO_2	1,670	2,006	2,314	2,576	2,536	2,525	2,560	2,423	2,423	2,284	2,253	2,252
	Total			kt-CO_2	2,229	2,570	2,882	3,104	3,024	2,957	2,955	2,829	2,832	2,666	2,621	2,589

4.5.1. Lubricant Use (2.D.1.)

a) Category Description

CO_2 is emitted from the oxidation of lubricants and grease during use. Emissions from the total loss type of engine oil are reported in the energy sector (see 1.A.3.), and emissions from other types than the above-mentioned type of engine oil are reported under this sector. The *2006 IPCC Guidelines* do not provide estimation methodology for CH_4/N_2O, and therefore these emissions were reported as "NE".

b) Methodological Issues

- ***Estimation Method***

Emissions were calculated by multiplying lubricant and grease consumption amounts per oil type, by the carbon content and Oxidized During Use (ODU) factor per oil type, based on the Tier 2 method given in the *2006 IPCC Guidelines* (see below).

$$E = \Sigma_i \, (LC_i \times CC_i \times ODU_i \times 44/12)$$

E : Emissions from the oxidation of lubricants and grease during use [kt-CO_2]
LC_i : Lubricant and grease consumption amounts [TJ]
CC_i : Carbon content of fuel [kt-C/TJ]

ODU_i : ODU factor for oil
i : Type of lubricant and grease

- ***Emission Factors***

For carbon content, the carbon emission factors of lubricants and heavy oil products in the *General Energy Statistics* are used. For the ODU factor, the default values in the *2006 IPCC Guidelines* are used. (lubricants: 0.2, grease: 0.05)

- ***Activity Data***

For lubricants, the consumption amounts for types other than total loss types of engine oil are calculated by subtracting the consumption amounts of the total loss type from the total of consumption amounts of engine oil (see section 3.2.8. Activity data).

For grease, the consumption amounts are calculated by multiplying the domestic sales amounts in the *Yearbook of Mineral Resources and Petroleum Products Statistics* (METI) and the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* (METI), by the calorific values of heavy oil products in the *General Energy Statistics*. However, for years FY1992 to FY1999, the domestic sales data are not available from these statistics. Therefore, the domestic sales for these years are estimated by subtracting the total of exports and stocks at the end of the year, from the total of stocks at the start of the year and production and imports, which are respectively shown in these statistics.

Table 4-52 Consumption of Engine Oil (for Types Other Than Total-Loss Types) and grease

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Consumption of engine oil (for types other than total loss types)	TJ	35,328	36,727	37,057	34,083	31,256	26,582	23,897	24,040	23,538	21,934	20,769	18,855
Consumption of grease	TJ	3,152	2,503	2,435	2,658	2,622	2,478	2,464	1,863	1,998	1,914	1,881	1,884

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainty of emission factors, a 50% default value specified in the *2006 IPCC Guidelines* was applied for both lubricants and grease. For the uncertainty of the activity data, a 5% default value specified in the *2006 IPCC Guidelines* was applied for both lubricants and grease. As a result, the uncertainty of emissions was assessed to be 50% for both lubricants and grease.

- ***Time-series Consistency***

For activity data, the same source the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* etc. are used throughout the time-series. The emission factors are constant throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

Recalculations occurred due to the updates of the *General Energy Statistics* for FY2023. See chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.5.2. Paraffin Wax Use (2.D.2.)

a) Category Description

CO_2 is emitted from the oxidation of paraffin wax during use. The *2006 IPCC Guidelines* do not provide estimation methodology for CH_4/N_2O emissions, and therefore these emissions were reported as "NE".

b) Methodological Issues

- ***Estimation Method***

Emissions were calculated based on the Tier 1 method given in the *2006 IPCC Guidelines* (see below).

$$E_{CO2} = PW \times CC_{Wax} \times ODU_{Wax} \times 44/12$$

E_{CO2} : Emissions from paraffin wax during use [t-CO_2]
PW : Paraffin wax consumption amounts [TJ]
CC_{Wax} : Carbon content of paraffin wax [kg-C/GJ]
ODU_{Wax} : ODU factor for paraffin wax

- ***Emission Factors***

For carbon content, the carbon emission factor of heavy oil products in the *General Energy Statistics* is used. For the ODU factor, the default value in the *2006 IPCC Guidelines* is used (0.2).

- ***Activity Data***

The consumption amounts are calculated by multiplying the domestic sales amounts in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* and *Yearbook of Mineral Resources and Petroleum Products Statistics*, by the calorific values of heavy oil products in the *General Energy Statistics*.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainty of emission factors, a 100% default value specified in the *2006 IPCC Guidelines* was applied. For the uncertainty of the activity data, a 5% default value specified in the *2006 IPCC Guidelines* was applied. As a result, the uncertainty of emissions was assessed to be 100%.

- ***Time-series Consistency***

For activity data, the same source-the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* etc. are used throughout the time-series. The emission factors are constant throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.5.3. Other (2.D.3.)

4.5.3.1. Road Paving with Asphalt (2.D.3.b.)

Roads in Japan are paved with asphalt, but almost no CO_2 are thought to be emitted in the process. It is not possible, however, to be completely definitive about the absence of emissions. Emissions have also never been actually measured, and as no default emission factor is available, it is not currently possible to calculate emissions.

4.5.3.2. Asphalt Roofing (2.D.3.c.)

Asphalt roofing is manufactured in Japan, but information on the manufacturing process and activity data is inadequate, and it is not possible to definitively conclude that CO_2 is not emitted from the manufacturing of asphalt roofing. Emissions have also never been actually measured, and as no default emission factor is available, it is not currently possible to calculate emissions.

4.5.3.3. Urea used as a catalyst (2.D.3.d.-)

a) Category Description

The urea SCR system for cars is a technology to reduce NOx emissions, by the reduction of NOx in exhaust gas using ammonia and decomposing it into N_2 and H_2O. By spraying urea aqueous into high temperature exhaust gas, this is hydrolyzed to yield ammonia gas, and CO_2 is emitted as follows.

$$CO(NH_2)_2 + H_2O \rightarrow 2NH_3 + CO_2$$

b) Methodological Issues

- ***Estimation Method***

Emissions were calculated based on the *2006 IPCC Guidelines* (see below).

$$E_{CO2} = AD \times 12/60 \times P \times 44/12$$

AD : Consumption amount of urea-based additives in urea SCR systems [kt]
P : Ratio of urea in urea-based additives [%] (Default value: 32.5%)

- ***Emission Factors***

For the Ratio of urea in urea-based additives (P), the default value of 32.5% in the *2006 IPCC Guidelines* is used.

- ***Activity Data***

The cumulative number of cars with urea SCR systems (data provided by the Japan Automobile Manufacturers Association) is first multiplied by the consumption amount of diesel oil per car, and then further multiplied by ratio of consumption amount of urea-based additives to diesel, to yield the consumption amount of urea-based additives.[6].

[6] Domestically produced urea is from CO_2 recovered from ammonia production processes. The CO_2 associated with it is already subtracted from the emissions allocated under 2.B.1. Ammonia production.

$$AD = \Sigma_i (N_i \times L_i \times R \times D)$$

AD : Consumption amount of urea -based additives in urea SCR systems [kt]
N : Cumulative number of cars with urea SCR systems [thousand cars]
L : Consumption amount of diesel oil per car [kL/car]
R : Ratio of consumption amount of urea-based additives to diesel [%]
D : Density of diesel oil [t/kL]
i : Vehicle type (Regular cargo trucks, Buses, Special-purpose vehicles)

Table 4-53 Parameters Used to Calculate the Consumption Amount of Urea-Based Additives, and Their Sources and Methods of Establishment

Item	Sources and methods of establishment
Cumulative number of cars with urea SCR systems [thousand cars]	Data provided by the Japan Automobile Manufacturers Association
Consumption amount of diesel oil per car [kL/car]	Calculated by dividing the total consumption amount of diesel based on the *Statistical Yearbook of Motor Vehicle Transport* and *Statistical Yearbook of Motor Vehicle Fuel Consumption* (Ministry of Land, Infrastructure, Transport and Tourism) by the total number of registered cars
Ratio of consumption amount of urea-based additives to diesel [%]	2%, as a median value of 1 to 3 % in the *2006 IPCC Guidelines*
Density of diesel oil [t/kL]	0.8831 t/kL, based on the *Handbook on the General Energy Statistics*

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainty of emission factor, a 5% default value in the *2006 IPCC Guidelines* (cars – combustion origin) was applied. For the uncertainty of the activity data, a 5% default value specified in the *2006 IPCC Guidelines* was applied. As a result, the uncertainty of emissions was assessed to be 7%.

- ***Time-series Consistency***

For activity data, the same source-data provided by the Japan Automobile Manufacturers Association, etc. are used throughout the time-series. The emission factors are constant throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.5.3.4. NMVOC Incineration (2.D.3.d.-)

a) Category Description

CO_2 is emitted in the process of NMVOC incineration from facilities, etc. that use solvents. CH_4/N_2O emissions do not exceed 3,000 t-CO_2 eq, which is the threshold to estimate determined by the Committee for GHG Emissions Methods. Therefore, it was reported as “NE” (considered insignificant) (see Annex 6).

b) Methodological Issues

- ***Estimation Method***

CO_2 emissions from NMVOC incineration were calculated, for five use types – Paint, Cleansing agents, Printing, Chemical products, and Other, by estimating the domestic supply of solvents, the emissions into the atmosphere, the material recycle amounts, and then subtracting emissions into the atmosphere and the material recycle amounts from the domestic supply of solvents, to yield the amounts incinerated. CO_2 emissions from the incineration of some used solvents are already accounted for in the energy sector (alternative fuel use) and waste sector (waste incineration without energy recovery), and therefore are subtracted out from emissions in this category.

$$E_{CO2} = \Sigma_i (I_i \times C_i \times 44/12)$$

E_{CO2}	: CO_2 emissions from NMVOC incineration [t]
I_i	: NMVOC incineration amounts for use type *i* [t]
C_i	: Average carbon content of NMVOCs for use type *i*
Reference	: *Committee for Greenhouse Gas Emissions Estimation Methods in FY2022*

where,

$$I_i = S_i - E_i - R_i$$

I_i	: NMVOC incineration amounts for use type *i* [t]
S_i	: Domestic supply of solvents for use type *i* [t]
E_i	: NMVOC emissions into the atmosphere for use type *i* [t]
R_i	: Material recycle amounts for use type *i* [t]

- ***Emission Factors***

The average carbon content is calculated by weighting it by the composition rate of each NMVOC substance emitted from each source. (Same values are used as those for conversion to indirect CO_2) The carbon contents of each substance are obtained from molecular formulae, and the type of substance and composition rate of NMVOCs are estimated based on the national emission inventory for Volatile Organic Compounds (VOC) by MOE and other information.

- ***Activity Data***

Parameters are set as follows:

➢ ***Domestic supply of solvents for use type i***

For paint, the data for total amount of solvents in paint from the *Compilation of Estimation Results of VOC Emissions from Paint* (Japan Paint Manufacturers Association), and shipment amounts of thinners for paint given in the *Survey on the Actual Conditions of the Paint Manufacturing Industry* (Japan Paint Manufacturers Association), etc., were used. For cleansing agents, printing, chemical products, and other, the data for national sales amounts of solvents by use from the *VOC Emission Inventory Report* (MOE, March 2007), and demand for 'other' use of acetone from the *Petrochemical Industry of Japan* (The Heavy and Chemical Industries News Agency), etc., were used. (For years lacking data, interpolation or extrapolation using product sales amounts, etc. was applied to estimate)

➢ ***NMVOC emissions into the atmosphere for use type i***

For NMVOC emissions into the atmosphere E_i, NMVOC emissions by source was used. (For details of estimation methods, see Annex 5)

➢ ***Material recycle amounts for use type i***

The material recycle amounts of solvents for use type i in the year FY2011 was first estimated by multiplying the supply of solvents for use type i in the year FY2011, by the ratio of external recycle amounts for use type i in the year FY2011 (*Survey on Organic Solvents Use and Emission Treatment*, Japan Solvent Recycling Industry Association, May, 2012) to the solvent supply amounts for use type i in the year FY2011. This was then multiplied by the growth rate (based on the *Survey on Solvent Recycle Amounts*, Japan Solvent Recycling Industry Association) of solvent collection amounts from FY2011.

Table 4-54 NMVOC Incineration Amounts by Use Type

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Paints	kt	266	289	331	339	296	263	285	286	267	242	254	258
Cleansing agents	kt	85	100	90	108	65	45	46	45	49	59	58	56
Printing solvents	kt	172	195	237	234	231	232	219	164	169	162	150	153
Chemical products	kt	51	79	131	150	182	190	193	193	205	198	198	197
Other	kt	148	201	202	290	331	362	363	367	379	366	354	349

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainty of emission factor, a 2%, uncertainty of the specially controlled industrial waste (waste oil) was applied. For the uncertainty of activity data, a 60%, uncertainty of the specially controlled industrial waste (waste oil) was applied. As a result, the uncertainty of emissions was assessed to be 60%.

- ***Time-series Consistency***

Consistent activity data and emission factors are used throughout the time-series as much as possible.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

Recalculations occurred due to updates of NMVOC emissions into the atmosphere for all years. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.6. Electronics Industry (2.E.)

This category covers N_2O, HFC, PFC, SF_6, and NF_3 emissions from the manufacturing of the electronic devices. This section deals with the following sources: Semiconductor (2.E.1.), Liquid Crystals (2.E.2.), Photovoltaics (2.E.3.), Heat transfer fluid (2.E.4.), and Microelectromechanical systems (2.E.5.).

In 2024, emissions from this category were 1,987 kt-CO_2 eq. and represented 0.2% of Japan's total GHG emissions (excluding LULUCF). N_2O emissions are 16.5 times of 1990. The total of HFCs, PFCs, SF_6, and NF_3 decreased by 17.7% compared to 1990.

Table 4-55 Emissions from Electronics Industry (2.E.)

Gas			Units	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
N_2O	2.E.1	Semiconductor	kt-N_2O	0.01	0.02	0.04	0.10	0.15	0.24	0.29	0.29	0.41	0.41	0.29	0.21
	Total		kt-CO_2 eq.	3	6	10	25	41	65	77	77	110	109	78	56
Gas			Units	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
HFCs	2.E.1	Semiconductor	kt-CO_2 eq.	55	415	432	312	217	129	124	150	110	96	97	64
	2.E.2	Liquid crystals	kt-CO_2 eq.	0.001	0.2	2	2	3	2	2	1	1	1	1	1
	Total		kt-CO_2 eq.	55	416	434	315	220	131	126	151	111	97	98	65
PFCs	2.E.1	Semiconductor	kt-CO_2 eq.	1,286	3,443	5,905	4,126	1,973	1,393	1,429	1,675	1,413	1,452	1,231	1,297
	2.E.2	Liquid crystals	kt-CO_2 eq.	28	78	192	137	42	68	78	69	70	52	30	25
	Total		kt-CO_2 eq.	1,314	3,521	6,097	4,263	2,015	1,461	1,507	1,744	1,483	1,503	1,261	1,322
SF_6	2.E.1	Semiconductor	t	35.65	46.13	67.73	49.94	20.14	15.15	15.18	14.60	12.78	12.73	11.61	13.46
	2.E.2	Liquid crystals	t	4.81	6.22	38.48	31.22	11.79	7.45	8.39	6.09	5.64	5.28	3.08	2.57
	Total		t	40.46	52.36	106.21	81.16	31.93	22.60	23.57	20.69	18.42	18.01	14.69	16.02
	Total		kt-CO_2 eq.	951	1,230	2,496	1,907	750	531	554	486	433	423	345	377
NF_3	2.E.1	Semiconductor	t	1.43	8.81	5.21	8.43	9.98	5.79	7.78	16.20	18.10	18.83	11.45	9.98
	2.E.2	Liquid crystals	t	0.15	0.91	3.83	4.10	1.53	1.24	1.29	1.10	1.10	0.87	0.51	0.42
	Total		t	1.58	9.71	9.04	12.53	11.51	7.03	9.07	17.31	19.20	19.70	11.96	10.40
	Total		kt-CO_2 eq.	25	156	145	202	185	113	146	279	309	317	193	167
Total of F-gases			kt-CO_2 eq.	2,346	5,323	9,172	6,687	3,170	2,237	2,332	2,660	2,336	2,341	1,897	1,931

4.6.1. Semiconductor (2.E.1.)

a) Category Description

N_2O is used as an oxidizing agent to form an insulative oxide film during semiconductor/liquid manufacturing, and the remaining is considered to be released into the atmosphere.

HFCs (HFC-23, HFC-32, HFC-41), PFCs (PFC-14, PFC-116, PFC-218, PFC-c318), SF_6, and NF_3 are emitted from the manufacturing of semiconductors.

b) Methodological Issues

1) N_2O

- ***Estimation Method***

Emissions were estimated based on the Tier 2c method in the *2019 Refinement*.

$$E = \Sigma_p \left(C_p \times (1 - U_p) \times (1 - D_p)\right)$$

E : N_2O emissions of unreacted N_2O input gas from the production process [t]
p : Process type (Thin-film deposition (TFD) (≦200mm), TFD (300mm), other)
C_p : N_2O input gas consumption for process p[t]
U_p : Use rate of N_2O gas for process p
D_p : Fraction of reduction by the emissions control system for overall process p

where,

$$D_p = d_p \times r_p$$

d_p : Destruction removal efficiency (DRE) for process p
r_p : Fraction of N_2O gas controlled for process p

- ***Emission Factors***

For the use rate of N_2O gas and the destruction removal efficiency, the default values given in the *2019 Refinement* were applied. For the fraction of gas controlled, the values estimated by Japan Electronics

and Information Technology Industries Association (JEITA) based on the ratio of installation and the fraction of uptime of emissions control systems were used.

Table 4-56 Use Rate of N_2O Gas and DRE During Semiconductor Manufacturing

Process type	TFD (≦200mm)	TFD (300mm)	Other
Use rate of N_2O	0	0.5	0
DRE	0.6		

Reference: Default values from the *2019 Refinement* (Vol. 3 Table 6.10, Table 6.11 and Table 6.17)

Table 4-57 Fraction of N_2O Gas Controlled

Process type	1990 to 2021	2022	2023	2024
TFD (≦200mm)	0.572	0.512	0.524	0.551
TFD (300mm)	1.000	1.000	0.919	1.000
Other	0.698	0.816	0.827	0.897

- ***Activity Data***

For the N_2O gas consumption, the N_2O domestic sales amounts of semiconductor material gas provided on the website of JIMGA was used. For the breakdown of the consumption by the process types, estimates were made by using the composition ratios of processes based on the consumption data of N_2O gas provided by JEITA, due to the lack of process-level breakdowns of the data. For 2020 and before, in which data was lacking, the composition ratios for 2021 were applied. The heel (remaining amount in the shipment container after use) is assumed to be zero in order to avoid underestimation.

2) HFCs, PFCs, SF_6, and NF_3

- ***Estimation Method***

Emissions were estimated based on the Tier 2a method in the *2019 Refinement*.

$$E_{total} = \Sigma_i (E) + \Sigma_k (BPE) + \Sigma_i (EAB)$$
$$E_i = FC_i \times (1 - h_i) \times (1 - U_i) \times (1 - a_i \times d_i \times UT)$$
$$BPE_k = \Sigma_i (FC_i \times B_{i,k} \times (1 - h_i) \times (1 - a_i \times d_k \times UT))$$
$$EAB_i = FC_i \times (1 - h_i) \times (1 - U_i) \times (1 - \eta) \times AB_{i,CF4}$$

E_{total} : Emissions from semiconductor manufacturing [t]
E_i : Emissions from unreacted input gas i from the production process [t]
BPE_k : Emissions from by-product k generated from the conversion of all input gases i [t]
EAB_i : CF_4 emissions from combustion emissions control systems when NF_3 is used in RPC processes or F_2 is used [t]
i : Input gas (HFC-23, HFC-32, HFC-41, PFC-14, PFC-116, PFC-218, PFC-c318, SF_6, NF_3, C_5F_8, C_4F_6, F_2 and COF_2)
k : By-product gas (HFC-23, HFC-32, HFC-41, PFC-14, PFC-116, PFC-218, PFC-c318)
FC : Purchased amount of gas[1] [t]
h : Heel factor[2]
U : Use rate of gas[3]
a : Ratio of installation of emissions control systems[2]
d : Destruction removal efficiency (DRE)[3]
UT : Fraction of uptime of emissions control systems [2]
B : By-production rate[3] [t/t]
η : Ratio of emissions control systems certified not to form CF_4 within emissions control systems to the total number of emissions control systems in the facility (0%)[2]
AB : Fraction of CF_4 generated from the combustion emissions control system (NF_3 Remote : 9.3%、F_2 : 11.6%)[4]

Reference:

1) Data provided by the JEITA.
2) Data provided by METI
3) Default value of the 2019 Refinement (Vol. 3 Table 6.7 and Table 6.17)
4) Default value of the 2019 Refinement (Vol. 3 chap. 6, page 30)

Regarding the treatment of the heel, these emissions are reported under this category when there is recharging and subsequent shipment. In cases of decomposing the residue and cleansing the containment shell, or releases into the atmosphere, these emissions are reported under "2.B.9. Fluorochemical production – fugitive emissions".

Relevant indices are shown in Table below. The ratio of installation of emissions control systems is not reported here due to confidentiality reasons.

Table 4-58 Indices Related to Emissions of F-gases from Semiconductor Manufacturing

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
HFC-23 purchased	t	0.1	48	49	42	67	67	86	81	90	96	74	90
HFC-32 purchased	t	0	0	0	0	0	0	0	95	117	130	91	125
HFC-41 purchased	t	0	0	0	0	0	0	0	25	28	29	23	32
PFC-14 purchased	t	113	313	300	232	265	218	285	407	421	424	349	418
PFC-116 purchased	t	76	210	561	393	194	118	96	86	77	76	68	55
PFC-218 purchased	t	0.01	0.03	10	182	167	106	111	106	111	112	91	70
PFC-c318 purchased	t	0.2	0.6	39	25	36	42	63	266	310	382	304	393
SF_6 purchased	t	70	91	132	97	77	58	68	96	95	106	104	122
NF_3 purchased	t	9	54	106	407	861	905	1,232	2,283	2,561	2,692	2,154	2,666
C_5F_8 purchased	t	0	0	0	0	0	0	0	1	1	1	1	1
C_4F_6 purchased	t	0	0	0	0	0	0	0	247	313	312	232	311
COF_2,F_2 purchased	t	0	0	0	0	0	0	0	0	19	12	9	13
Heel factor	%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
Fraction of uptime of emissions control systems	%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Ratio of emissions control systems certified not to form CF_4 within emissions control systems to the total number of emissions control systems in the facility	%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
HFC emissions	kt-CO_2 eq.	55	415	432	312	217	129	124	150	110	96	97	64
PFC emissions	kt-CO_2 eq.	1,286	3,443	5,905	4,126	1,973	1,393	1,429	1,675	1,413	1,452	1,231	1,297
SF_6 emissions	kt-CO_2 eq.	838	1,084	1,592	1,174	473	356	357	343	300	299	273	316
NF_3 emissions	kt-CO_2 eq.	23	142	84	136	161	93	125	261	291	303	184	161

Reference: The *Documents of Fluorocarbons etc. Measures Working Group*, and data provided by METI, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Table 4-59 Use Rate of Gases During Semiconductor Manufacturing and Fraction of Gas Controlled

Gas	Use rate	DRE	Gas	Use rate	DRE
HFC-23	53%	98%	PFC-c318	87%	98%
HFC-32	80%	98%	SF_6	45%	95%
HFC-41	65%	98%	NF_3	82%	95%
PFC-14	27%	89%	NF_3 remote	98%	-
PFC-116	45%	95%	F_2, COF_2	20%	-
PFC-218	60%	99%			

Reference: Default values from the *2019 Refinement* (Vol. 3 Table 6.7 and Table 6.17)

Table 4-60 HFCs and PFCs by-production Rate During Semiconductor Manufacturing

Input Gas / By-product gas	HFC-23	HFC-32	HFC-41	PFC-14	PFC-116	PFC-218	PFC-c318
HFC-23	NA	5.7%	1.5%	4%	0.2%	0.00012%	2.2%
HFC-32	0.082%	NA	0.21%	0.57%	NA	NA	0.026%
HFC-41	0.43%	0.43%	NA	0.21%	NA	NA	0.04%
PFC-14	8.2%	6.1%	2.8%	NA	19%	20%	9.9%
PFC-116	4.5%	4.4%	1%	4.3%	NA	0.0018%	2%
PFC-218	NA	NA	NA	NA	NA	NA	NA
PFC-c318	0.021%	7.1%	0.65%	0.14%	NA	NA	NA

Table 4-60 HFCs and PFCs by-production Rate During Semiconductor Manufacturing (Cont.)

By-product gas \ Input Gas	C_5F_8	C_4F_6	NF_3	NF_3 Remote	SF_6	F_2,COF_2
HFC-23	0.53%	1.8%	0.68%	NA	0.14%	NA
HFC-32	NA	0.003%	0.023%	NA	0.00021%	NA
HFC-41	NA	0.064%	0.22%	NA	0.09%	NA
PFC-14	5.3%	6%	6.7%	3.4%	12%	15%
PFC-116	4.7%	6.3%	1.4%	NA	9.5%	5%
PFC-218	0.0055%	NA	NA	NA	NA	NA
PFC-c318	NA	0.51%	NA	NA	NA	NA

Reference: Default values from the *2019 Refinement* (Vol. 3 Table 6.7)

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using available domestic HFC, PFC, and SF_6 shipment amount, and NF_3 production amount data which is thought to be proportional to HFC, PFC, SF_6, and NF_3 emissions, and extrapolating for these years.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For N_2O, a 120% default value in the *2019 Refinement* was applied for the uncertainties of the emission factors. For the uncertainty of activity data, 10% was applied, using the upper limit value in the *2006 IPCC Guideline*. As a result, the uncertainty of the emissions of N_2O are determined to be 120%.

For HFCs, PFCs, SF_6, and NF_3, *2006 IPCC Guidelines* default values of 100%, 80%, 300%, and 70% were respectively applied to the uncertainties of the emission factors for HFCs, PFCs, SF_6, and NF_3. For the uncertainties of the activity data, 10% was applied for all HFCs, PFCs, SF_6, and NF_3, using the upper limit value in the *2006 IPCC Guidelines*. As a result, the uncertainties of the emissions for HFCs, PFCs, SF_6, and NF_3, were determined to be 100%, 81%, 300%, and 71%, respectively.

- ***Time-series Consistency***

For N_2O, activity data are estimated based on the data provided by JIMGA in a consistent manner throughout the time-series. The emission factors are constant throughout the time-series.

For HFCs, PFCs, SF_6, and NF_3, same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

For N_2O, same as Cement Production (2.A.1.). See section 4.2.1. d).

For HFCs, PFCs, SF_6, and NF_3, same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. d).

e) Category-specific Recalculations

Recalculations of N_2O emissions occurred due to the update of the N_2O gas consumption for 2021 to 2023. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.6.2. Liquid Crystals (2.E.2.)

a) Category Description

HFCs, PFCs, SF_6, and NF_3 are emitted from the manufacturing of liquid crystals.N_2O emissions during liquid crystal and semiconductor manufacturing are combined and reported under the Semiconductor (2.E.1.), and therefore N_2O emissions from liquid crystal manufacturing are reported as "IE".

b) Methodological Issues

- ***Estimation Method***

The Tier 2a method in the *2006 IPCC Guidelines* is used to estimate emissions from manufacturing of liquid crystals. These emissions are estimated with purchased amounts of F-gases, process supply rates, use rates of F-gases, fractions of gas destroyed, by-product generation rates and fractions of gas destroyed for by-products. In principle, default values are applied for the use rate of F-gases, the by-product generation rates, and the fractions of gas destroyed. World LCD Industry Cooperation Committee has established a voluntary action plan to reduce PFC emissions and has engaged in reducing PFC emissions. In these activities, IPCC methods should be applied.

Regarding the treatment of the 10% residue after process supply, these emissions are reported under this category when there is a 90% recharging and subsequent shipment. In cases of decomposing the residual 10% and cleansing the containment shell, or release into the atmosphere, these emissions are reported under "Fluorochemical production –Fugitive Emissions (2.B.9.b.))".

JEITA data are used for F-gases purchased.

The below methods for emissions estimation for liquid crystals manufacturing are applied for each gas.

$$E = FC \times P \times (1 - U) \times (1 - a \times d)$$

E : HFC-23, PFCs (PFC-14, PFC-116, PFC-218, PFC-c318), SF_6, and NF_3 emissions [t]
FC : Purchased amount of gas [t]
P : Process supply rate
U : Use rate of gas
a : Fraction of gas controlled
d : Fraction of gas destroyed

$$BPE = FC \times B \times P \times (1 - a \times d)$$

BPE : By-produced PFC-14, etc. emissions [t]
FC : Purchased amount of gas [t]
B : By-production rate
P : Process supply rate
a : Fraction of gas controlled
d : Fraction of gas destroyed

Relevant indices are shown in Table below. The fraction of gas controlled is not reported here due to confidentiality reasons.

Table 4-61 Indices Related to Emissions of F-gases from Liquid Crystal Manufacturing

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
HFC-23 purchased	t	0.0003	0.1	0.7	1.6	1.1	1.3	1.1	0.9	0.7	1.0	0.6	0.5
PFC-14 purchased	t	7.5	20.7	47.3	77.8	93.7	154.5	177.1	174.9	193.6	136.9	79.8	66.5
PFC-116 purchased	t	0.1	0.4	2.7	9.9	0	0	0	0	0	0	0	0
PFC-c318 purchased	t	0	0	0	0.8	1.6	1.4	1.1	0.9	0.4	0.5	0.3	0.2
SF_6 purchased	t	8.9	11.5	85.3	101.4	176.9	107.4	126.6	95.1	87.1	84.4	49.3	41.0
NF_3 purchased	t	1.3	8.1	106.9	232.2	764.1	783.8	808.0	718.1	805.7	630.7	368.0	306.6
Process supply rate	%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
HFC emissions	kt-CO_2 eq.	0.001	0.2	2	2	3	2	2	1	1	1	1	1
PFC emissions	kt-CO_2 eq.	28	78	192	137	42	68	78	69	70	52	30	25
SF_6 emissions	kt-CO_2 eq.	113	146	904	734	277	175	197	143	133	124	72	60
NF_3 emissions	kt-CO_2 eq.	2	15	62	66	25	20	21	18	18	14	8	7

Reference: *Documents of Fluorocarbons etc. Measures Working Group*, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Table 4-62 Use Rate of Gases and Fractions of Gas Destroyed During Liquid Crystal Manufacturing

Gas	Use rate	Fractions of gas destroyed
HFC-23	80%	90%
PFC-14	40%	
PFC-116	0%	
PFC-c318	90%	
SF_6	40%	
NF_3	70%	95%
NF_3 remote	97%	

Reference: Default values from the *2006 IPCC Guidelines* (Vol. 3 Table 6.4 Tier 2a and Table 6.6). Since there is no default for use rate of PFC-116, 0% was used so as not to underestimate emissions.

Table 4-63 By-production Rate of CHF_3, CF_4, and C_2F_6 During Liquid Crystal Manufacturing

Gas	CHF_3 by-production rate	CF_4 by-production rate	C_2F_6 by-production rate
HFC-23	NA	7%	5%
PFC-c318	2%	0.9%	NA

Reference: Default values from the *2006 IPCC Guidelines* (Vol. 3 Table 6.4 Tier 2a)

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using available domestic HFC, PFC, SF_6 shipment, and NF_3 production amount data, which is thought to be proportional to HFC, PFC, SF_6, and NF_3 emissions, and extrapolating for these years.

For 2023, the purchased amounts of gas are confidential due to the fact that the number of manufactures has become equal or less than two, and therefore extrapolation using the production data of liquid crystal devices are applied for 2023 and onward.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainties of the emission factors, *2006 IPCC Guidelines* default values of 100%, 80%, 300%, and 70% were respectively applied for HFCs, PFCs, SF_6, and NF_3. For the uncertainties of the activity data, 10% was applied for all HFCs, PFCs, SF_6, and NF_3, using the upper limit value in the *2006 IPCC Guidelines*. As a result, the uncertainties of the emissions for HFCs, PFCs, SF_6, and NF_3, were determined to be 100%, 81%, 300%, and 71%, respectively.

- ***Time-series Consistency***

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. d)

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.6.3. Photovoltaics (2.E.3.)

Photovoltaics manufacturing using PFCs is only done by one company inside Japan. Therefore, emissions are confidential and included in PFC emissions from semiconductor manufacturing and reported as “IE”.

4.6.4. Heat Transfer Fluid (2.E.4.)

In the process of electronics manufacturing, fluorinated compounds are used for temperature control. These fluorinated compounds are released through evaporative losses during the cooling of process equipment, etc. Emissions were reported as “IE” since PFCs in this category are included in the total reported in Solvents (2.F.5.), where liquid PFCs, etc. are collectively captured.

4.6.5. Other‐ Microelectromechanical systems (MEMS) (2.E.5.a.)

Microelectromechanical systems (MEMS) manufacturing processes utilize fluorinated compounds during plasma etching of silicon containing materials or during the cleaning process. Typical MEMS manufacturers in Japan are electronic component manufactures. The JEITA collects data on HFC/PFC purchased amounts to use for cleaning electronic components and as solvents. The data includes the purchased amounts used for MEMS production. All of the purchased amounts are already accounted under the category of Solvent (2.F.5.) as emissions. Therefore, emissions are reported as “IE”.

By-product gases from MEMS manufacturing processes are reported as “NE” since the actual status of emissions from this source is unknown.

4.7. Product Uses as Substitutes for ODS (2.F.)

This category covers HFC and PFC emissions from the use of the products that are substitutes for ozone depleting substances (ODS). This section deals with the following sources: Refrigeration and air conditioning (2.F.1.), Foam blowing agents (2.F.2.), Fire protection (2.F.3.), Aerosols (2.F.4.), and Solvents (2.F.5.).

In 2024, emissions from this category were 28,515 kt-CO_2 eq. and represented 2.7% of Japan’s total GHG emissions (excluding LULUCF). The emissions are 6.7 times of 1990.

Table 4-64 Emissions from Product Uses as Substitutes for ODS (2.F.)

Gas			Units	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
HFCs	2.F.1	Refrigeration and air conditioning	kt-CO_2 eq.	NO	828	2,668	7,142	14,037	19,165	23,348	27,189	27,380	26,474	25,298	24,427
		Commercial refrigeration	kt-CO_2 eq.	NO	30	252	2,828	7,643	10,721	13,698	17,016	17,182	16,365	15,750	15,544
		Domestic refrigeration	kt-CO_2 eq.	NO	11	52	244	432	263	199	1	1	1	0.4	0.2
		Industrial refrigeration	kt-CO_2 eq.	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
		Transport refrigeration	kt-CO_2 eq.	NO	NO	1	24	78	164	195	305	315	324	327	340
		Mobile air-conditioning	kt-CO_2 eq.	NO	787	2,290	2,899	2,660	2,743	2,629	2,496	2,437	2,317	2,261	2,123
		For car air conditioners	kt-CO_2 eq.	NO	786	2,287	2,866	2,537	2,578	2,445	2,277	2,217	2,094	2,040	1,898
		Stationary Air-Conditioning (Household)	kt-CO_2 eq.	NO	NO	73	1,147	3,224	5,274	6,628	7,370	7,445	7,468	6,959	6,421
	2.F.2	Foam blowing agents	kt-CO_2 eq.	1	452	440	829	1,538	1,957	2,179	2,571	2,586	2,591	2,589	2,570
	2.F.3	Fire protection	kt-CO_2 eq.	NO	NO	4	7	8	8	9	9	9	9	9	9
	2.F.4	Aerosols	kt-CO_2 eq.	NO	1,365	2,835	1,592	653	473	519	626	568	426	323	310
	2.F.5	Solvents	kt-CO_2 eq.	NO	NO	NO	6	61	110	127	128	129	129	129	125
	Total		kt-CO_2 eq.	1	2,645	5,948	9,575	16,297	21,714	26,182	30,524	30,673	29,630	28,348	27,442
PFCs	2.F.5	Solvents	kt-CO_2 eq.	4,228	11,684	2,834	2,542	1,567	1,395	1,394	1,343	1,279	1,406	1,682	1,072
Total of All Gases			kt-CO_2 eq.	4,230	14,328	8,781	12,117	17,864	23,108	27,576	31,867	31,952	31,036	30,030	28,515

4.7.1. Refrigeration and Air Conditioning Equipment (2.F.1.)

4.7.1.1. Commercial Refrigeration (2.F.1.a.)

4.7.1.1.a. Commercial Refrigeration (2.F.1.a.)

a) Category Description

1) HFCs

HFCs are emitted from the manufacturing, installation, maintenance, accidents, and disposal of commercial refrigeration.

2) PFCs

Emissions from manufacturing were reported as “NO” since Japan has no record from past to present of PFC use in the manufacturing of products. The emissions were also reported as “NO” for use and disposal, because according to survey results of Fluorocarbons in imported products in the past three years, no use of PFC was detected, and it is unlikely that PFCs are refilled into imported products. The Japan Refrigeration and Air Conditioning Industry Association[1)] confirmed with its member companies that no use of PFC was found in imported commercial refrigeration also for the previous years.

Note: 1) https://www.jraia.or.jp/english/index.html

b) Methodological Issues

- ***Estimation Method***

Estimation is mainly conducted using a model, by taking into account the type of device and year of production, etc., and based on the principles of the *2006 IPCC Guidelines*. Using the number of devices produced per type and amount of refrigerant per type contained, etc. for each year, emissions of each species of F-gases from 1) manufacturing, 2) installation, 3) operation and 4) disposal are estimated for each of the devices shown in Table 4-66, and then aggregated.

Emission factors used for the estimation of emissions from operation were determined by a large sample survey conducted on the amount of refrigerant charge and the occurrence of failure in a certain time-

period, by each type of equipment[7]. (260,000 sample units, conducted from 2007 to 2009). In April 2015, a law named the Act on Rational Use and Appropriate Management of Fluorocarbons (Fluorocarbon Emissions Control Act) became effective, and placed obligations on users of equipment to inspect and to create/archive records of inspection history in order to prevent refrigerant leakage during use. The Refrigerant Management System (RaMS), which started its operation under the care of the Japan Refrigerants and Environment Conservation Organization, enabled the tracking of data managed by equipment registered in the System. This allowed for establishing emission factors for 2016 and onward based on the data of RaMS and material flow of refrigerants, etc. The amount of refrigerant contained within the equipment during manufacturing and installation (hereafter, "initial refrigerant") were revised based on a survey on the actual amounts of refrigerants for the types of equipment with higher emission contributions (Condensing units, packaged air conditioners for buildings, packaged air conditioners for stores, packaged air conditioners for facilities, gas-engine heat pump (GHPs)) and centrifugal refrigerating machines, screw refrigerating machines, refrigeration units, built-in refrigeration showcases, and commercial refrigerators, by equipment and gas, etc. For the initial refrigerant of the separately-installed refrigeration showcases, the number of the condensing units sold (outdoor units of the separately-installed refrigeration showcases) were used for the estimation (see Table 4-66).

Methods for HFC emissions from commercial refrigeration are calculated for each type of device and refrigerant using the following principles.

- ***Emissions from manufacturing***

$$E_{manufacturing} = \Sigma \left(N_{produced} \times m_{manufacturing} \times x_{manufacturing}\right)$$

$E_{manufacturing}$	: Emissions from manufacturing [t]
$N_{produced}$	: Number of devices produced [device]
$m_{manufacturing}$	: Amount of refrigerant contained [t/device]
$x_{manufacturing}$	: Fugitive refrigerant ratio from manufacturing

- ***Emissions from installation***

$$E_{installation} = \Sigma \left(N_{installation} \times m_{installation} \times x_{installation}\right)$$

$E_{installation}$	: Emissions from installation [t]
$N_{installation}$	: Number of devices charged at installation site [device]
$m_{installation}$	: Amount of refrigerant contained [t/device]
$x_{installation}$	: Fugitive refrigerant ratio from installation

- ***Emissions from operation***

$$E_{operation} = \Sigma \left(N_{operated} \times m_{operation} \times x_{operation}\right) - R_{operation}$$

$E_{operation}$	: Emissions from operation (includes emissions during servicing, accidents, and breakdowns) [t]
$N_{operated}$	: Number of devices operated [device]
$m_{operation}$	: Amount of refrigerant contained [t/device]
$x_{operation}$	: Fugitive refrigerant ratio from operation
$R_{operation}$	: Amount collected during servicing [t]

[7] For details, refer to *document 1-1 and 1-2 of the 21st meeting of the Group for Prevention of Global Warming, Chemical and Bio Sub-Group, Industrial Structure Council, Ministry of Economy Trade and Industry*, held on March 17, 2009.

➢ *Emissions from disposal*

$$E_{disposal} = \Sigma\ (N_{disposed} \times x_{disposal}) - R_{disposal}$$

$E_{disposal}$: Emissions from disposal [t]
$N_{disposed}$: Number of devices disposed [device]
$x_{disposal}$: Average amount of refrigerant contained [t/device]
$R_{disposal}$: Amount collected after use [t]

Note: In estimating the emissions from operation, the yearly decrease is reflected in the "amount of refrigerant contained." The "number of devices operated" and "number of devices disposed" are estimated from the amount of shipment and lifetime of device.

The associated indices are given in the table below.

Table 4-65 Indices Related to Emissions of HFCs from Commercial Refrigeration

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Number of HFC devices produced	1,000 devices	NO	214	373	1,241	1,122	1,303	1,228	1,171	1,267	1,243	1,203	1,146
Average amount of refrigerant charged at production	g/device	372	372	586	3,281	3,280	3,413	3,473	3,150	2,960	3,015	3,081	3,364
Fugitive refrigerant ratio at production	%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.3%	0.2%	0.1%	0.2%	0.3%	0.2%
Number of HFC devices charged in installation place	1,000 devices	NO	9	32	104	106	129	141	139	137	131	130	138
Average amount of refrigerant during installation	g/device	11,871	11,871	6,853	17,620	22,925	20,778	20,562	14,602	14,574	14,656	13,490	13,182
Fugitive refrigerant ratio during installation	%	1.2%	1.2%	1.5%	1.8%	1.6%	1.7%	1.7%	1.7%	1.7%	1.7%	1.8%	1.8%
Number of HFC devices operated	1,000 devices	NO	375	1,956	6,723	11,495	14,058	15,440	18,033	18,291	18,486	18,603	18,647
Average amount of refrigerant during operation	g/device	791	791	878	3,782	4,758	5,227	5,501	5,419	5,379	5,341	5,310	5,263
Fugitive refrigerant ratio during operation	%	6.6%	6.6%	6.8%	4.8%	4.6%	4.9%	5.0%	4.2%	4.1%	3.8%	3.7%	3.6%
Number of HFC devices disposed	1,000 devices	NO	1	23	127	392	567	727	1,101	1,147	1,178	1,217	1,239
Amount of HFCs collected under law during maintenance	t	NO	NO	NO	NO	548	682	772	990	993	1,179	1,096	1,077
Amount of HFCs collected under law after use	t	NO	NO	NO	183	269	689	735	1,712	1,844	2,242	2,524	2,563
Weighted average GWP for manufacturing	-	NO	1,300	2,062	1,999	2,403	2,343	2,219	1,952	1,828	1,757	1,683	1,683
Weighted average GWP for stocks	-	NO	1,300	1,762	1,915	2,214	2,310	2,321	2,302	2,284	2,261	2,232	2,195
Weighted average GWP for disposal	-	NO	1,300	1,459	1,722	1,909	1,975	1,962	1,946	1,960	1,983	1,994	1,998
Emissions from manufacturing	kt-CO_2 eq.	NO	2	7	83	113	127	134	79	72	69	68	66
Emissions from stocks	kt-CO_2 eq.	NO	25	205	2,345	5,601	8,319	9,949	9,472	9,212	8,530	8,140	7,770
Emissions from disposal	kt-CO_2 eq.	NO	2	39	398	1,903	2,255	3,596	7,460	7,896	7,765	7,542	7,708
Emissions	kt-CO_2 eq.	NO	30	251	2,827	7,617	10,701	13,679	17,011	17,180	16,364	15,749	15,544

Reference: The *Documents of Fluorocarbons etc. Measures Working Group*, and data provided by METI, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Note 1: From 2002 onward, "amount of refrigerant" and "fugitive refrigerant ratio from installation" increased because devices became larger with the increase of commercial package AC devices.

Note 2: Emissions are calculated by gas but are reported as an unspecified mix due to confidentiality reasons.

Table 4-66 Type of HFC and Emission Factors During Operation, by Type of Commercial Refrigeration

Type of commercial refrigeration		Main Type of HFC	Amount of refrigerant[4]		Emission factor		Share in the number of HFC devices operated (2024)
			-2015	2016-	- 2015[3]	2016 -	
Large-size refrigerators	Centrifugal refrigerating machines	HFC-134a, R404A	300 - 2,300 kg	1,450 kg	7%	5.3%	0.02%
	Screw refrigerating machines	HFC-134a, R404A	600 - 200 kg	80 kg	12%	8.9%	0.04%
Mid-size refrigerators	Separately-installed refrigeration showcases	R-404A, R-410A	20 - 41 kg		16%	8.9%	7%
	Refrigeration units	R-404A	2 - 30 kg	1 kg	17%	8.9%	2%
	Condensing units (including showcases)	R-404A, R-410A	2 - 30 kg	26 kg	13%	8.9%	2%
	Chilling units for refrigerators	R-407C, R-410A	2 - 30 kg		6%	0.8%	0.4%
	Other[1]	R-404A, HFC-134a	2 - 30 kg		15%	8.9%	2%
Commercial air conditioning devices	Packaged air conditioners for buildings	R-410A, R-407C	37 kg	18kg	3.5%	2.9%	9%
	Packaged air conditioners for stores	R-410A, R-32	3 - 43 kg	3 kg	3%	1.0%	42%
	Packaged air conditioners for facilities	R-410A, R-407C	3～43 kg	19kg	4.5%	1.8%	3%
	GHPs	R-410A, R-407C	3～43 kg	23kg	5%	2.7%	2%
	Chilling units for air conditioners	R-410A	3～43 kg		6%	0.8%	0.4%
Small-size refrigerators	Built-in refrigeration showcases	R-404A, HFC-134a	0.1 - 3 kg	0.5 kg	2%	1.0%	10%
	Other[2]	HFC-134a, R-410A	0.1 - 3 kg		2%	1.0%	20%

Reference: *Committee for Greenhouse Gas Emissions Estimation Methods in FY2023, FY2024 and FY2025*.

Note: 1) Refrigeration unit for vehicles, refrigeration unit for vessels, other transport refrigeration units

2) Ice makers, water coolers, dehumidifiers, commercial refrigerators

3) *Documents of the 2nd Refrigerant Policy Working Group, Group for Prevention of Global Warming, Chemical and Bio Sub-Group, Industrial Structure Council, Ministry of Economy Trade and Industry* (July 26, 2010), and data provided by METI

4) The sum of the amount of refrigerant charged into the equipment during manufacturing and installation.

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using HFC shipment amounts which is thought to be proportional to the number of HFC devices produced and number of devices charged at installation sites, and the average amount of refrigerant charged at production for 1995, fugitive refrigerant ratio at production for 1995, average amount of refrigerant during installation for 1995, fugitive refrigerant ratio during installation for 1995, amount of refrigerant during operation from 1995, fugitive refrigerant ratio during use for 1995, and extrapolating, etc. for these years.

The *2006 IPCC Guidelines* specifies estimation methods for fugitive emissions from refrigerant containers, however, upon consideration of emissions from non-refillable cylinders (NRCs) that are not captured under other sources, the emissions estimated does not exceed 500 kt-CO_2 eq. This combined with there being no statistics or survey data that can be used as activity data, estimation is not required, as determined by the Committee for Greenhouse Gas Emissions Estimation Methods. It is therefore reported as “NE” (considered insignificant) (see Annex 6). The fugitive emissions from NRCs were

estimated by multiplying the refrigerant amount charged at the time of shipment of unrecovered NRCs by the ratio of the refrigerant remaining in used NRCs. The refrigerant amount charged at the time of shipment of unrecovered NRC was estimated by multiplying the total domestic shipment amount by NRCs, by the ratio of unrecovered NRCs.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainties of the emission factors, the 30% upper limit value for electrical equipment specified in the *2006 IPCC Guidelines* was applied for manufacturing. For use, a 5% value based on a previous METI survey was applied. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry specified in the *2006 IPCC Guidelines* was applied for all manufacturing, use, and disposal. As a result, the uncertainties of the emissions for manufacturing, use, and disposal were determined to be 32%, 11%, and 10%, respectively.

- ***Time-series Consistency***

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. c). From 1995 onward, production amount is taken from the same industry organization of device manufacturers, and the EFs are values reported by Ministry of Trade and Industry in 2009.

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. d).

e) Category-specific Recalculations

Recalculations occurred due to the updates of the average amount of refrigerant contained (during manufacturing and installation) for 2016 to 2023. Corrections to the amount of refrigerant contained during operation also contributed to recalculations for 1996 to 2015. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.7.1.1.b. Automatic Vending machines (2.F.1.a.)

a) Category Description

1) HFCs

HFCs are emitted from manufacturing, accidents, and disposals of automatic vending machines.

2) PFCs

Emission from this source in the “production” category was reported as “NO” as Japan had no record of their use in production. The emissions were also reported as “NO” in the “use” and “disposal” categories, because it was unlikely that PFCs were used in imported products or refrigerants were refilled.

b) Methodological Issues

- ***Estimation Method***

Emissions of F-gases from 1) manufacturing, 2) accidents and 3) disposals are estimated, based on production and shipment amounts and amounts of refrigerants charged. Emission factors are country-specific.

➢ ***Emissions from manufacturing***

$$E_{manufacturing} = \Sigma \left(N_{produced} \times m_{manufacturing} \times x_{manufacturing}\right)$$

$E_{manufacturing}$	: Emissions from manufacturing [t]
$N_{produced}$	: Number of devices produced [device]
$m_{manufacturing}$	: Amount of refrigerant contained [t/device]
$x_{manufacturing}$	: Fugitive refrigerant ratio from manufacturing

➢ ***Emissions from accidents***

$$E_{accident} = \Sigma \left(N_{operated} \times m_{operation} \times A \times x_{accident}\right)$$

$E_{accident}$	: Emissions from accident [t]
$N_{operated}$	: Number of devices operated [device]
$m_{operation}$	: Amount of refrigerant contained [t/device]
A	: Incidence rate
$x_{accident}$	: Average fugitive rate in accident

➢ ***Emissions from disposals***

(a) until 2001 $E_{disposal} = \Sigma \left\{N_{disposed} \times m_{disposal} \times (1 - \eta)\right\}$

(b) from 2002 onward $E_{disposal} = \Sigma \left(N_{disposed} \times m_{disposal\text{-}avg}\right) - R$

$E_{disposal}$	: Emissions from disposal [t]
$N_{disposed}$	: Number of devices disposed [device]
$m_{disposal}$	: Amount of refrigerant contained [t/device]
η	: Collection rate
$m_{disposal\text{-}avg}$	: Average amount of refrigerant contained [t/device]
R	: Amount collected [t]

For HFC emissions from automatic vending machines, the values shown in the *Documents of the Fluorocarbons etc Measures Working Group, Group for Chemical Substance Policy, Manufacturing Industries Sub-Group, Industrial Structure Council, Ministry of Economy Trade and Industry* is reported. The associated indices are given in the table below.

Table 4-67 Indices Related to Emissions of HFCs from Automatic Vending Machines

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Number of HFC devices produced	1,000 devices	NO	NO	272	355	173	10	7	2	2	0.2	0.2	0.1
Refrigerant charged per device	g	NO	NO	300	220	219	219	219	219	219	219	219	219
Fugitive refrigerant ratio at production	%	NO	0.4%	0.4%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
Number of devices operated	1,000 devices	NO	NO	284	1,999	2,279	1,530	748	66	48	40	32	25
Incidence rate	%	NO	0.4%	0.4%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
Fugitive refrigerant ratio (failure)	%	NO	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
Fugitive refrigerant ratio (fixing)	%	NO	1%	1%	1%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%
Number of devices disposed	1,000 devices	NO	NO	NO	NO	286	273	266	77	20	9	7	7
Emissions from manufacturing	kt-CO_2 eq.	NO	NO	0.5	0.4	0.2	0.01	0.01	0.002	0.002	0.0002	0.0002	0.0001
Emissions from stocks	kt-CO_2 eq.	NO	NO	0.1	1	0.5	0.3	0.1	0.01	0.01	0.01	0.01	0.004
Emissions from disposal	kt-CO_2 eq.	NO	NO	NO	NO	25	19	19	5	1	1	1	1
Emissions	t	NO	NO	0.39	0.54	16.05	15.16	14.69	4.22	1.10	0.48	0.41	0.39
	kt-CO_2 eq.	NO	NO	1	1	26	20	19	5	1	1	1	1

Reference: *Documents of Fluorocarbons etc. Measures Working Group*, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

For the years 1990 to 1994, it was confirmed that no automatic vending machines with HFCs were used, and therefore emissions for these years are reported as "NO". (Ministry of the Environment press release, July 31, 2000, *Projections of disposal etc. of refrigerant CFCs, HCFCs, and HFCs (Reference material 1)*)

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainties of the emission factors, the 30% upper limit value for electrical equipment specified in the *2006 IPCC Guidelines* was applied for all manufacturing, use, and disposal. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry specified in the *2006 IPCC Guidelines* was applied for all manufacturing, use, and disposal. As a result, the uncertainties of the emissions for all manufacturing, use, and disposal were determined to be 32%.

- ***Time-series Consistency***

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.7.1.2. Domestic Refrigeration (2.F.1.b.)

a) Category Description

1) HFCs

HFCs are emitted from the production, use (including failure of devices), and disposal of domestic refrigeration.

2) PFCs

Emission from this source in the "production" category was reported as "NO" as Japan had no record of their use in the production of the products. The emission was also reported as "NO" in the "use" and "disposal" categories, because it was unlikely that PFCs were used in imported products, or refrigerants were refilled.

b) Methodological Issues

- ***Estimation Method***

1) Fugitive refrigerants during manufacturing, 2) fugitive refrigerants during use (including failure of devices), and 3) refrigerants contained at the time of disposal minus the amount of HFCs collected under law were estimated separately and then were summed up.

Emissions from use and disposal were estimated by summing up the values calculated for each year of the production of devices. Emission factors are country-specific.

$$E_{total} = M_{manufacturing} \times k + \Sigma\,(N_{operated} \times m_{operation} \times x_{operation}) + \Sigma\,(N_{disposed} \times m_{disposal}) - R$$

E_{total}	: HFC emissions from domestic refrigeration [t]
$M_{manufacturing}$	: Total refrigerant contained at production [t]
k	: Fugitive refrigerant ratio at production
$N_{operated}$	: Number of operated devices containing HFCs [device]
$m_{operation}$	: Refrigerant contained per operated device [t]
$x_{operation}$	: Fugitive refrigerant ratio from use
$N_{disposed}$	: Number of disposed devices containing HFCs [device]
$m_{disposal}$	: Refrigerant contained per disposed device [t]
R	: Collected amount of HFCs [t]

The associated indices are given in the table below.

Table 4-68 Indices Related to Emissions of HFCs from Domestic Refrigeration

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Total HFCs charged in the year of production	t	NO	520	590	0.3	NO	NO	NO	NO	NO	NO	NO	NO
Fugitive refrigerant ratio at production	%	1%	1%	1%	0.2%	NO	NO	NO	NO	NO	NO	NO	NO
Number of operated HFC devices	1,000 devices	NO	7,829	33,213	41,796	28,085	17,637	11,691	2,747	1,881	1,229	759	459
Refrigerant charged per device at production	g	150	150	125	125	125	125	125	125	125	125	125	125
Operational fugitive ratio (including failure)	%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
Number of HFC devices disposed	1,000 devices	NO	NO	177	1,839	3,588	3,204	2,451	672	467	321	212	142
Amount of HFCs collected under law	t/year	–	–	–	52	111	189	144	128	113	99	83	72
Emissions from manufacturing	kt-CO_2 eq.	NO	7	8	0.001	NO	NO	NO	NO	NO	NO	NO	NO
Emissions from stocks	kt-CO_2 eq.	NO	5	16	20	14	9	6	1	1	1	0.4	0.2
Emissions from disposal	kt-CO_2 eq.	NO	NO	28	224	418	254	194	NO	NO	NO	NO	NO
Emissions	kt-CO_2 eq.	NO	11	52	244	432	263	199	1	1	1	0.4	0.2

Reference: the *Documents of Fluorocarbons etc. Measures Working Group*, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Note: Emissions from disposal were estimated by summing up the values calculated for each year of the production of devices, and therefore the refrigerant contained per disposed device cannot be easily provided. However, based on the premise that refrigerators are sealed tight, the refrigerant contained per disposed device in the estimation model is considered equal to refrigerant charged per device.

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using domestic refrigeration shipment amounts, the ratio of devices with HFCs, and HFCs charged per shipment amount (derived from shipment amounts from 1995, the ratio of devices with HFCs from 1995, and total HFCs charged during production from 1995), fugitive refrigerant ratio at production from 1995, refrigerant charged per device at production from 1995, operational fugitive ratio from 1995, number of HFC devices disposed from 1995, and extrapolating, etc. for these years.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainties of the emission factors, the 30% upper limit value for electrical equipment specified in the *2006 IPCC Guidelines* was applied for production and use. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry specified in the *2006 IPCC Guidelines* was applied for production, use, and disposal. As a result, the uncertainties of the emissions for production and use were determined to be 32%, and 10% for disposal.

- ***Time-series Consistency***

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.7.1.3. Industrial Refrigeration (2.F.1.c.)

1) HFCs

HFCs emissions have been reported as “IE”, as they are included in Commercial Refrigeration (2.F.1.a.). It is not possible to separate emissions between commercial refrigeration and industrial refrigeration because the industrial association which provides data does not differentiate between the two in its data collection process.

2) PFCs

Emission from this source in the “production” category was reported as “NO” since Japan had no record of their use in the production of the products. The emission was also reported as “NO” in the “use” and “disposal” categories, because it was unlikely that PFCs were used in imported products or refrigerants were refilled.

4.7.1.4. Transport Refrigeration (2.F.1.d.)

a) Category Description

1) HFCs

HFCs are emitted from the manufacturing, operation, and disposal of transport refrigeration.

2) PFCs

Same as Commercial Refrigeration (2.F.1.a.).

b) Methodological Issues

- ***Estimation Method***

Same as Commercial Refrigeration (2.F.1.a.). The associated indices are given in the table below.

Table 4-69 Indices Related to Emissions of HFCs from Transport Refrigeration (Railways)

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Number of HFC devices produced[1)]	devices	0	0	30	0	0	0	0	0	0	0	0	0
Refrigerant HFC charged per device at production[1)]	kg	0	0	3	0	0	0	0	0	0	0	0	0
Fugitive refrigerant ratio at production	%	0%	0%	0.2%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fugitive refrigerant ratio during use	%	0%	0%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%
Number of HFC devices disposed	devices	0	0	0	0	14	14	21	0	1	2	0	0
Refrigerant stock in device disposed	kg	0	0	0	0	1.5	1.5	1.5	0	1.5	1.5	0	0
Collection rate	%	0%	0%	0%	0%	31%	34%	38%	0%	40%	44%	0%	0%
Emissions from manufacturing	kt-CO_2 eq.	NO	NO	0.001	NO	NO	NO	NO	NO	NO	NO	NO	NO
Emissions from stocks	kt-CO_2 eq.	NO	NO	0.1	0.4	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Emissions from disposal	kt-CO_2 eq.	NO	NO	NO	NO	0.1	0.1	0.1	NO	0.004	0.01	NO	NO
Emissions (railways)	kt-CO_2 eq.	NO	NO	0.1	0.4	1	1	1	1	1	1	1	1

Reference: *Railway Statistical Yearbook* (Ministry of Land, Infrastructure, Transport and Tourism), IPCC default values.
1) are based on information from manufacturers.

Table 4-70 Indices Related to Emissions of HFCs from Transport Refrigeration (Vessels)

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Fugitive refrigerant ratio at production	%	0%	0%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
Fugitive refrigerant ratio during use	%	0%	0%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%
Collection rate	%	0%	0%	0%	0%	31%	34%	38%	41%	40%	44%	40%	40%
Emissions from manufacturing	kt-CO_2 eq.	NO	NO	0.01	0.1	0.1	0.4	0.2	0.3	0.3	0.2	0.1	0.1
Emissions from stocks	kt-CO_2 eq.	NO	NO	1	24	77	163	192	298	310	319	325	337
Emissions from disposal	kt-CO_2 eq.	NO	NO	NO	NO	0.02	0.8	1.7	5.9	4.2	3.6	1.8	1.9
Emissions (vessels)	kt-CO_2 eq.	NO	NO	1	24	78	164	194	305	315	323	327	339

Reference: IPCC default values, *Report on Maritime Affairs* (Ministry of Land, Infrastructure, Transport and Tourism), etc.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

Same as Commercial Refrigeration (2.F.1.a.). See section 4.7.1.1.a.c).

- ***Time-series Consistency***

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.7.1.5. Mobile Air-Conditioning (2.F.1.e.)

a) Category Description

1) HFCs

HFCs are emitted from manufacturing, operation, breakdowns, accidents, and disposals of mobile air-conditioning devices (car air conditioners, and railway and vessel air conditioners).

2) PFCs

Emission from this source in the "production" category was reported as "NO" since Japan had no record of their use in production. The emission was also reported as "NO" in the "use" and "disposal" categories, because it was unlikely that PFCs were used in imported products or refrigerants were refilled.

b) Methodological Issues

- ***Estimation Method***

In accordance with the IPCC Guidelines, emissions of each species of F-gases from 1) manufacturing, 2) operation, 3) breakdowns, 4) accidents and 5) disposals are estimated. Emission factors are country-specific. The below thinking is applied for each type of car.

➢ ***Emissions from manufacturing***

$$E_{manufacturing} = \Sigma \left(N_{produced} \times m_{manufacturing} \times x_{manufacturing}\right)$$

$E_{manufacturing}$	: Emissions from manufacturing [t]
$N_{produced}$	: Number of devices produced [device]
$m_{manufacturing}$	: Amount of refrigerant contained [t/device]
$x_{manufacturing}$	: Fugitive refrigerant ratio from manufacturing

➢ ***Emissions from operation***

$$E_{operation} = \Sigma \left(N_{operated} \times m_{operation} \times x_{operation}\right)$$

$E_{operation}$	: Emissions from operation [t]
$N_{operated}$	: Number of cars operated [device]
$m_{operation}$	: Amount of refrigerant contained [t/device]
$x_{operation}$	: Fugitive refrigerant ratio from operation

Note: In the estimation of emissions from operation, the yearly decrease is reflected in the "amount of refrigerant contained."

➢ ***Emissions from breakdowns***

$$E_{breakdowns} = \Sigma \left(N_{operated} \times m_{operation} \times A \times x_{accident}\right)$$

$E_{breakdowns}$	: Emissions from maintenance [t]
$N_{operated}$	: Number of cars operated [device]

$m_{operation}$: Amount of refrigerant contained [t/device]
A : Rate of breakdowns
$x_{accident}$: Fugitive refrigerant ratio from breakdowns

➢ *Emissions from accident*

$$E_{accident} = \Sigma (N_{destroyed} \times m_{operation})$$

$E_{accident}$: Emissions from accident [t]
$N_{destroyed}$: Number of cars in completely destroyed [device]
$m_{operation}$: Amount of refrigerant contained at time of accident [t/device]

➢ *Emissions from disposal*

(a) until 2001 $E_{disposal} = \Sigma \{N_{disposed} \times m_{disposal} \times (1 - \eta)\}$
(b) from 2002 onward $E_{disposal} = \Sigma (N_{disposed} \times m_{disposal\text{-}avg}) - R$

$E_{disposal}$: Emissions from disposal [t]
$N_{disposed}$: Number of cars disposed [device]
$m_{disposal}$: Amount of refrigerant contained [t/device]
η : Collection rate
$m_{disposal\text{-}avg}$: Average amount of refrigerant contained [t/device]
R : Amount collected [t]

Relevant indices are shown in Table below.

Table 4-71 Indices Related to Emissions of HFC-134a from Car Air Conditioners

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Number of cars produced	1,000 devices	0	9,681	9,761	10,407	9,292	9,613	9,273	5,148	4,034	2,805	1,752	1,210
Fugitive refrigerant during production	g	4	4	4	3	1	1	1	1	1	1	1	1
Number of cars operated with HFC air conditioners	1,000 devices	0	15,655	42,374	60,364	66,043	72,054	73,272	72,333	70,309	67,611	64,118	60,183
Average refrigerant charged per device	g	700	700	615	548	497	497	497	497	497	497	497	497
Fugitive refrigerant during use per year per device (normal car)	g	15	15	15	10	10	10	10	10	10	10	10	10
Rate of breakdown incidences	%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%	4%
Fugitive refrigerant ratio from breakdown cars	%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%
Number of cars completely destroyed	1,000 devices	0	50	136	193	211	231	234	231	225	216	205	193
Average refrigerant charged in completely destroyed cars	g	681	681	610	522	448	417	404	379	374	366	373	366
Number of cars disposed	1,000 devices	0	116	789	2,058	2,895	2,835	2,694	2,763	2,667	2,384	2,383	2,224
Average refrigerant charged at time of disposal	g	676	676	593	522	444	412	380	339	337	334	357	352
Amount of HFC collected (under law from FY2002)	t/year	-	-	-	531	898	785	710	625	579	501	489	447
Emissions from manufacturing	kt-CO_2 eq.	NO	44	44	41	12	10	9	5	4	2	2	1
Emissions from stocks	kt-CO_2 eq.	NO	640	1,635	2,119	2,020	2,069	2,027	1,867	1,797	1,709	1,570	1,461
Emissions from disposal	kt-CO_2 eq.	NO	102	608	707	505	498	409	405	415	383	469	436
Emissions	kt-CO_2 eq.	NO	786	2,287	2,866	2,537	2,578	2,445	2,277	2,217	2,094	2,040	1,898

Reference: *Documents of Fluorocarbons etc. Measures Working Group*, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Table 4-72 Indices Related to Emissions of HFCs from Air Conditioners (Railways)

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Fugitive refrigerant ratio at production	%	0%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
Fugitive refrigerant ratio during use	%	0%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Emissions from manufacturing	kt-CO_2 eq.	NO	0.003	0.03	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.04
Emissions from stocks	kt-CO_2 eq.	NO	0.3	1.5	6.3	14.2	18.1	20.8	27.7	29.3	30.7	30.9	31.8
Emissions from disposal	kt-CO_2 eq.	NO	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.1	0.04	0.04	0.1
Emissions (railways)	kt-CO_2 eq.	NO	0.4	2	6	14	18	21	28	29	31	31	32

Reference: *Railway Statistical Yearbook*, *Yearbook of Railway Car Production Statistics* (Ministry of Land, Infrastructure, Transport and Tourism), IPCC default values, etc.

Table 4-73 Indices Related to Emissions of HFCs from Air Conditioners (Vessels)

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Fugitive refrigerant ratio at production	%	0%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%
Fugitive refrigerant ratio during use	%	0%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
Collection rate	%	0%	0%	0%	0%	31%	34%	38%	41%	40%	44%	40%	40%
Emissions from manufacturing	kt-CO_2 eq.	NO	0.0003	0.004	0.1	0.2	0.2	0.2	0.1	0.05	0.05	0.04	0.04
Emissions from stocks	kt-CO_2 eq.	NO	0.1	0.9	25.8	108.2	147.2	162.3	189.9	188.5	189.2	187.5	190.1
Emissions from disposal	kt-CO_2 eq.	NO	NO	NO	NO	0.01	0.1	0.2	1.6	2.6	2.4	2.2	2.2
Emissions (vessels)	kt-CO_2 eq.	NO	0.1	1	26	108	148	163	192	191	192	190	192

Reference: IPCC default values, *Report on Maritime Affairs, etc*.

For car air conditioners, due to the lack of data necessary to estimate emissions for the years 1992 to 1994 in which HFCs were used, estimates have been done by using HFC shipment amounts which is thought to be proportional to the number of car produced, and the fugitive refrigerant during production from 1995, average refrigerant charged per device from 1995, fugitive refrigerant ratio during use per year per device (normal car) from 1995, rate of breakdown incidences from 1995, fugitive refrigerant ratio from breakdown cars from 1995, number of cars completely destroyed in 1995, the number of cars operated with HFC air conditioners from 1995, average refrigerant charged in completely destroyed cars from 1995, number of cars disposed from 1995, average refrigerant charged at the time of disposal from 1995, and extrapolating, etc. for these years.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

Same as Automatic Vending machines (2.F.1.a.). See section 4.7.1.1.b.c).

- ***Time-series Consistency***

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.7.1.1.b.c)

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. d).

e) Category-specific Recalculations

For 2023, recalculations occurred due to updates to the *Railway Statistical Yearbook* and to the number of cars operated with HFC air conditioners, etc,. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.7.1.6. Stationary Air-Conditioning (Household) (2.F.1.f.)

a) Category Description

1) HFCs

HFCs are emitted from the manufacturing, operation, and disposals of household stationary air-conditioning devices.

2) PFCs

Emission from this source in the "production" category was reported as "NO" since Japan had no record of their use in production. The emission was also reported as "NO" in the "use" and "disposal" categories, because it was unlikely that PFCs were used in imported products or refrigerants were refilled.

b) Methodological Issues

- **Estimation Method**

In accordance with the IPCC Guidelines, emissions of each species of F-gases from 1) manufacturing, 2) operation, 3) disposals are estimated, based on production and shipment amounts and amounts of refrigerants charged. Emission factors are country-specific.

➢ **Emissions from manufacturing**

$$E_{manufacturing} = \Sigma \left(N_{produced} \times m_{manufacturing\text{-}avg} \times x_{manufacturing}\right)$$

$E_{manufacturing}$	: Emissions from manufacturing [t]
$N_{produced}$	: Number of devices produced [device]
$m_{manufacturing\text{-}avg}$	: Average amount of refrigerant contained [t/device]
$x_{manufacturing}$	: Fugitive refrigerant ratio from manufacturing

➢ **Emissions from operation**

$$E_{operation} = \Sigma \left(N_{operated} \times m_{operation\text{-}avg} \times x_{operation}\right)$$

$E_{operation}$	: Emissions from operation [t]
$N_{operated}$	: Number of devices operated [device]
$m_{operation\text{-}avg}$	: Average amount of refrigerant contained [t/device]
$x_{operation}$	: Fugitive refrigerant ratio from operation

➢ **Emissions from disposal**

$$E_{disposal} = \Sigma \left(N_{disposed} \times m_{disposal\text{-}avg}\right) - R$$

$E_{disposal}$	: Emissions from disposal [t]
$N_{disposed}$	: Number of devices disposed [device]
$m_{disposal\text{-}avg}$	: Average amount of refrigerant contained [t/device]
R	: Amount collected [t]

Note: In the estimation of emissions from operation, the yearly decrease is reflected in the "average amount of refrigerant contained." The "number of devices for shipment" and "number of devices disposed" are estimated from amount of shipment and lifetime of device.

The associated indices are given in the table below.

Table 4-74 Indices Related to Emissions of HFCs from Stationary Air-Conditioning (Household)

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Number of HFC devices produced	1,000 devices	NO	NO	1,077	3,981	3,460	3,920	4,160	4,078	3,406	3,624	4,142	3,836
Refrigerant charged per device	g	1,000	1,000	1,000	1,000	1,000	939	738	706	706	703	702	702
Fugitive refrigerant ratio at production	%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.1%	0.1%	0.1%	0.1%	0.05%	0.04%
Number of devices operated	1,000 devices	NO	NO	1,726	26,091	61,540	83,349	94,197	117,693	120,810	123,383	125,223	127,438
Average refrigerant charged during use	g/device	NO	NO	1,000	1,000	1,000	993	957	851	833	817	801	786
Fugitive refrigerant ratio during use	%	2%	2%	2%	2%	2%	2%	2%	1%	1%	1%	1%	1%
Number of devices disposed	1,000 devices	NO	NO	2	83	764	1,907	2,990	5,720	6,181	6,581	6,912	7,204
Average refrigerant stock in device disposed	g/device	NO	NO	954	911	841	802	777	719	707	694	681	666
Amount of HFCs collected under law	t/year	-	-	-	10	231	466	570	1,599	1,622	1,647	1,953	2,105
Emissions from manufacturing	kt-CO_2 eq.	NO	NO	4	15	12	10	4	2	1	1	1	1
Emissions from stocks	kt-CO_2 eq.	NO	NO	66	1,004	2,367	3,149	3,230	2,593	2,419	2,236	2,050	1,870
Emissions from disposal	kt-CO_2 eq.	NO	NO	3	128	844	2,115	3,394	4,775	5,024	5,230	4,909	4,550
Emissions	kt-CO_2 eq.	NO	NO	73	1,147	3,224	5,274	6,628	7,370	7,445	7,468	6,959	6,421

Reference: *Documents of Fluorocarbons etc. Measures Working Group*, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

For the years 1990 to 1994, it was confirmed that no household stationary air-conditioning with HFCs were used, and therefore emissions for these years are reported as “NO”. (Ministry of the Environment press release, July 31, 2000, *Projections of disposal etc of refrigerant CFCs, HCFCs, and HFCs (Reference material 1)*)

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

Same as Commercial Refrigeration (2.F.1.a.). See section 4.7.1.1.a.c)

- ***Time-series Consistency***

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. d).

e) Category-specific Recalculations

For 2016 to 2023, recalculations occurred due to the update of the fugitive refrigerant ratio during use to the same value used for package air conditioners for stores, based on information obtained from the equipment manufacturer. The update of the amount of refrigerant contained during manufacturing for 2012 onward also contributed to recalculations. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.7.2. Foam Blowing Agents (2.F.2.)

4.7.2.1. Closed Cells (2.F.2.a.)

4.7.2.1.a. Urethane Foam (2.F.2.a.)

a) Category Description

HFC-134a, HFC-245fa, and HFC-365mfc are emitted as a result of foam blowing agent use.

b) Methodological Issues

- ***Estimation Method***

In accordance with the IPCC Guidelines (closed-cell foams), emissions were calculated assuming that 10% of the emission from foam blowing agents used each year occurred within the first year after production, with the remainder emitted over 20 years at the rate of 4.5% per year. The data on the amount of foam blowing agents used each year was provided by the Japan Urethane Foam Association, Japan Urethane Raw Materials Association.

It is difficult to separate the "use" emission from that at the time of "disposal" because urethane foams were disposed of at various times. Accordingly, the emissions in the "use" and "disposal" categories were combined and reported under the "use" category, while the emission in the "disposal" category was reported as "IE".

$$E = E_{manufacturing} + E_{use}$$
$$= (M \times EF_{FYL}) + (Bank \times EF_{AL})$$

E	:	HFC emissions [t]
$E_{manufacturing}$	:	Emissions during production [t]
E_{use}	:	Emissions during use [t]
M	:	Amount of HFC used [t]
EF_{FYL}	:	Leakage during foam blowing [%]
$Bank$	:	Total amount used up to the previous year [t]
EF_{AL}	:	Percentage of annual emissions during use [%]

Table 4-75 Indices Related to Emissions of HFCs from Urethane Foam

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
HFC-134a use	t	NO	NO	167	224	66	28	12	NO	NO	NO	NO	NO
HFC-245fa use	t	NO	NO	NO	3,893	2,365	2,570	2,230	618	551	445	336	137
HFC-365mfc use	t	NO	NO	NO	1311	900	921	779	203	186	151	105	42.6
Leakage during foam blowing	%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
Annual emissions rate during use	%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%	4.5%
HFC-134a emissions	kt-CO_2 eq.	NO	NO	22	102	121	126	126	125	115	105	93	80
HFC-245fa emissions	kt-CO_2 eq.	NO	NO	NO	408	953	1,263	1,431	1,732	1,751	1,763	1,771	1,766
HFC-365mfc emissions	kt-CO_2 eq.	NO	NO	NO	132	322	427	480	572	578	582	584	582

Reference: *Documents of Fluorocarbons etc. Measures Working Group*, and data provided by the METI, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Note: As regards HFC-245fa and HFC-365mfc, their use increased because they replaced HCFC-141b whose production ended in January 2004.

For the years 1990 to 1994, it was confirmed that no urethane foam with HFCs was used, and therefore emissions for these years are reported as "NO". (*FY2011 PRTR (Pollutant Release and Transfer Register) Estimation methods for releases from sources not required to report* (MOE)

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainties of the emissions for both manufacturing and use, *the 2006 IPCC Guidelines* value of 50% was used.

- ***Time-series Consistency***

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.7.2.1.b. Extruded Polystyrene Foam (2.F.2.a.)

a) Category Description

HFC-134a is emitted as a result of foam blowing agent use.

b) Methodological Issues

- ***Estimation Method***

Emissions were calculated assuming that 25% of the emission of foam blowing agents occurs within the first year after production, with the remainder emitted at the rate of 0.75% per year. The amount of foam blowing agents used each year was provided by the Extruded Polystyrene Foam Industry Association. This assumption is consistent with the *2006 IPCC Guidelines* and the estimation method under PRTR for the amount of transferred HCFC at polystyrene foam production sites.

It is difficult to separate the “use” emission from that at the time of “disposal” because heat insulation material is disposed of at various times such as the renovation and dismantling of buildings, and in times of disaster. Since disposed polystyrene foam is considered to be emitting HFCs as same as that in use, these emissions are combined and reported under “use”, while the emissions from “disposal” were reported as “IE”.

$$E = E_{manufacturing} + E_{use}$$
$$= (M \times EF_{FYL}) + (Bank \times EF_{AL})$$

E	: HFC-134a emissions [t]
$E_{manufacturing}$	: Emissions during production [t]
E_{use}	: Emissions during use [t]
M	: Amount of HFC-134a used in particular year [t]
EF_{FYL}	: Leakage during foam blowing (25%)
$Bank$	: Total amount used in the past up to the previous year [t]

EF_{AL} : Annual emission rate during use [%]

Table 4-76 Indices Related to Emissions of HFC-134a from Extruded Polystyrene Foam

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
HFC-134a use	t	NO	NO	NO	26	NO	NO	NO	NO	NO	NO	NO	NO
Foam productization rate	%	-	-	-	75%	75%	75%	75%	75%	75%	75%	75%	75%
Annual emission rate during use	%	-	-	-	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%	0.8%
Emissions during production	t	NO	NO	NO	6.50	NO	NO	NO	NO	NO	NO	NO	NO
Emissions during use	t	NO	NO	NO	9.00	9.23	9.23	9.23	9.23	9.23	9.23	9.23	9.23
Emissions	t	NO	NO	NO	15.50	9.23	9.23	9.23	9.23	9.23	9.23	9.23	9.23
Emissions during production	kt-CO_2 eq.	NO	NO	NO	8	NO	NO	NO	NO	NO	NO	NO	NO
Emission during use	kt-CO_2 eq.	NO	NO	NO	12	12	12	12	12	12	12	12	12
Emissions	kt-CO_2 eq.	NO	NO	NO	20	12	12	12	12	12	12	12	12

Reference: *Documents of Fluorocarbons etc. Measures Working Group*, *Documents of the first meeting of the Breakout Group on F-gases (FY2013) etc.*

For the years 1990 to 1994, it was confirmed that no extruded polystyrene foam with HFCs was used, and therefore emissions for these years are reported as "NO". (*FY2011 PRTR (Pollutant Release and Transfer Register) Estimation methods for releases from sources not required to report*)

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

Same as Urethane Foam (2.F.2.a.). See section 4.7.2.1.a. c).

- ***Time-series Consistency***

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.7.2.2. Open Cells (2.F.2.b.)

4.7.2.2.a. High Expanded Polyethylene Foam (2.F.2.b.)

a) Category Description

HFC-134a and HFC-152a is emitted as a result of foam blowing agent use.

b) Methodological Issues

- ***Estimation Method***

In accordance with the IPCC Guidelines (open-cell foams), emissions were calculated assuming that all of the emissions from foam blowing agents used occurred at the time of production. The amount of

blowing agents used each year was provided by the High Expanded Polyethylene Foam Industry Association.

Table 4-77 Indices Related to Emissions of HFC-134a from High Expanded Polyethylene Foam

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
HFC-134a use	t	1	346.00	322.00	128.00	99.86	99.86	99.86	99.86	99.86	99.86	99.86	99.86
Emissions	t	1	346.00	322.00	128.00	99.86	99.86	99.86	99.86	99.86	99.86	99.86	99.86
	kt-CO_2 eq.	1	450	419	166	130	130	130	130	130	130	130	130

Reference: *Documents of Fluorocarbons etc. Measures Working Group,* and data provided by the METI, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Table 4-78 Indices Related to Emissions of HFC-152a from High Expanded Polyethylene Foam

Item	Unit	1990	1995	1998 onward
HFC-152a use	t	0.04	14.00	NO
Emissions	t	0.04	14.00	NO
	kt-CO_2 eq.	0.005	2	NO

Reference: *Documents of Fluorocarbons etc. Measures Working Group*, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using domestic HFC shipment amounts which is thought to be proportional to use amounts of foam blowing agents, and extrapolating for these years.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

Same as Urethane Foam (2.F.2.a.). See section 4.7.2.1.a. c).

- ***Time-series Consistency***

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.7.3. Fire Protection (2.F.3.)

a) Category Description

HFCs (HFC-23 and HFC-227ea) are emitted during production, use, and disposal of fire extinguishers.

b) Methodological Issues

- **Estimation Method**

➢ **Emissions from production**

HFC-23 and HFC-227ea are used for the production of fire extinguishers. However, as of 2004, only HFC-227ea is filled in the bottles for fire extinguishing equipment, and for HFC-23, each company purchases pre-filled HFC-23 fire extinguisher bottles, and therefore no emissions occur at production. HFCs emissions from this category was reported as "NO" by expert judgment since HFC-227ea was a very small amount, 0.0007 [t] when emission from production in FY2004 was estimated.

➢ **Emissions from use**

For use, in 1995, almost no HFC filled fire extinguishers existed on the market, and therefore it is assumed that there was no use, resulting in "NO" for 1995 and earlier years. For 1996 and following years, calculations were performed using the following equation and based on the HFC extinguishing agent installation amounts, for each gas.

$$E_{use} = Bank \times EF$$

E_{use} : HFC emissions during use [t]
$Bank$: Cumulative amount of HFC extinguishing agents installed[t]
EF : Emission factor during use

➢ **Emissions from disposal**

The data of installation (from 2006 onward) and registration (from 2008 onward) amounts of HFC extinguishing agents are collected in Japan. The value calculated by subtracting the registration amount of HFC extinguishing agents for the estimation year from the sum of the installation amount for the estimation year and registration amount for the previous year, equals the sum of the recycle amount (R), emissions during recycling operation (E1), and emissions from events other than recycling operation, such as accidents (E2). Emissions from disposal can be estimated by subtracting R from this value (which would equal the sum of E1 and E2). However, since the amounts of R, E1, and E2 for HFC extinguishing agents are not collected, the calculations were performed using the following equation for each gas.

$$E_{disposal\,(n)} = (I_{(n)} + REG_{(n-1)} - REG_{(n)}) \times EF$$

$E_{disposal\,(n)}$: Emissions of HFC extinguishing agent from disposal in year n [t]
$I_{(n)}$: Installation amounts of HFC extinguishing agents in year n [t]
$REG_{(n-1)}$: Registration amounts of HFC extinguishing agents in year n-1 [t]
$REG_{(n)}$: Registration amounts of HFC extinguishing agents in year n [t]
EF : Emission factor based on actual data of halon fire extinguishing agents

Before 2008, due to lack of data, emissions from disposal for each year are assumed to be proportional to emissions during use and were calculated by multiplying the emission during use for that year by the ratio (3.8%) of the total emissions from disposal for 2009 to 2022 to the total emissions during use for 2009 to 2022.

- ***Emission Factors***

➢ ***Emissions from use***

There are still no findings on the emission factor of HFC extinguishing agents when using them. The emission rate (0.00088) determined from refills of halons (provided by the Fire and Disaster Management Agency), which are similar extinguishing agents, was adopted as the emission factor for use.

Table 4-79 References for the Emission Factor of Fire Extinguishers
(The Emission Ratio of Halon Fire Extinguishers)

Item	Unit	2002	2003	2004	2005	2006	2007	Average
Installations of halon 1301 (A)	t	17,094	17,090	17,060	16,994	17,075	16,889	17,034
Refills of halon 1301 (B)	t	13	13	22	13	14	15	15
(B) / (A)	—	0.00076	0.00076	0.00129	0.00076	0.00082	0.00089	**0.00088**

➢ ***Emissions from disposal***

A value of 2%, calculated using the following equation with available actual data of halon extinguishing agents provided by the Syoubou Kankyo Network, was used since HFC extinguishing agent data of recycled amounts (R), emissions from recycling operation (E1) and emissions from events other than recycling operation, such as accidents (E2) were not available. Regarding the recovery and disposal operation of HFC extinguishing agents, similar processes are followed as those of halon extinguishing agents.

$$EF = (E1 + E2) / (R + E1 + E2)$$

E1 : Emissions from recycling operation of halon extinguishing agents (Total from 2012 to 2022) [t]
E2 : Emissions from events other than recycling operation such as accidents of halon extinguishing agents (Total from 2012 to 2022) [t]
R : Recycled amount of halon extinguishing agents (Total from 2012 to 2022) [t]

Table 4-80 Actual Data of Halon Extinguishing Agents Used for Establishing the Emission Factor

Item	Unit	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Emissions from recycling operation (E1)	t	25	11	6	5	6	8	6	4	4	4	3
Emissions from events other than recycling operation, such as accidents (E2)	t	5	11	7	10	6	10	19	12	7	12	9
Recycled amounts (R)	t	1,824	1,426	842	693	775	1,120	900	584	649	584	517

For years prior to 2008 where data was not available, see the section “Estimation Method”.

- ***Activity Data***

➢ ***Emissions from use***

The cumulative amount of HFC installed (provided by the Syoubou Kankyo Network) was used as activity data for HFC emissions from fire extinguishing agents use.

Table 4-81 Installation Amounts of the HFC Extinguishing Agents

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Installation amounts of HFC-23	t	NO	NO	56.29	19.02	10.84	4.03	13.18	0.12	1.79	NO	0.40	0.77
Cumulative amounts of HFC-23 installed	t	NO	NO	306.38	478.27	523.12	536.67	559.43	580.09	581.88	581.88	582.28	583.05
Installation amounts of HFC-227ea	t	NO	NO	44.74	31.95	24.25	43.53	52.57	16.45	11.39	10.27	1.09	3.63
Cumulative amounts of HFC-227ea installed	t	NO	NO	225.28	391.73	522.44	639.97	738.32	862.29	873.68	883.95	885.04	888.67

➢ ***Emissions from disposal***

The amounts of installation and registration of HFC extinguishing agents provided by the Syoubou Kankyo Network were used.

Table 4-82 Amount of Installation/Registration of HFC Extinguishing Agents

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Installation amounts of HFC-23	t					10.84	4.03	13.18	0.12	1.79	NO	0.40	0.77
Registration amounts of HFC-23	t					42.58	54.38	75.01	91.51	92.84	91.84	91.19	90.19
Installation amounts of HFC-227ea	t					24.25	43.53	52.57	16.45	11.39	10.27	1.09	3.63
Registration amounts of HFC-227ea	t					123.48	243.86	339.41	469.93	481.41	491.61	492.98	496.37

For years prior to 2008 due where data was not available, see the section “Estimation Method”.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainties of the emissions, *the 2006 IPCC Guidelines* value of 16% was used.

- ***Time-series Consistency***

Calculations are performed with a consistent method to the extent possible, based on data received from the Syoubou Kankyo Network.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.7.4. Aerosols (2.F.4.)

4.7.4.1. Metered Dose Inhalers (2.F.4.a.)

a) Category Description

HFCs are emitted from the manufacturing and use of metered dose inhalers (MDIs).

b) Methodological Issues

- ***Estimation Method***

In accordance with the IPCC Guidelines, emissions were calculated on the assumption that from the amount used each year, 50% of the emission occurred in the year of production, with the remaining 50% emitted in the following year.

The amount of purchased gas, the amount of the use of domestically manufactured MDI and the use of imported MDI, and the amount of disposal of MDI were provided by the Federation of Pharmaceutical Manufacturers’ Associations of Japan (FPMAJ). FPMAJ estimates the amount of HFC disposal by mainly including destructed MDI that were defective products.

$$E_n = E_{manufacturing} + E_{potential\ (n-1)} \times EF_{first} + E_{potential\ (n)} \times (1 - EF_{first}) - R_{(n)}$$

E_n : F-gas (HFC-134a, HFC-227ea) emissions in year n [t]
$E_{manufacturing}$: Fugitive emissions during manufacturing [t]

$E_{potential\ (n-1)}$, $E_{potential\ (n)}$: F-gas potential emissions in year n – 1 or in year n [t]
EF_{first} : 50[%]
$R_{(n)}$: Amount of disposal of F-gas contained in MDI [t]

$$E_{potential} = U_{domestic} + U_{import}$$

$U_{domestic}$: Use amount of domestically manufactured MDI [t]
U_{import} : Use amount of imported MDI [t]

The associated indices are given in the table below.

Table 4-83 Indices Related to Emissions of HFC-134a from MDI

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Usage of domestic MDI	t	NO	NO	1.40	0.90	1.07	0.60	0.59	0.75	0.60	0.75	0.75	0.75
Usage of imported MDI	t	NO	NO	42.00	70.70	57.05	46.04	41.34	34.55	30.47	28.16	29.35	30.11
Amount collected and destroyed	t	NO	NO	0.10	1.90	2.52	0.72	3.56	0.04	0.34	0.96	0.06	0.29
HFC-134a emissions	t	NO	NO	37.20	62.75	55.52	47.23	39.35	34.48	32.94	29.15	29.58	30.29
	kt-CO_2 eq.	NO	NO	48	82	72	61	51	45	43	38	38	39

Reference: *Documents of Fluorocarbons etc. Measures Working Group*, and data provided by METI, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Table 4-84 Indices Related to Emissions of HFC-227ea from MDI

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Usage of domestic MDI	t	NO	NO	NO	41.00	35.96	25.11	22.96	20.06	19.76	19.19	19.56	17.43
Usage of imported MDI	t	NO	NO	3.60	2.10	0.42	0.73	18.75	39.85	30.51	33.39	33.12	39.07
Amount collected and destroyed	t	NO	NO	NO	1.20	0.80	0.77	0.70	0.02	0.05	0.03	0.04	0.30
HFC-227ea emissions	t	NO	NO	1.80	48.05	33.14	26.93	31.70	59.16	55.15	51.87	52.81	54.79
	kt-CO_2 eq.	NO	NO	6	161	111	90	106	198	185	174	177	184

Reference: *Documents of Fluorocarbons etc. Measures Working Group,* and data provided by METI, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Note: The production of MDIs using HFC-134a started in 1997, and those using HFC-227ea started in 2001 (with production using imported HFC-227ea starting in 2000).

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, emissions have been estimated to be “NO” for these years, since for HFC-134a, 1995 and 1996 amounts of usage of domestic MDI and usage of imported MDI are each zero, and for HFC-227ea, 1995 to 1999 amounts of usage of domestic MDI and usage of imported MDI are each zero.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainties of the emission factors, 0% was applied for all production, use and disposal, due to the fact that the amount of emissions is equal to the amount of MDI used. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry specified in the *2006 IPCC Guidelines* was applied for all production, use and disposal. As a result, the uncertainties of the emissions for all production, use and disposal were determined to be 10%.

- ***Time-series Consistency***

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. d).

e) Category-specific Recalculations

Recalculations occurred for 2023 due to the updated amounts of imported MDI used. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.7.4.2. Other – Aerosols (2.F.4.b.-)

a) Category Description

HFCs are emitted from the manufacturing and use of aerosols.

b) Methodological Issues

- ***Estimation Method***

In accordance with the *2006 IPCC Guidelines*, emissions were calculated on the assumption that 50% of the emission from the amount of aerosol filled in the products (potential emissions) occurred in the year of production, with the remaining 50% emitted in the following year. Fugitive emissions from manufacturing are considered as the balance between the amount used for production and the actual measurement amount filled in the products, and it is included in the emissions. The data on the amount used for production and the amount filled in the products were provided by the Aerosol Industry Association of Japan.

HFC is considered to be actually remaining in disposed aerosols at some level. However, all potential emissions including that for "disposal" are allocated under "use" in accordance with the *2006 IPCC Guidelines*.

$$E_n = E_{manufacturing} + E_{potential\ (n-1)} \times EF_{first} + E_{potential\ (n)} \times (1 - EF_{first})$$

E_n	: HFC emissions in year n [t]
$E_{manufacturing}$	: Fugitive emissions during manufacturing [t]
$E_{potential\ (n-1)}$, $E_{potential\ (n)}$	: HFC potential emissions in year n-1 or in year n [t]
EF_{first}	: 50 [%]

$$E_{manufacturing\ (n)} = M_{(n)} - E_{potential\ (n)}$$

$E_{manufacturing\ (n)}$	: Fugitive emissions during manufacturing [t]
$M_{(n)}$	: HFC consumed during manufacturing in year n [t]
$E_{potential\ (n)}$	: HFC potential emissions [t]

The associated indices are given in the table below.

Table 4-85 Indices Related to Emissions of HFC-134a from Aerosols

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Potential emissions	t	NO	1,300.00	2,044.10	604.40	199.92	168.00	206.00	246.00	183.00	98.00	57.76	65.90
Fugitive emissions during production	t	NO	NO	80.20	24.90	8.08	7.00	15.00	48.00	44.50	21.00	1.54	1.90
Emissions in the year produced, during use	t	NO	650.00	1,022.05	302.20	99.96	84.00	103.00	123.00	91.50	49.00	28.88	32.95
Remaining (emissions in the next year)	t	NO	650.00	1,022.05	302.20	99.96	84.00	103.00	123.00	91.50	49.00	28.88	32.95
HFC-134a emissions	t	NO	1,050.00	2,137.10	908.15	223.04	174.85	229.50	284.00	259.00	161.50	79.42	63.73
	kt-CO_2 eq.	NO	1,365	2,778	1,181	290	227	298	369	337	210	103	83

Reference: *Documents of Fluorocarbons etc. Measures Working Group*, *Documents of the first meeting of the Breakout Group on F-gases (FY2013) etc*

Note: Fugitive emissions from 1992 to 1997 are included in potential emissions.

Table 4-86 Indices Related to Emissions of HFC-152a from Aerosols

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Potential emissions	t	NO	NO	34.10	1,299.50	558.00	320.00	279.00	27.00	30.00	30.00	29.87	29.70
Fugitive emissions during production	t	NO	NO	1.10	28.90	638.00	249.00	108.50	17.00	1.00	NO	0.43	0.70
Emissions in the year produced, during use	t	NO	NO	17.05	649.75	279.00	160.00	139.50	13.50	15.00	15.00	14.93	14.85
Remaining (emissions in the next year)	t	NO	NO	17.05	649.75	279.00	160.00	139.50	13.50	15.00	15.00	14.93	14.85
HFC-152a emissions	t	NO	NO	18.15	1,216.95	1,299.00	680.00	424.50	101.50	29.50	30.00	30.37	30.48
	kt-CO_2 eq.	NO	NO	3	168	179	94	59	14	4	4	4	4

Reference: *Documents of Fluorocarbons etc. Measures Working Group, Documents of the first meeting of the Breakout Group on F-gases (FY2013) etc.*
Note: The production of aerosols using HFC-152a started in 2000.

Table 4-87 Indices Related to Emissions of HFC-245fa from Aerosols

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2017 onward
Potential emissions	t	NO	NO	NO	0.80	0.39	0.17	0.28	NO
Fugitive emissions during production	t	NO	NO	NO	NO	NO	NO	NO	NO
Emissions in the year produced, during use	t	NO	NO	NO	0.40	0.19	0.09	0.14	NO
Remaining (emissions in the next year)	t	NO	NO	NO	0.40	0.19	0.09	0.14	NO
HFC-245fa emissions	t	NO	NO	NO	0.55	0.35	0.63	0.69	NO
	kt-CO_2 eq.	NO	NO	NO	0.5	0.3	0.5	0.6	NO

Reference: *Documents of Fluorocarbons etc. Measures Working Group*, *Documents of the second meeting of the Breakout Group on F-gases, FY2014 Committee for the Greenhouse Gas Emissions Estimation Methods etc*

Table 4-88 Indices Related to Emissions of HFC-365mfc from Aerosols

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2017 onward
Potential emissions	t	NO	NO	NO	1.12	NO	NO	0.24	NO
Fugitive emissions during production	t	NO	NO	NO	NO	NO	NO	NO	NO
Emissions in the year produced, during use	t	NO	NO	NO	0.56	NO	NO	0.12	NO
Remaining (emissions in the next year)	t	NO	NO	NO	0.56	NO	NO	0.12	NO
HFC-365mfc emissions	t	NO	NO	NO	0.74	NO	0.14	0.24	NO
	kt-CO_2 eq.	NO	NO	NO	1	NO	0.1	0.2	NO

Reference: *Documents of Fluorocarbons etc. Measures Working Group*, *Documents of the second meeting of the Breakout Group on F-gases, FY2014 Committee for the Greenhouse Gas Emissions Estimation Methods etc.*

Table 4-89 Indices Related to Emissions of HFC-43-10mee from Aerosols

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2017 onward
Potential emissions	t	NO	NO	NO	NO	NO	NO	0.34	NO
Fugitive emissions during production	t	NO	NO	NO	NO	NO	NO	0.01	NO
Emissions in the year produced, during use	t	NO	NO	NO	NO	NO	NO	0.17	NO
Remaining (emissions in the next year)	t	NO	NO	NO	NO	NO	NO	0.17	NO
HFC-43-10-mee emissions	t	NO	NO	NO	NO	NO	NO	0.43	NO
	kt-CO_2 eq.	NO	NO	NO	NO	NO	NO	0.7	NO

Reference: Data provided by METI

Table 4-90 Indices Related to Emissions of HFC-227ea from Aerosols

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2016 onward
Potential emissions	t	NO	NO	NO	NO	NO	NO	NO	NO
Fugitive emissions during production	t	NO	NO	NO	NO	NO	NO	NO	NO
Emissions in the year produced, during use	t	NO	NO	NO	NO	NO	NO	NO	NO
Remaining (emissions in the next year)	t	NO	NO	NO	NO	NO	NO	NO	NO
HFC-227ea emissions	t	NO	NO	NO	NO	NO	NO	1.04	NO
	kt-CO_2 eq.	NO	NO	NO	NO	NO	NO	3	NO

Reference: Data provided by METI

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by domestic HFC shipment amounts which are thought to be proportional to potential emissions, and extrapolating, etc. for these years.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainties of the emission factors, 0% was applied for all production, use and disposal, due to the fact that the amount of emissions is equal to the amount of aerosols used. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry specified in the *2006 IPCC Guidelines* was applied for all production, use, and disposal. As a result, the uncertainties of the emissions for all production, use and disposal were determined to be 10%.

- ***Time-series Consistency***

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.7.5. Solvents (2.F.5.)

a) Category Description

Liquid HFC-365mfc is used as an industrial dry cleaning solvent by the name of Solkane Dry, and is released into the atmosphere through volatilization, etc. HFCs and PFCs are also emitted from the use of solvents for the cleaning of general electronic parts, and semiconductor/liquid crystal manufacturing. The liquid PFCs used were C_5F_{12} (PFC-41-12) and C_6F_{14} (PFC-51-14). Data on HFCs used as solvents in the cleaning of general electronic parts, and semiconductor/liquid crystal manufacturing are confidential; therefore, these are reported as included under the total of PFCs.

b) Methodological Issues

- ***Estimation Method***

➢ ***HFCs***

The annual use amount of Solkane Dry is estimated by multiplying the aggregate number of dry cleaning machines using Solkane Dry (from the domestic manufacturers, and subtracting out the number of machines disposed), by the average solvent amount used. All that is used (=solvent amount replenished) is assumed to have been emitted.

$$E = (N_{special} - D_{special}) \times U_{special} + (N_{partial} - D_{partial}) \times U_{partial}$$

E	: HFC-365mfc emissions
$N_{special}$	: Aggregate number of dry cleaning machines specialized for Solkane Dry use
$D_{special}$	: Aggregate number of specialized machines disposed
$U_{special}$	: Average solvent amount used in specialized machines
$N_{partial}$	: Aggregate number of dry cleaning machines partially using Solkane Dry
$D_{partial}$	: Aggregate number of partial-use machines disposed
$U_{partial}$	: Average solvent amount used in partial-use machines

The average solvent amount used in dry cleaning machines using Solkane Dry is set based on the actual amounts of Solkane Dry sold and actual number of operating machines at a large manufacturer (see the Table below). For the average solvent amount used in Solkane Dry-specialized dry cleaning machines in years 2011 and before, the average value for 2012 to 2017 is used. For the dry cleaning machines partially using Solkane Dry, the average solvent amount used is set by multiplying the amount for specialized machines by a ratio.

Since there is no shipment of dry cleaning machines using Solkane Dry for 2002 and before, emissions only start occurring in 2003.

Table 4-91 Number of Dry Cleaning Machines Using Solkane Dry and Average Solvent Amount Used

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Cumulative number of specialized and mixed-use machines	units	0	0	0	12	121	216	246	292	297	298	299	300
Average solvent use per year (specialized)	kg/unit	0	0	0	673	673	678	699	602	602	602	602	602

➢ ***PFCs***

Assuming that almost all of the total amount of liquid PFC shipment was used in cleaners and for cleaning purposes each year, the entire amount was reported in the ”use” category as the amount of emissions. (Emissions are calculated by gas but are reported as an unspecified mix due to confidentiality reasons. Average GWP for 2024 is 7,910.) Emission from manufacturing was reported as ”NO” since there is no practice to blend before use. Emission at the time of disposal was reported as “IE” on the assumption, from the point of view of conservativeness, that the entire amount including that was disposed of, was emitted during use, because of the difficulty in determining the status of the disposal of PFCs. It is confirmed that no disposals were identified in 1995.

Emissions from PFCs contained in railway silicon rectifiers (Refer to 2.G.2. for details) are subtracted from liquid PFC emissions to yield the total PFC emissions.

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using domestic PFC shipment amounts which is thought to be proportional to PFC emissions and extrapolating for these years.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainties of the HFC emission factors, -5% to +5% was applied. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry specified in the *2006 IPCC Guidelines* was applied. As a result, the uncertainties of the emissions were determined to be -11% to +11%.

For the uncertainties of the PFC emission factors, 0% was applied, due to the fact that the amount of emissions is equal to the amount of solvent used. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry specified in the *2006 IPCC Guidelines* was applied. As a result, the uncertainties of the emissions were determined to be 10%.

- ***Time-series Consistency***

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.7.6. Other Applications (2.F.6.)

Refrigerants filled in research and medical equipment are captured and included in other refrigerant categories.

4.8. Other Product Manufacture and Use (2.G.)

This category covers N_2O, HFCs, PFC, and SF_6 emissions from other product manufacture and use. This section deals with the following sources: Electrical equipment (2.G.1.), Military applications (2.G.2.), Accelerators (2.G.2.), Other – Railway silicon rectifiers (2.G.2.), Medical applications (2.G.3.), Use during Semiconductor/Liquid Crystal Manufacturing (2.G.3.), and PFCs and HFCs from Waterproofing electronic circuits (2.G.4).

In FY2024, emissions from this category were 1,592 kt-CO_2 eq. and represented 0.2% of Japan's total GHG emissions (excluding LULUCF). The total emissions of N_2O from this category decreased by 61.8% compared to FY1990. The total of HFCs, PFCs and SF_6 decreased by 83.5% compared to 1990.

Table 4-92 Emissions from Other Product Manufacture and Use (2.G.)

Gas			Units	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
N_2O	2.G.3	N_2O from Product Uses - Medical applications	kt-N_2O	0.93	1.41	1.10	0.86	0.32	0.25	0.22	0.28	0.33	0.35	0.36	0.35
	Total		kt-CO_2 eq.	245	374	291	228	85	67	58	75	87	92	95	94
Gas			Units	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
HFCs	2.G.4	PFCs and HFCs from Waterproofing electronic circuits	kt-CO_2 eq.	6	5	6	4	3	2	2	5	6	6	6	5
PFCs	2.G.2	Other-Railway silicon rectifiers	kt-CO_2 eq.	NO	NO	NO	0.2	4	9	7	48	58	60	62	43
	2.G.4	PFCs and HFCs from Waterproofing electronic circuits	kt-CO_2 eq.	15	12	15	10	7	5	5	12	12	13	13	12
	Total		kt-CO_2 eq.	15	12	15	10	11	14	12	60	71	72	75	55
SF_6	2.G.1	Electrical equipment	t	355.81	460.46	127.62	40.70	30.03	29.75	29.18	25.06	26.20	24.72	28.19	26.19
	2.G.2	Military applications	t	NO	NO	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23	1.23
		Accelerators	t	30.77	35.16	34.49	35.69	33.89	35.18	34.40	33.33	33.39	33.50	33.69	33.76
	Total		t	386.58	495.62	163.34	77.61	65.15	66.16	64.80	59.62	60.82	59.45	63.11	61.18
	Total		kt-CO_2 eq.	9,085	11,647	3,839	1,824	1,531	1,555	1,523	1,401	1,429	1,397	1,483	1,438
Total of F-gases			kt-CO_2 eq.	9,106	11,665	3,860	1,839	1,545	1,571	1,537	1,466	1,506	1,475	1,564	1,498

4.8.1. Electrical Equipment (2.G.1.)

a) Category Description

SF_6 are emitted during the manufacturing and use of electrical equipment.

b) Methodological Issues

- ***Estimation Method***

Emissions from producing electrical equipment were calculated by multiplying the amount of SF_6 purchased by assembly fugitive rate. Emissions from the use of electrical equipment were calculated based on the fugitive rate during the use of electrical equipment. Emission factors are country-specific. Emissions from the inspection and disposal of electrical equipment were obtained by actual measurements of SF_6.

In CRT, the emission was reported as “IE” after including the emission from disposal into the use of electrical equipment.

➢ ***Emissions from the production***

$$E_{manufacturing} = AD \times EF_{manufacturing}$$

$E_{manufacturing}$: SF_6 emissions from the production
AD : SF_6 amounts purchased
$EF_{manufacturing}$: Assembly fugitive rate [%]

➢ ***Emission from the use***

$$E_{use} = Stock \times EF_{use}$$

E_{use} : SF_6 emission from the use
$Stock$: Stocks of SF_6
EF_{use} : Rate of emitted SF_6 into the environment during the use of electrical equipment (0.1%)

➢ ***Emission from the inspection***

$$E_{inspection} = E_{measured}$$

$E_{inspection}$: SF_6 emission from the inspection
$E_{measured}$: Actual measurements of SF_6

➢ ***Emission from the disposal***

$$E_{disposed} = E_{measured}$$

$E_{disposed}$: SF_6 emission from the disposal
$E_{measured}$: Actual measurements of SF_6

The associated indices are given in the table below.

Table 4-93 Indices Related to Emissions of SF_6 from Electrical Equipment

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
SF_6 amounts purchased	t	1,066	1,380	649	630	317	234	300	226	255	194	218	240
Assembly fugitive rate	%	29%	29%	15%	3%	3%	3%	3%	2%	1%	2%	2%	2%
Emissions during manufacturing	kt-CO_2 eq.	7,264	9,400	2,362	569	227	166	225	103	92	88	115	106
SF_6 emissions during use, maintenance, and disposal	kt-CO_2 eq.	1,098	1,421	638	388	479	533	460	486	524	493	547	510

Reference: the *Documents of Fluorocarbons etc. Measures Working Group*, and data provided by the METI, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using domestic SF_6 shipment amounts which is thought to be proportional to amounts of SF_6 purchased and stocks of SF_6, amounts of SF_6 charged to electrical equipment from 1995, the assembly fugitive rate from 1995, and the operational fugitive rate from 1995, and extrapolating for these years.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainties of the emission factors, -30 to +30% was applied for manufacturing and use, and -20 to +40% was applied for disposal, in accordance with the *2006 IPCC Guidelines*' default value. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry specified in the *2006 IPCC Guidelines* was applied for all manufacturing, use, and disposal. As a result, the uncertainty of the emissions for manufacturing and use was determined to be -32 to +32%, and -22 to +41% for disposal.

- ***Time-series Consistency***

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

Same as Fluorochemical Production – By-product Emissions - Production of HCFC-22 (2.B.9.a.i.). See section 4.3.9.1. d).

e) Category-specific Recalculations

Recalculations occurred due to the update of the amounts of SF_6 purchased for 2023. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.8.2. SF_6 and PFCs from Other Product Use (2.G.2.)

4.8.2.1. Military Applications (2.G.2.a.)

a) Category Description

SF_6 is used as an insulating medium in the radar systems of AWACS (Airborne Warning and Control System). When the plane ascends, SF_6 is automatically released from the system and into the atmosphere to maintain the appropriate pressure difference between the system and the outside air. When the plane descends, SF_6 is automatically charged into the system from an SF_6 container on board.

b) Methodological Issues

- ***Estimation Method***

Emissions are calculated using a method corresponding to the Tier 2 method (user mass-balance method) in the *2006 IPCC Guidelines*.

$$E = D + M - R - I$$

E : SF_6 Emissions [kg]
D : Decrease of SF_6 in the container on board the AWACS [kg]
M : SF_6 leakage during acquisition/replacement of SF_6 container on AWACS [kg]
R : SF_6 collected/destroyed [kg]
I : Net increase in AWACS fleet charge [kg]

The four-fleet AWACS was officially authorized for use on March 24, 1999, and therefore SF_6 emissions are considered to have started in 1999.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

No emission factor is set, and therefore the uncertainty of emissions is assessed by assessing the uncertainty of activity data. A 10% uncertainty of metal industry is taken for the uncertainty of activity data. As a result, the uncertainty of emissions is 10%.

- ***Time-series Consistency***

Emissions are estimated in a manner consistent across the time-series methodologically, and from the point of view of data source.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.8.2.2. Accelerators (2.G.2.b.)

a) Category Description

SF_6 is used in university and research facility-operated particle accelerators, and in industrial/medical accelerators (for cancer therapy) as an insulating gas. When the equipment requires maintenance, the SF_6 is transferred into storage tanks, and therefore losses occur primarily during gas transfer.

b) Methodological Issues

- ***Estimation Method***

Emissions are calculated using the Tier 1 method in the *2006 IPCC Guidelines*.

$E = N \times U \times C \times EF$

E : SF_6 Emissions [kg]
N : Number of accelerators
U : SF_6 use factor
C : SF_6 charge factor [kg/accelerator]
EF : SF_6 emission factor

The SF_6 use factor, SF_6 charge factor, SF_6 emission factor, and number of accelerators used for estimating emissions are shown below by type of accelerator.

Table 4-94 SF_6 Use Factor, SF_6 Charge Factor, SF_6 Emission Factor by Type of Accelerator

Item	University and research operated particle accelerators	Industrial particle accelerators	Medical particle accelerators [1)]	Small-scale electron accelerators
SF_6 use factor	33%	100%	100%	100%
SF_6 charge factor [kg/accelerator]	2,400	1,300	0.5	400 [2)]
SF_6 emission factor [kg/kg]	See below Table	0.07	2.0	0.07

Note: 1) Among the medical particle accelerators, cyclotrons and synchrotrons are not considered to use SF_6, and therefore are not estimated for.
Reference: *2006 IPCC Guidelines* default values excluding the 2) value are from results of interviews with main accelerator manufacturers.

Table 4-95 SF_6 Emission Factor for Particle Accelerators at University/Research Facilities

Item	1990-2004	2005-2009	2010-2014	2015-2019	2019-2024
SF_6 emission factor [kg/kg]	0.070	0.063	0.063	0.052	0.045

Reference: Calculated based on JAEA-Technology 2010-023: Operation and Management of the High-pressure Gas Facility for the Tandem Accelerator, and 2011-2018 Environmental Reports (Japan Atomic Energy Agency).

Table 4-96 Number of Accelerators by Type

Item	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Number of particle accelerators (University/Research facilities)	188	214	212	209	218	225	241	239	239	239	239	239
Number of particle accelerators (Industrial use)	143	164	145	181	174	188	193	198	198	198	198	198
Number of particle accelerators (Medical use)	531	641	754	857	926	1,068	1,108	1,132	1,132	1,132	1,132	1,132
Number of small-scale (below 1MeV) electron accelerators	243	276	314	282	218	201	201	200	202	206	213	215

Reference: *Statistics on the Use of Radiation in Japan* (Japan Radioisotope Association), except for the *Nuclear Yearbook* (The Japan Atomic Industrial Forum), etc for small-scale electron accelerators

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the EF, a -50 to +400% uncertainty from the *2006 IPCC Guidelines* (particle accelerators – medical use) was applied. A -10 to +10% uncertainty of metal industry is taken for the uncertainty of activity data. As a result, the uncertainty of emissions is -51 to +400%.

- ***Time-series Consistency***

Emissions are estimated in a manner consistent across the time-series methodologically, and from the point of view of data source.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.8.2.3. Soundproof windows (2.G.2.c.)

The *2006 IPCC Guidelines* specifies estimation methods for this sub-category, however, emissions do not exceed the 3,000 t-CO_2 eq threshold for estimation, determined by the Committee for Greenhouse Gas Emissions Estimation Methods, and therefore is reported as "NE" (considered insignificant) (see Annex 6).

4.8.2.4. Adiabatic properties: shoes and tyres (2.G.2.d.)

PFC and SF_6 use for rubber with adiabatic properties are not found in Japan, and therefore emissions are reported as "NO".

4.8.2.5. Other – Railway Silicon Rectifiers (2.G.2.e.ii.-)

a) Category Description

PFCs are emitted at disposal of railway silicon rectifiers.

b) Methodological Issues

- ***Estimation Method***

Based on the number of devices containing PFC-51-14, the amount of PFC-51-14 contained, and lifetime of the devices installed on ground and on car respectively, given in the *Survey on Management Methods of Halons/Liquid PFCs etc* (2006), and the *Survey on Destruction of Halons/PFCs etc* (2010), the amount of PFC-51-14 disposed after use in railway silicon rectifiers in each fiscal year was estimated. This was done by multiplying the number of railway silicon rectifiers disposed per year, by the amount of PFC contained in each device. PFC emissions are calculated by subtracting the amount of PFC-51-14 destroyed in a specific fiscal year from the PFC disposed after use in railway silicon rectifiers in the same fiscal year.

$$E = M_{disposal} - R$$

E : PFC emissions at disposal of railway silicon rectifiers
$M_{disposal}$: PFC disposed after use in railway silicon rectifiers

R : PFC destroyed

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainty of the emission factor, the 0% value for solvents was applied since it is a similar source category. For the uncertainties of the activity data, the 10% value of the Tier 2 method for metal industry specified in the *2006 IPCC Guidelines* was applied. As a result, the uncertainties of the emissions were determined to be 10%.

- ***Time-series Consistency***

Emissions are estimated in a manner consistent across the time-series methodologically, and from the point of view of data source.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.8.3. N_2O from Product Uses − Medical Applications (2.G.3.a.)

a) Category Description

Nitrous oxide is emitted during anesthetics (laughing gas) use. Since 2006, some hospitals have installed N_2O destruction units, and the reductions achieved are reflected in the total emissions. CO_2 is not used as an anesthetic in Japan.

b) Methodological Issues

- ***Estimation Method***

In relation to emissions of N_2O from use of laughing gas, the actual amount of N_2O shipped as an anesthetic by pharmaceutical manufacturers or importers has been reported for 2005 and preceding years. For 2006 and beyond, the amount of N_2O collected is calculated using the amount of laughing gas used in domestic hospitals equipped with N_2O destruction units for anesthesia, and a destruction rate of 99.9 %. This is subtracted from the N_2O shipped for medical use to yield the amount of N_2O emitted.

$$E = S - (U \times DR)$$

E : Amount of N_2O emitted during the use of laughing gas [t]
S : N_2O shipped for medical use [t]
U : Amount of laughing gas used in hospitals equipped with N_2O destruction units [t]
DR : Destruction rate

- ***Emission Factors***

It is assumed that all of the N_2O used as laughing gas escapes into the atmosphere, unless collected. Therefore, no emission factor has been established.

- ***Activity Data***

The amount of shipments (calendar year basis) of general anesthetics (N_2O) given in the *Statistics of Production by Pharmaceutical Industry* (Ministry of Health, Labour and Welfare) is used. For 2006 to 2009, the amount of N_2O collected in three, and from 2010 and onward collected in four domestic hospitals equipped with N_2O destruction units is subtracted from the above-mentioned shipment.

Table 4-97 Shipment Amount of General Anesthetics (Laughing Gas) and N_2O Collected in Domestic Hospitals

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Laughing gas shipment amount	kg-N_2O	926,030	1,411,534	1,099,979	859,389	320,110	253,218	219,011	283,333	330,111	345,452	357,170	353,532
N_2O collected in domestic hospitals	kg-N_2O	NO	NO	NO	NO	914	509	NO	NO	NO	NO	NO	NO

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

Because all N_2O used for laughing gas are assumed to escape into the atmosphere, no emission factor has been set. Therefore, the uncertainty for activity data is also the uncertainty for emissions. As *Statistics of Production by Pharmaceutical Industry* is a fundamental statistic based on statistical law, a 5% uncertainty was given for this emission source.

- ***Time-series Consistency***

The amount of shipments of general anesthetics (N_2O) are taken from the *Statistics of Production by Pharmaceutical Industry* in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.8.4. Other – PFCs and HFCs from Waterproofing electronic circuits (2.G.4.-)

a) Category Description

In the process of adding waterproofing layers onto assembled electronic circuit boards, there is a method of forming fluorocarbon polymers using gas-phase reaction in a plasma. This process can result in emissions of PFCs (CF_4 (PFC-14), C_2F_6 (PFC-116) and CHF_3 (HFC-23).

b) Methodological Issues

- ***Estimation Method***

Following the Tier 1 method in the *2019 Refinement*, emissions were estimated.

$$E_i = EF_i \times n \times I$$

E_i : Emissions of gas i
EF_i : Emission factor for gas i [g/number of assembled electronic circuit boards]
n : Number of assembled electronic circuit boards manufactured [a)]

I : Waterproofing rate by a plasma processing (1%[b])

Note: The number of assembled electronic circuit boards manufactured (hereafter, assembled boards manufactured) for 1990 to 2011 are not available. Therefore, the number of assembled boards manufactured for 1990 to 2011 are estimated based on the assumption that they are proportional to the number of electronic circuit boards manufactured (before assembly), and by using the number of assembled boards manufactured for 2012.

Reference:

a) *Yearbook of Current Production Statistics – Machinery*

b) *Committee for Greenhouse Gas Emissions Estimation Methods in FY2022*

The emission factor for each gas used for the estimation are as shown in the following table.

Table 4-98 Emission Factors for Estimation Emissions from Waterproofing Assembled Electronic Circuit Boards

Item	CF_4 (PFC-14)	C_2F_6 (PFC-116)	CHF_3 (HFC-23)
Emission factor [g/number of assembled electronic circuit boards]	0.006	0.004	0.003

Reference: Default values given in the *2019 Refinement.*

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainties of the emission factors for PFCs and HFCs, 200%, the upper limit value of the Tier 1 method for semiconductors specified in the *2006 IPCC Guidelines* was applied. For the uncertainties of the activity data, since the *Yearbook of Current Production Statistics* is a fundamental statistics based on statistical law, a 5% value was applied. As a result, the uncertainties of the emissions were determined to be -200 to +200%.

- ***Time-series Consistency***

Emissions are estimated in a manner consistent across the time-series methodologically, and from the viewpoint of data source, with the method described in the section above to supplement for the lack of data of assembled boards manufactured before 2010.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

Recalculations occurred due to the update of the *Yearbook of Current Production Statistics* for 2023. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.9. Other (2.H.)

This category covers CO_2 emissions from other sources. This section deals with the following sources: Food and beverages industry (2.H.2.), Imported carbonated gas (2.H.3.-), and Utilization of carbonated gas (2.H.3.-).

In FY2024, emissions from this category were 921 kt-CO_2 and represented 0.1% of Japan's total GHG emissions (excluding LULUCF). The emissions increased by 4.6% compared to FY1990.

Table 4-99 Emissions from Other (2.H.)

Gas				Units	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
CO_2	2.H.2	Food and beverages industry		kt-CO_2	95	108	102	105	102	117	123	134	141	139	143	147
	2.H.3	Emissions from imported carbonated gas		kt-CO_2	0.3	0.3	0.2	0.2	1	11	14	16	7	10	25	46
		Utilization of carbonated gas	Direct Utilization of CO_2													
			Dry ice	kt-CO_2	285	286	306	316	332	361	371	348	369	342	331	313
			Welding	kt-CO_2	286	324	304	319	364	351	356	290	288	297	292	283
			Cooling	kt-CO_2	114	130	121	113	85	84	82	73	65	66	62	60
			Other	kt-CO_2	100	114	106	98	44	52	71	79	94	87	84	72
			Re-emissions from CO_2 fixed in CO_2-origin carbonate materials	kt-CO_2	NO	NO	NO	NO	NO	NO	NO	0.01	0.003	0.00002	0.0003	NO
			Environmentally friendly concrete (CO_2 fixing during manufacturing)	kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	-0.01	-0.01	-0.01	-0.004
	Total			kt-CO_2	880	962	940	951	928	976	1,017	940	963	941	937	921

4.9.1. Reporting Related to Direct Utilization of CO_2

CO_2 recoveries were subtracted from the emissions of the source category where the CO_2 was recovered, and then the same amount of CO_2 was all allocated as emissions to the category in which the CO_2 was utilized, without omission, based on the thinking of the *2006 IPCC Guidelines* (see Figure 4-1).

Figure 4-1 Allocation of CO_2 Recovery/Utilization (FY2024)

Source categories		Emissions [kt-CO2] (without reflecting recovery/utilization)		Recovery [kt-CO_2]		Utilization [kt-CO_2]		Emissions [kt-CO_2] (reflecting recovery/utilization)
1.A.1.b.	Petroleum refining	28,677	−	584	+	0	→	28,093
1.A.2.a.	Iron and steel	108,613		22		0		108,591
2.B.1.	Ammonia production	996		346		0		649
2.B.8.d.	Ethylene oxide production	178		29		0		149
2.B.10.	Chemical industry—Other	16		0		62		77
2.C.1.	Iron and steel production	4,726		0		44		4,771
2.H.2.	Food and Beverages Industry	0		0		147		147
2.H.3.-	Utilization of Carbonated Gas							
	Dry ice	0		0		313		313
	Welding	0		0		283		283
	Cooling	0		0		60		60
	Other	0		0		72		72
Total		143,206		981		981		143,206

The amounts of CO_2 recovery/utilization are estimated as shown below, based on the survey of the actual situation of CO_2 direct utilization by the Committee for the Greenhouse Gas Emissions Estimation Methods (FY2023 and FY2024) with the cooperation of JIMGA and the DryIce Maker Association.

a) Methodological Issues

- ***Amount of CO_2 Recovery***

For the amount of CO_2 recoveries for liquefied CO_2, the sales data of liquefied CO_2 provided by JIMGA was used, based on the assumption that CO_2 recoveries are equal to the amount of CO_2 utilized. For FY2009 and before, in which data are lacking, extrapolation using the production data of liquefied CO_2 provided by JIMGA was applied. For the breakdown of the amount of CO_2 recovery by the sources, estimates were made by using the source composition ratios based on the production data of liquefied CO_2. For fiscal years lacking data on the breakdown by the sources - 1990 to 1991, 1993 to 1995, 1998 to 1999, 2001 to 2004, 2006 to 2008, 2010, 2012 and 2014, interpolation using the composition ratios from other fiscal years were applied.

Table 4-100 CO_2 Recoveries for Liquefied CO_2 by Source

Sources (Categories)	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Petroleum refining (1.A.1.b.)	kt	244	278	310	363	397	379	362	375	377	404	411	387
Iron (1.A.2.a.)	kt	70	100	85	76	9	10	31	24	25	24	25	22
Ammonia (2.B.1.)	kt	282	315	263	225	268	280	268	222	243	237	238	230
Ethylene oxide (2.B.8.d.)	kt	66	59	45	53	34	37	73	56	51	41	28	29

For the amount of CO_2 recoveries for dry ice, the domestic shipment data of dry ice provided by the DryIce Maker Association was used, based on the assumption that CO_2 recoveries are equal to domestic shipment of dry ice. For FY2009 and before, in which data are lacking, extrapolation using the carbonated gas production given in the *Yearbook of Current Production Statistics – Chemical Industry* was applied. For the breakdown of the amount of CO_2 recovery by the sources, estimates were made by using the source composition ratios based on the production data of liquefied CO_2.

Table 4-101 Dry Ice Domestic Shipment Amounts and CO_2 Recoveries by Source

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Dry ice shipment amount	kt	285	286	306	316	332	361	371	348	369	342	331	313
Sources (categories)													
Petroleum refining (1.A.1.b.)	kt	132	134	166	195	198	208	213	219	224	215	210	197
Ammonia production (2.B.1.)	kt	152	152	141	121	134	154	158	130	144	126	121	117

- ***Amount of CO_2 Utilized***

For the amount of liquefied CO_2 utilized, the sales data of liquefied CO_2 by the use provided by JIMGA was used. For FY2009 and before, in which data are lacking, the amount of CO_2 recoveries for liquefied CO_2 estimated by the method described above was used, based on the assumption that the amount utilized is equal to recovery. For the breakdown of the amount of CO_2 utilized by the uses, estimates were made by using the composition ratios of the uses based on the actual shipment data of liquefied CO_2 provided by the website of JIMGA. For FY2003 and before, in which data are lacking on the breakdown by use, the composition ratios for FY2004 were applied.

Table 4-102 Amount of CO_2 Utilized Domestically for Liquefied CO_2 by Use and Allocation Category

Uses (Allocated category)	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Chemical (2.B.10.b.-)	kt	40	45	42	39	67	58	59	64	66	76	75	62
Iron (2.C.1.f.-)	kt	26	30	28	42	46	45	43	37	42	41	46	44
Beverage (2.H.2.)	kt	95	108	102	105	102	117	123	134	141	139	143	147
Feeding (2.H.3.-)	kt	286	324	304	319	364	351	356	290	288	297	292	283
Cooling (2.H.3.-)	kt	114	130	121	113	85	84	82	73	65	66	62	60
Other (2.H.3.-)	kt	100	114	106	98	44	52	71	79	94	87	84	72

For the amounts of CO_2 utilized for dry ice, all dry ice shipments are allocated under the Emissions from Imported Carbonated Gas (2.H.3.-) category.

b) Category-specific Recalculations

There have been no source-specific recalculations.

4.9.2. Food and Beverages Industry (2.H.2.)

Of the amount of CO_2, which was recovered for liquefied CO_2 and subtracted from the emissions from Petroleum refining (1.A.1.b.), Iron and steel (1.A.2.a.), Ammonia production (2.B.1.), and Ethylene oxide production (2.B.8.d.) categories, the utilized amounts in the beverages industry are allocated under this category. See section 4.9.1. for details.

4.9.3. Emissions from Imported Carbonated Gas (2.H.3.-)

a) Category Description

CO_2 are emitted from the use of imported carbonated gas.

b) Methodological Issues

The total amount of imported carbonated gas was used for estimating emissions.

- ***Estimation Method***

No emission factors are established since the activity data is directly the emissions.

- ***Activity Data***

The import quantities of carbon dioxide in the *Trade Statistics of Japan* are used for estimating emissions.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

No emission factor has been set because all CO_2 is emitted from the use of imported carbonated gas and are assumed to escape into the atmosphere. Therefore, the uncertainty for activity data is also the uncertainty for emissions. For the uncertainty of activity data, a 5% value, which is the uncertainty for the use of electric arc furnaces in steel production referred to in the *Trade Statistics of Japan,* was used.

- ***Time-series Consistency***

The import quantities of carbon dioxide in the *Trade Statistics of Japan* are consistently used.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.9.4. Utilization of Carbonated Gas (2.H.3.-)

a) Category Description

CO_2 is emitted from utilization of liquefied CO_2 and dry ice.

b) Methodological Issues

- ***Estimation Method***

Of the amount of CO_2, which was recovered for liquefied CO_2 and subtracted from the emissions from Petroleum refining (1.A.1.b.), Iron and steel (1.A.2.a.), Ammonia production (2.B.1.), and Ethylene oxide production (2.B.8.d.) categories, all utilized amounts for welding, cooling and other uses are allocated under this category. All the amount of CO_2, which was recovered for dry ice and subtracted from emissions from Petroleum refining (1.A.1.b.) and Ammonia production (2.B.1.) categories, are

assumed to be emitted into the atmosphere, and therefore are allocated under this category. See section 4.9.1. for details. Additionally, the amount of CO_2, which was recovered for CO_2-origin carbonate material and subtracted from the emissions from the Non-metallic minerals (1.A.2.f.) category, assumed to be fully emitted again after being fixed in the CO_2-origin carbonate material for a short period of time, and therefore are allocated under this category. See section 4.9.5.2. for details. CO_2 fixations by environmentally friendly concrete (one of the products of CO_2 fixing type during manufacturing) are subtracted from the CO_2 emissions from this category. See section 4.9.5.1.a for details.

$$E = E_{liquefied\text{-}CO2} + E_{dry\text{-}ice} + E_{re\text{-}emit} - F_{concrete}$$

E	: Amount of CO_2 emissions from utilization of liquefied CO_2 and dry ice [t-CO_2]
$E_{liquefied\text{-}CO2}$	: Amount of CO_2 emissions from utilization of liquefied CO_2 (welding, cooling and other uses) [t-CO_2]
$E_{dry\text{-}ice}$	: Amount of CO_2 emissions from utilization of dry ice [t-CO_2]
$E_{re\text{-}emit}$	: Amount of CO_2 emissions from utilization of CO_2-origin carbonate material (re-emissions after being fixed for a short period of time) [t-CO_2]
$F_{concrete}$	: Amount of CO_2 fixation by environmentally friendly concrete (CO_2 fixing type during manufacturing) [t-CO_2]

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainty for activity data is also the uncertainty for emissions. For the uncertainty of activity data, a 2% default value given by the *2006 IPCC Guidelines* for CO_2 recoveries based on plant data for ammonia production was applied.

- ***Time-series Consistency***

For activity data, the same source-data are used to the extent possible throughout the time-series. Therefore, emission has been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.9.5. Reporting Related to CO_2 Fixation by CCU Technology

Following the inclusion of the promotion of innovation in CCU, etc. in Japan's Plan for Global Warming Countermeasures (Cabinet approved on October 22, 2021), the methods for reflecting CO_2 reduction in the inventory using various CCU technologies have been under consideration by the Committee for the Greenhouse Gas Emission Estimation Methods since FY2021. As a result of consideration, the amount of CO_2 fixation by environmentally friendly concrete and by CO_2-origin carbonate materials are estimated.

Table 4-103 Amount of CO_2 Fixation by CCU Technologies

Environmentally Friendly Concreate													
Type (allocated category)	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
CO_2 fixing during manufacturing (1.A.2.f.)	t	NO	NO	NO	NO	NO	NO	NO	NO	-0.2	NO	-0.2	-1
CO_2 fixing during manufacturing (2.H.3.-)	t	NO	NO	NO	NO	NO	NO	NO	NO	-6	-8	-5	-4
Biochar (4.H.)	t	NO	NO	NO	NO	NO	NO	NO	NO	NO	-6	-99	-98
CO_2-origin Carbonate Material													
Type (allocated category)	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Long term (1.A.2.f.)													
Concrete/cement	t	NO	NO	NO	NO	NO	NO	NO	NO	-7	-13	-17	-6
Backfill materials for piling work	t	NO	NO	NO	NO	NO	NO	NO	NO	-1	-0.2	NO	NO
Building materials for other uses	t	NO	NO	NO	NO	NO	NO	NO	NO	NO	-0.04	NO	NO
Short term (1.A.2.f.)													
Release agent for aluminum formwork/desulfurization of exhaust gas	t	NO	NO	NO	NO	NO	NO	NO	-13	-3	NO	NO	NO
Other (samples, etc.)	t	NO	NO	NO	NO	NO	NO	NO	-0.01	-0.1	-0.02	-0.3	NO

4.9.5.1. Environmentally Friendly Concrete

The amount of CO_2 fixation by environmentally friendly concrete are estimated and subtracted from the emissions of the category where the CO_2 was recovered for the manufacturing of the environmentally friendly concrete.

4.9.5.1.a. CO_2 Fixing Concrete During Manufacturing (1.A.2.f., 2.H.3.-)

a) Category Description

This category deals with the amount of CO_2 forcibly fixed inside concrete as calcium carbonates, during manufacturing. This type of product is manufactured by mixing in a special admixture with conventional materials (water, cement, and aggregates). This special admixture has the property of hardening through a reaction with CO_2. By curing the concrete with CO_2 during the manufacturing process, the special admixture undergoes carbonation, reacting with CO_2, which results in CO_2 being fixed within the concrete. At present, two products with data made available by the manufacturer is estimated for.

b) Methodological Issues

- ***Estimation Method***

The amount of CO_2 fixation are estimated by multiplying the production amount of CO_2 fixing concrete during manufacturing by the CO_2 fixation factor. The CO_2 fixation factors are established based on measurements by product and by specification, because the amount of CO_2 fixation fluctuates depending on the surface area and structures (such as pores), as well as the mixture ratio of the CO_2 fixing concrete product and/or the manufacturing technique (curing temperature and CO_2 exposure concentration), etc.

$$F_{CO2} = \Sigma_{i,j} (V_{i,j} \times f_{i,j})$$

F_{CO2} : Amount of CO_2 fixation by the CO_2 fixing concrete during manufacturing [t-CO_2]
$V_{i,j}$: Production amount of product i with specification j [m^3]
$f_{i,j}$: Amount of CO_2 fixation per unit volume of product i with specification j [t-CO_2/m^3]
Reference: *Committee for Greenhouse Gas Emissions Estimation Methods in FY2023, FY2024 and FY2025*

- ***Fixation factors***

CO_2 fixation factors per unit volume of product are established by the product and by specification of the product, based on the results of the actual measurement of the samples and quality control data for actual product manufacturing provided by the manufacturer. The CO_2 fixation factors for product-A

are 0.065 t-CO_2/m^3 for specification-a and 0.147 t-CO_2/m^3 for specification-b. The CO_2 fixation factor for product-B is confidential. These fixation factors are values unique to each product and its specifications, obtained under specific conditions.

- ***Activity Data***

The production amount by each of the specifications of the product provided by the manufacturer was used.

Table 4-104 The production amount of CO_2 fixing concrete product-A during manufacturing

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Specification-a	m^3	0	0	0	0	0	0	0	0	26	56	38	16
Specification-b	m^3	0	0	0	0	0	0	0	0	29	28	19	24

The AD for product-B is confidential.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainty of fixation factors, -17% to 10% based on the results of analysis of product-A samples of CO_2 fixation by the manufacturer was applied. For the uncertainty of activity data, the default value of 5% for the Tier 3 method for chemical industry specified in the *2006 IPCC Guidelines* was applied. As a result, the uncertainty of CO_2 fixations was estimated to be -18% to 11%.

- ***Time-series Consistency***

CO_2 fixations are estimated in a manner consistent across the time-series methodologically, and from the point of view of data source.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

Recalculations occurred for FY2023 due to the addition of a new specification to product-B in the emissions estimation. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.9.5.1.b. Concrete Using CO_2-origin Material (1.A.2.f.)

This category deals with the amount of CO_2 fixed inside the concrete manufactured by using carbonate material that fixes CO_2. Data on the use of CO_2-origin carbonated materials was acquired as a source of activity data. This data also includes the amounts for uses other than environmentally friendly concrete, enabling the comprehensive capturing of the amounts of CO_2 fixation by CO_2-origin carbonated materials (see section 4.9.5.2.).

4.9.5.1.c. Concrete Using Biochar (4.H.)

a) Category Description

This category deals with the amount of CO_2 fixed in concrete that stores carbon, by mixing in biochar made with carbonated woody biomass. The amount of CO_2 fixation is estimated by the property of biochar because it fluctuates depending on the property. At present, one example of product use in construction road work, using domestic sawdust and with data made available by the manufacturer is estimated for.

b) Methodological Issues

- ***Estimation Method***

Following the Tier 3 method in the *2006 IPCC Guidelines* for HWP in the LULUCF sector, the estimation was conducted as shown below.

$$F_{CO2,n} = \Sigma_i \ \Delta C_{n,i} \times 44/12$$

$F_{CO2,n}$: Amount of CO_2 fixation by concrete using biochar in fiscal year n [t-CO_2]
$\Delta C_{n,i}$: Amount of carbon stock change in the product pool of concrete using biochar i in fiscal year n [t-C/year]

where,

$$\Delta C_{n,i} = Inflow_{n,i} - Outflow_{n,i}$$

$Inflow_{n,j}$: Inflow of carbon to the product pool of concrete using biochar in fiscal year n [t-C/year]
$Outflow_{n,j}$: Outflow of carbon from the product pool of concrete using biochar in fiscal year n [t-C/year]

$$Inflow_{n,i} = m_{n,i} \times C_i$$

$m_{n,i}$: Amount of consumption of biochar i in fiscal year n [t]
C_i : Carbon factor of biochar i [t-C/t]
Reference : *Committee for Greenhouse Gas Emissions Estimation Methods in FY2023*

$$Outflow_{n+k,i} = Inflow_{n,i}$$

k : Lifetime of the product using biochar i [year]

Note: The planned service life of concrete structures given in the *Japanese Architectural Standard Specification* by the Architectural Institute of Japan, are defined as short term (about 30 years), standard term (about 65 years), long term (about 100 years) and super-long term (more than 100 years). A 65-year, standard term planned service life, was applied based on expert judgement, taking into account the assessment of data of the compressive strength, etc. of biochar concrete by the manufacturer.

- ***Fixation factors***

Fixation factors based on the actual measurements of the carbon content of biochar used for the product were used. The fixation factor is confidential.

- ***Activity Data***

The consumption amount of biochar for concrete using biochar, by the property of biochar was used. The AD is confidential.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainty of fixation factors, -2% to 4% based on the results of the analysis of the variability

of carbon content by the manufacturer is used. For the uncertainty of activity data, the default value of 5% for the Tier 3 method for chemical industry specified in the *2006 IPCC Guidelines* was applied. As a result, the uncertainty of CO_2 fixations was estimated to be -5% to 6%.

- ***Time-series Consistency***

CO_2 fixations are estimated in a manner consistent across the time-series methodologically, and from the point of view of data source.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

Information on the service life and disposal of the concrete using biochar will be collected and the methodology will be revised as appropriate.

4.9.5.2. CO_2-origin Carbonate Material (1.A.2.f., 2.H.3.-)

a) Category Description

This category deals with the amount of CO_2 fixed in CO_2-origin carbonate material, which is used in environmentally friendly concrete, etc. At present, two products with data made available by the manufacturer are estimated for. For product-A, CO_2 is fixed as calcium carbonate in the CO_2-origin carbonate material by blowing CO_2 from exhaust gas, etc. into an amino solution that extracts calcium sources from industrial by-products such as steelmaking slag and concrete waste. For product-B, CO_2 is fixed as calcium carbonate by agitating CO_2 into a solution containing cement (cement slurry).

b) Methodological Issues

- ***Estimation Method***

The amount of CO_2 fixation is estimated by multiplying the consumption amount of CO_2-origin carbonate material by the CO_2 fixation factor. The CO_2 fixation factors are established based on measurements by product and by specification, because the amount of CO_2 fixation fluctuates depending on the type and mixture (formulation) of the CO_2-origin carbonated materials.

CO_2 fixation amounts are subtracted from the emissions from the category (1.A.2.f.) where the CO_2 was recovered. CO_2 in the CO_2-origin carbonate material can be emitted again after being fixed for a short period of time, if the material was used under high temperatures such as over 500 degrees for a long period of time or under conditions with possible chemical reaction processes occurring such as neutralization during acidification. Therefore, for these uses considered to be short-term fixation, the same amount of CO_2 as was subtracted was all allocated as emissions to the category (2.H.3.-) in which the CO_2 was emitted, without omission.

$$F_{CO2} = \Sigma_{i,j} (m_{i,j} \times F_{i,j})$$

F_{CO2} : Amount of CO_2 fixation by CO_2-origin carbonate material [t-CO_2]
m : Consumption amount of specification-j the CO_2-origin carbonate material product-i [t]

F : Amount of CO_2 fixation per unit weight of specification-j in CO_2-origin carbonate material product-i [t-CO_2/t]
Reference: *Committee for Greenhouse Gas Emissions Estimation Methods in FY2024 and FY2025*

- ***Fixation Factor***

Fixation factors are established based on data provided by manufacturers. For product-A, the amount of CO_2 fixation per unit weight (0.42 t-CO_2/t) was established, based on the consideration of the purity of $CaCO_3$ (actual measurement) of the materials provided by the manufacturer of the CO_2-origin carbonate material. For product-B, the CO_2 fixation amount based on actual measurement results of cement slurry samples was used as a fixation factor (confidential). These fixation factors are values unique to each product and its specifications, obtained under specific conditions.

- ***Activity Data***

The data provided by manufacturers are used. For product-A, the actual sales amount of the CO_2-origin carbonate material by the uses provided by the manufacturer of the CO_2-origin carbonate material was used. For product-B, the cement slurry consumption (confidential) was used.

Table 4-105 Actual Sales Amount of the CO_2-origin Carbonate Material Product-A by Use

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Concrete/cement	t	0	0	0	0	0	0	0	0	17	31	41	13
Backfill materials for piling work	t	0	0	0	0	0	0	0	0	1	0.4	0	0
Building materials for other uses	t	0	0	0	0	0	0	0	0	0	0.1	0	0
Release agent for aluminum formwork/desulfurization of exhaust gas	t	0	0	0	0	0	0	0	31	6	0	0	0
Other (samples, etc.)	t	0	0	0	0	0	0	0	0.02	0.3	0.04	1	0

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainty of fixation factors, -3% to 3%, based on the results of the measurements of purity of $CaCO_3$ of the CO_2-origin material product-A provided by the manufacturer was applied. For the uncertainty of activity data, the default value of 5% for the Tier 3 method for chemical industry specified in the *2006 IPCC Guidelines* was applied. As a result, the uncertainty of CO_2 fixations was estimated to be -6% to 6%.

- ***Time-series Consistency***

The amount of CO_2 fixations are estimated in a manner consistent across the time-series methodologically, and from the point of view of data source.

d) Category-specific QA/QC and Verification

Same as Cement Production (2.A.1.). See section 4.2.1. d).

e) Category-specific Recalculations

Recalculations for FY2022 to FY2023 occurred due to an addition of product-B to the emissions estimation. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

Activity data will be re-examined as appropriate, based on comparison of results to that of the CO_2 fixation using consumption data of CO_2-origen carbonate material provided by the manufactures of the concrete.

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Chapter 5. Agriculture (CRT sector 3)

5.1. Overview of Sector

Greenhouse gas emissions from the agricultural sector are calculated in seven categories: 3.A., 3.B., 3.C., 3.D., 3.F., 3.G., and 3.H. In 3.A.: Enteric Fermentation, CH_4 gas generated and emitted by cattle, buffalo, sheep, goats, horses, and swine as the result of enteric fermentation is reported. In 3.B.: Manure Management, CH_4 and N_2O generated by treatment of manure excreted by cattle, buffalo, sheep, goats, horses, swine, poultry (hen and broiler), rabbit, and mink are reported. In 3.C.: Rice Cultivation, CH_4 emissions from paddy fields (continuously flooded and intermittently flooded) cultivated for rice production are reported. In 3.D.: Agricultural Soils, N_2O emitted directly and indirectly from agricultural soil are reported. Emissions for 3.E.: Prescribed Burning of Savannahs are reported as "NO", since Japan has no emission source in this category, while CH_4 and N_2O (as well as CO and NO_X, which is described in Annex 5) emissions from field burning of grains, legumes, root crops, and sugar cane during agricultural activities are reported in 3.F.: Field Burning of Agricultural Residues. 3.G.: Liming and 3.H.: Urea Application, CO_2 emissions by application of limestone and urea to soil are reported.

GHG emissions in the agricultural sector in FY2024 were 30,278 kt-CO_2 eq., comprising 2.9% of total emissions (excluding LULUCF). The value represents a 22.9% decrease from FY1990.

Tier of methodology used in Agriculture sector are showed in Table 5-1.

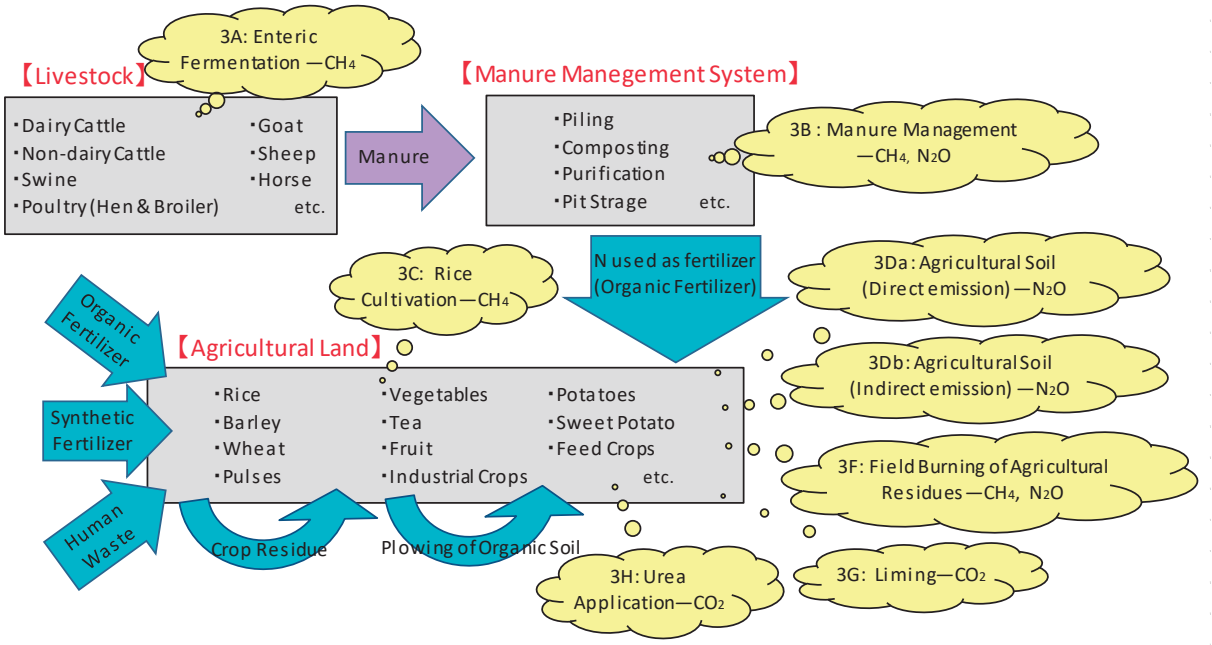

Figure 5-1 Relationships among the categories in the agricultural sector

Table 5-1 Tier of methodology used in Agriculture sector

GREENHOUSE GAS CATEGORIES	CO_2		CH_4		N_2O	
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
3.A. Enteric fermentation			CS,T1	CS,D		
3.B. Manure management			CS,T1	CS,D	CS,T1	CS,D
3.C. Rice cultivation			T3	CS		
3.D. Agricultural soils					CS,T2	CS,D
3.F. Field burning of agricultural residues			T1	D	T1	D
3.G. Liming	T1	D				
3.H. Urea application	T1	D				

Note: D: IPCC default, T1: IPCC Tier 1, T2: IPCC Tier 2, T3: IPCC Tier 3, CS: country-specific method or emission factor

5.2. Enteric Fermentation (3.A.)

Ruminants such as cattle, buffalo, sheep, and goats have multi-chamber stomachs. The rumen carries out anaerobic fermentation to decompose cellulose and other substances, thereby releasing CH_4. Horses and swine are not ruminants and have monogastric stomachs, but fermentations in their digestive tracts produce a small amount of CH_4, which is released into the atmosphere. These CH_4 emissions are calculated and reported in the Enteric Fermentation (3.A.) section.

GHG emissions from enteric fermentation in FY2024 were 8,459 kt-CO_2 eq., comprising 0.8% of total emissions (excluding LULUCF). The value represents a decrease by 19.9% from FY1990. The main driver of the emission reduction from FY1990 is a reduction of cattle population (particularly for dairy cattle). The main reason for the decreasing dairy cattle population is the decreasing number of dairy farmers, which is caused by the aging population of dairy farm owners and the lack of successors. In recent years, however, owing to the implementation of production infrastructure measures (MAFF, 2015), the number of dairy cattle reared per farmer have been increasing.

Table 5-2 CH_4 emissions from enteric fermentation (3.A.)

Gas	Livestock species	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
CH_4	3.A.1.- Dairy cattle	kt-CH_4	192.1	184.4	171.2	162.9	146.3	139.7	136.4	135.5	137.6	134.8	132.0	130.4
	3.A.1.- Non-dairy cattle		166.5	172.2	171.7	163.7	161.7	152.2	149.0	157.2	159.7	163.7	162.8	157.7
	3.A.2. Sheep		0.167	0.115	0.097	0.071	0.159	0.138	0.140	0.160	0.190	0.197	0.185	0.185
	3.A.3. Swine		15.9	13.9	13.7	13.5	13.7	13.4	13.0	13.0	12.5	12.5	12.3	12.3
	3.A.4.- Buffalo		0.011	0.007	0.006	0.005	0.004	0.005	0.006	0.006	0.006	0.006	0.006	0.005
	3.A.4.- Goats		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	3.A.4.- Horses		2.1	2.1	1.9	1.6	1.3	1.3	1.3	1.3	1.2	1.3	1.4	1.4
	Total	kt-CH_4	376.9	372.7	358.7	341.8	323.2	306.9	300.0	307.3	311.4	312.7	308.8	302.1
		kt-CO_2eq.	10,554	10,437	10,042	9,569	9,051	8,592	8,401	8,604	8,718	8,756	8,646	8,459

5.2.1. Cattle (3.A.1.)

a) Category Description

This section provides the estimation methods for CH_4 emissions from enteric fermentation in Dairy cattle (3.A.1.a.) and Non-dairy cattle (3.A.1.b.).

b) Methodological Issues

- ***Estimation Method***

In accordance with decision tree of the *2006 IPCC Guidelines* (Vol. 4, Page 10.25, Figure 10.2), calculations for dairy and non-dairy cattle should be performed using the Tier 2 method. In the Tier 2

method, emission factors are calculated by multiplying the total energy intake of livestock by the CH_4 conversion factor. However, estimation using amount of dry matter intake (DMI) has been practiced in Japan on livestock-related research. It is considered that applying the results of research using amount of DMI for the estimation provides more accurate results which is in accordance with the actual situation of emissions. For that reason, a technique similar to the Tier 2 method but specific to Japan was used for the calculation of CH_4 emissions associated with enteric fermentation by cattle. The emissions were calculated by multiplying the cattle population (dairy and non-dairy) by the emission factors established based on their dry matter intake.

$$E = \sum (EF_i \times A_i)$$

E : CH_4 emissions from enteric fermentation for cattle [kg-CH_4/yr]
EF_i : CH_4 emission factor of enteric fermentation of cattle type i [kg-CH_4 /head/yr]
A_i : Population of each cattle type i [head]
i : Cattle type

As cattle begin to eat coarse feed in real at the age about two months, the calculation of the CH_4 emissions associated with enteric fermentation includes cattle aged two months or older (cattle under two months are excluded from the calculation). To reflect the actual situation in Japan, categorization of cattle is defined as shown in the Table 5-3, and CH_4 emissions from enteric fermentation in cattle are estimated by types and ages.

Table 5-3 Categorization and assumptions underlying calculation of CH_4 emissions associated with enteric fermentation in cattle

Type of cattle					Assumptions for calculation of emissions	Additional information for each animal type
Dairy cattle	Lactating	Primipara			Population by calving time: calculated by multiplying the ratio of population by calving in *Record of Dairy Herd Performance Test* by the population in *Livestock Statistics*.	Lactating cattle. Population of 2 years old and over are written in *the Livestock Statistics*.
		Secondipara				
		Multipara (3 and more)				
	Non-lactating				—	Cattle in non-lactating period at present.
	Heifers	Under 2 years old and over 5 months old			Calculation excludes 6/24 of the population which was assumed to be 5 months old or younger; therefore covering 18/24 of the population under 2 years old.	Dairy cattle which are under 2 years old. Population of under 2 years old are described in *the Livestock Statistics*.
		2 to 5 months old			Comprising 4/24 of the population under 2 years old.	
		Under 2 months old			Covering 2/24 of the population under 2 years old. Excluded from CH_4 emission estimation.	
Non-dairy cattle	Breeding cows	2 years old and over			—	Breeding cow excluding dairy breeds. Population of under 1 year old, 1 year old, 2 years old, and 3 years old and over are described in *the Livestock Statistics*.
		Under 2 years old and over 5 months old			Calculation excludes 6/12 of the population which was assumed to be 5 months to 1 year old for under 1 year old and addition of the population under 1 year old.	
		2 to 5 months old			Comprising 4/12 of the population under 1 year old.	
		Under 2 months old			Covering 2/12 of the population under 1 year old. Excluded from CH_4 emission estimation.	
	Fattening cattle	Wagyu (Male)	1 year old and over		—	Cattle of native breeds in Japan called “Wagyu”, which breeds for meat only. Population of under 1 year, 1 year and 2 years old and over are described as beef cattle (Male) in *the Livestock Statistics*.
			Under 1 year old and over 5 months old		Calculation excludes 6/12 of the population which was assumed to be 5 months old or younger; therefore covering 6/12 of the population under 1 year old.	
			2 to 5 months old		Comprising 4/12 of the population under 1 year old.	
			Under 2 months old		Covering 2/12 of the population under 1 year old. Excluded from CH_4 emission estimation.	
		Wagyu (Female)	1 year old and over		—	Cattle of native breeds in Japan called “Wagyu”, which breeds for meat only. Population of under 1 year, 1 year and 2 years old (more than 7 categories) are described as beef cattle (Female) in *the Livestock Statistics*.
			Under 1 year old and over 6 months old		Same as the same months of age of Wagyu (Male).	
			2 to 5 months old		Same as the same months of age of Wagyu (Male).	
			Under 2 months old		Same as the same months of age of Wagyu (Male). Excluded from CH_4 emission estimation.	
		Dairy breeds	Dairy breeds	Over 5 months old	Calculation excludes 6/24 of the population which was assumed to be 5 months old or younger; therefore covering 18/24 of the population under 2 years old.	Cattle of dairy breeds for meat such as Holsteins.
				2 to 5 months old	Comprising 4/24 of the population under 2 years old.	
				Under 2 months old	Covering 2/24 of the population under 2 years old. Excluded from CH_4 emission estimation.	
			Hybrid	Over 5 months old	Same as the same months of age of Dairy breeds.	F1 hybrid for beef which female dairy breeds are delivered with crossing with male beef breed cattle.
				2 to 5 months old	Same as the same months of age of Dairy breeds.	
				Under 2 months old	Same as the same months of age of Dairy breeds. Excluded from CH_4 emission estimation.	

- ***Emission Factors***

The emission factor for CH_4 associated with enteric fermentation in cattle has been established on the basis of the result of breath testing of ruminant livestock in Japan: the measured data for volume of CH_4

per dry matter intake. Results of measurements have made clear that it is possible to estimate CH_4 from enteric fermentation in ruminant livestock using the equation given below, which uses dry matter intake as the explanatory variable (Shibata et al., 1993).

$$EF = Y / L_{CH4} \times Mol_{CH4} \times Day$$

$$Y = -17.766 + 42.793 \times DMI - 0.849 \times (DMI)^2$$

EF	: CH_4 emission factor associated with enteric fermentation for cattle [kg-CH_4/head/yr]
Y	: Volume of CH_4 generated per head per day [l/head/day]
L_{CH4}	: Volume of 1 mol CH_4 [l/mol] (=22.4)
Mol_{CH4}	: Molecular weight of CH_4 [kg/mol] (=0.016)
Day	: Days in a year [day] (=365 or 366)
DMI	: Dry matter intake [kg/day]

Annual emission factors by cattle types were established by applying the DMI to the above equation. The DMI was calculated by substituting body weight, and daily weight gain by growth into the equation established for each type of cattle in *Japanese Feeding Standard* compiled by National Agriculture and Food Research Organization (NARO). Fat corrected milk amount (FCM) is also used for DMI calculation for dairy cattle. The equations to estimate DMI were revised in 2006 for dairy cattle (lactating and non-lactating) and in 2008 and 2022 for non-dairy cattle (Wagyu (M)).

The amount of fat corrected milk was calculated by estimated milk yield from data in the *Statistics on Milk and Dairy Products* (Ministry of Agriculture, Fisheries and Forestry; MAFF) and the *Livestock Statistics* (MAFF), and from the fat content in milk data in the *Statistics of Livestock Production Costs* (MAFF). Both sets of the data are updated on a yearly basis.

The average body weights of cattle by each calving time which were firstly calculated by applying the average month of age by calving time described in the *Record of dairy herd performance test* (Livestock Improvement Association of Japan) into the growth curve of cattle described in *Japanese Feeding Standard* was adopted to the body weight for lactating and non-lactating dairy cattle. The average months of age for primipara for all years were described in the *Record of dairy herd performance test*, however, the record of the average months of age for second calving and more has started since 2015. Therefore, the values of average ages for second calving and more for FY2015 were substituted for before 2015. The regression equation expressing growth curve of dairy cattle have been revised in 1994, 1999, 2006 and each revised regression equation was applied after the revision. Data for body weight and weight gain by daily growth for heifer and non-dairy cattle were obtained from the table of weight by the average months of age for each type of cattle included in the *Japanese Feeding Standard*. Body weights by the months of age of non-dairy cattle have been revised in 1995, 2000, 2008, 2022 editions of the *Japanese Feeding Standard for Beef Cattle*. The values between each year were interpolated.

Table 5-4 Equation to estimate dry matter intake (*DMI*) by cattle

Type of cattle		Equation
Dairy cattle	Lactating	Before FY2006: $DMI = 2.98120 + 0.00905 \times W + 0.41055 \times FCM$ $FCM = (15 \times FAT / 100 + 0.4) \times MILK$ Since FY2006: $DMI = 1.3922 + 0.05839 \times W^{0.75} + 0.40497 \times FCM$ $DMI = 1.9120 + 0.07031 \times W^{0.75} + 0.34923 \times FCM$ (Primipara) $FCM = (15 \times FAT / 100 + 0.4) \times MILK$
	Non-lactating	$DMI = 0.017 \times W$
	Heifers	$DMI = 0.49137 + 0.01768 \times W + 0.91754 \times DG$
Non-dairy cattle	Breeding cows	For under 49 months old: $DMI = MERC / (q \times 4.4)$ $MERC = 0.1067 \times W^{0.75} + (0.0639 \times W^{0.75} \times DG) / (0.78 \times q + 0.006)$ $q = 0.4213 + 0.1491 \times DG$ For 49 months old and over: DMI = $MERC / 1.81$ $MERC = 0.1119 \times W^{0.75} + (0.0639 \times W^{0.75} \times DG) / (0.78 \times q + 0.006)$ Additional daily nutrient requirements for pregnant cows during last 2 months of pregnant: + 1.0 kg / day on calculated DMI Additional daily nutrient requirements for lactating cows during 5 months of lactation: + 0.5 kg / day to calculated DMI * Target ages are till 120 months old
	Wagyu (M)	Before FY2001: $DMI = MERC / (q \times 4.4)$ $MERC = 0.1124 \times W^{0.75} + (0.0546 \times W^{0.75} \times DG) / (0.78 \times q + 0.006) \times (1.653 - 0.00123 \times W)$ $q = 0.5304 + 0.0748 \times DG$ FY2008: (Interpolation from FY2001 to FY2007) $DMI = -3.481 + 2.668 \times DG + 4.548 \times 10^{-2} \times W - 7.207 \times 10^{-5} \times W^2 + 3.867 \times 10^{-8} \times W^3$ $MERC = 0.1124 \times W^{0.75} + (0.0546 \times W^{0.75} \times DG) / (0.78 \times q + 0.006) \times (1.416 - 0.0008948 \times W)$ $q = 0.4834 + 0.008959 \times DG + 0.0002088 \times W$ Since FY2022: (Interpolation from FY2009 to FY2021) $DMI = 2.027 + 2.244 \times DG + 15.4 \times 10^{-3} \times W - 17.08 \times 10^{-6} \times W^2 + 8.078 \times 10^{-9} \times W^3$ $MERC = 0.1124 \times W^{0.75} + (0.0574 \times W^{0.75} \times DG) / (0.78 \times q + 0.006) \times (1.54036 - 0.000943 \times W)$ $q = 0.4834 + 0.008959 \times DG + 0.0002088 \times W^3$
	Wagyu (F)	$DMI = MERC / (q \times 4.4)$ $MERC = 0.1108 \times W^{0.75} + (0.0609 \times W^{0.75} \times DG) / (0.78 \times q + 0.006)$ $q = 0.5018 + 0.0956 \times DG$
	Dairy breeds (over 6 months old)	$DMI = MERC / (q \times 4.4)$ $MERC = 0.1291 \times W^{0.75} + (0.0510 \times W^{0.75} \times DG) / (0.78 \times q + 0.006)$ $q = (0.933 + 0.00033 \times W) \times (0.498 + 0.0642 \times DG)$
	Dairy breeds (3 to 6 months old)	$DMI = MERC / (q \times 4.4)$ $MERC = 0.1291 \times W^{0.75} + \{(1.00 + 0.030 \times W^{0.75}) \times DG\} / (0.78 \times q + 0.006)$ $q = (0.859 - 0.00092 \times W) \times (0.790 + 0.0411 \times DG)$
	Hybrid	$DMI = MERC / (q \times 4.4)$ $MERC = 0.1208 \times W^{0.75} + (0.0531 \times W^{0.75} \times DG) / (0.78 \times q + 0.006)$ $q = (0.933 + 0.00033 \times W) \times (0.498 + 0.0642 \times DG)$

Note: *W*: Weight, *FCM*: Fat Corrected Milk, *FAT*: Fat content in milk, *MILK*: Milk Yield, *DG*: Daily Gain, *q*: Energy metabolic rate, *MERC*: Metabolizable energy requirement in calories

Reference: *Japanese Feeding Standard (for dairy cattle and non-dairy cattle)*

Table 5-5 Milk yield (*MILK*) of cattle and fat content in milk (*FAT*)

Item		Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Milk yield	Multipara (3 and more)	kg/head/day	21.9	23.6	24.7	26.6	26.9	27.4	28.6	30.0	30.5	30.2	30.0	30.9
	Secundipara	kg/head/day	21.4	23.1	24.2	26.0	26.4	26.9	27.9	29.2	29.7	29.5	29.3	30.0
	Primipara	kg/head/day	18.5	19.9	20.9	22.4	22.7	23.1	24.0	25.2	25.7	25.3	25.2	25.7
Fat content in milk		%	3.7	3.8	3.9	4.0	3.9	3.9	3.9	3.9	4.0	4.0	4.0	4.0

Table 5-6 Weight by cattle (*W*) [kg /head]

Type of cattle			1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Dairy cattle		Lactating (Multipara (3 and more))	653.8	653.5	673.7	673.4	685.6	685.2	684.7	683.3	682.8	682.4	681.3	681.1
		Lactating (Secundipara)	598.4	601.6	622.6	622.6	623.9	623.9	623.9	622.0	621.1	620.1	620.1	619.6
		Lactating (Primipara)	517.2	528.0	551.1	538.3	523.6	524.6	523.6	519.5	518.5	518.5	517.4	518.5
		Non-lactating	601.0	602.4	625.3	618.5	623.3	620.1	617.4	612.7	611.7	611.3	610.5	610.6
		Heifer: under 2 yr, over 5 mth	342.4	349.3	364.9	374.2	376.1	376.1	376.1	376.1	376.1	376.1	376.1	376.1
		Heifer: 2 to 5 mth	118.9	119.2	123.0	135.3	137.8	137.8	137.8	137.8	137.8	137.8	137.8	137.8
Non-dairy cattle	Breeding	2 yr and over	471.1	471.1	512.8	474.8	461.0	474.6	483.6	506.1	510.7	515.2	515.2	515.2
		Under 2 yr, over 5 mth	314.9	314.9	383.0	354.4	333.2	327.2	323.2	313.1	311.1	309.1	309.1	309.1
		2 to 5 mth	118.4	118.4	127.2	119.3	115.1	115.7	116.2	117.3	117.5	117.7	117.7	117.7
	Fattening cattle	Wagyu (M): 1 yr and over	562.8	562.8	562.8	560.9	566.8	577.4	584.4	602.1	605.6	609.1	609.1	609.1
		under 1 yr, over 5 mth	257.0	257.0	257.0	258.3	260.8	263.4	265.1	269.5	270.4	271.2	271.2	271.2
		2 to 5 mth	120.5	120.5	120.5	121.6	123.2	124.8	125.9	128.6	129.1	129.6	129.6	129.6
		Wagyu (F): 1 yr and over	382.4	382.4	456.4	422.1	399.7	397.0	395.2	390.7	389.8	388.9	388.9	388.9
		under 1 yr, over 5 mth	219.8	219.8	266.0	246.7	231.4	225.8	222.1	212.7	210.8	209.0	209.0	209.0
		2 to 5 mth	118.4	118.4	127.2	119.3	115.1	115.7	116.2	117.3	117.5	117.7	117.7	117.7
		Dairy breed: over 5 mth	479.8	479.8	479.8	479.8	479.8	479.8	479.8	479.8	479.8	479.8	479.8	479.8
		2 to 5 mth	160.4	160.4	160.4	160.4	160.4	160.4	160.4	160.4	160.4	160.4	160.4	160.4
		Hybrid: over 5 mth	479.8	479.8	479.8	479.8	479.8	479.8	479.8	479.8	479.8	479.8	479.8	479.8
		2 to 5 mth	160.4	160.4	160.4	160.4	160.4	160.4	160.4	160.4	160.4	160.4	160.4	160.4

Table 5-7 Daily Gain by cattle (*DG*) [kg /head /day]

Type of cattle			1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Dairy cattle		Lactating	—	—	—	—	—	—	—	—	—	—	—	—
		Non-lactating	—	—	—	—	—	—	—	—	—	—	—	—
		Heifer: under 2 yr, over 5 mth	0.60	0.63	0.65	0.59	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
		Heifer: 2 to 5 mth	0.70	0.71	0.76	0.91	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
Non-dairy cattle	Breeding	2 yr and over	0.02	0.02	0.01	0.01	0.01	0.02	0.02	0.03	0.03	0.03	0.03	0.03
		Under 2 yr, over 5 mth	0.50	0.50	0.60	0.56	0.53	0.53	0.53	0.53	0.53	0.53	0.53	0.53
		2 to 5 mth	0.74	0.74	0.93	0.86	0.80	0.78	0.76	0.73	0.72	0.71	0.71	0.71
	Fattening cattle	Wagyu (M): 1 yr and over	0.62	0.62	0.62	0.61	0.63	0.67	0.70	0.76	0.78	0.79	0.79	0.79
		under 1 yr, over 5 mth	1.07	1.07	1.07	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06	1.06
		2 to 5 mth	0.81	0.81	0.81	0.82	0.83	0.84	0.85	0.86	0.87	0.87	0.87	0.87
		Wagyu (F): 1 yr and over	0.29	0.29	0.29	0.27	0.27	0.30	0.32	0.36	0.37	0.38	0.38	0.38
		under 1 yr, over 5 mth	0.71	0.71	0.96	0.88	0.80	0.76	0.73	0.66	0.65	0.63	0.63	0.63
		2 to 5 mth	0.74	0.74	0.93	0.86	0.80	0.78	0.76	0.73	0.72	0.71	0.71	0.71
		Dairy breed: over 5 mth	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
		2 to 5 mth	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14
		Hybrid: over 5 mth	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
		2 to 5 mth	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14	1.14

Table 5-8 Dry matter intake by cattle (*DMI*) [kg /day]

Type of cattle			1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Dairy cattle		Lactating (Multipara (3 and more))	17.5	18.3	19.1	19.9	20.0	20.1	20.6	21.2	21.4	21.4	21.3	21.7
		Lactating (Secundipara)	16.9	17.7	18.4	19.3	19.2	19.4	19.8	20.4	20.6	20.6	20.5	20.9
		Lactating (Primipara)	14.9	15.7	16.4	17.0	17.4	17.6	17.9	18.3	18.5	18.4	18.3	18.6
		Non-lactating	10.2	10.2	10.6	10.5	10.6	10.5	10.5	10.4	10.4	10.4	10.4	10.4
		Heifer: under 2 yr, over 5 mth	7.1	7.2	7.5	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7
		Heifer: 2 to 5 mth	3.2	3.2	3.4	3.7	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Non-dairy cattle	Breeding	2 yr and over	7.7	7.7	8.0	7.7	7.5	7.7	7.8	8.1	8.2	8.2	8.2	8.2
		Under 2 yr, over 5 mth	6.3	6.3	7.4	6.9	6.6	6.5	6.5	6.4	6.4	6.4	6.4	6.4
		2 to 5 mth	3.4	3.4	3.7	3.5	3.4	3.3	3.3	3.3	3.3	3.3	3.3	3.3
	Fattening cattle	Wagyu (M): 1 yr and over	8.2	8.2	8.2	7.9	7.8	8.0	8.2	8.5	8.5	8.6	8.6	8.6
		under 1 yr, over 5 mth	6.5	6.5	6.5	6.8	7.0	7.1	7.2	7.4	7.4	7.5	7.5	7.5
		2 to 5 mth	3.6	3.6	3.6	3.4	3.7	4.2	4.6	5.4	5.6	5.8	5.8	5.8
		Wagyu (F): 1 yr and over	5.6	5.6	6.3	5.9	5.7	5.8	5.8	6.0	6.0	6.0	6.0	6.0
		under 1 yr, over 5 mth	4.7	4.7	5.9	5.5	5.1	4.9	4.8	4.5	4.4	4.4	4.4	4.4
		2 to 5 mth	3.0	3.0	3.4	3.2	3.0	3.0	3.0	3.0	2.9	2.9	2.9	2.9
		Dairy breed: over 5 mth	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5	8.5
		2 to 5 mth	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4	4.4
		Hybrid: over 5 mth	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3	8.3
		2 to 5 mth	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6

Table 5-9 Emission factors associated with enteric fermentation by cattle [kg-CH_4 /head /yr]

Type of cattle			1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Dairy cattle		Lactating (Multipara (3 and more))	122.9	125.9	127.7	129.8	129.9	130.3	131.6	132.4	132.8	132.8	133.0	133.3
		Lactating (Secundipara)	120.5	123.8	125.8	128.1	128.0	128.5	129.9	130.8	131.3	131.2	131.3	131.8
		Lactating (Primipara)	112.7	116.4	118.9	121.1	122.6	123.0	124.4	125.3	125.9	125.7	125.8	126.3
		Non-lactating	86.3	86.6	89.0	88.2	88.7	88.4	88.3	87.6	87.5	87.4	87.6	87.3
		Heifer: under 2 yr, over 5 mth	63.4	64.7	66.9	67.8	68.0	68.0	68.1	68.0	68.0	68.0	68.1	68.0
		Heifer: 2 to 5 mth	29.1	29.3	30.4	33.8	34.4	34.4	34.5	34.4	34.4	34.4	34.5	34.4
Non-dairy cattle	Breeding	2 yr and over	68.3	68.5	70.7	67.8	66.9	68.3	69.3	71.3	71.7	72.1	72.3	72.1
		Under 2 yr, over 5 mth	56.9	57.0	66.0	61.8	59.1	58.8	58.8	57.9	57.8	57.6	57.8	57.6
		2 to 5 mth	30.3	30.3	33.7	31.6	30.3	30.2	30.2	29.9	29.9	29.8	29.9	29.8
	Fattening cattle	Wagyu (M): 1 yr and over	72.1	72.3	72.1	69.6	69.2	70.7	71.8	74.1	74.6	75.0	75.3	75.0
		under 1 yr, over 5 mth	58.8	59.0	58.8	60.7	62.5	63.5	64.3	65.7	66.1	66.4	66.6	66.4
		2 to 5 mth	33.0	33.1	33.0	31.2	33.5	38.4	41.8	49.6	51.1	52.7	52.8	52.7
		Wagyu (F): 1 yr and over	51.0	51.2	57.2	53.4	51.7	52.4	53.0	54.0	54.2	54.4	54.6	54.4
		under 1 yr, over 5 mth	43.1	43.2	53.7	49.6	46.2	44.6	43.7	41.0	40.4	39.9	40.0	39.9
		2 to 5 mth	26.7	26.8	30.9	28.6	27.1	26.9	26.8	26.4	26.3	26.2	26.3	26.2
		Dairy breed: over 5 mth	74.2	74.4	74.2	74.2	74.2	74.2	74.4	74.2	74.2	74.2	74.4	74.2
		2 to 5 mth	40.2	40.3	40.2	40.2	40.2	40.2	40.3	40.2	40.2	40.2	40.3	40.2
		Hybrid: over 5 mth	73.0	73.2	73.0	73.0	73.0	73.0	73.2	73.0	73.0	73.0	73.2	73.0
		2 to 5 mth	42.1	42.2	42.1	42.1	42.1	42.1	42.2	42.1	42.1	42.1	42.2	42.1

- ***Activity Data***

For activity data of this source, the population of each type of cattle on 1st February in each year, recorded by the MAFF in its *Livestock Statistics* is used.

Table 5-10 Livestock population for cattle [1000 head]

Type of cattle			1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Dairy cattle		Lactating (Multipara (3 and more))	510	467	447	391	374	334	317	293	293	284	282	279
		Lactating (Secundipara)	260	250	241	229	196	202	194	192	200	194	188	186
		Lactating (Primipara)	313	318	283	280	235	236	241	241	244	236	234	232
		Non-lactating	332	299	249	231	195	185	185	184	188	182	185	185
		Heifer: under 2 yr, over 5 mth	491	445	379	379	351	328	306	334	335	344	317	309
		Heifer: 2 to 5 mth	109	99	84	84	78	73	68	74	75	77	71	69
		Heifer: under 2 mth	55	49	42	42	39	36	34	37	37	38	35	34
Dairy cattle total			**2,068**	**1,927**	**1,725**	**1,636**	**1,467**	**1,395**	**1,345**	**1,356**	**1,371**	**1,356**	**1,313**	**1,293**
Non-dairy cattle	Breeding	2 yr and over	612	591	555	536	575	520	511	567	575	578	570	543
		Under 2 yr, over 5 mth	84	69	68	71	78	62	64	53	50	54	56	55
		2 to 5 mth	12	9	8	9	11	9	9	9	8	9	9	9
		Under 2 mth	6	4	4	5	5	5	5	4	4	4	5	4
	Fattening cattle	Wagyu (M): 1 yr and over	368	412	385	374	409	381	371	389	403	406	405	403
		under 1 yr, over 5 mth	125	133	114	119	127	115	109	139	126	140	146	140
		2 to 5 mth	83	89	76	80	85	77	72	93	84	94	97	94
		under 2 mth	42	44	38	40	42	38	36	46	42	47	49	47
		Wagyu (F): 1 yr and over	197	265	246	290	336	328	293	299	318	323	330	334
		under 1 yr, over 5 mth	102	105	93	89	101	91	86	115	102	114	115	111
		2 to 5 mth	68	70	62	59	67	60	57	77	68	76	77	74
		under 2 mth	34	35	31	30	34	30	29	38	34	38	38	37
		Dairy breed: over 5 mth	665	541	333	351	309	276	249	188	185	176	156	138
		2 to 5 mth	148	120	74	78	69	61	55	42	41	39	35	31
		under 2 mth	74	60	37	39	34	31	28	21	21	20	17	15
		Hybrid: over 5 mth	140	267	511	438	362	363	379	394	416	427	425	420
		2 to 5 mth	31	59	114	97	81	81	84	88	93	95	95	93
		under 2 mth	16	30	57	49	40	40	42	44	46	47	47	47
Non-dairy cattle total			**2,805**	**2,901**	**2,806**	**2,755**	**2,763**	**2,567**	**2,479**	**2,605**	**2,614**	**2,687**	**2,672**	**2,595**

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainties for emission factors were calculated by finding the 95% confidence interval in accordance with the equation indicated in the section Emission Factors (Dairy cattle: -26% to +32%, non-dairy cattle: -40% to +49%). Populations of cattle (activity data) are decided by survey of total

population in the *Livestock Statistics*, thus standard error for cattle is not described. Therefore, the uncertainties for activity data were substituted by 1% of swine in the *Livestock Statistics*. As a result, the uncertainties of the emissions were determined to be -26% to +32% for dairy cattle and -40% to +49% for non-dairy cattle.

- ***Time-series Consistency***

Emission factors were calculated consistently from FY1990 onward by the method mentioned in the section on Emission Factors. Activity data were used consistently from FY1990 onward from the data in the *Livestock Statistics*.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Annex 4.

It was pointed out by implementation of QA activity (QAWG) in FY2016 that ablactation of dairy cattle is at the age about three months, and CH_4 was actively generated from them. By taking this into account and discussions within the Committee for Greenhouse Gas Emission Estimation Methods, improvement to estimate the emission from cattle at the age three and four months was conducted in 2017 submission inventory.

Comparison between results of Japan's estimation method and IPCC Tier 2 method was conducted. For Tier2 method, equations indicated in the *2006 IPCC Guidelines* (Vol.4, Chapter 10, Equation 10.3~10.16) are used, and estimation is conducted by classification described in Table 5-3 above. If data is available, Japan's data are used (e.g. values of Table 5-4 to Table 5-8 above and values of DE calculated from data described in the *Japanese Feeding Standards*). If not available, default data described in the *2006 IPCC Guidelines* are used (e.g. Y_m, Cf_i and $C_{pregnancy}$).

As a result, for both dairy cattle and non-dairy cattle, considering the error of CH_4 conversion factor (Y_m = 6.5%±1.0%), the emissions based on Japan's method were in the range calculated by IPCC Tier 2 method. Therefore, it is considered that there were no significant differences between emissions of Japan's method and IPCC Tier 2 method.

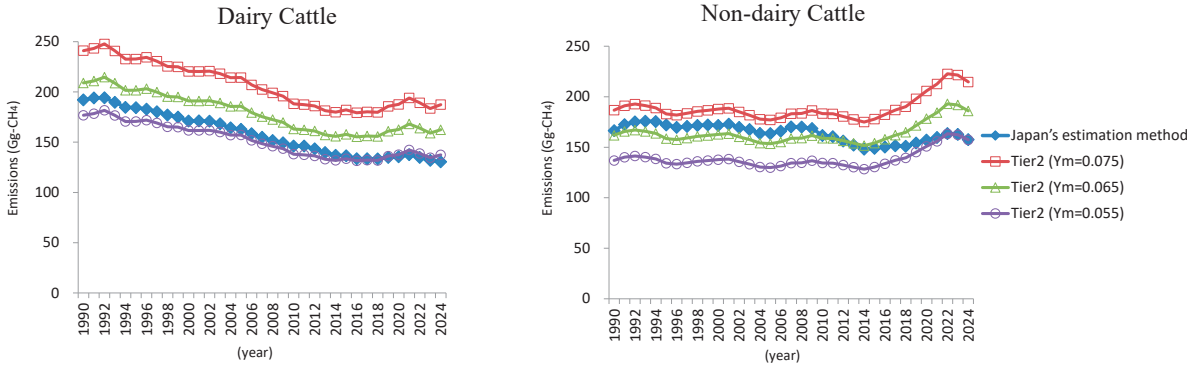

Figure 5-2 Comparison between results of Japan's estimation method and IPCC Tier 2 method

e) Category-specific Recalculations

Since the population of dairy cattle by calving in *Record of Dairy Herd Performance Test* for FY2023

was updated, the emissions from dairy cattle for FY2023 were recalculated. Due to the revision of application of the *Japanese Feeding Standard for Beef Cattle*, the emissions from non-dairy cattle were recalculated for all fiscal years. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

It is planned to discuss the development of the estimation method, which reflects the emissions reduction with technologies that suppress methane emission by controlling the rumen fermentation (such as by the addition of fatty acid calcium to feed) and by improving the feed efficiency with the total mixed ration (TMR) feeding.

5.2.2. Sheep, Swine, Buffalo, Goats & Horses (3.A.2., 3.A.3., 3.A.4.-)

a) Category Description

This section provides the estimation methods for CH_4 emissions from enteric fermentation in sheep, swine, buffalo, goats, and horses.

b) Methodological Issues

- ***Estimation Method***

CH_4 emissions were calculated using the Tier 1 method in accordance with the decision tree of the *2006 IPCC Guidelines*.

$E = EF \times A$

E	: CH_4 emissions from enteric fermentation for each livestock [kg-CH_4/yr]
EF	: CH_4 emission factor for enteric fermentation of each livestock [kg-CH_4 /head/yr]
A	: Population of each livestock [head]

- ***Emission Factors***

The emission factors for swine have been established on the basis of results of research conducted in Japan. The emission factor for sheep, goats, horses and buffalo are the default values given in the *2006 IPCC Guidelines*.

Table 5-11 Emission factors for CH_4 associated with enteric fermentation in sheep, swine, buffalo, goats, and horses

Livestock species	CH_4 emission factor [kg-CH_4/head/yr]	Reference
Sheep	8	2006 IPCC Guidelines
Swine	1.4	Estimated from Saito (1988)
Buffalo	55.0	2006 IPCC Guidelines
Goats	5	
Horses	18.0	

- ***Activity Data***

For activity data of sheep and goats, livestock population data given in the *Statistical Document of Livestock Breeding* offered by the Japan Livestock Industry Association until FY2009 and the *Status Report regarding Health Management for Livestock Feeding* by the MAFF from FY2010 onward are used. For swine, population on 1st February in each year recorded in the *Livestock Statistics* by the MAFF are used. The data in FY2004, FY2009 and FY2014 were interpolated. For horses, livestock

population given in the *Statistical Document of Horse* offered by the MAFF until FY2009 and the *Status Report regarding Health Management for Livestock Feeding* by the MAFF from FY2010 onward are used. For buffalo, livestock population given in the *Survey Result of Feeding Livestock and Poultry* by Okinawa Prefecture are used.

Table 5-12 Livestock population for sheep, swine, buffalo, goats and horses [1000 head]

Livestock species	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Sheep	21	14	12	9	20	17	18	20	24	25	23	23
Goats	26	19	22	16	19	20	17	20	22	22	22	22
Swine	11,335	9,900	9,788	9,620	9,768	9,537	9,313	9,290	8,950	8,956	8,798	8,798
Horses	116	118	105	87	75	74	74	73	68	74	78	78
Buffalo	0.21	0.12	0.10	0.08	0.08	0.10	0.11	0.12	0.11	0.11	0.12	0.10

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainties Assessment***

An uncertainty assessment was conducted by each livestock category. The uncertainties for emission factors for swine were decided by the Committee of GHG Emissions Estimation Methods. The uncertainties for emission factors of livestock other than swine were applied 50% of default data given in the *2006 IPCC Guidelines*. As the uncertainty for activity data of swine, 1% of standard error for swine given in the *Livestock Statistic* was applied. For activity data of livestock other than swine, uncertainty was substituted by the value of broiler (9%) described in the *Livestock Statistics*. As a result, the uncertainties of the emissions were determined to be -72% to +157% for swine and 51% for buffalo, sheep and goats and horses.

- ***Time-series Consistency***

For emission factors, same values were used consistently. For activity data, the data given in the *Statistical Document of Livestock Breeding*, the *Livestock Statistics*, the *Statistical Document of Horse*, the *Survey Result of feeding Livestock and Poultry* by Okinawa, and the *Status Report regarding Health Management for Livestock Feeding* are used, and consistent estimation method by each livestock are used since FY1990.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Annex 4.

e) Category-specific Recalculations

Since the population of sheep, goats and horse were updated, the emissions from sheep, goats and horse for FY2023 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

5.2.3. Other Livestock (3.A.4.-)

Deer, alpaca, which are not reported above, but default emission factors are reported in the *2006 IPCC Guidelines*, are farmed as livestock in Japan. However, their population size is small, and the emissions from each of them are lower than 3,000t-CO_2 equivalent, which is the threshold to estimate in this GHG

inventory decided by the Committee for GHG Emissions Estimation Methods. Therefore, it was reported as “NE” as considered insignificant (See Annex 6).

5.3. Manure Management (3.B.)

In livestock manure management process, CH_4 is generated by decomposing organic content in livestock manure with CH_4 fermentation. In addition, CH_4 generated by enteric fermentation dissolved in manure is released by aeration or agitation. In manure management, N_2O is produced mainly by microorganism via nitrification and denitrification processes.

CH_4 and N_2O emissions from manure management in FY2024 are 2,477 kt-CO_2 eq. and 3,066 kt-CO_2 eq., comprising 0.2% and 0.3% of total emissions (excluding LULUCF), respectively. The value represents a decrease by 34.6% for CH_4 and a decrease by 20.7% for N_2O from FY1990. Main driver of the CH_4 emission decrease from FY1990 is a reduction of dairy cattle population, and of the N_2O emission decrease from FY1990 is a reduction for indirect N_2O emission by atmospheric deposition because of a reduction of livestock population.

For amount of nitrogen in excretion of swine, decrease was seen in trend since 1990. The reason is that amount of crude protein in feeds has been decreased with the decrease of proportion of soybean meal in feeds year by year.

Table 5-13 CH_4 and N_2O emissions from livestock manure management (3.B.)

Gas	Livestock species	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
CH_4	3.B.1.- Dairy cattle	kt-CH_4	107.0	103.1	96.5	94.5	86.8	82.7	81.0	79.3	79.0	75.6	72.0	69.8
	3.B.1.- Non-dairy cattle		3.7	3.8	3.9	4.1	4.7	5.1	5.5	7.0	7.6	7.9	8.3	8.5
	3.B.2. Sheep		0.006	0.004	0.003	0.002	0.006	0.005	0.005	0.006	0.007	0.007	0.006	0.006
	3.B.3. Swine		22.2	19.3	17.7	12.5	8.7	8.0	7.6	7.0	7.0	7.2	7.3	7.5
	3.B.4.- Buffalo		0.0004	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
	3.B.4.- Goats		0.005	0.004	0.004	0.003	0.004	0.004	0.003	0.004	0.004	0.004	0.004	0.004
	3.B.4.- Horses		0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	3.B.4.- Poultry		2.0	1.9	1.9	2.1	2.4	2.5	2.4	2.5	2.5	2.4	2.4	2.4
	3.B.4.- Rabbit		0.001	0.001	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
	3.B.4.- Mink		0.1053	0.0073	0.0038	0.0004	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005	0.0005
	Total	kt-CH_4	135.2	128.4	120.2	113.4	102.7	98.5	96.7	96.0	96.2	93.3	90.2	88.5
		kt-CO_2 eq.	3,786	3,595	3,365	3,176	2,877	2,757	2,707	2,687	2,694	2,612	2,527	2,477
N_2O	3.B.1.- Dairy cattle	kt-N_2O	2.1	2.1	2.1	2.3	2.4	2.3	2.2	2.0	2.0	1.9	1.8	1.8
	3.B.1.- Non-dairy cattle		2.4	2.5	2.5	2.5	2.6	2.4	2.3	2.3	2.2	2.2	2.1	2.0
	3.B.2. Sheep		IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	3.B.3. Swine		3.7	3.2	3.2	3.8	4.5	4.3	4.1	4.1	3.9	3.8	3.6	3.5
	3.B.4.- Buffalo		0.00012	0.00007	0.00006	0.00005	0.00004	0.00005	0.00006	0.00007	0.00006	0.00006	0.00007	0.00006
	3.B.4.- Goats		IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	3.B.4.- Horses		IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	3.B.4.- Poultry		1.1	1.1	1.1	1.1	1.2	1.0	1.0	0.9	0.9	0.8	0.8	0.8
	3.B.4.- Rabbit		0.004	0.004	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005
	3.B.4.- Mink		0.0223	0.0016	0.0008	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	3.B.5. Indirect emissions		5.2	4.8	4.5	4.0	3.9	3.7	3.6	3.7	3.7	3.6	3.5	3.5
	Total	kt-N_2O	14.6	13.7	13.3	13.9	14.6	13.6	13.1	13.0	12.7	12.3	11.9	11.6
		kt-CO_2 eq.	3,865	3,638	3,529	3,676	3,860	3,599	3,484	3,448	3,370	3,255	3,156	3,066
Total of all gases		kt-CO_2 eq.	7,651	7,234	6,894	6,852	6,736	6,356	6,191	6,135	6,064	5,867	5,683	5,543

5.3.1. Cattle, Swine and Poultry (Hen and Broiler) (3.B.1., 3.B.3., 3.B.4.-)

a) Category Description

This section provides the estimation methods for CH_4 and N_2O emissions for manure management from cattle (dairy cattle and non-dairy cattle), swine and poultry (hen and broiler). For grazing animal, CH_4 emissions were reported in this category and N_2O emissions were reported in “3.D.1.c. Urine and dung deposited by grazing animals”.

b) Methodological Issues

- ***Estimation Method***

CH_4 emissions associated with the manure management were calculated by multiplying the amount of organic matter contained in manure from each type of livestock by the emission factor for each type of management system.

$$E_{CH4} = \sum \left(EF_{CH4-n} \times A_{CH4-n} \right)$$

E_{CH4}	: CH_4 emissions associated with the management of manure excreted by cattle, swine and poultry [kt-CH_4/yr]
EF_{CH4-n}	: Emission factor for management system *n* [kg-CH_4/kg-organic matter]
A_{CH4-n}	: Amount of organic matter contained in manure managed by system *n* [kt-organic matter/yr]
n	: Manure management system

N_2O emissions were calculated by multiplying the amount of nitrogen contained in manure of each type of animal by the emission factor for each type of management system.

$$E_{N2O} = \sum (EF_{N2O-n} \times A_{N2O-n}) \times 44/28$$

E_{N2O}	: N_2O emission associated with management of manure excreted by cattle, swine and poultry [kt-N_2O/yr]
EF_{N2O-n}	: Emission factor for management system *n* [kg-N_2O-N/kg-N]
A_{N2O-n}	: Amount of nitrogen contained in manure managed by system *n* [kt-N/yr]
n	: Manure management system

- ***Emission Factors***

CH_4 and N_2O Emission factors for each manure management system (hereafter, MMS) associated with Manure Management have been established for each treating method in Japan of for each type of livestock on the basis of the results of research by actual measurements carried out in Japan after reviewing its validity in accordance with the decision tree shown in Figure 5-3. Table 5-16 and Table 5-17 show these emission factors.

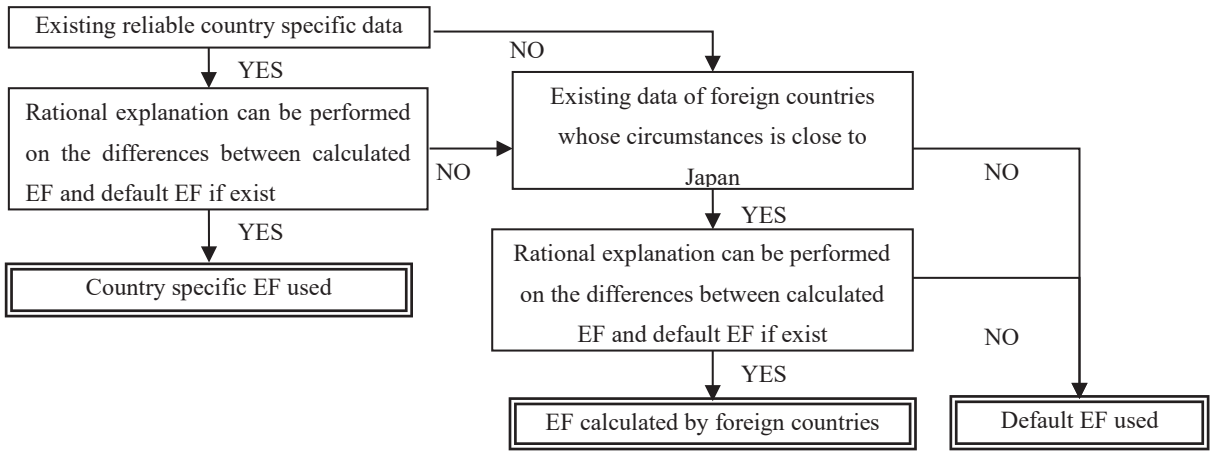

Figure 5-3 Decision tree for determination of EF

Emission factors indicated by "D (default value)" in Table 5-16 and Table 5-17 are based on the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (the *2019 Refinement*). CH_4 emission factors among them were calculated by following equation with *Bo* (maximum methane producing capacity) (Dairy cattle: 0.24, Non-dairy cattle: 0.18, Swine: 0.45, Hen: 0.39, Broiler: 0.36) and MCF (methane conversion factor, Table 5-14) in "Other Regions - High productivity systems" indicated in the *2019 Refinement*. Since MCF for composting and pit storage are described by each climate zone in the *2019 Refinement*, MCF values are calculated with regional MCF decided by the average temperature in each region, which are weighted average by regional livestock population. Average temperature by region used for development of MCF values is shown in the following Table 5-15. These temperatures were established by using the average temperatures in each municipality where livestock are mainly housed.

For country-specific emission factors, MCF values are not established because emission factors are estimated directly from results of actual measurement data.

$$EF_{CH4\text{-}n} = Bo \times 0.67 \times MCF$$

$EF_{CH4\text{-}n}$: Emission factor for management system *n* [kg-CH_4/kg-organic matter]
Bo : Maximum methane producing capacity [m^3-CH_4/kg-organic matter]
0.67 : Conversion factor from volume to weight [kg-CH_4/m^3-CH_4]
MCF : Methane conversion factor [%]

Table 5-14 MCFs (methane conversion factor) used for calculation of default emission factors

Treating method	MCF	System classification in the *2019 Refinement*
Composting - Intensive windrow (dairy cattle)	0.7%	Estimated on the basis of Composting - Intensive windrow
Composting - Intensive windrow (non-dairy cattle)	0.9%	Estimated on the basis of Composting - Intensive windrow
Composting - Intensive windrow (swine and poultry)	1.0%	Estimated on the basis of Composting - Intensive windrow
Composting - Intensive windrow (urine)	0 %	Estimated on the basis of Aerobic treatment
Composting - In-Vessel	0.5 %	Estimated on the basis of Composting - In-Vessel
Pit storage (non-dairy cattle)	28.6%	Estimated on the basis of Liquid/Slurry and Pit storage
Pit storage (non-dairy cattle), (within a month)	11.6%	Estimated on the basis of Liquid/Slurry and Pit storage – 1 month
Pit storage (non-dairy cattle), (over a month)	32.9%	Estimated on the basis of Liquid/Slurry and Pit storage – 3, 4, 6, 12 months
Pit storage (swine)	30.6%	Estimated on the basis of Liquid/Slurry and Pit storage
Pit storage (swine), (within a month)	12.5%	Estimated on the basis of Liquid/Slurry and Pit storage – 1 month
Pit storage (swine), (over a month)	35.1%	Estimated on the basis of Liquid/Slurry and Pit storage – 3, 4, 6, 12 months

Note: For other treating method than the above, MCF values are not established because country-specific emission factors are used.
Reference: the *2019 Refinement*, Vol.4 Table10.17

Table 5-15 Average temperature by region used for development of MCF values [°C]

Region	Dairy cattle	Non-dairy cattle	Swine	Hen	Broiler
Hokkaido	6.2	6.2	7.4	8.2	8.2
Tohoku	9.9	11.0	10.1	10.9	10.8
Kanto	13.0	12.1	14.4	15.6	16.4
Hokuriku	15.1	14.0	12.7	13.3	13.3
Tokai	17.1	14.3	15.0	16.0	15.5
Kinki	16.9	16.0	13.5	15.5	16.5
Chugoku	15.3	15.0	14.4	13.9	15.0
Shikoku	16.5	16.1	15.5	16.6	16.1
Kyusyu and Okinawa	16.7	16.5	16.3	17.3	16.5

For “Sun drying” for dairy cattle, non-dairy cattle and swine, CH_4 emission factors in Ishibashi et al. (2003) were adopted.

For “Sun drying” for hen and broiler, emission factors were established based on actual measurement data at poultry manure management facility with drying system (Poultry manure is dried out with agitation on conveyer belt machinery in tunnel ventilation barn) (Tsuchiya et al., 2014).

For “Thermal drying”, emission factor was set as 0 % by assuming that CH_4 emission from this manure management system theoretically does not occur.

For “Carbonization” for cattle and swine, emission factors were not established because carbonization is not applied. For “Carbonization” for hen and broiler, CH_4 emission factors were those for “Thermal drying”, and N_2O emission factors were referred by Canatoy et al. (2022).

For “Composting - In-Vessel (feces)” and “Composting - In-Vessel (feces and urine mixed)” for swine, emission factor is referred to *Project Report of Survey on Prevention of Global Warming in the Agriculture, Forest and Fisheries Sector within the Environment and Biomass Comprehensive Strategy Promotion Project in FY2008* (Nationwide Survey) (Hereinafter called “*Report of Survey Project in FY2008* (Nationwide Survey)”).

For emission factors of “Composting - In-Vessel (feces)” for hen and broiler, emission factor of these treating methods for swine is applied on the bases of expert judgment that characteristics of feces such as percentage of moisture and the condition of feces are close to that of swine. Because emission factors by treating methods by livestock are much different by treating methods rather than by livestock.

For “Piling”, the most major manure management practice in Japan, Osada et al. (2005) measured actual CH_4 and N_2O emissions by using chamber system covering compost heap, and Japan’s emission factors for dairy cattle, non- dairy cattle and swine were set from these data.

For “Piling” of hen and broiler, emission factors were established on the basis of actual GHG measurement data using chamber, which covers piled up manure, at piling composting management facility in three areas of Japan. Detail method is described in the report by MAFF (2014).

For “Incineration”, emission factor written in *GHGs emissions control in livestock industry Summary* (Japan Livestock Technology Association, 2002) is used.

For “Purification” for cattle, Shiraishi et al. (2017) measured actual CH_4 and N_2O emissions for urine and the mixture of feces and urine of dairy cattle from a purification plant. Emission factors based on the result of this study were applied to the purification of urine and the mixture of feces and urine from dairy and non-dairy cattle.

For “Purification” for swine, emission factor is from the *Project on Survey and Investigation for Elaboration of GHG Emissions from Agriculture, Forest and Fisheries Sector, within the Project on Development for Method of Promotion for Countermeasures of Global Environment in the Agriculture, Forest and Fisheries Sector in FY2012* (MAFF 2013) (Hereinafter called "*the Report of Project* (MAFF 2013)").

For CH_4 emission factors of “Pit storage” and “Methane fermentation” for dairy cattle, regional emission factors of 9 regions in Japan were established by using air temperature as a parameter, and based on actual measurement data on pit storage system and methane fermentation system by using measurement technique such as floating chamber method (*The Report of Project on Survey and Investigation for*

Elaboration of GHG Emissions from Agriculture, Forest and Fisheries Sector, within the Project on Development for Method of Promotion for Countermeasures of Global Environment in the Agriculture, Forest and Fisheries Sector in FY2011, 2012). Therefore, integrated emission factors for all Japan, which are weighted averages of the regional emission factors with dairy cattle population in each region (described in the *Livestock Statistics*), are used (see Table 5-18). Emission factors in latest year are lower than 1990 because ratio of livestock population in Hokkaido region, where temperature is low and emission factor is low, has gradually increased (FY1990: 42% and FY2021: 62%).

For "Pasture, range and paddock" of dairy cattle and non-dairy cattle, emission factors were established by actual measurement data of collected manure set in chamber in grazing area (Mori and Hojito, 2015).

For "Industrial waste treatment", emission factors for "Pit storage" is adopted. For "Other", emission factors were established based on the maximum value in each state of manure (feces, urine, and feces and urine mixed).

Table 5-16 CH_4 Emission factors for each method of treating manure from cattle, swine, and poultry

[%: kg-CH_4/kg-organic matter]

Treating method	Dairy cattle		Non-dairy cattle		Swine		Hen		Broiler	
Sun drying	0.20 %	J[2)]	0.20 %	J[2)]	0.20 %	J[2)]	0.14 %			J[10)]
Thermal drying	0 %									Z[3)]
Carbonization	—		—		—		0%			TD
Composting – Intensive windrow (feces)	0.113 %	D[1]	0.109 %	D[1)]	0.302 %	D[1]	0.261 %	D[1)]	0.241%	D[1)]
Composting – Intensive windrow (urine)	0.000%	D[1]	0.000 %	D[1)]	0.000 %	D[1]	—			
Composting – Intensive windrow (feces and urine mixed)	0.113%	D[1]	0.109%	D[1)]	0.302 %	D[1]	—			
Composting – In-Vessel (feces)	0.08 %	D[1)]	0.06 %	D[1)]	0.08 %	J[7)]	0.08 %			Sw
Composting – In-Vessel (urine)					0.151 %	D[1)]	—			
Composting – In-Vessel (feces and urine mixed)					0.08 %	J[7)]	—			
Piling	3.8 %	J[4)]	0.13 %	J[4)]	0.16 %	J[4)]	0.13 %	J[12)]	0.02 %	J[12)]
Incineration	0.4 %									O[3)]
Purification	0.3%			J[13)]	0.91 %	J[11)]	—			
Pit storage	Table 5-18	JR[8)]	3.4 %	D[1)]	9.2 %	D[1)]	0.13 %	Pl	0.02 %	Pl
Pit storage (within a month)			1.4 %	D[1)]	3.8 %	D[1)]				
Pit storage (over a month)			4.0 %	D[1)]	10.6 %	D[1)]				
Methane fermentation (feces)	3.8%	Pl	0.13%	Pl	0.16%	Pl	0.13 %	Pl	0.02 %	Pl
Methane fermentation (urine, feces and urine mixed)	Table 5-18	JR[8)]	3.5%	JR[8)]	3.6%	JR[8)]	—			
Industrial waste treatment	Table 5-18	JR[8)]	3.4 %	PS	9.2 %	PS	0.13 %	PS	0.02 %	PS
Pasture, range and paddock	0.076%			J[9)]	—		0.14%			SD
Other (feces)	3.8%	M	0.4%	M	0.4%	M	0.4%			M
Other (urine, feces and urine mixed)	3.8%	M	4.0%	M	10.60%	M	—			

Note: See notation and references of Table 5-17 below.

D: Default value of the *2019 Refinement*
J: Established by actual data of Japan
JR: Established using regional emission factors for dairy cattle and regional population of each livestock in Japan
O: Established by data of other countries
Z: No emission occurrence because of the mechanism
Pl: Application for the value of "Piling"
SD: Application for the value of "Sun drying"
TD: Application for the value of "Thermal draying"
PS: Application for the value of "Pit storage"
Sw: Application for the value of "Swine"
Dc: Application for the value of "Dairy cattle"
M: Application of the maximum values of the treating methods for "feces" or "feces and urine mixed"

Table 5-17 N_2O Emission factors for each method of treating manure from cattle, swine and poultry

[%: kg-N_2O-N/kg-N]

Treating method	Dairy cattle		Non-dairy cattle		Swine		Hen		Broiler	
Sun drying	2.0 %					D[1)]	0.33%			J[10)]
Thermal drying	2.0 %									D[1)]
Carbonization	—						0.021%			O[3)]
Composting – Intensive windrow (feces)	0.5 %						0.5 %			Sw
Composting – Intensive windrow (urine)	1.0 %					D[1)]	—			
Composting – Intensive windrow (feces and urine mixed)	0.5 %						—			
Composting – In-Vessel (feces)	0.25 %			J[5)]	0.16 %	J[7)]	0.16 %			Sw
Composting – In-Vessel (urine)	0.6%					D[1)]	—			
Composting – In-Vessel (feces and urine mixed)	0.25%			J[5)]	0.16%	J[7)]	—			
Piling	2.4 %	J[4)]	1.6 %	J[4)]	2.5 %	J[4)]	0.54%	J[12)]	0.08%	J[12)]
Incineration	0.1 %									O[3)]
Purification	2.88 %			J[13)]	2.87%	J[11)]	—			
Pit storage	0.02%	J[8)]	0 %			D[1)]	0.54%	PI	0.08%	PI
Methane fermentation (feces)	2.4 %	Pl	1.6 %	Pl	2.5 %	Pl	0.54%	Pl	0.08%	Pl
Methane fermentation (urine, feces and urine mixed)	0.15%	J[8)]	0.15%			Dc	—			
Industrial waste treatment	0.02%	PS	0 %			PS	0.54%	PS	0.08%	PS
Pasture, range and paddock	0.684%			J[9)]	—		0.33%			SD
Other (feces)	2.4%	M	2.0%	M	2.5%	M	2.0%			M
Other (urine, feces and urine mixed)	2.88%	M	2.88%	M	2.87%	M	—			

Note: 1) Manure excreted by hen and broiler was categorized as feces since it contains a very small amount of urine.
2) For the emission factors of "Composting" for FY2018 and before, which were not separated by its aeration system, the weighted average of EFs for "Intensive windrow" and "In-Vessel" by the proportion for each of system are used.

References for Table 5-16 and Table 5-17:

1) the *2019 Refinement*
2) Ishibashi et al. (2003)
3) Japan Livestock Technology Association, (2002)
4) Osada et al. (2005)
5) Osada et al. (2000)
6) Osada (2003)
7) Report of Survey Project in FY2008 (Nationwide Survey), (2009)
8) MAFF, *the Report of Project on Survey and Investigation in FY2011*, (2012)
9) Mori and Hojito (2015)
10) Tsuchiya et al. (2014)
11) MAFF, *the Report of Project on Survey and Investigation in FY2012*, (2013)
12) MAFF, *the Report of Project on Survey and Investigation in FY2013*, (2014)
13) Shiraishi et al. (2017)
14) Canatoy et al. (2022)

Table 5-18 Annual CH_4 Emission factors for "Pit storage" and "Methane fermentation" for dairy cattle

[%: kg-CH_4/kg-organic matter]

Item	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Pit storage	2.47%	2.44%	2.42%	2.40%	2.37%	2.37%	2.36%	2.34%	2.34%	2.34%	2.34%	2.33%
Methane fermentation	3.22%	3.17%	3.14%	3.11%	3.06%	3.06%	3.05%	3.02%	3.01%	3.01%	3.00%	3.00%

Note: These figures are weighted averages of regional emission factors for dairy cattle from *the Report of Project in FY2011*, (MAFF 2012) by annual dairy cattle population in each region.

- ***Activity Data***

The values used for the activity data are estimates of the amount of organic matter and the amount of nitrogen excreted annually by various type of livestock by management system, respectively.

$$A_{CH4\text{-}n} = P \times Ex \times Day \times Org \times Mix_n \times MS_n / 1000$$

$$A_{N2O\text{-}n} = P \times Nex \times Day \times Mix_n \times MS_n / 1000$$

$A_{CH4\text{-}n}$	: Amount of organic matter contained in manure by management system *n* by livestock [kt-organic matter/yr]
$A_{N2O\text{-}n}$	: Amount of nitrogen contained in manure by management system *n* by livestock [kt-N/yr]
P	: Population of each livestock [1000 heads]
Ex	: Amount of feces and urine excreted per head per day from each livestock [kg/head/day]
Org	: Organic matter content in feces and urine from each livestock [%]
Nex	: Nitrogen content of feces and urine excreted per head per day from each livestock [kg-N/head/day]
Day	: Days in a year [day]
Mix_n	: Proportion of separated and mixed treatment of manure by type of livestock [%]
MS_n	: Proportion of each manure management system by animal [%]
n	: Manure management system

Total amount of organic matter by livestock was calculated by multiplying the population of each type of animal by the amount of manure per head by the organic matter content in feces or urine. Total nitrogen amount was calculated by multiplying the population of each type of animal by the nitrogen content of feces or urine excreted per head (Table 5-19, Table 5-20, Table 5-21, Table 5-22, Table 5-23). The amount of organic matter and nitrogen were allocated to each manure management system by multiplying the total amount by the proportion of separated and mixed treatment of manure and the proportion of manure management system by type of animal (Table 5-32, Table 5-33, Table 5-34).

Table 5-19 Amount of excretion (*Ex*) and amount of nitrogen in excretion (*Nex*) from dairy cattle

Item				1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Dairy Cattle	Amount of excretion [kg/head/day]	Feces	Lactating (Multipara (3 and more))	41.5	43.1	44.5	46.0	46.1	46.4	47.3	48.4	48.8	48.8	48.6	49.4
			Lactating (Secundipara)	40.3	41.8	43.3	44.8	44.7	45.0	45.8	46.8	47.3	47.2	47.0	47.8
			Lactating (Primipara)	36.7	38.2	39.5	40.6	41.4	41.6	42.2	42.9	43.3	43.2	43.0	43.5
			Non-lactating	27.9	27.9	28.7	28.5	28.6	28.5	28.4	28.3	28.2	28.2	28.2	28.2
			Heifer: under 2 yr, over 5 mth	22.1	22.4	22.9	23.1	23.2	23.2	23.2	23.2	23.2	23.2	23.2	23.2
			Heifer: 2 to 5 mth	14.9	14.9	15.1	15.8	15.9	15.9	15.9	15.9	15.9	15.9	15.9	15.9
		Urine	Lactating (Multipara (3 and more))	16.9	16.9	17.0	17.0	17.0	17.0	16.9	16.9	17.0	17.0	17.0	17.0
			Lactating (Secundipara)	17.1	17.1	17.2	17.2	17.2	17.1	17.1	17.1	17.1	17.2	17.2	17.2
			Lactating (Primipara)	18.8	18.8	18.9	18.9	18.8	18.8	18.7	18.7	18.7	18.8	18.8	18.8
			Non-lactating	15.2	15.2	15.4	15.3	15.4	15.3	15.3	15.3	15.3	15.3	15.3	15.3
			Heifer: under 2 yr, over 5 mth	12.3	12.3	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5	12.5
			Heifer: 2 to 5 mth	4.4	4.4	4.8	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1	5.1
	Amount of N in excretion [g-N/head/day]	Feces	Lactating (Multipara (3 and more))	155.7	164.4	172.7	181.7	182.1	184.0	189.1	195.5	198.2	198.1	196.8	201.7
			Lactating (Secundipara)	148.5	157.4	165.5	174.3	173.9	175.7	180.5	186.3	188.9	188.7	187.5	191.8
			Lactating (Primipara)	128.6	136.7	144.1	150.2	154.7	156.1	159.5	163.7	165.8	165.0	164.0	167.0
			Non-lactating	82.7	83.0	86.8	85.6	86.4	85.9	85.5	84.7	84.5	84.4	84.3	84.3
			Heifer: under 2 yr, over 5 mth	53.3	54.5	57.2	58.3	58.5	58.5	58.5	58.5	58.5	58.5	58.5	58.5
			Heifer: 2 to 5 mth	20.6	20.7	21.6	24.3	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9
		Urine	Lactating (Multipara (3 and more))	76.1	81.0	83.2	87.9	89.5	90.8	93.5	96.9	98.0	97.5	97.1	99.0
			Lactating (Secundipara)	85.8	90.2	92.2	96.6	98.4	99.6	102.1	105.0	106.1	105.6	105.2	106.7
			Lactating (Primipara)	88.8	92.5	94.4	98.7	92.8	94.2	97.2	101.3	103.0	101.9	101.3	103.1
			Non-lactating	98.6	98.8	103.1	101.9	102.8	102.2	101.7	100.8	100.6	100.5	100.4	100.4
			Heifer: under 2 yr, over 5 mth	65.1	66.6	69.7	70.9	71.1	71.1	71.1	71.1	71.1	71.1	71.1	71.1
			Heifer: 2 to 5 mth	27.4	27.6	37.4	43.1	44.2	44.2	44.2	44.2	44.2	44.2	44.2	44.2

Table 5-20 Amount of excretion (*Ex*) and amount of nitrogen in excretion (*Nex*) from non-dairy cattle

Item				1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Non-dairy cattle	Amount of excretion [kg/head/day]	Feces	Breeding: 2 yr and over	17.4	17.4	18.2	17.3	17.0	17.4	17.7	18.3	18.4	18.6	18.6	18.6
			under 2 yr, over 5 mth	12.6	12.6	14.2	13.5	13.0	12.9	12.9	12.7	12.6	12.6	12.6	12.6
			2 to 5 mth	5.9	5.9	5.7	5.6	5.6	5.7	5.8	5.9	5.9	5.9	5.9	5.9
			Wagyu (M): 1 yr and over	12.3	12.3	12.3	10.8	10.9	11.1	11.1	11.4	11.4	9.4	9.4	9.4
			under 1 yr, over 5 mth	8.4	8.4	8.4	9.5	10.7	11.2	11.5	12.4	12.5	10.5	10.5	10.5
			2 to 5 mth	5.0	5.0	5.0	3.9	4.9	7.3	8.9	13.0	13.8	13.4	13.4	13.4
			Wagyu (F): 1 yr and over	10.0	10.0	11.2	10.5	10.2	10.2	10.3	10.4	10.4	10.4	10.4	10.4
			under 1 yr, over 5 mth	7.2	7.2	8.2	7.8	7.5	7.4	7.3	7.0	7.0	6.9	6.9	6.9
			2 to 5 mth	4.5	4.5	4.7	4.5	4.4	4.5	4.5	4.5	4.5	4.5	4.5	4.5
			Dairy breed: over 5 mth	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6	14.6
			2 to 5 mth	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2
			Hybrid: over 5 mth	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4	14.4
			2 to 5 mth	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7	9.7
		Urine	Breeding: 2 yr and over	7.1	7.1	7.4	7.0	6.9	7.1	7.2	7.5	7.5	7.6	7.6	7.6
			under 2 yr, over 5 mth	5.8	5.8	6.8	6.4	6.0	6.0	6.0	5.9	5.9	5.9	5.9	5.9
			2 to 5 mth	3.1	3.1	3.4	3.2	3.1	3.1	3.1	3.1	3.0	3.0	3.0	3.0
			Wagyu (M): 1 yr and over	7.6	7.6	7.6	7.3	7.2	7.4	7.5	7.8	7.9	7.9	7.9	7.9
			under 1 yr, over 5 mth	6.0	6.0	6.0	6.2	6.4	6.5	6.6	6.8	6.8	6.9	6.9	6.9
			2 to 5 mth	3.3	3.3	3.3	3.2	3.4	3.9	4.2	5.0	5.2	5.3	5.3	5.3
			Wagyu (F): 1 yr and over	5.2	5.2	5.8	5.4	5.2	5.3	5.4	5.5	5.5	5.5	5.5	5.5
			under 1 yr, over 5 mth	4.3	4.3	5.4	5.0	4.7	4.5	4.4	4.1	4.1	4.0	4.0	4.0
			2 to 5 mth	2.7	2.7	3.1	2.9	2.8	2.8	2.8	2.7	2.7	2.7	2.7	2.7
			Dairy breed: over 5 mth	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8	7.8
			2 to 5 mth	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0
			Hybrid: over 5 mth	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7
			2 to 5 mth	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
	Amount of nitrogen in excretion [g-N/head/day]	Feces	Breeding: 2 yr and over	58.9	58.9	61.8	58.3	57.3	58.9	59.9	62.6	63.1	63.6	63.6	63.6
			under 2 yr, over 5 mth	46.1	46.1	56.2	51.5	48.5	48.2	47.9	47.2	47.1	46.9	46.9	46.9
			2 to 5 mth	21.5	21.5	24.3	22.6	21.5	21.4	21.4	21.2	21.2	21.1	21.1	21.1
			Wagyu (M): 1 yr and over	63.5	63.5	63.5	60.5	60.0	61.8	63.0	66.1	66.7	67.3	67.3	67.3
			under 1 yr, over 5 mth	48.1	48.1	48.1	50.2	52.2	53.3	54.1	55.9	56.3	56.6	56.6	56.6
			2 to 5 mth	23.7	23.7	23.7	22.2	24.1	28.3	31.2	38.7	40.2	41.7	41.7	41.7
			Wagyu (F): 1 yr and over	40.1	40.1	46.4	42.5	40.7	41.5	41.9	43.1	43.3	43.5	43.5	43.5
			under 1 yr, over 5 mth	32.5	32.5	42.7	38.7	35.4	33.9	33.0	30.6	30.1	29.6	29.6	29.6
			2 to 5 mth	18.7	18.7	22.0	20.2	19.0	18.8	18.7	18.4	18.4	18.3	18.3	18.3
			Dairy breed: over 5 mth	61.3	61.3	61.3	61.3	61.3	61.3	61.3	61.3	61.3	61.3	61.3	61.3
			2 to 5 mth	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8	31.8
			Hybrid: over 5 mth	60.2	60.2	60.2	60.2	60.2	60.2	60.2	60.2	60.2	60.2	60.2	60.2
			2 to 5 mth	33.2	33.2	33.2	33.2	33.2	33.2	33.2	33.2	33.2	33.2	33.2	33.2
		Urine	Breeding: 2 yr and over	73.9	73.9	76.7	73.3	69.9	71.7	72.8	75.8	76.4	77.0	77.0	77.0
			under 2 yr, over 5 mth	57.5	57.5	69.4	64.0	61.5	60.9	60.5	59.3	59.1	57.7	57.7	57.7
			2 to 5 mth	35.5	35.5	43.6	40.6	47.1	45.9	45.1	43.2	42.8	31.2	31.2	31.2
			Wagyu (M): 1 yr and over	76.9	76.9	76.9	73.5	72.8	74.9	76.3	79.8	80.5	81.2	81.2	81.2
			under 1 yr, over 5 mth	65.1	65.1	65.1	66.5	71.8	72.2	72.5	73.2	73.4	70.8	70.8	70.8
			2 to 5 mth	41.0	41.0	41.0	40.5	50.7	53.4	55.1	59.6	60.5	54.0	54.0	54.0
			Wagyu (F): 1 yr and over	49.8	49.8	57.2	52.6	50.6	51.4	52.0	53.3	53.6	53.8	53.8	53.8
			under 1 yr, over 5 mth	44.8	44.8	57.5	52.9	51.5	49.2	47.7	44.0	43.2	37.9	37.9	37.9
			2 to 5 mth	33.9	33.9	42.3	39.2	44.6	43.4	42.5	40.5	40.1	29.8	29.8	29.8
			Dairy breed: over 5 mth	84.2	84.2	84.2	84.2	85.5	85.5	85.5	85.5	85.5	83.1	83.1	83.1
			2 to 5 mth	57.2	57.2	57.2	57.2	61.8	61.8	61.8	61.8	61.8	51.2	51.2	51.2
			Hybrid: over 5 mth	82.0	82.0	82.0	82.0	83.0	83.0	83.0	83.0	83.0	81.1	81.1	81.1
			2 to 5 mth	57.0	57.0	57.0	57.0	65.8	65.8	65.8	65.8	65.8	51.0	51.0	51.0

Table 5-21 Amount of excretion (*Ex*) and amount of nitrogen in excretion (*Nex*) from swine

Item				Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Swine	Excretion	Feces	Growing-finishing	kg/head/day	1.7	1.7	1.7	1.7	1.8	1.8	1.8	1.9	1.9	1.9	1.9	1.9
			Breeding	kg/head/day	2.2	2.2	2.3	2.3	2.3	2.4	2.4	2.4	2.4	2.4	2.4	2.4
		Urine	Growing-finishing	kg/head/day	4.3	4.2	4.1	4.0	3.9	3.8	3.7	3.9	3.9	3.8	3.8	3.8
			Breeding	kg/head/day	5.5	5.5	5.5	5.2	5.1	4.9	4.8	4.7	4.7	4.6	4.6	4.5
	Nitrogen	Feces	Growing-finishing	g-N/head/day	14.0	14.0	13.3	13.3	13.6	13.7	13.6	14.2	14.3	14.2	14.2	14.2
			Breeding	g-N/head/day	20.2	20.2	20.2	19.4	19.7	19.8	19.7	19.7	19.7	19.7	19.7	19.7
		Urine	Growing-finishing	g-N/head/day	27.9	27.6	26.8	25.9	25.3	24.5	24.0	25.2	25.3	24.9	24.7	24.4
			Breeding	g-N/head/day	36.0	35.6	35.7	33.8	33.0	31.8	31.1	30.7	30.7	30.1	29.9	29.5

Table 5-22 Amount of excretion (*Ex*) and amount of nitrogen in excretion (*Nex*) from Hen and Broiler (*Nex*)

Item				Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Poultory	Excretion	Hen	Adult	kg/head/day	0.086	0.087	0.088	0.088	0.087	0.095	0.091	0.087	0.087	0.087	0.086	0.087
			Poult	kg/head/day	0.041	0.041	0.039	0.040	0.040	0.042	0.041	0.040	0.040	0.040	0.039	0.040
		Broiler		kg/head/day	0.097	0.098	0.098	0.096	0.101	0.094	0.089	0.083	0.083	0.082	0.082	0.082
	Nitrogen	Hen	Adult	g-N/head/day	2.18	2.16	2.06	1.93	1.86	1.82	1.78	1.71	1.71	1.70	1.69	1.69
			Poult	g-N/head/day	1.04	1.03	0.97	0.98	1.01	0.99	0.98	0.98	0.98	1.00	1.00	1.00
		Broiler		g-N/head/day	2.06	2.04	1.95	1.75	1.86	1.56	1.53	1.45	1.47	1.44	1.45	1.46

Table 5-23 Organic matter content in feces and urine, by type of livestock (wet base) (*Org*) [1)]

Livestock species	Organic matter content	
	Feces	Urine
Dairy cattle	16%	0.5%
Non-dairy cattle	18%	2.0%[2)]
Swine	20%	1.4%[3)]
Hen	15%	—
Broiler	15%	—

Reference: 1) Japan Livestock Technology Association, *GHGs emissions control in livestock Summary*. (2002)
2) Expert judgement
3) Estimated value based on *Guide for processing and using livestock manure*, Livestock Industry's Environmental Improvement Organization, 1998

For livestock population, same references indicated in '3.A. Enteric Fermentation' for dairy cattle non-dairy cattle and swine are used.

Livestock population for hen described in the *Livestock Statistics* are used (see the following Table 5-24) but the data in FY2004, FY2009, FY2014 and FY2019 are interpolated.

For broiler from FY1990 to FY2008, livestock population described in the *Statistics on Livestock Products Marketing* are used. For FY2009 onwards, as livestock population are not surveyed in the statistics, livestock population are estimated by using the number of shipments of broiler in the same statistics (see the following Table 5-25). 5-year average (0.170) from FY2004 to FY2008 of "livestock population" / "annual number of shipments", is multiplied by the number of shipments of each year. In addition, days of feeding to shipment are shorter than the past. Therefore, 0.919 (= 49 days/ 53.3 days), ratio of feeding days until shipment of present (*Planning for Breeding Improvement of Poultry*, 2015) and past (*Questionnaire Survey on Current Feeding Status for Broiler*, 2008) is multiplied.

Table 5-24 Livestock population for hen [1000 heads]

Livestock species	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Hen	188,786	190,634	186,202	180,697	178,546	174,806	175,733	183,373	182,661	172,265	170,776	170,776

Note: Data of non-surveyed year (in 2019) were interpolated.
Reference: *The Livestock Statistics*

Table 5-25 Livestock population for broiler [1000 heads]

Item	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Livestock Population in statistics (broiler)	142,740	118,123	106,311	103,687								
Number of Shipment (broiler)				606,898	633,799	653,999	669,899	728,009	735,530	737,217	745,636	749,130
Livestock Population used in this inventory (broiler)	142,740	118,123	106,311	103,687	98,913	102,066	104,547	113,616	114,790	115,053	116,367	116,912

Note: From 1990 to 2008, livestock population data in the statistics are used. For 2009 onwards, estimated data by using the number of shipments are used.
Reference: MAFF, *Statistics on Livestock Products Marketing*

Amount of feces per head per day for dairy cattle is calculated by using the multiple regression equation which is written in *Japanese Feeding Standard for dairy cattle* and has two explanatory variables, DMI and Natural Detergent Fiber of organic matter (%) (NDFom). Amount of urine excreted per head per day for dairy cattle is calculated by the multiple regression equation which is written in Otani et al. (2010) and has three explanatory variables, Nitrogen Intake (NI), potassium Intake (KI) and milk yield. DMI and milk yield are used same data described in '3.A. Enteric Fermentation'. NDFom was set at 35% referred to *Japanese Feeding Standard for dairy cattle*. NI was calculated by dividing Crude Protein (CP) by 6.25. CP were calculated following with formulas in *Japanese Feeding Standard* with DMI, milk yield, weight, fat content in milk and daily gain which are same data in '3.A. Enteric Fermentation' (Table 5-28). The preferable CP content in feed dry matter is 12% and over for the most effective digestion of feed and fermentation by microorganism in rumen, described in *Japanese Feeding Standard*. Therefore, CP values are adjusted to be 12% of DMI when the calculated CP was lower than 12% of DMI. KI was set with referring to Kume et al. (2010) (Table 5-26).
Nitrogen contents in excretion per head per day for dairy cattle, for both in feces and urine, were calculated with the regression equation in Choumei et al. (2006) (Table 5-26). DMI is from Table 5-8 described above. CP is calculated with formula from *Japanese Feeding Standard for dairy cattle* in Table 5-28.

Table 5-26 Equation to estimate amount of excretion and nitrogen content in excretion for dairy cattle

	Equation
Amount of feces[1)]	$F = -8.4753 + 1.8657 \times DMI + 0.4948 \times NDFom$ ($NDFom$: 35%)
Amount of urine[2)]	$U = -2.2870 + 0.0231 \times NI + 0.0581 \times KI - 0.3350 \times MILK$ ($NI = CP / 6.25$)
Potassium Intake[3)]	KI = : 380g/day (Primipara) : 350g/day (2nd calving and over) : 250g/day (Non-lactating) : 220g/day (Heifer: 7 to 24 months) : 100g/day (Heifer: 3 to 6 months)
Nitrogen content in feces[4)]	$N_f = 5.01 \times DMI^{1.2}$ (Lactating) $N_f = 4.97 \times DMI^{1.21}$ (Non-lactating and Heifer)
Nitrogen content in urine[4)]	$N_u = 16.57 \times (CP / 1000 / DMI) \times 100 - 138.6$ (Lactating) $N_u = 0.24 \times (CP / 6.25)^{1.14}$ (Non-lactating and Heifer)

Note: See notation and references of Table 5-27 below.

For amount of excretion per head per day for non-dairy cattle, amount of feces and urine each are separately calculated by using DMI and TDN% provided in *Japanese Feeding Standard* for variables instead of GE and DE%, based on the equation 10.24 in the *2006 IPCC Guidelines* (Vol 4, page 10.42) which is for the dry-organic matter in excretion (Table 5-27). The conversion factor for dietary GE per kg of dry matter (1/18.45) for converting energy unit into weight unit provided in *2006 IPCC Guidelines* was not used because DMI itself stands for weight. TDN% is the most used evaluation value of dietary energy in Japan and could be converted into DE% using the following equation:

TDN 1kg = 4.41 Mcal DE (*Japanese Feeding Standard for beef cattle*)

For non-dairy cattle, percentage of moisture contents in feces for Wagyu (Male), Wagyu (Female) and Breeding cows had been decided as 80%, and that for Dairy breeds and Hybrid had been decided as 85% based on the expert judgement in the Committee for GHG Emissions Estimation Methods (FY2020). Organic matter content in urine had also been decided to be 2.0% in the Committee. Nitrogen contents in excretion per head per day for non-dairy cattle were calculated with the regression equation in Choumei et al. (2006) for both feces and urine (Table 5-27). Nitrogen content in feces is calculated in formula with a variable of DMI and nitrogen content in urine is calculated with formula with a variable CP. DMI and MERC is from Table 5-8 described above. CP is calculated with formula from *Japanese*

Feeding Standard for *beef cattle* in Table 5-28.

Therefore, CP values are adjusted to be 12% of DMI when the calculated CP was lower than 12% of DMI, as same as in case of dairy cattle.

Table 5-27 Equation to estimate amount of excretion and nitrogen content in excretion for non-dairy cattle

	Equation
Amount of feces	$F = F_{dry} / (1\text{-}MC)$ $F_{dry} = DMI \times (1 - TDN\%)$ $TDN\% = TDN / DMI$, $TDN = MERC / 3.62$ MC: 80% (Wagyu (M), Wagyu (F), Breeding) [5], 85% (Dairy breed, Hybrid) [5]
Amount of urine	$U = VSU / OC$ $VSU = DMI \times UE \times (1 - ASH)$ OC = 2.0% [5], UE = 2.0% [5], ASH = 8.0% [6]
Nitrogen content in feces[4]	$N_f = 7.22 \times DMI^{1.00}$ (for dairy breeds) $N_f = 4.97 \times DMI^{1.21}$ (for other non-dairy cattle)
Nitrogen content in urine[4]	$N_u = -14.96+0.60 \times NI$ (for dairy breeds) $N_u + N_m = 0.24 \times NI^{1.14}$ (for other non-dairy cattle) (N_m =0, $NI = CP / 6.25$)

Note: for Table 5-26, Table 5-27 and Table 5-28

F: Feces wet weight (kg/day)
DMI: Dry matter intake (kg/day)
NDFom: Natural detergent fiber of organic matter (%)
U: Urine weight (kg/day)
NI: Nitrogen intake (kg/day)
KI: Potassium intake (kg/day)
MILK: Milk yield (kg/day)
Nf: Nitrogen content in feces (kg/day)
Nu: Nitrogen content in urine (kg/day)
CP: Crude protein (g)
Fdry : Feces dry weight (kg/day)
MC: Percentage of moisture contents in feces (%)
TDN%: Percentage of total digestible nutrients
TDN: Total digestible nutrients (kg/day)
MERC: Metabolizable energy requirement in calories
VSU: Volatile solid excretion rate in urine (kg/day)
OC: Organic matter content in urine (%)
UE: Urinary energy (%)
ASH: Ash content (%)
CFA: Correction factor
W: Body weight (kg)
FAT: Fat content in milk (%)
NP: Net protein for preservation and gain for growth
EP: Conversion efficiency of crude protein to net protein on growth
FN: Metabolic fecal nitrogen for growth after ablactation (for heifers which body weight is 66kg and over) (g/day)
UN: Endogenous urinary nitrogen (g/day)
SP: Shedding skin protein (g/day)
RP: Protein accumulation associate with gain (g/day)
DG: Daily gain (kg/day)
DCPR: Digestible crude protein requirement (g/day)
TP(t): Total protein accumulation in pregnant uterus until (t) days after conception (g)
t: Days after conception (day)
MCP: Microbial crude protein (g/day)
MPu: Undigestible crude protein from feed (g/day)
MPR: Metabolic protein requirement (g/day)
MPd: Metabolic protein delivered by microbial (g/day)
MPm: Metabolic protein requirement for maintenance (g/day)
MPg: Metabolic protein requirement for growth (g/day)
Adj: Adjustment value
MPc: Metabolic protein requirement for conception (g/day)
PP(t): Protein accumulation in pregnant uterus at (t) days after conception (g/day)
BW: Birth weight (kg)
MPℓ: Metabolic protein for lactation (g/day)

Reference: 1) *Japanese Feeding Standard (for dairy cattle and non-dairy cattle)*
2) Otani et al. (2010)
3) Kume et al. (2010)
4) Chomei et al. (2006)
5) Expert judgement
6) *2006 IPCC Guidelines*, Vol.4

Table 5-28 Equation to estimate crude protein (*CP*)[1)]

		Equation
Dairy cattle	Lactating	$CP = (CP1 + CP2) \times CFA$ $CP1 = 2.71 \times W^{0.75} / 0.6 \times$ Correction factor by calving Correction factor by calving: primipara: 1.3, 2nd calving: 1.15, 3rd calving and more: 1 $CP2 = (26.6 + 5.3 \times \text{FAT}) \times MILK / 0.65$ $CFA = 1 + MILK / 15 \times 0.04$
	Non-lactating	$CP = 2.71 \times W^{0.75} / 0.6$
	Heifer	$CP = NP / EP$ $NP = FN \times 6.25 + UN \times 6.25 + SP + RP$ $FN = 30 \times DMI / 6.25$ $UN = 2.75 \times W^{0.5} / 6.25$ $SP = 0.2 \times W^{0.6}$ $RP = 10 \times DG \times 23.5505 \times W^{-0.0645}$ $EP = 0.51$ (for body weight 120kg and over) 0.63 (for body weight 67-119kg)
Non-dairy cattle	Before FY2008 and Since FY2022	$CP = NP / EP$ $NP = FN \times 6.25 + UN \times 6.25 + SP + RP$ *EP*: 0.51 (for body weight 150kg and over) : 0.56 (for body weight 101-149kg) : 0.66 (for body weight 51-100kg) (Breeding cows, additional *CP* for the last 2 months of pregnancy period) $CP = DCPR / 0.75$ $DCPR = TP / 38.5 \times 30.0 / 63 / 0.6 \times 1000 + FN \times 6.25$ $TP = TP(t) - TP(t - 63)$ $TP(t) = (1.486 \times 10^{-4} \times t^3 - 4.247 \times 10^{-2} \times t^2 + 3.173 \times t - 0.328) \times (- 0.323 \times 10^{-6} \times t^3 + 3.000 \times 10^{-4} \times t^2 - 9.430 \times 10^{-2} \times t + 11.263) \times 6.25$ $FN = 4.80 \times 3.21 / 2.7$ (Breeding cows, additional *CP* for 5 months of lactation period) $CP = DCPR / 0.65$ $DCPR = 53 \times MILK$
	From FY2008 to FY2021	$CP = (MCP / 0.85 + MPu / 0.80) / 1.15$ $MCP = 100 \times TDN$ (except Breeding cows) $MCP = 130 \times TDN$ (Breeding cows) $MPu = MPR - MPd$ $MPR = MPm + MPg$ $MPm = (FN \times 6.25 + UN \times 6.25 + SP) / 0.67$ $MPg = RP / 0.492 MPd = 0.8 \times 0.8 \times MCP$ (Dairy breeds under 200kg of body weight) $CP = NP / EP$ $NP = FN \times 6.25 + UN \times 6.25 + SP + RP$ *EP*: 0.51 (Breeding cows, additional *CP* for the last 2 months of pregnancy period) $MPc = PP(t) / 0.65$ $PP(t) = BW / 40 \times TP(t) \times 34.37e^{-0.00262t}$ $TP(t) = 10^{3.707-5.698e^{\wedge}0.0022t}$ (Breeding cows, additional *CP* for 5 months of lactation period) $MP\ell = (38 \times MILK) / 0.65$
	Parameters for each type	$FN = 4.80 \times DMI - Adj$ Before FY2008: $Adj = 0$ Since FY2008 to FY2021: Dairy cattle weighing less than 200 kg $Adj = 0$ Hybrids, Wagyu, Dairy cattle weighing over 200 kg $Adj = (100 \times TDN \times 0.64 \times 0.25 \times 0.5) / 6.25$ Breeding cows $Adj = (130 \times TDN \times 0.64 \times 0.25 \times 0.5) / 6.25$ Since FY2022: Wagyu (Male) $Adj = 0$ Dairy breeds, Hybrids, Wagyu (Female) and Breeding cows $Adj = (130 \times TDN \times 0.64 \times 0.25 \times 0.5) / 6.25$ $UN = 0.44 \times W^{0.5}$ $SP = 0.2 \times W^{0.6}$ $RP = DG \times (235 - 0.195 \times W)$ (Dairy Cattles) $RP = DG \times (235 - 0.234 \times W)$ (Hybrids, Wagyu (Male)) $RP = DG \times (235 - 0.293 \times W)$ (Wagyu (Female) and Breeding cows (before 49 months old)) $RP = 0$ (Breeding cows (49 months old and over))

Note: See notation and references of Table 5-27 above.

The amount of feces for swine was calculated by using DMI and Digestion Rate for feed (DR (%)) instead of GE and DE%, on the basis of equation 10.24 in the *2006 IPCC Guidelines*. The amount of urine was calculated on the basis of amount of nitrogen in excretion per head per day explained in below. Categorization for calculation is for 2 types as growing-finishing pig and breeding pig.

Nitrogen contents in excretion per head per day from swine are calculated by dividing the total nitrogen in excretion per head of every class by total days of raising (Estimated on the basis of *The report of the fact-finding survey for pig farming (The result of National tabulation results)*, Japan Pork Producers Association). Nitrogen contents in excretion per head is calculated by subtracting amount of nitrogen accumulated in body from amount of nitrogen intake for each body weight class written in *Japanese Feeding Standard for Swine*. Nitrogen intake was calculated by using the CP content in feeds and the amount of feed intake. The CP content in feeds is established as the average CP content in feed calculated by using the CP content in each feedstuff and the proportion of feedstuffs to feed (Estimated on the basis of *Feed bulletin*, MAFF) (Table 5-30). Nitrogen contents in feces and urine per day is calculated by multiplying the ratio between feces and urine to nitrogen contents in excretion per day (Table 5-29). Ratio of feces is calculated by dividing the nitrogen amount converted from the sum of the amount of undigested crude protein in feed, amount of excretion of endogenous crude protein and the amount of crude protein to be lost as fallen hair or skin by the nitrogen contents in excretion on the basis of Ogino et al. (2020). All remains are assumed to be allocated to urine, and therefore the proportion allocated to urine is estimated. For "CP content in milk" and "Amount of milk" of lactating sows, the values in Niwa (1994) were adopted.

Table 5-29 Equation to estimate amount of nitrogen content in excretion for swine

	Equation
Amount of feces	$F = F_{dry} / (1 - MC)$ MC: 72% [1)] $F_{dry} = DMI \times (1 - DR\%)$
Amount of urine	$U = N_u / (OC \times 0.469)$ OC = 1.4% [1)]
Nitrogen content in feces [2)]	$N_f = N_{out} \times f$ $f = (UDCP + ECP + CP_{loss}) / 6.25 / N_{out}$ $UDCP = UD \times F_{intake}$ $UD = 1 - \Sigma n\ (CPFS\text{-}n \times DCP\text{-}n)$ $ECP = 14.05 \times \Sigma i\ DMIi$ [4)] $CP_{loss} = \Sigma i\ 104.7 \times Day \times AVW^{0.75}$ [4)]
Nitrogen content in urine	$N_u = N_{out} \times u$ $u = (1 - f)$
Nitrogen content in excretion	$N_{out} = N_{in} - N_{PR}$ $N_{out} = N_{in} - N_M$ (Lactating sow) $N_{in} = (CP \times F_{intake}) / 6.25$ $F_{intake} = F_{demand} \times Day$ $N_{PR} = (149.2 \times W^{-0.0154} \times WG) / 6.25$ (Growing-finishing pigs before FY2005) $N_{PR} = (-0.121 \times W + 119.2 \times WG + 25.5) / 6.25$ (Growing-finishing pigs since FY2005) $N_{PR} = ((5.78 \times NWG + 103.87) / 5.56) / 6.25$ (Pregnant sows) $N_M = \Sigma(CP_M \times MILK) / 6.25$ (Lactating sows)

Note:

F: Feces wet weight (kg/day)
F_{dry}: Feces dry weight (kg/day)
MC: Percentage of moisture contents in feces (%)
DMI: Dry matter intake (kg/day)
DR%: Digestion Rate for feed (%)
U: Urine weight (kg/day)
Nu: Nitrogen content in urine (kg/day)
OC: Organic matter content in urine (%)
N_f: Nitrogen content in feces (kg/day)
N_{out}: Nitrogen content in excretion (g)
f: Proportion of feces to excretion
UDCP: Undigested crude protein in feed (g)
ECP: Excretion of endogenous crude protein (g)
CP_{loss}: Amount of crude protein to be lost as fallen hair or skin (g)
UD: Undigestibility (%)
F_{intake}: Feed intake (kg)
n: Varieties of feedstuffs
CPFS: Crude protein content in feedstuffs (%)

DCP: Percentage of digestible crude protein in feedstuffs (%)
AVW: Averaged body weight (kg)
i: Body weight class for growing-finishing pigs
u: Proportion of urine to excretion
Day: Total days of raising (day)
N_{in}: Nitrogen content in feed intake (g)
N_{PR}: Nitrogen amount in accumulated protein in body (g)
N_M: Nitrogen amount in milk (g)
CP: Crude protein contents in feed intake (%)
F_{demand}: Daily demand of feed intake (kg/day)
W: Body weight (kg)
WG: Daily weight gain (kg/day)
NWG: Weight gain by pregnant sow in gestational period without conceptus (kg)
CP_M: Crude protein content in milk (%)
MILK: Amount of milk (g)

Reference: 1) *Guide for processing and using livestock manure*
2) Ogino et al. (2020)
3) *Japanese Feed Standard for Swine*
4) National Research Council of the National Academies (NRC) (2012)

Table 5-30 CP content in feedstuffs (%) and proportion of feedstuffs in feed material

	CP content (%)[1)]			Proportion of feedstuffs in feed material[2)]								
				Swine			Hen			Broiler		
Name of feed material	1995	2001	2009	1995	2001	2009	1995	2001	2009	1995	2001	2009
Corn	8.8	8.0	7.6	0.471	0.503	0.541	0.589	0.606	0.581	0.485	0.444	0.427
Grain sorghum (Milo)	9.0	8.8	8.8	0.161	0.136	0.104	0.059	0.034	0.046	0.151	0.189	0.183
Wheat	12.1	12.1	12.1	0.005	0.005	0.011	0.000	0.000	0.000	0.000	0.000	0.000
Barley (Naked variety)	10.5	10.5	10.5	0.006	0.006	0.013	0.000	0.000	-	0.000	0.000	0.000
Rice	7.9	7.9	7.5	0.011	0.008	0.010	0.010	0.006	0.010	0.017	0.013	0.026
Wheat feed flour	15.5	15.5	15.5	0.010	0.008	0.008	0.000	0.000	0.001	0.001	0.001	0.003
Rye	10.9	10.4	10.0	0.029	0.024	0.004	0.000	0.000	-	0.000	0.000	0.000
Oats	9.8	9.8	9.8	0.000	0.000	0.000	-	-	-	-	-	-
Other grains	10.1	10.1	10.1	0.008	0.010	0.012	0.001	0.001	0.001	0.001	0.001	0.002
Soybean, Soybean meal	36.7	36.7	36.7	-	0.004	0.004	-	0.001	0.001	-	0.001	0.001
Other beans	25.7	25.7	25.7	-	0.000	0.000	-	0.000	-	-	0.000	-
Wheat bran / Barley bran	15.4	15.7	15.7	0.012	0.009	0.009	0.008	0.006	0.005	0.001	0.001	0.000
Rice bran	14.8	14.8	14.8	0.004	0.003	0.001	0.009	0.006	0.004	0.002	0.001	0.001
Defatted rice bran	17.7	17.5	18.6	0.006	0.007	0.007	0.009	0.008	0.008	0.001	0.001	0.001
Gluten feed	19.8	19.8	20.9	0.009	0.008	0.008	0.017	0.019	0.015	0.001	0.001	0.001
Gluten meal	51.5	51.5	51.3	0.000	0.000	0.000	0.035	0.033	0.031	0.004	0.002	0.003
Hominy feed	9.6	9.6	9.0	0.000	0.000	-	0.000	0.000	-	0.000	0.000	-
Screening pellet	12.3	12.3	12.3	0.000	0.000	-	0.000	0.000	-	-	-	-
Beat pulp	10.9	10.9	8.5	0.000	0.000	0.000	-	0.000	-	-	-	0.000
DDGS	30.8	30.8	30.8	-	-	-	-	-	-	-	-	-
Other chaff and bran	12.2	12.2	12.2	0.002	0.002	0.009	0.005	0.004	0.020	0.001	0.001	0.007
Alfalfa meal pellet cube	16.7	16.7	16.2	0.004	0.003	0.003	0.003	0.003	0.001	0.000	0.000	0.000
Soyabean meal	46.1	46.1	45.0	0.143	0.148	0.142	0.127	0.162	0.162	0.199	0.231	0.221
Rapeseed meal	37.1	37.1	37.3	0.032	0.035	0.041	0.035	0.039	0.050	0.023	0.025	0.027
Cotton seed meal	35.4	35.4	35.4	0.000	0.000	0.000	0.000	-	0.000	0.000	-	-
Other plant seed meals	32.7	32.7	32.7	0.004	0.006	0.005	0.008	0.011	0.011	0.002	0.002	0.002
Fish meal	59.8	59.8	59.6	0.014	0.010	0.008	0.023	0.014	0.010	0.021	0.011	0.009
Fish Soluble Powder	56.1	56.1	56.1	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000	0.000
Dried skim milk	35.8	35.8	34.6	0.005	0.004	0.002	0.000	-	-	0.000	0.000	0.000
Dried whey	12.0	12.0	12.0	0.003	0.004	0.004	0.000	0.000	0.000	-	-	0.000
Meat meal / Meat and bone meal	60.8	60.8	59.6	0.015	0.005	0.001	0.035	0.015	0.007	0.034	0.018	0.016
Feather meal	84.5	84.5	83.1	0.000	0.000	0.000	0.002	0.001	0.000	0.004	0.002	0.004
Other animal origin feed	43.5	43.5	43.3	0.001	0.000	0.001	0.001	0.001	0.002	0.004	0.004	0.008
Animal fat	0.0	0.0	0.0	0.013	0.013	0.011	0.018	0.024	0.027	0.042	0.046	0.048
Vegetable cooking oil	0.0	0.0	0.0	0.000	0.000	0.000	0.001	0.001	0.001	0.000	0.000	0.001
Molasses	9.4	9.4	9.4	0.005	0.004	0.004	0.000	0.000	0.000	0.000	0.000	0.000
Feed additives	0.0	0.0	0.0	0.004	0.004	0.005	0.003	0.003	0.004	0.004	0.004	0.006
Special feed	0.0	0.0	0.0	0.016	0.019	0.018	-	-	-	-	-	-
Other feed	13.1	13.1	13.0	0.005	0.009	0.013	0.001	0.002	0.004	0.001	0.001	0.003
Amino acid	100.0	100.0	100.0	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.003
Total				1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

Note: Estimated based on references below. The values for 1995, 2001 and 2009 are extracted and shown.
Reference: 1) National Agriculture and Food Research Organization compiled, *Tables of Feed Composition in Japan*, Japan Livestock Industry Association.
2) Ministry of Agriculture, Forestry and Fisheries of Japan, *Feed bulletin*.

The amount of excretion of poultry was calculated from the feed intake per head per day, based on Equation 10.24 of the *2006 IPCC Guidelines*. Since the amount of feed intake at each growing stage of chicks is different, the amount of excretion per chick was calculated as the weighted average of the amount of excretion by the proportion of the number of chicks at each growing stage (Table 5-31).

The amount of nitrogen in the excretion of poultry per head per day, based on the method for calculating nitrogen excretion in Ogino et al. (2017), was calculated by subtracting the amount of nitrogen in the laid eggs and in the gaining body from the total amount of ingested nitrogen, assuming the remaining amount of nitrogen was excreted. Nitrogen intake was calculated by using the CP content in feed and the amount of feed intake, same with swine. Since broilers and chicks of layers do not lay eggs, only the amount of nitrogen in the gaining body was subtracted from the amount of ingested nitrogen, and the remaining amount of nitrogen was assumed to be excreted. Since the amount and composition of feed intake at each growing stage of chicks of layers were different, the amount of excretion for a chick was calculated as the weighted average of the amount of excretion by the proportion of the number of chicks at each growing stage. Feed intake, daily weight gain, CP content in daily weight gain, and body weight were drawn from the *Breeding Management Guidelines for Commercial Chicken* (GHEN Corporation CO., Ltd.).

Table 5-31 Equation to estimate amount of nitrogen content in excretion for poultry

	Equation [1)]
Amount of feces	$F_{dry} = Intake \times Dry \times (1 - DR\%)$ Dry：87%[2)] $F_{wet} = F_{dry} / (1 - MC)$ MC：hen 78%、broiler 80% [3)]
Nitrogen content in excretion	$N_{out} = N_{in} - N_{egg} - N_{wg}$ (hen) $N_{in} = F_{intake} \times W_{egg} \times CP_{feed} / 6.25$ $N_{egg} = W_{egg} \times CP_{egg} / 6.25$ CP_{egg}：12%[2)] $N_{wg} = WG \times CP_{wg} / 6.25$ CP_{wg}：19.2% $N_{out} = N_{in} - N_{wg}$ (chicks of layer) $N_{in} = Intake \times CP_{feed} / 6.25$ $N_{wg} = WG \times CP_{wg} / 6.25$ CP_{wg}：19.2% $N_{out} = N_{in} - N_{pr}$ (broiler) $N_{in} = F_{intake} \times WG \times CP_{feed} / 6.25$ $N_{pr} = WG \times CP_{chiken} / 6.25$ $CP_{chicken}$：19.2% $WG = W / 47$

Note:

F_{dry}: Feces dry weight (kg/day)

Intake: Amount of feed intake (g/day)

Dry: Dry matter fraction of feed (%)

DR%: Digestion Rate for feed (%)

F_{wet}: Feces wet weight (kg/day)

MC: Percentage of moisture contents in feces (%)

N_{out}: Nitrogen content in excretion (gN/day)

N_{in}: Nitrogen content in feed intake (gN/day)

N_{egg}: Nitrogen content in egg (gN/day)

N_{wg}: Nitrogen content in daily weight gain (gN/day)

F_{intake}: Feed intake (Hen: g/g-egg weight/day, broiler: g/g-body weight (47days old))

W_{egg}: Daily egg production weight (g/day)

CP_{feed}: Crude protein content in feed (%)

CP_{egg}: Crude protein content in egg (%)

WG: Daily weight gain (g/day)

CP_{wg}: Crude protein content in daily weight gain (%)

N_{PR}: Nitrogen amount in accumulated protein in body (g)

W: Body weight (47days old) (g)

$CP_{chicken}$: Crude protein content in chicken (%)

Reference: 1) Ogino et al. (2017)
2) *Japanese Feeding Standard for Poultry*
3) Tsuiki and Harada (1997)

The “Proportion of separated and mixed treatment of manure” and “Proportion of manure management system by type of livestock” were set from percentage of treating method of manure and proportion of separated and mixed treatment of manure for 1997 in *GHGs emissions control in livestock industry Summary* (Japan Livestock Technology Association, March 2002), and *GHGs emissions control in livestock Part4*. (Japan Livestock Technology Association,1999) and percentage of treating method of manure and proportion of separated and mixed treatment of manure in the *Survey of current status for livestock manure management system 2009*, (MAFF, 2011), *Survey of current status for livestock manure management system and others 2019*, (MAFF, 2021) and *Survey of actual conditions for livestock manure management system and others, 2024,* (MAFF, 2025). The 1997 survey is data before enforcement of the “Act on the Appropriate Treatment and Promotion of Utilization of Livestock Manure” which has been in force since 1999 and prohibits inappropriate manure management and induced changes of percentage of manure management. Therefore, the 1997 survey results were applied until FY1999, the 2009 survey results were applied for FY2009 and the 2019 survey results were applied since FY2019 (Table 5-32, Table 5-33 and Table 5-34). For FY2000 to FY2008 and FY2010 to FY2018, data is estimated by interpolation using the result from 1997, 2009 and 2019 survey.

Table 5-32 Proportion of separated and mixed treatment of manure, by type of livestock (Mix_n)

Livestock species	Separated				Mixed			
	~1999	2009	2019	2024	~1999	2009	2019	2024
Dairy cattle	60.0%	45.5%	30.9%	23.3 %	40.0%	54.5%	69.1%	76.7 %
Non-dairy cattle	7.0%	4.8%	2.5%	2.2 %	93.0%	95.2%	97.5%	97.8 %
Swine	70.0%	73.9%	76.3%	75.8 %	30.0%	26.1%	23.7%	24.2 %
Hen	100.0%	100.0%	100.0%	100.0 %	—	—	—	–
Broiler	100.0%	100.0%	100.0%	100.0 %	—	—	—	–

Note: For Hen and Broiler, the proportion is reported at the mixed in the report of survey in 2019 but the proportion is reported at the separated in the NID due to maintaining consistency in the inventory.
Reference: Until 1999: Japan Livestock Technology Association, *GHGs emissions control in livestock Summary*
At 2009: *Survey of current status for livestock manure management system, 2009*
At 2019: *Survey of current status for livestock manure management system and others, 2019*
At 2024: *Survey of actual conditions for livestock manure management system and others, 2024*

Table 5-33 Proportion of manure management system by type of livestock (dairy cattle, non-dairy cattle and swine) (MS_n)

State of Manure		Treating method	Dairy cattle				Non-dairy cattle				Swine			
			~1999	2009	2019	2024	~1999	2009	2019	2024	~1999	2009	2019	2024
Separated	Feces	Sun drying	2.8%	2.0%	2.7%	4.5%	1.5%	0.9%	2.1%	6.3%	7.0%	0.7%	0.8%	0.7%
		Thermal drying	0.0%	0.0%	0.0%[3)]	—	0.0%	0.0%	0.0%	—	0.7%	0.1%	0.0%	0.4%
		Carbonization			—	0.0%			—	0.0%			—	0.0%
		Composting	9.0%	6.6%	9.0%	13.2%	11.0%	8.1%	4.7%	30.4%	62.0%	48.2%	57.9%	73.3%
		Open Composting			7.9%	11.7%			4.5%	17.7%			26.3%	34.3%
		Aeration				3.8%				2.9%				2.8%
		Agitation				5.0%				11.5%				14.8%
		Aeration and Agitation				2.9%				3.3%				16.7%
		Closed Composting			1.0%	1.5%			0.2%	12.7%			31.6%	39.0%
		Piling	88.0%	90.1%	87.3%	77.5%	87.0%	89.8%	92.9%	62.2%	29.6%	49.3%	39.9%	23.6%
		Pit storage (within a month)			0.5%	0.6%			0.1%	0.6%			0.1%	0.3%
		Pit storage (over a month)			0.0%	—			0.1%	—			—	—
		Incineration	0.2%	0.0%	0.1%	0.1%	0.5%	—	—	—	0.7%	0.6%	0.9%	0.4%
		Methane fermentation		—[2)]	0.3%	3.7%		—	—	0.1%		0.1%	0.1%	0.5%
		Public sewage		0.0%	0.0%	0.2%		—	—	—		—	—	—
		Industrial waste treatment			0.0%	0.0%			0.0%	0.2%			0.1%	0.7%
		Pasturage		0.0%				—				—		
		Other		1.3%	—	0.1%		1.2%		0.3%		1.0%	0.0%	0.1%
	Urine	Sun drying		0.0%				0.0%				0.0%		
		Composting (urine)	1.5%	1.7%	8.6%	8.3%	9.0%	1.2%	19.3%	8.2%	10.0%	5.4%	7.9%	12.2%
		Open Composting			6.2%	5.4%			17.8%	6.6%			7.1%	10.9%
		Closed Composting			2.5%	2.9%			1.5%	1.6%			0.9%	1.3%
		Purification	2.5%	5.1%	5.4%	5.5%	2.0%	4.4%	7.8%	8.8%	45.0%	76.3%	84.3%	81.7%
		Discharge			3.2%	4.0%			7.2%	6.3%			71.1%	76.5%
		Reuse			2.1%	1.5%			0.5%	2.5%			13.2%	5.2%
		Pit storage	96.0%	89.6%	82.1%	78.8%	89.0%	91.4%	68.2%	78.7%	45.0%	15.3%	6.0%	3.2%
		PS (within a month)			12.4%	6.7%			10.3%	11.6%			2.0%	1.2%
		PS (over a month)			69.7%	72.1%			58.0%	67.1%			4.0%	2.0%
		Methane fermentation		1.9%	2.7%	6.0%		0.0%	4.5%	3.6%		0.5%	1.0%	1.6%
		Public sewage		0.8%	1.1%	1.1%		0.6%	0.2%	0.0%		0.4%	0.6%	1.1%
		Industrial waste treat.			0.0%	0.1%			—	0.2%			0.0%	0.2%
		Other		0.9%	0.1%	0.2%		2.4%	0.0%	0.4%		2.1%	0.0%	0.1%
Mixed		Sun drying	4.4%[1)]	1.1%	1.9%	2.5%	3.4%[1)]	0.7%	1.3%	1.7%	6.0%	0.2%	0.2%	0.5%
		Thermal drying	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	—	0.1%	0.0%	0.0%	—	0.0%
		Carbonization			—	—			0.0%	0.0%			—	0.0%
		Composting (urine)	18.7%[1)]	22.9%	12.0%	17.2%	21.8%[1)]	10.8%	14.5%	27.4%	29.0%	21.3%	23.2%	40.6%
		Open Composting			11.2%	16.4%			13.6%	26.7%			13.7%	27.7%
		Aeration				4.3%				4.3%				1.9%
		Agitation				6.7%				11.5%				10.2%
		Aeration and Agitation				5.4%				10.9%				15.6%
		Closed Composting			0.7%	0.8%			0.9%	0.7%			9.5%	12.9%
		Piling	13.1%[1)]	50.8%	45.1%	35.9%	73.2%[1)]	85.7%	77.4%	60.2%	20.0%	51.4%	52.1%	29.2%
		Purification	0.3%[1)]	0.2%	0.2%	0.3%	0.0%	0.0%	0.0%	0.0%	22.0%	18.5%	12.9%	16.9%
		Discharge			0.0%	0.2%			0.0%	0.0%			11.7%	14.9%
		Reuse			0.2%	0.1%			—	0.0%			1.1%	2.0%
		Pit storage	57.0%[1)]	15.4%	32.2%	34.0%	0.6%[1)]	0.1%	5.4%	8.1%	23.0%	4.0%	5.9%	9.7%
		PS (within a month)			6.5%	3.6%			1.8%	2.3%			3.2%	4.9%
		PS (over a month)			25.7%	30.4%			3.6%	5.8%			2.8%	4.8%
		Incineration		0.1%	0.0%	0.1%		0.0%	0.0%	0.1%		0.0%	0.1%	0.1%
		Methane fermentation		1.7%	5.9%	6.0%		0.0%	0.1%	0.2%		2.0%	4.4%	2.0%
		Public sewage		0.1%	0.0%	0.0%		0.0%	0.0%	0.0%		0.7%	0.8%	0.5%
		Industrial waste treat.			0.1%	0.1%			0.1%	0.3%			0.4%	0.2%
		Pasturage	6.5%[1)]	6.5%	2.5%	3.3%	1.1%[1)]	1.1%	1.2%	1.9%		0.0%	0.0%	0.1%
		Other		1.2%	0.0%	0.4%		1.6%	0.0%	0.0%		1.9%	0.0%	0.1%

Reference: ~1999: Japan Livestock Technology Association, *GHGs emissions control in livestock Part4*.
2009: *Survey of current status for livestock manure management system, 2009*
2019: *Survey of current status for livestock manure management system and others, 2019*
2024: *Survey of actual conditions for livestock manure management system and others, 2024*

Note: 1) For dairy cattle and non-dairy cattle, percentage of "Pasturage" are not indicated in Japan Livestock Association data (1999) but are indicated in the result of survey for 2009 (MAFF, 2011). Therefore, the percentages of "Pasturage" indicated in MAFF (2011) are applied to the years before FY2009 consistently. In addition, each percentage of the mixed management of dairy cattle and non-dairy cattle is adjusted so that the sum of the percentages can be 100%.
2) The symbol '—' is applied to for no-existing management.
3) '0.0%' is used for the value less than a unit.
4) Blank is for non-listed item on the survey.

Table 5-34 Percentage of manure management system by type of livestock (hen and broiler) (MS_n)

State of Manure		Treating method	Hen				Broiler			
			~1999	2009	2019	2024	~1999	2009	2019	2024
Separated	Feces	Sun drying	30.0%	8.2%	4.1%	2.8%	15.0%	2.5%	0.8%	0.3%
		Thermal drying	3.0%	2.2%	0.9%	0.7%	0.0%	1.1%	0.3%	—
		Carbonization			0.2%	0.0%			0.9%	1.1%
		Composting	42.0%	49.6%	52.0%	67.4%	5.1%	19.3%	10.8%	12.7%
		Open Composting			29.0%	40.8%			9.4%	11.6%
		Aeration				6.4%				1.0%
		Agitation				19.8%				6.0%
		Aeration and Agitation				14.6%				4.6%
		Closed Composting			23.0%	26.6%			1.4%	1.1%
		Piling	23.0%	36.8%	35.3%	22.3%	66.9%	36.6%	27.3%	19.1%
		Pit storage (within a month)			1.1%	0.9%			2.3%	2.0%
		Pit storage (over a month)			1.1%	1.5%			1.3%	2.6%
		Incineration	2.0%	1.6%	2.9%	2.1%	13.0%	30.4%	46.8%	44.4%
		Methane fermentation		—	0.1%	0.0%		0.1%	0.3%	0.2%
		Public sewage		—	—	—		—	—	—
		Industrial waste treatment			2.0%	2.2%			5.8%	15.0%
		Pasturage		0.0%	0.0%	0.0%		0.1%	—	—
		Other		1.6%	0.2%	0.1%		9.9%	3.5%	2.6%

Reference: See Table 5-33 above

- ***Background information for livestock manure management in Japan***

In Europe, slurry spreading (liquid system) is major manure management system. On the other hand, in Japan, composting system ("Composting" and "Piling") are major management system. Osada et al. (2005), which investigated emission factors by actual measurement for "Piling", described that "Proper recycling of nutritive salts from livestock compost cannot be completed only by circulation in an area where the livestock density per unit area is especially high. Thus, livestock excrement can be made more manageable through the composting process, and the resulting product can be distributed over a wide area". Composting ("Composting" and "Piling") is widely practiced in Japan because, among other things: (1) it is essential for Japanese livestock farmers to facilitate transportation and handling, because the lack of space required for the on-site reduction of manure makes it necessary to direct the manure for uses outside their farms; and (2) compost is in considerably higher demand as a fertilizer for various crops than slurry or liquid manure in Japan where fertilizers tend to be lost by heavy rain and the expectations of the protection of water quality, prevention of odor, and sanitary management are high.

- ***Reporting in Common Reporting Tables (CRT)***

In the CRT it is required to report allocation and amount of nitrogen excretion by MMS ("Anaerobic lagoons", "Liquid systems", "Daily spread", "Solid storage", "Pit storage", "Dry lot", "Deep bedding", "Pasture, range and paddock", "Composting", "Digesters", "Burned for fuel or as waste", and "Other").

For cattle, swine, and poultry, Japan's country-specific manure treatment method and the implementation rates of the treatment method have been established for each type of animal. For details and correspondence of the Japanese manure treatment method to Manure management system (MMS) in CRT, see Table 5-35.

"Anaerobic Lagoons" have been reported as "NO". Because there are quite small number of livestock farmers who has enough area of field to spread manure, and it is assumed that there are no livestock farmers who use anaerobic lagoons. There are cases when manure is spread to fields in Japan, but even in these cases, stirring is conducted before the spreading. Therefore, there are no anaerobic manure management systems.

Table 5-35 Correspondence of the Japanese manure treatment method to CRT classification (Manure management system)

Classification in Japan			Classification in CRT (MMS)	Description of manure treatment method
State of Manure		Manure treatment method		
Separated	Feces	Sun drying	Dry lot	Dried under sunlight to facilitate handling (for storage and odor prevention).
		Thermal drying	Other	Dried by heat to facilitate handling.
		Carbonization	Other	Produced carbide by pyrolyzing organic matter under high temperature in the no oxygen or the absence of oxygen.
		Composting	Composting	Fermented for several days to several weeks with forced aeration and agitation in open or closed tanks.
		Open composting	Composting	Fermented for several days to several weeks with forced aeration and/or agitation in open systems as scoop type composting facilities. And the breakdown of this method includes aeration, agitation, and aeration plus agitation.
		Closed composting	Composting	Fermented for several days to several weeks with forced aeration and/or agitation in closed systems as closed vertical tank type composting facilities.
		Piling	Composting	Piling system is a method of composting. Piled about 1.5-2m height on compost bed or in shed to ferment for several months with occasional turning.
		Pit storage (within a month)	Pit storage	Stored in the storage tank (Slurry store etc.) within a month and utilize in agriculture by spreading to farm field or other way after storage.
		Pit storage (over a month)	Liquid system	Stored in the storage tank (Slurry store etc.) for over a month and utilize in agriculture by spreading to farm field or other way after storage.
		Incineration	Burned for fuel or as waste	For amount reduction, disposal, or use as an energy source (e.g. chicken manure boiler).
		Methane fermentation	Digesters	Slurry livestock manure is fermented under anaerobic conditions. Generated methane gas is used as an energy source.
		Public sewage	—	Released into public sewage without purification or aeration management. Emissions are included in the Waste sector.
		Industrial waste treatment	Other	Disposed as industrial waste.
		Pasture/Range/ Paddock	Pasture, range and paddock	Livestock are fed on a land with vegetation to eat. N_2O Emissions are reported in the 'Urine and dung deposited by grazing animals (3.D.1.c.)'.
		Other	Other	Treated with the method not mentioned above.
	Urine	Liquid composting	Composting	Treated in an aeration storage tank.
		Open composting (aeration treatment)	Composting	Aerated in open systems.
		Closed composting (aeration treatment)	Composting	Aerated in closed systems.
		Purification	Other	Separate pollutants using aerobic microorganisms, such as activated sludge.
		Purification - discharge	Other	Discharged after removing substance causing water pollution by microorganisms in activated sludge.
		Purification - agricultural use	Other	Utilized in agriculture by spreading to farm filed or other way after removing substance causing water pollution by microorganisms in activated sludge.
		Pit storage	Liquid systems	Stored in a storage tank.
		Pit storage (within a month)	Pit storage	Same as above (Pit storage (within a month) for feces).
		Pit storage (over a month)	Liquid system	Same as above (Pit storage (over a month) for feces).
		Methane fermentation	Digesters	Same as above (Methane fermentation for feces).
		Public sewage	—	Same as above (Public sewage for feces).
		Industrial waste treatment	Other	Same as above (Industrial waste treatment for feces).
		Other	Other	Treated with the method not mentioned above.

Table 5-35 Correspondence of the Japanese manure treatment method to CRT classification (Manure management system) (Continued)

Classification in Japan		Classification in CRT (MMS)	Description of manure treatment method
State of Manure	Manure treatment method		
Mixed	Sun drying	Dry lot	Dried under sunlight to facilitate handling.
	Thermal drying	Other	Same as above (Thermal drying).
	Carbonization	Other	Same as above (Carbonization).
	Liquid composting	Composting	Treated in an aeration storage tank.
	Open composting	Composting	Same as above (Open composting for feces).
	Closed composting	Composting	Same as above (Closed composting for feces).
	Piling	Composting	Same as above (Piling).
	Purification	Other	Same as above (Purification).
	Purification - discharge	Other	Same as above (Purification - discharge).
	Purification - agricultural use	Other	Same as above (Purification - agricultural use).
	Pit storage	Liquid systems	Stored in a storage tank (e.g. slurry storage).
	Pit storage (within a month)	Pit storage	Same as above (Pit storage (within a month)).
	Pit storage (over a month)	Liquid system	Same as above (Pit storage (over a month)).
	Methane fermentation	Digesters	Same as above (Methane fermentation).
	Public sewage	—	Same as above (Public sewage).
	Industrial waste treatment	Other	Same as above (Industrial waste treatment).
	Pasture/Range/ Paddock	Pasture, range and paddock	Same as above (Pasture/Range and paddock).
	Other	Other	Treated with method not mentioned above.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the uncertainties of the CH_4 emission factors, Tier 2 values (20%) described in the *2006 IPCC Guidelines* were applied. For N_2O emission factors, uncertainty was calculated by synthesis of default uncertainties of each parameter described in the *2006 IPCC Guidelines* uncertainty.

For the uncertainties of livestock population for the activity data, 1% (the standard error for swine given in the *Livestock Statistics*) was applied to swine, and 9% (the standard error for broiler given in the *Livestock Statistics*) was applied to poultry. For cattle, 1% is adopted, same as "Enteric Fermentation, Cattle". For the uncertainties of nitrogen content of feces and urine excreted per head per day from each livestock, 50% was applied from trial calculation of the Committee for GHG Emissions Estimation Methods, for the uncertainties of proportion of separated and mixed treatment of manure and proportion of each manure management system, 1% was applied from the *survey of current status for livestock manure management system and others.*

As a result, the uncertainties of the emissions for dairy cattle, non-dairy cattle and swine were

determined to be -20% to +20% for CH_4 and -87% to +123% for N_2O, and emissions for poultry were determined to be -22% to +22% for CH_4 and -87% to +123% for N_2O.

- ***Time-series Consistency***

Emission factors were used consistently from FY1990 onward by the method. Activity data were calculated consistently from FY1990 onward from the data in the *Livestock Statistics*.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Annex 4.

Country-specific emission factors are used for CH_4 and N_2O emission factors for grazing cattle, and these values are lower than the value calculated from the default data described in the *2006 IPCC Guidelines*. It is guessed that andosol and brown forest soil, which drainage is well, are dominant for grazing land in Japan. Therefore, CH_4 and N_2O emission factors are low in Japan.

Country-specific emission factors are used for CH_4 and N_2O emission factors by pit storage for dairy cattle, and these values are lower than the value calculated from the default data described in *2006 IPCC Guidelines*. For CH_4, the reasons are assumed that pit storage period of slurry in Japan is comparatively shorter than other countries and the short period stored slurry is spread to agriculture and grazed meadow soil before further activation of CH_4 emissions. For N_2O, the inferred reason of lower value of the emission factor is the same as CH_4, the Japanese shorter period pit storage doesn't reach to occurrence of scum which is guessed as N_2O source.

In the inventory review, the ERT pointed out that Japan's IEFs for dairy cattle are much higher than other countries. This reason is that "Piling" is major manure management system in Japan, and EF for "Piling" is very high. Moisture for dairy cattle feces is high, and they easily make anaerobic condition. It is considered to be the reason for high CH_4 emission factor of piling.

For emission factors by piling for poultry, hen's EF is higher than broiler's one. For CH_4, the reason is guessed to be that moisture content of manure for hen is higher than for broiler. Country-specific emission factors of N_2O by pilling for poultry is lower than the default emission factors. The reason is guessed to be that the default emission factors include not only poultry but also other animals (such as cattle and swine) (Nitrification is less likely to occur in poultry manure than cattle or swine manure).

Country-specific emission factors of N_2O for sun drying of poultry is lower than the default emission factors. The reason is guessed to be that the default emission factors include not only poultry but also other animals, which are the same reason for emission factors by piling for poultry.

e) Category-specific Recalculations

Since the population of dairy cattle by calving in *Record of Dairy Herd Performance Test*, averaged age in days of shipment in *The report of the fact-finding survey for pig farming*, and egg production and feed intake per day for hen for FY2023 were updated, the emissions from dairy cattle, swine and hen for FY2023 were recalculated. Since the *Survey of actual conditions for livestock manure management system and others, 2024* (MAFF, 2025) was applied, the emissions from cattle, swine, and poultry from FY2020 were recalculated. Due to the revision of application of the *Japanese Feeding Standards for Beef Cattle*, and the emissions from beef cattle for all fiscal years were recalculated. See Chapter 10 for

impact on trend.

f) Category-specific Planned Improvements

As research on actual emissions and information collection for emission reduction method has been continuously conducted by the organizations and agencies concerned, a review of emission factors and parameters will be implemented when the new data are obtained.

5.3.2. Sheep, Buffalo, Goats, Horses, Rabbit and Mink (3.B.2., 3.B.4.-)

a) Category Description

This section provides the estimation methods for CH_4 and N_2O emissions for manure management from sheep, buffalo, goats, horses, rabbit and mink.

b) Methodological Issues

- ***Estimation Method***

CH_4 and N_2O emissions were calculated by using the Tier 1 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 4, Page 10.36, Fig 10.3 and Page 10.55, Fig. 10.4).

$$E_{CH_4} = EF_{CH_4} \times P$$

$$E_{N_2O} = \sum(EF_{N_2O\text{-}n} \times P \times Nex \times MS_n)$$

E_{CH_4}	: CH_4 emissions associated with manure management [kg-CH_4/yr]
E_{N_2O}	: N_2O emissions associated with manure management [kg-N_2O/yr]
EF_{CH_4}	: CH_4 emission factor [kg-CH_4/head/yr]
$EF_{N_2O\text{-}n}$	: N_2O emission factor of manure management *n* [kg-N_2O/kg-N]
P	: Population of each livestock [head]
Nex	: Nitrogen content in manure [kg-N/head/yr]
MS_n	: Percentage of manure management system *n* [%]

- ***Emission Factors***

For the emission factors for CH_4, the default values for temperate zones in industrialized nations, given in the *2006 IPCC Guidelines* were used. For buffalo, the default value given for the temperate zone in Asia was used (Table 5-36).

For the emission factors for N_2O, the default values given in the *2006 IPCC Guidelines* and the *2019 Refinement* were used (Table 5-37).

Table 5-36 CH_4 emission factors for sheep, buffalo, goats, horses, rabbit and mink

Livestock species	CH_4 Emission factors [kg-CH_4/head/yr]	Reference
Sheep	0.28	*2006 IPCC Guidelines*, Vol. 4, p. 10.40, Table 10.15
Goats	0.20	
Horses	2.34	
Buffalo	2	*2006 IPCC Guidelines*, Vol. 4, p. 10.39, Table 10.14
Rabbit	0.08	*2006 IPCC Guidelines*, Vol. 4, p. 10.41, Table 10.16
Mink	0.68	

Table 5-37 N_2O Emission factors for sheep, buffalo, goats, horses, rabbit and mink

Manure management system	N_2O Emission factors [%: kg-N_2O-N/kg-N]
Dry lot	2.0%
Pasture/Range/Paddock (buffalo)	0.6%
Pasture/Range/Paddock (sheep, goats, horses)	0.3%
Daily spread	0%
Burned for fuel	0%

Reference: Dry lot, Daily Spread, Burned for fuel: *2006 IPCC Guidelines*, Vol.4, page 10.62, Table 10.21, Pasture Range and Paddock: the *2019 Refinement*, Vol.4, page 11.11, Table 11.1

- ***Activity Data***

For livestock population for sheep, goats, horses and buffalo, same data described in '3.A. Enteric Fermentation' are used (See Table 5-12). For rabbit and mink, population data in the *Statistical Document for small animals and laboratory animals* by MAFF are used (See Table 5-38 below).

For N_2O, in order to determine the total nitrogen amount for each livestock, first, it was calculated by multiplying the population of each type of animal by the nitrogen content of manure per head of animal (or by the nitrogen amount in manure per weight and livestock weight). Then, the amount of nitrogen per manure management category was calculated by multiplying the total nitrogen by the percentage of each manure management system (Table 5-39). For the percentage of manure management system for buffalo, the default values given in the *2006 IPCC Guidelines* were used (classification is "Asia") (Table 5-40).

For rabbit and mink, percentage of manure management system usage (MS_n) is considered by expert judgment that all manure are managed by "Dry lot" because default values are not described in the *2006 IPCC Guidelines*. For the percentage of manure management system usage (MS_n) for sheep, goats and horses, the *2006 IPCC Guidelines* (Vol.4, p.10.61) described that "Manure from other animal categories is typically managed in pasture and grazing operations". Therefore, it is assumed that their livestock manures are managed by grazing system.

Table 5-38 Livestock population for rabbit and mink [1000 heads]

Livestock Species	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Rabbit	15	16	21	19	18	18	18	18	18	18	18	18
Mink	155	11	6	1	1	1	1	1	1	1	1	1

Reference: *Statistical Document for small animals and laboratory animals* (MAFF)

Table 5-39 Body weight and N excretion rate for sheep, buffalo, goats, horses, rabbit and mink (*Nex*)

Livestock species	Body weight [kg]	N excretion rate per weight [kg-N/1000kg-body weight/day]	N excretion rate [kg-N/head/yr]
Sheep	48.5	1.17	(20.7)
Buffalo	380	0.32	(44.4)
Goats	38.5	1.37	(19.3)
Horses	377	0.46	(63.3)
Rabbit	—	—	8.10
Mink	—	—	4.59

Note: Values in parentheses are calculated values using body weight and N excretion rate per weight.

Reference: *2006 IPCC Guidelines*, Vol.4, page 10.79, Table 10A-6, page 10.82, Table 10A-9, page 10.59, Table 10.19

Table 5-40 Percentage of manure management system for buffalo (MS_n)

Manure management system	Percentage
Lagoons	0%
Liquid/Slurry	0%
Solid storage	0%
Dry lot	41%
Pasture/Range/Paddock	50%
Daily spread	4%
Digester	0%
Burned for fuel	5%
Other	0%

Reference: *2006 IPCC Guidelines*, Vol.4, page 10.79, Table 10A-6

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

An uncertainty assessment was conducted for individual livestock categories. With respect to the uncertainties for emission factors for CH_4, Tier 1 default value (30%) described in the *2006 IPCC Guidelines* was applied. For N_2O, the uncertainty was calculated by synthesis of default values of each parameter described in the *2006 IPCC Guidelines*. For the activity data, uncertainty was substituted by the value of broiler (9%) described in the *Livestock Statistics*. As a result, the uncertainties of the emissions were determined to be -31% to +31% for CH_4, and -72% to +112% for N_2O for each livestock.

- ***Time-series Consistency***

For emission factors, same values were used consistently for all the years. For Activity data were calculated consistently for all the years from the data in the *Statistical Document of Livestock Breeding,* the *Statistical Document of Horse,* the *Survey Result of Feeding Livestock and Poultry* by Okinawa and the *Status Report regarding Health Management for Livestock Feeding*.

d) Category-specific QA/QC and Verification

Same as Sheep, Swine, Buffalo, Goats & Horses (3.A.2., 3.A.3., 3.A.4.-) in Enteric Fermentation. See section 5.2.2. d).

e) Category-specific Recalculations

Since the population of sheep, goats, and horses were updated, the emissions from sheep, goats and horse for FY2023 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

5.3.3. Other Livestock (3.B.4.-)

Deer, reindeer, fox, and other poultries (duck, turkey, etc.), which are other livestock than those listed above, are reported in the *Statistical Document for Small Animals and Laboratory Animals* (MAFF). However, their population size is small, and each emission was lower than 3000t-CO_2 equivalent, which is the threshold to estimate in this GHG inventory decided by the Committee for GHG Emissions Estimation Methods. Therefore, it was not reported (See Annex 6).

5.3.4. Indirect N_2O Emissions (3.B.5.)

5.3.4.1. Atmospheric Deposition (3.B.5.-)

a) Category Description

This section provides the estimation methods for N_2O indirect emissions caused by atmospheric deposition of nitrogen volatilized as NH_3, NOx and N_2 from livestock manure management.

b) Methodological Issues

- ***Estimation Method***

N_2O emissions have been calculated by Tier 2 method in accordance with decision tree of the *2019 Refinement* (Vol.4, Page 10.79, Fig. 10.4).

$$E = N_{Volatilization\text{-}MMS} \times EF \times 44 / 28$$

E	: N_2O emissions by atmospheric deposition in the process of livestock manure management [kg-N_2O/yr]
$N_{Volatilization\text{-}MMS}$	: Nitrogen amount volatilized as NH_3 and NOx in the process of livestock manure management [kg (NH_3-N+NO_X-N)/yr]
EF	: Emission factor [kg-N_2O-N/kg (NH_3-N+NO_X-N)]

- ***Emission Factors***

0.014 [kg-N_2O-N/kg-NH_3-N & NO_X-N deposited] (default value, the *2019 Refinement,* Vol.4, Page 11.26, Table11.3, Wet climate).

- ***Activity Data***

For cattle, swine, and poultry (hen and broiler), as described in the following equation, amount of nitrogen that volatilized as ammonia and nitrogen oxides from livestock manure management ($N_{Volatilizaiton\text{-}MMS}$) is calculated using the nitrogen amount included in each treatment method ($A_{N2O\text{-}i}$) which calculated in the above 5.3.1., and volatilization rate as NH_3 and NOx from manure in each livestock barn ($Frac_{GASM1i}$) and in each process of treatment ($Frac_{GASM2i}$). The volatilization rate as NH_3 and NOx from manure are estimated from data described in Hojito et al. (2003) (See Table 5-41). For "Purification", it is considered that there are not volatilized in treatment process. Indirect N_2O emissions form grazing animal are reported in 5.5.2.1. Atmospheric Deposition (3.D.2.a.).

$$N_{Volatilization\text{-}MMS} = \sum \{ A_{N2O\text{-}i} \times Frac_{GASM1i} + (A_{N2O\text{-}i} - A_{N2O\text{-}i} \times Frac_{GASM1i}) \times Frac_{GASM2i} \}$$

$N_{Volatilization\text{-}MMS}$	: Nitrogen amount volatilized as NH_3 and NOx in the process of livestock manure management [kg (NH_3-N+NO_X-N)/yr]
$A_{N2O\text{-}i}$	: Nitrogen amount in livestock manure by treatment method *i* [kg-N/yr]
$Frac_{GASM1i}$	: Volatilization rate as NH_3 and NO_X in livestock barn by treatment method *i* [kg-NH_3-N + NO_X-N/kg-N]
$Frac_{GASM2i}$	: Volatilization rate as NH_3 and NO_X in process of treatment by treatment method *i* [kg-NH_3-N + NO_X-N/kg-N]

Table 5-41 Volatilization rate as NH_3 and NOx from manure (in livestock barn and in process of treatment)

Livestock species	Treatment method		Volatilization rate in livestock barn ($Frac_{GASM1}$)	Volatilization rate in process of treatment ($Frac_{GASM2}$)
Dairy cattle	Feces	Other than Composting	10.3%	13.7%
		Composting	10.3%	1.9%
	Urine	Other than Purification	10.3%	11.0%
		Purification	10.3%	0%
	Mixed	Other than Purification, Pit storage, Methane fermentation	4.5%	13.7%
		Purification	10.3%	0%
		Pit storage, Methane fermentation	10.3%	10.8%
Non-dairy cattle	Feces	Other than Composting	6.38%	13.7%
		Composting	6.38%	1.9%
	Urine	Other than Purification	6.38%	11%
		Purification	6.38%	0%
	Mixed	Other than Purification, Pit storage, Methane fermentation	6.38%	13.7%
		Purification	6.38%	0%
		Pit storage, Methane fermentation	6.38%	10.8%
Swine	Feces	All management	14.7%	19.7%
	Urine	Other than Purification	14.7%	27.0%
		Purification	14.7%	0%
	Mixed	Other than Purification, Pit storage, Methane fermentation	15.8%	24.2%
		Purification	14.7%	0%
		Pit storage, Methane fermentation	14.7%	25.0%
Hen and Broiler	Feces	All management	8.4%	51.5%

Reference: Hojito et al. (2003)

For buffalo, rabbit, and mink, nitrogen amount volatilized as NH_3 and NOx from manure were estimated by multiplying total nitrogen amount of manure of each livestock by default volatilization rate described in the *2006 IPCC Guidelines* (Vol.4, Page10.65, Table10.22, Other-Solid storage: 12%).

$$N_{Volatilization\text{-}MMS} = (P \times N_{ex} \times MS_n) \times Frac_{GASM}$$

$N_{Volatilization\text{-}MMS}$: Nitrogen amount volatilized as NH_3 and NOx in the process of livestock manure management [kg (NH_3-N+NO_X-N)/yr]

P : Population of each livestock [head]

N_{ex} : Nitrogen content in manure per head [kg-N/head/yr]

MS_n : Percentage of manure management n [%]

$Frac_{GASM}$: Volatilization rate as NH_3 and NO_X in process of treatment for management system [%]

Table 5-42 Nitrogen amount volatilized as NH_3 and NOx in the process of livestock manure management

[kt (NH_3-N+NO_X-N)]

Livestock Species	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Dairy cattle	26.6	26.1	24.6	23.4	20.5	19.7	19.6	19.8	20.1	19.6	19.1	19.0
Non-dairy cattle	22.3	23.0	23.0	21.8	21.6	20.4	19.9	21.0	21.3	21.4	21.2	20.5
Swine	53.1	46.1	43.5	39.2	37.3	35.6	34.1	34.8	33.6	33.4	32.7	32.4
Poultry (Hen, Broiler)	134.0	124.4	111.5	99.7	98.1	90.4	89.8	91.2	91.0	87.1	87.6	87.6
Other livestocks (Buffalo, Mink, Rabbit)	0.10	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Total	236.1	219.5	202.7	184.1	177.5	166.0	163.4	166.7	166.1	161.5	160.6	159.6

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

Uncertainty (-106% to +447%) described in “Agricultural Soils (Atmospheric Deposition)” below was applied.

- ***Time-series Consistency***

For emission factors, consistent values (default values) were used in all time-series. For activity data, constant value for volatilized factor and constant estimation method for manure amount calculated in 5.3.1. were used.

d) Category-specific QA/QC and Verification

Country specific values for volatilization rate as NH_3 from manure management (Hojito et al., 2003) exclude volatilization when the manure is applied to soil to avoid double counting of the NH_3 emissions from agricultural soil in the category of atmospheric deposition (3.D.b.1), though the default values of $Frac_{GasMS}$ from *2006 IPCC Guidelines* account for N volatilization during the manure management and when the manure is applied to soil. There is a possibility that the differences between the country specific values and the default values come from differences in the boundaries between them. Furthermore, for "feces and urine mixed – Composting", in which the largest amount of excretion for dairy cattle and non-dairy cattle is treated, the low moisture content in feces due to the mixture of sub materials lead to low NH_3 volatilization during composting. Volatilization rate as NH_3 from manure for non-dairy cattle particularly tend to be lower than the default values because of the lower moisture content in feces. Thus these country specific values are considered to have high accuracy.

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Annex 4.

e) Category-specific Recalculations

The amount of nitrogen content in excretion for dairy cattle, swine and hen were revised due to updates in the population of dairy cattle by calving in *Record of Dairy Herd Performance Test* of FY2023, averaged age in days of shipment in *The report of the fact-finding survey for pig farming*, and egg production and feed intake per day for hen, resulting in the recalculation in emissions for FY2023. Since the *Survey of actual conditions for livestock manure management system and others, 2024* (MAFF, 2025) was applied, the emissions from cattle, swine, and poultry from FY2020 were recalculated. Due to the revision of application of the *Japanese Feeding Standards for Beef Cattle*, the emissions for all fiscal years were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

Refer to the section "5.3.1. Cattle, Swine and Poultry (Hen and Broiler)".

5.3.4.2. Nitrogen Leaching and Run-off (3.B.5.-)

In Japan, under the "*Act on the Appropriate Treatment and Promotion of Utilization of Livestock Manure*", taking some measures to prevent flowing wastewater out of manure management, such as introducing concrete-clad floor, or using waterproof sheet, is required; so, the possibility of nitrogen leaching and run-off to subsurface water is very low. Therefore, this source is reported as "NO".

5.4. Rice Cultivation (3.C.)

CH_4 is generated under anaerobic conditions by microbes' activity. Therefore, paddy fields provide favorable conditions for CH_4 generation. In Japan, all paddy fields are irrigated, and intermittently and

continuously flooded paddy fields are targeted in this category. In Japan, rice cultivation is practiced mainly on intermittently flooded paddy field.

CH_4 emissions from rice cultivation in FY2024 are 11,841 kt-CO_2 eq., comprising 1.1% of total emissions (excluding LULUCF). The value represents a decrease by 12.8% from FY1990.

Table 5-43 CH_4 emissions from rice cultivation (3.C.)

Gas	Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
CH_4	3.C.1.- Continuously flooded	kt-CH_4	68.5	74.9	69.1	67.6	68.3	67.6	67.0	64.9	65.1	63.6	63.6	59.2
	3.C.1.- Intermittently flooded		416.6	448.8	418.0	421.1	419.1	415.5	410.6	408.7	412.0	403.1	401.4	363.7
	Total	kt-CH_4	485.2	523.7	487.0	488.6	487.4	483.1	477.6	473.6	477.1	466.7	465.0	422.9
		kt-CO_2 eq.	13,585	14,663	13,636	13,682	13,649	13,527	13,374	13,260	13,359	13,068	13,021	11,841

5.4.1. Irrigated (Continuously Flooded and Intermittently Flooded (Single Aeration)) (3.C.1.)

a) Category Description

This section provides the estimation methods for CH_4 emissions from intermittently flooded and continuously flooded rice cultivation.

- ***Water management regime in Japanese paddy fields***

The general practice of mid-season drainage and subsequent intermittent flooding by paddy farmers in Japan is different in nature from the intermittently flooded paddy field (multi aeration) concept in the *2006 IPCC Guidelines*. Therefore, Japan reports its practice as "Intermittent flooding (Single aeration)" in the CRT (Figure 5-4 presents the outline). Intermittently flooded paddy fields with prolonged mid-season drainage for the mitigation of CH_4 emissions is included in this sub-category.

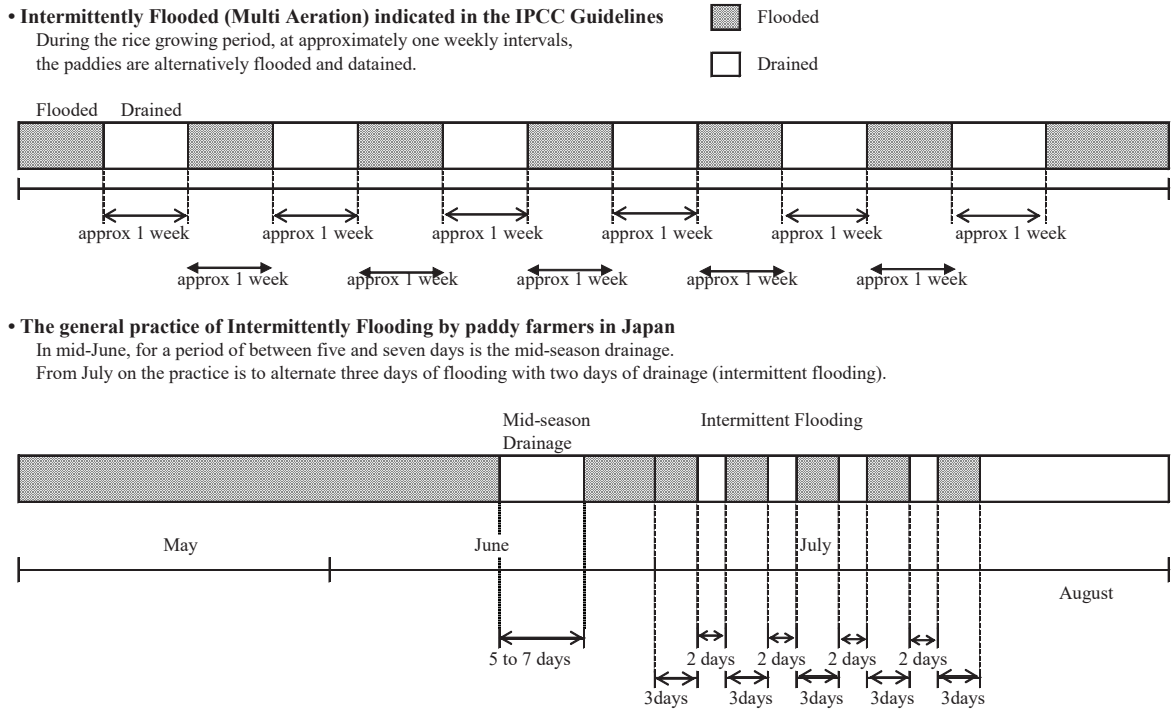

Figure 5-4 Comparison of water management regime in Japan and intermittent flooding (multi aeration) indicated in the *2006 IPCC Guidelines*

b) Methodological Issues

- ***Estimation Method***

Based on the calculation method in the *2006 IPCC Guidelines*, the emissions were estimated using emission factors calculated by the regression formula of CH_4 emission flux estimated by DeNitrification-DeComposition-Rice model (DNDC-Rice model, Fumoto et al. (2010)), which is the mathematical model to estimate change of CH_4 emissions with methods of organic matter application and/or water regime on paddy field, and the following formula established on the basis of the model. The DNDC-Rice model, the improved model, is based on the DNDC model and has developed in Japan so as to estimate CH_4 emissions from paddy field in Japan. Figure 5-5 is a conceptual scheme of the DNDC-Rice model.

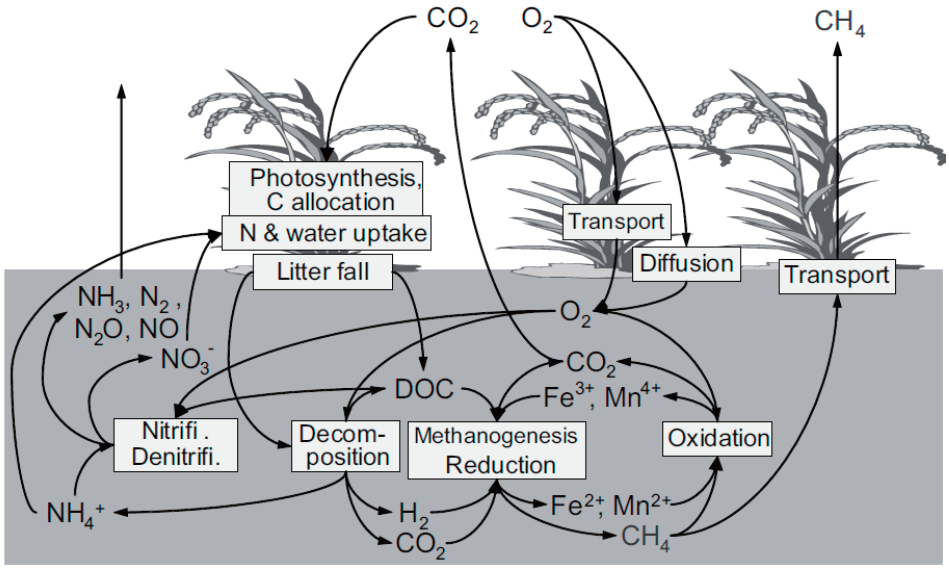

Figure 5-5 Conceptual scheme of the DNDC-Rice model
Reference: Fumoto et al. (2010)

Tier3 method (DNDC-Rice model) was used to establish emission factor, and modified Tier2 method was used to estimate emissions. The area for paddy fields with prolonged mid-season drainage were extracted, and percentage of CH_4 emission reduction (30%) was used as a parameter of the emission factor for it.

Estimation method used in this section was developed through discussion in the Committee for Greenhouse Gas Emissions Estimation Methods on the basis of a paper of Katayanagi et al. (2016), Katayanagi et al. (2017) and relevant paper.

$$E = \sum_{i,j,k,l,m} \{(A_{i,m} \times f_{Di,j} \times f_{Wi,k} \times f_{Ol}) \times EF_{i,j,k,l,m}\} \times 16 / 12$$

$$EF = aX + b$$

E : CH_4 emissions from paddy field [kgCH_4/yr]
i : Region (7 regions in Japan)
j : Type of drainage (Poorly drained, one day drained, 4 hours drained)
k : Type of water regime (Intermittently flooded, continuously flooded)

l	: Type of organic matter application (rice straw, compost, non-amendment)
m	: Type of mid-season drainage (prolonged, conventional)
A	: Crop area of rice paddy field by region [ha]
f_D	: Proportion of drainage
fw	: Proportion of water regime
f_O	: Proportion of organic matter application
EF	: EFs by region, drainage, water regime, organic matter application, prolonged mid-season drainage [kgCH_4-C/ha/yr]
X	: Amount of organic matter [t-C/ha/yr]
a	: Slope (from the regression formula for CH_4 emissions calculated by the DNDC-Rice model and amount of organic matter)
b	: Intercept (from the regression formula for CH_4 emissions calculated by the DNDC-Rice model and amount of organic matter)

- ***Emission Factors***

The DNDC-Rice model was used to calculate the emission factor.

EFs were established on the basis of the information on nationwide 986 points of paddy field. The input data are soil (soil organic carbon content, pH, clay content, dry density, etc.), field drainage (maximum drainage rate), meteorological data (temperature, precipitation), and field management information (the day of transplantation, harvest date, plowing date, tillage method, fertilization date, fertilizer amount, organic matter application date, amount of organic matter application, organic C/N ratio, flooded date, drained date). The following are input data and references.

- Soil physical and chemical properties: data in 986 points described in the *Basic Survey of Soil Environment* (MAFF), which includes all data needed to be input in the DNDC-Rice model
- Field drainage: Maximum drainage rate of survey sites were set as 15 mm day^{-1}, 10 mm day^{-1} and 5 mm day^{-1} based on the data provided in “Flooded Situation” (4 hours drained, one day drained, poor drainage) in *Fourth Basic Survey on Infrastructure Development of Land Use* (MAFF, 2006)
- Meteorological data: Daily lowest temperature, daily highest temperature, and precipitation of the nearest AMeDAS point from each survey site were used.
- Field management information: data set created by Hayano et al. (2013) which were divided the whole Japan to 136 regions in accordance with the primary subdivision area by Japan Meteorological Agency and included cultivated history on the basis of the data published by Japan Agricultural Cooperatives or similar organization in each region were used.
- Amount of organic matter application: By using the method described by Yagasaki and Shirato (2014), application amount of compost and rice straw plowed into soil by each prefecture in 1981 to 2019 were estimated. In other words, the amount of rice straw plowed into soil were estimated by multiplying rice straw yield estimated from the yield of paddy rice in normal years by the percentage plowed into the soil, then, by dividing the value by the rice cropping area. For amount of compost application, the average application amount per 10a in Production Cost of Rice in the *Statistics on Farm Management* (MAFF) is used.

Using the DNDC-Rice model and the above input data, CH_4 flux of each 986 points from 1981 to 2010 (30 years) were estimated by total 8 scenarios (water management 2 scenarios (intermittently flooded

and continuously flooded) and organic matter applied 4 scenarios (straw and compost[1], rice straw only, compost only, non-organic matter). Taking into account statistical significant difference of their results, CH_4 flux were sorted out by seven regions, drainage (3 levels), water regime, and organic matter application, and estimated averages of each year by each classification. In addition, the regression equation (linear function) to predict CH_4 flux (mean values for each year of each category) were determined by amount of organic matter application. Intercept "b" of the regression equation were fixed to the CH_4 emissions flux estimated non-organic application scenario.

Total amount of organic matter application by prefecture which was estimated by the method described in Yagasaki and Shirato (2014) were aggregated to region level. In addition, to induce amount of organic matter application by region and application type (X) which are used in estimation for the inventory, their data of total amount of organic matter by region and proportion of organic matter management (Table 5-49) were used. The proportion of organic matter management is based on the survey result of *Basic Survey of Soil Environment*, *Survey of Greenhouse Gas Emissions from Soils and Soil Carbon Sequestration*, *The Project of Basic Survey on Greenhouse Gas Emission Estimation from Agricultural Land Soil*, and *The Project of Basic Survey for Carbon Stock on Agricultural Land Soil*. Amount of organic matter application in each input segment by region and the emission factor of each segment calculated these input, and they are shown in Table 5-44, and Table 5-45 below, respectively.

For "Intermittently flooded paddy fields with prolonged mid-season drainage", the emission factors were established by multiplying the emission factor of "Intermittently flooded paddy fields with conventional mid-season drainage" by (1-0.3), using percentage of CH_4 emission reduction (30%) derived from Itoh et al. (2011).

Table 5-44 Amount of organic matter application by region and type (X) [t-C/ha/yr]

Item		1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Rice straw	Hokkaido	1.73	1.74	1.92	2.03	2.12	1.96	2.06	1.98	2.00	1.99	2.00	1.90
	Tohoku	1.49	1.73	2.02	2.11	2.07	1.95	2.05	2.08	2.15	2.12	2.12	1.94
	Hokuriku	2.69	2.62	2.74	2.82	2.75	2.45	2.49	2.53	2.54	2.51	2.51	2.43
	Kanto	1.32	1.49	1.77	1.96	1.96	1.80	1.85	1.90	1.91	1.89	1.89	1.67
	Tokai and Kinki	2.01	1.98	2.22	2.33	2.23	2.01	2.13	2.22	2.22	2.20	2.20	2.09
	Chugoku and Shikoku	1.74	1.83	2.10	2.13	2.15	1.93	1.98	1.80	1.79	1.77	1.77	1.67
	Kyusyu and Okinawa	1.17	1.14	1.26	1.36	1.40	1.24	1.30	1.31	1.29	1.27	1.27	1.02
Compost	Hokkaido	1.69	1.86	2.10	2.05	2.18	1.87	1.88	1.91	2.04	1.97	2.12	1.83
	Tohoku	1.69	1.86	2.10	2.05	2.18	1.87	1.88	1.91	2.04	1.97	2.12	1.83
	Hokuriku	1.69	1.86	2.10	2.05	2.18	1.87	1.88	1.91	2.04	1.97	2.12	1.83
	Kanto	1.69	1.86	2.10	2.05	2.18	1.87	1.88	1.91	2.04	1.97	2.12	1.83
	Tokai and Kinki	1.69	1.86	2.10	2.05	2.18	1.87	1.88	1.91	2.04	1.97	2.12	1.83
	Chugoku and Shikoku	1.69	1.86	2.10	2.05	2.18	1.87	1.88	1.91	2.04	1.97	2.12	1.83
	Kyusyu and Okinawa	1.69	1.86	2.10	2.05	2.18	1.87	1.88	1.91	2.04	1.97	2.12	1.83

1 The application scenario "straw and compost" was constructed in the model. However, since proportion of organic matter management to input both straw and compost in Japan (f_O) is not available, its scenario is not used for inventory emission estimation.

Table 5-45 CH_4 emission factors in each segment (conventional mid-season drainage) [kg-CH_4-C/ha/yr]

Item			1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Poorly drained field, Continuously flooded	Rice straw	Hokkaido	585	588	636	665	690	647	676	652	658	655	658	632
		Tohoku	573	636	714	739	727	696	722	732	749	742	742	692
		Hokuriku	741	725	753	772	754	684	694	702	705	698	698	679
		Kanto	181	202	237	260	259	240	246	252	253	250	250	224
		Tokai and Kinki	436	429	477	499	478	435	459	477	478	473	472	451
		Chugoku and Shikoku	422	439	491	499	501	458	468	433	431	427	427	407
		Kyusyu and Okinawa	158	155	169	181	186	167	174	175	172	170	170	140
	Compost	Hokkaido	574	621	686	670	708	621	624	634	669	649	690	613
		Tohoku	627	673	736	721	758	673	676	686	720	700	741	665
		Hokuriku	507	548	603	590	622	548	550	559	589	571	607	541
		Kanto	226	248	277	270	287	248	249	254	269	260	279	244
		Tokai and Kinki	372	406	454	443	470	407	409	416	441	427	457	400
		Chugoku and Shikoku	411	445	492	481	508	446	448	455	480	465	495	439
		Kyusyu and Okinawa	221	242	271	264	281	243	244	248	264	255	273	239
	No-amendment	Hokkaido	114	114	114	114	114	114	114	114	114	114	114	114
		Tohoku	175	175	175	175	175	175	175	175	175	175	175	175
		Hokuriku	113	113	113	113	113	113	113	113	113	113	113	113
		Kanto	18	18	18	18	18	18	18	18	18	18	18	18
		Tokai and Kinki	35	35	35	35	35	35	35	35	35	35	35	35
		Chugoku and Shikoku	77	77	77	77	77	77	77	77	77	77	77	77
		Kyusyu and Okinawa	16	16	16	16	16	16	16	16	16	16	16	16
Poorly drained field, Intermittently flooded	Rice straw	Hokkaido	585	588	636	665	690	647	676	652	658	655	658	632
		Tohoku	547	610	687	711	700	669	694	704	721	714	714	665
		Hokuriku	552	539	562	578	563	505	513	520	522	516	516	501
		Kanto	164	182	213	234	233	216	221	227	228	226	226	202
		Tokai and Kinki	352	346	386	405	388	352	371	387	387	383	383	364
		Chugoku and Shikoku	377	393	441	448	450	411	419	387	386	382	382	363
		Kyusyu and Okinawa	139	136	148	159	162	146	152	153	151	149	149	123
	Compost	Hokkaido	574	621	686	670	708	621	624	634	669	649	690	613
		Tohoku	600	646	709	694	730	646	649	659	693	673	713	638
		Hokuriku	359	392	438	427	454	393	395	402	426	412	441	386
		Kanto	204	223	250	243	259	223	225	229	243	235	251	220
		Tokai and Kinki	300	328	367	358	381	328	330	336	357	345	370	323
		Chugoku and Shikoku	367	399	442	432	457	399	401	408	431	417	445	393
		Kyusyu and Okinawa	192	210	235	229	243	210	211	215	228	221	236	207
	No-amendment	Hokkaido	114	114	114	114	114	114	114	114	114	114	114	114
		Tohoku	153	153	153	153	153	153	153	153	153	153	153	153
		Hokuriku	33	33	33	33	33	33	33	33	33	33	33	33
		Kanto	17	17	17	17	17	17	17	17	17	17	17	17
		Tokai and Kinki	21	21	21	21	21	21	21	21	21	21	21	21
		Chugoku and Shikoku	57	57	57	57	57	57	57	57	57	57	57	57
		Kyusyu and Okinawa	19	19	19	19	19	19	19	19	19	19	19	19
One day drained field, Continuously flooded	Rice straw	Hokkaido	342	344	375	394	410	382	400	385	389	387	389	372
		Tohoku	423	471	530	549	540	516	536	544	556	551	551	513
		Hokuriku	556	543	566	581	566	510	517	524	526	521	521	506
		Kanto	122	135	157	172	171	159	163	167	168	166	166	149
		Tokai and Kinki	198	194	217	228	218	197	209	217	218	215	215	205
		Chugoku and Shikoku	166	174	196	199	201	182	186	171	170	169	169	160
		Kyusyu and Okinawa	131	129	141	151	155	139	145	146	144	142	142	116
	Compost	Hokkaido	335	365	407	397	421	366	367	374	396	383	410	360
		Tohoku	463	499	547	536	564	499	501	509	535	519	550	492
		Hokuriku	366	399	444	433	459	399	401	408	432	418	447	393
		Kanto	151	164	183	179	189	164	165	168	178	172	184	162
		Tokai and Kinki	167	184	206	201	214	184	185	188	200	193	208	181
		Chugoku and Shikoku	162	176	197	192	204	176	177	181	191	185	198	174
		Kyusyu and Okinawa	185	202	227	221	235	203	204	208	221	213	228	199
	No-amendment	Hokkaido	39	39	39	39	39	39	39	39	39	39	39	39
		Tohoku	119	119	119	119	119	119	119	119	119	119	119	119
		Hokuriku	46	46	46	46	46	46	46	46	46	46	46	46
		Kanto	17	17	17	17	17	17	17	17	17	17	17	17
		Tokai and Kinki	6	6	6	6	6	6	6	6	6	6	6	6
		Chugoku and Shikoku	17	17	17	17	17	17	17	17	17	17	17	17
		Kyusyu and Okinawa	12	12	12	12	12	12	12	12	12	12	12	12

Table 5-45 CH_4 emission factors in each segment (conventional mid-season drainage) [$kgCH_4$-C/ha/yr] (Continued)

Item			1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
One day drained field, Intermittently flooded	Rice straw	Hokkaido	236	237	259	272	284	264	277	266	269	267	269	257
		Tohoku	297	333	378	392	385	367	382	388	397	393	393	365
		Hokuriku	403	393	410	421	410	369	375	380	381	377	377	366
		Kanto	90	100	116	127	126	117	120	123	123	122	122	110
		Tokai and Kinki	89	87	98	103	98	89	94	98	98	97	97	92
		Chugoku and Shikoku	88	92	105	107	107	97	99	91	91	90	90	85
		Kyusyu and Okinawa	75	73	80	86	88	79	82	83	82	81	81	66
	Compost	Hokkaido	231	252	281	275	292	252	254	258	274	265	283	248
		Tohoku	328	354	390	382	403	354	356	362	381	370	393	349
		Hokuriku	264	288	321	313	332	289	290	295	313	302	323	284
		Kanto	111	121	135	131	139	121	122	124	131	127	136	119
		Tokai and Kinki	75	83	93	90	96	83	83	85	90	87	93	81
		Chugoku and Shikoku	86	94	105	103	109	94	95	96	102	99	106	93
		Kyusyu and Okinawa	105	115	129	126	134	116	116	118	126	121	130	114
	No-amendment	Hokkaido	21	21	21	21	21	21	21	21	21	21	21	21
		Tohoku	71	71	71	71	71	71	71	71	71	71	71	71
		Hokuriku	31	31	31	31	31	31	31	31	31	31	31	31
		Kanto	15	15	15	15	15	15	15	15	15	15	15	15
		Tokai and Kinki	2	2	2	2	2	2	2	2	2	2	2	2
		Chugoku and Shikoku	5	5	5	5	5	5	5	5	5	5	5	5
		Kyusyu and Okinawa	7	7	7	7	7	7	7	7	7	7	7	7
4 hour drained field, Continuously flooded	Rice straw	Hokkaido	308	310	338	355	369	344	361	347	351	349	351	335
		Tohoku	385	431	488	506	497	475	493	501	513	508	508	472
		Hokuriku	529	516	538	553	539	485	492	499	501	495	495	481
		Kanto	163	180	209	228	228	211	216	222	223	220	220	199
		Tokai and Kinki	212	208	232	243	233	212	224	233	233	230	230	219
		Chugoku and Shikoku	225	235	266	270	271	247	252	232	231	229	229	217
		Kyusyu and Okinawa	157	154	169	181	185	166	173	174	172	170	170	139
	Compost	Hokkaido	302	329	367	358	380	329	331	337	357	345	369	324
		Tohoku	424	458	504	493	520	458	460	467	492	477	507	452
		Hokuriku	348	379	422	412	437	380	382	388	411	398	425	374
		Kanto	201	218	243	237	251	218	219	223	236	229	244	215
		Tokai and Kinki	180	197	221	215	229	198	199	202	215	207	222	194
		Chugoku and Shikoku	220	239	266	260	275	239	240	245	259	251	268	236
		Kyusyu and Okinawa	222	243	272	265	282	243	244	249	264	255	274	239
	No-amendment	Hokkaido	33	33	33	33	33	33	33	33	33	33	33	33
		Tohoku	97	97	97	97	97	97	97	97	97	97	97	97
		Hokuriku	43	43	43	43	43	43	43	43	43	43	43	43
		Kanto	27	27	27	27	27	27	27	27	27	27	27	27
		Tokai and Kinki	13	13	13	13	13	13	13	13	13	13	13	13
		Chugoku and Shikoku	27	27	27	27	27	27	27	27	27	27	27	27
		Kyusyu and Okinawa	13	13	13	13	13	13	13	13	13	13	13	13
4 hour drained field, Intermittently flooded	Rice straw	Hokkaido	171	172	188	198	206	192	201	194	195	194	195	187
		Tohoku	268	301	342	355	349	333	346	351	360	357	357	330
		Hokuriku	356	347	362	372	362	326	331	335	336	333	333	323
		Kanto	111	123	144	157	157	145	149	153	153	152	152	136
		Tokai and Kinki	119	117	130	137	131	119	125	131	131	129	129	123
		Chugoku and Shikoku	156	163	184	187	188	170	174	160	160	158	158	150
		Kyusyu and Okinawa	93	91	100	107	109	98	102	103	101	100	100	82
	Compost	Hokkaido	167	183	205	200	212	183	184	188	199	192	206	180
		Tohoku	296	320	354	346	365	321	322	327	345	335	356	316
		Hokuriku	232	253	282	276	293	253	255	259	275	266	284	249
		Kanto	138	150	167	163	173	150	151	154	163	157	168	148
		Tokai and Kinki	101	111	124	121	129	111	111	113	120	116	125	109
		Chugoku and Shikoku	152	165	184	180	191	165	166	169	179	173	185	163
		Kyusyu and Okinawa	131	144	161	157	167	144	145	147	157	151	162	142
	No-amendment	Hokkaido	14	14	14	14	14	14	14	14	14	14	14	14
		Tohoku	59	59	59	59	59	59	59	59	59	59	59	59
		Hokuriku	22	22	22	22	22	22	22	22	22	22	22	22
		Kanto	16	16	16	16	16	16	16	16	16	16	16	16
		Tokai and Kinki	6	6	6	6	6	6	6	6	6	6	6	6
		Chugoku and Shikoku	17	17	17	17	17	17	17	17	17	17	17	17
		Kyusyu and Okinawa	7	7	7	7	7	7	7	7	7	7	7	7

- ***Activity Data***

For area of paddy rice field by region (*A*), data described in the *"Statistics of Cultivated and Planted Area"* by MAFF were used. For drainage (f_D), proportion of water regime (f_w), proportion of organic matter (f_O), survey data by MAFF etc. described in Table 5-46 to Table 5-49 were used respectively.

Area of paddy fields with "prolonged mid-season drainage" in the status report of *"the Direct Payments for Environmentally Friendly Agriculture* (MAFF)", with mid-season drainage of more than 14 consecutive days, were determined as area of "Intermittently flooded paddy fields with prolonged mid-season drainage" by FY2023. Prolonging mid-season drainage is assumed to have been started since FY2015 based on the available data indicating that the direct payment for "prolonged mid-season drainage" had been started from FY2015. The area of paddy fields with prolonged mid-season drainage in FY2024 were drawn from the area of prolonged mid-season drainage in the J-credit scheme.

Table 5-46 Area of paddy fields by region (*A*) [kha]

Item		1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Conventional midseason drainage	Hokkaido	146	163	135	119	115	113	111	105	103	102	102	83
	Tohoku	525	539	456	444	429	419	414	408	407	403	400	377
	Hokuriku	258	260	221	218	213	215	214	212	211	209	208	194
	Kanto	386	390	336	331	322	324	322	313	311	308	306	299
	Tokai and Kinki	261	264	217	208	199	198	182	176	174	172	169	175
	Chugoku and Shikoku	236	232	187	182	178	175	170	157	155	152	149	145
	Kyusyu and Okinawa	246	251	207	206	202	203	199	190	188	186	184	182
	Total	2,058	2,098	1,758	1,708	1,657	1,647	1,609	1,560	1,549	1,531	1,517	1,454
Prolonged midseason drainage	Hokkaido	—	—	—	—	—	—	0	0	0	0	0	19.49
	Tohoku	—	—	—	—	—	—	1.69	3.20	3.46	3.25	3.45	23.47
	Hokuriku	—	—	—	—	—	—	0.21	0.49	0.57	0.59	0.65	11.20
	Kanto	—	—	—	—	—	—	0	0	0	0.0005	0.0076	2.41
	Tokai and Kinki	—	—	—	—	—	—	11.50	11.16	10.98	10.82	10.74	2.35
	Chugoku and Shikoku	—	—	—	—	—	—	0	0.03	0.03	0	0.01	1.06
	Kyusyu and Okinawa	—	—	—	—	—	—	0.03	0	0	0	0	0.15
	Total	—	—	—	—	—	—	13.43	14.89	15.04	14.66	14.86	60.12

Note: Upon the estimation, Tokai and Kinki regions are aggregated as one region
Reference: Conventional mid-season drainage: *Statistics of Cultivated and Planted Area* (MAFF) Prolonged mid-season drainage: (FY2015- FY2023) *the Direct Payments for Environmentally Friendly Agriculture* (MAFF) (FY2024) Estimated by MAFF from *J-credit certification data*

Table 5-47 Proportion of drainage capacity categories (by region) (f_D)

Region	4 hours drained	One day drained	Poorly drained
Hokkaido	51%	42%	7%
Tohoku	63%	31%	6%
Hokuriku	69%	26%	4%
Kanto	59%	32%	9%
Tokai and Kinki	69%	23%	8%
Chugoku and Shikoku	65%	27%	8%
Kyusyu and Okinawa	74%	21%	5%

Reference: *Fourth Basic Survey on Infrastructure Development of Land Use, 2006*

Table 5-48 Proportion of water management practices (by region) (f_w)

Region	Continuously flooded	Intermittently flooded
Hokkaido	48%	52%
Tohoku	5%	95%
Hokuriku	4%	96%
Kanto	14%	86%
Tokai and Kinki	11%	89%
Chugoku and Shikoku	8%	92%
Kyusyu and Okinawa	7%	93%

Reference: *Survey of Greenhouse Gas Emissions from Soils and Soil Carbon Sequestration*

Table 5-49 Proportion of organic matter management methods by year in Japan (f_O)

Item	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Straw amendment	63%	70%	71%	72%	74%	84%	83%	83%	83%	84%	84%	83%
Various compost amendment	17%	10%	9%	8%	9%	7%	5%	6%	6%	5%	5%	6%
No-amendment	20%	20%	20%	20%	17%	9%	12%	11%	11%	11%	11%	11%

Reference: 1990-2007: *Basic Survey of Soil Environment*
2008-2012: *Survey of Greenhouse Gas Emissions from Soils and Soil Carbon Sequestration*
2013-2014: *The Project of Basic Survey on Greenhouse Gas Emissions from Agricultural Land Soils*
Since 2015: *The Project of Basic Survey for Carbon Stock on Agricultural Land Soil*

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the emission factors, uncertainty (6%) was calculated by the DNDC-Rice model. For the uncertainty of the activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied. As a result, the uncertainties of the emissions were determined to be 6%.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Annex 4.

Comparison of CH_4 emissions calculated by the DNDC-Rice model and emissions of actually measured data in the field was discussed and reported in the paper by Minamikawa et al. (2014), Fumoto et al. (2010), and Katayanagi et al. (2016). Figure 5-6 is comparison of annual methane emission between values observed and values simulated by the DNDC-Rice model described in Katayanagi et al. (2016). The Paper reports that simulated CH_4 emission was strongly and significantly correlated with the observations (r=0.861), reflecting the variations caused by differences among the sites and the treatments.

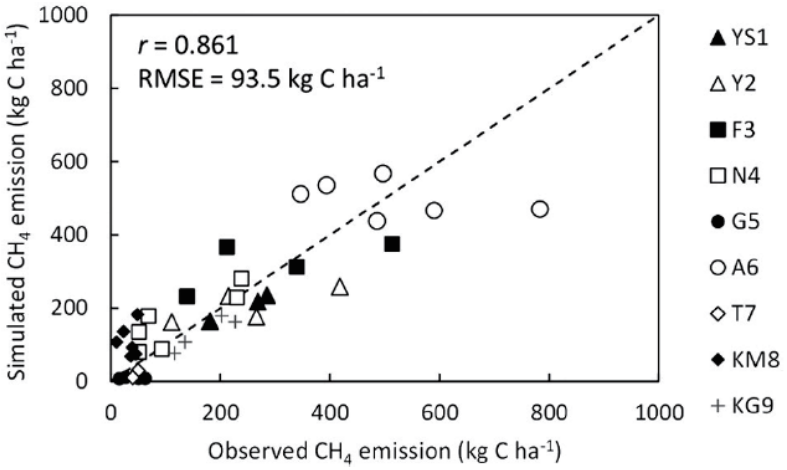

Figure 5-6 Comparison of annual methane emission between values obserbed and values simulated by the DNDC-Rice model

Reference: Quoted from Figure 3 in Katayanagi et al. (2016)

In addition, validation of application of the emission factors calculated by the DNDC-Rice model, into Japan's inventory has been conducted in Katayanagi et al. (2016) and also has been discussed in the Agriculture Breakout Group on the Committee of GHG Emission Estimation Methods.

e) Category-specific Recalculations

Due to the revision of the rice straw application amount from FY2021 to FY2023 the emissions from FY2021 to FY2023 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

In the future, if the research on the DNDC-Rice model progress and the model are improved and updated, application of the improved version will be considered.

5.4.2. Rain-fed, Deep Water and Other (3.C.2., 3.C.3., 3.C.4.)

As indicated in the *World Rice Statistics 1993–94*, International Rice Research Institute (IRRI) (1995), rainfed and deep water paddy fields do not exist in Japan. Therefore, this category has been reported as "NO".

Just as indicated in IRRI (1995), a possible source of emissions for other rice cultivation system is upland rice, but since upland rice field are not flooded, the soil condition is aerobic. The bacteria that generate CH_4 are obligatory anaerobic bacterium, and unless the soil is maintained in an anaerobic state, CH_4 will not be emitted. As generation of CH_4 is not feasible, this category was reported as "NA".

5.5. Agricultural Soils (3.D.)

This section provides the estimation methods for N_2O direct emissions from soils (by applied inorganic N fertilizers, organic fertilizers, grazing livestock manure, crop residue, mineralization by soil carbon loss, and plowing of organic soil), and for N_2O indirect emissions (by atmospheric deposition, and nitrogen leaching and run-off).

N_2O emissions from agricultural soils in FY2024 are 4,049 kt-CO_2 eq., comprising 0.4% of total emissions (excluding LULUCF). The value represents a decrease by 39.2% from FY1990. Main drivers of the emission reduction from FY1990 are decreases of nitrogen amount applied to soil of inorganic fertilizer and organic fertilizer from livestock manure. The main reasons of their decrease of fertilizer are that the area of cropping has been decreasing (Table 5-56) and reducing the usage of fertilizer has been recommended to mitigate nitrogen pollution in groundwater in some areas.

Table 5-50 N_2O emissions from agricultural soils (3.D.)

Gas	Item		Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
N_2O	3.D.1. Direct emission	1. Inorganic N fertilizers	kt-N_2O	6.2	5.3	5.0	4.8	4.2	4.2	3.9	3.6	4.3	3.8	2.8	2.8
		2. Organic N fertilizers		5.5	5.2	5.0	4.4	4.7	4.7	5.3	4.1	4.0	3.7	3.5	3.5
		3. Manure by grazing animal		0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		4. Crop residues		1.4	1.4	1.5	1.4	1.2	1.2	1.2	1.1	1.1	1.1	1.0	1.0
		5. Mineralization		1.5	1.5	1.4	1.4	1.4	1.4	1.4	1.3	1.3	1.3	1.3	1.3
		6. Cultivation of organic soil		0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
	3.D.2. Indirect emission	1. Atmospheric deposition		3.6	3.4	3.2	3.0	2.9	2.9	3.0	2.6	2.7	2.5	2.3	2.2
		2. N leaching and run-off		6.4	5.9	5.7	5.4	5.0	5.0	5.0	4.6	4.8	4.5	4.0	4.0
	Total		kt-N_2O	25.1	23.2	22.3	20.8	20.0	19.9	20.1	17.8	18.6	17.4	15.4	15.3
			kt-CO_2 eq.	6,658	6,137	5,902	5,515	5,303	5,269	5,338	4,719	4,938	4,605	4,092	4,049

5.5.1. Direct N_2O Emissions from Managed Soils (3.D.1.)

Application of inorganic fertilizers and organic fertilizers, and grazing livestock manure, or plowing of crop residues into soil generates ammonium ions in the soil. The soil emits N_2O in the process of oxidizing the ammonium ions into nitrate-nitrogen under aerobic conditions. N_2O is also emitted via denitrification of nitrate. In addition, N_2O is generated by decomposition of organic matter in mineral soil and plowing of organic soil because of nitrification and denitrification of nitrogen. N_2O emissions by the application of synthetic fertilizers and organic fertilizers to pastureland (included in the planted area for feed crops, see Table 5-56) are estimated in this category.

5.5.1.1. Inorganic N Fertilizers (3.D.1.a.)

a) Category Description

This section provides the estimation methods for N_2O emissions by the application of inorganic N fertilizers (synthetic fertilizers).

b) Methodological Issues

- ***Methodology for Estimating Emissions/Removals of GHGs***

N_2O emissions were calculated by Tier2 method, using country-specific emission factors in accordance with decision tree of the *2006 IPCC Guidelines* (Vol. 4, p.11.9, Fig.11.2).

In addition, estimation method for N_2O emission reduction from agricultural soil using synthetic N fertilizer with nitrification inhibitor is also established.

$$E = \sum_{i,j} (F_{SNi,j} \times EF_{1i,j}) \times 44/28$$

E	: N_2O emissions associated with the application of synthetic fertilizer in agricultural soil (crop field) [kg-N_2O]
$F_{SNi,j}$	: Nitrogen amount of synthetic fertilizer j applied to agricultural soil for crop type i [kg-N]
$EF_{1i,j}$	: N_2O emission factor of synthetic fertilizer j for crop type i [kg-N_2O-N/kg-N]
i	: Crop type
j	: Fertilizer type (with or without nitrification inhibitor)

- ***Emission Factors***

Emission factors were established by analyzing measured data in Japan, based on the amount of application of synthetic fertilizer and N_2O emissions. Emission factors of the application of synthetic fertilizer with nitrification inhibitor were established by multiplying their country-specific emission factor by N_2O reduction rate.

Comparing emission factors among various crops, it was identified that emission factor of tea was significantly higher and emission factor of rice was significantly lower than those of other crops. As there were not significant differences among the other crops, emission factors associated with the application of synthetic fertilizer in agricultural soil were defined three categories for rice, tea and other crops. Emission factor of Japan is lower than that of default value in the *2006 IPCC Guidelines*. It is the reason that the volcanic ash soil that is well-drained soil and widely distributed in Japan releases little N_2O emissions. The emission factor of rice is adopted as a default value within the *2006 IPCC Guidelines* and its validity has been internationally confirmed.

N_2O emission reduction rate using synthetic fertilizer with nitrification inhibitor was decided as 26%, the lower limit of N_2O reduction rate using fertilizer with dicyandiamide (26-36%) described in Akiyama et al. (2010). Although dicyandiamide is dominantly added as nitrification inhibitor in Japan, other chemical materials as inhibitor are used in a few products. Therefore, the lower limit of the rate of dicyandiamide was used to avoid overestimation of emission reduction. In addition, since nitrification seldom occur on flooded situation for paddy rice, synthetic fertilizer with nitrification inhibitor is never used. Therefore, EF with nitrification inhibitor for paddy rice was not developed.

Table 5-51 N_2O emission factor for synthetic fertilizer to agricultural soil

Crop type	Emission Factor without nitrogen inhibitor [%: kg-N_2O-N/kg-N]	Emission Factor with nitrogen inhibitor [%: kg-N_2O-N/kg-N]
Paddy rice	0.31%	—
Tea	2.9%	2.1% [=2.9%×(1-0.26)]
Other crops	0.62%	0.46% [=0.62%×(1-0.26)]

Reference: Akiyama et al. (2006 a)
Akiyama et al. (2006 b)
Akiyama et al. (2010)

- ***Activity Data***

For total nitrogen amount of synthetic fertilizer, demand for nitrogenous fertilizer described in *Yearbook of Fertilizer Statistics (Pocket Edition)* by Association of Agriculture and Forestry Statistics before FY2017 and the data surveyed by Agricultural Technology Promotion Division, MAFF since FY2017 are used for estimation. To estimate amount of synthetic fertilizer applied to the agricultural soil, amount of synthetic fertilizer applied to forest are subtracted from this total amount (Table 5-52). In addition, to estimate the amount of synthetic fertilizer applied by crop type, values corresponding to the amounts of nitrogen applied for each crop type are calculated by multiplying area of each crop field (Table 5-56) by the amounts of synthetic fertilizers applied per unit area for each crop type based on the results of studies (Tsuruta 2001) in Japan. Total synthetic fertilizer is apportioned to each crop type in accordance with the corresponding application amount for each crop type.

$$F_{SNi} = (F_T - F_{FRST}) \times \frac{(RA_i \times RF_i \times 10)}{\sum(RA_i \times RF_i \times 10)}$$

F_{SNi} : Nitrogen amount of synthetic fertilizer applied to agricultural soil for crop type *i* [t-N]
F_T : Total nitrogen amount of synthetic fertilizer [t-N]
F_{FRST} : Nitrogen amount of synthetic fertilizer applied to forest [t-N]
RA_i : Area planted of crop type *i* [ha]
RF_i : Nitrogen amount of synthetic fertilizer per area planted of crop type *i* [kg-N/10a]

The amounts of fertilizer applied by crop type are known because the amounts of synthetic and organic fertilizers applied for each crop type were determined by a farming study conducted in 2000 (Tsuruta 2001). Based on expert judgement, there is likely little year-on-year change in application amounts to crops except for paddy rice and tea, data on the amounts of synthetic fertilizer applied per unit area according to Tsuruta (2001) were applied uniformly for these crops in all the years (Table 5-54).

Fertilizer application amounts for tea change from year to year because of the influence of the transition of recommended rate of fertilizer application by local governments and other factors. The amounts of nitrogen applied to tea fields (the total amount of nitrogen from synthetic and organic fertilizer) in 1993, 1998, and 2002 investigated and summarized by Nonaka (2005) and the ratio of synthetic fertilizer and organic fertilizer applied to tea according to Tsuruta (2001) were used to estimate the amounts of

synthetic and organic fertilizer applied in FY1993, FY1998 and FY2002. Time-series data were prepared by interpolating calculated values by estimated fertilizer amount data of three years into from FY1993 to FY2002 and deferring the FY1993 data for previous years and the FY2002 data for subsequent years (see Table 5-55).

For paddy rice, the data of synthetic fertilizer application amount for unit area for each fiscal year in *Yearbook of Fertilizer Statistics* was used. The values of paddy rice were substituted for upland rice.

Shipping amount of synthetic fertilizer with nitrification inhibitor which is included in "N amount of synthetic fertilizer applied (agricultural soil)" is from surveyed data by MAFF since 1996, and 13% which is an average nitrogen content in production from major manufacturers was applied for emission estimation. It assumes little nitrification inhibitor was used prior to 1996, while there is no data available because this survey started from 1996. In addition, since synthetic fertilizer with nitrification inhibitor was not used for paddy rice nor feed crops, they were excluded from estimation.

Table 5-52 Nitrogen amount of synthetic fertilizer applied to soil [t-N/yr]

Item	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Total N amount in synthetic fertilizer	611,955	527,517	487,406	471,190	409,590	409,918	372,339	355,005	417,644	376,985	278,210	278,210
N amounut in synthetic fertilizer applied (forest soil)	288	248	229	222	193	193	175	167	196	177	131	131
N amounut in synthetic fertilizer applied (agricultural soil)	611,667	527,269	487,177	470,968	409,397	409,725	372,164	354,838	417,447	376,808	278,079	278,079

Note: This amount includes synthetic fertilizer with nitrification inhibitor.
Reference: Total N amount: *Yearbook of Fertilizer Statistics (Pocket Edition)* before FY2017
The data surveyed by Agricultural Technology Promotion Division, MAFF since FY2017
N amount to forest soil: Estimated on the basis of Forestry Agency Survey

Table 5-53 Nitrogen amount of synthetic fertilizer with nitrification inhibitor [t-N]

df	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
N amount in synthetic fertilizer with nitrification inhibitor	NE	NE	4,030	4,290	4,940	7,800	5,070	5,785	6,084	6,617	5,668	5,668

Note: The value is estimated based on the assumption that products have 13% of nitrogen contents.
Reference: Survey by MAFF

Table 5-54 Amount of synthetic fertilizers application per area by each crop type (other than rice and tea)

Crop type	Amount of application [kg-N/10a]
Vegetables	21.27
Fruit	14.70
Potatoes	12.70
Pulse	3.10
Feed crops	10.00
Sweet potato	6.20
Wheat	10.00
Coarse cereal (including Buckwheat)	4.12
Mulberries	16.20
Industrial crops	22.90
Tobacco	15.40

Reference: Tsuruta (2001)

Table 5-55 Amount of synthetic fertilizers application per area (rice and tea) [kg-N/10a]

Item	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
N amount in synthetic fertilizers application per area (rice)	9.65	8.71	7.34	6.62	5.95	6.10	5.85	5.85	5.85	5.85	5.85	5.85
N amount in synthetic fertilizers application per area (tea)	57.23	54.88	48.06	44.76	44.76	44.76	44.76	44.76	44.76	44.76	44.76	44.76

Reference: Rice: *Yearbook of Fertilizer Statistics (Pocket Edition)*, Tea: Nonaka (2005) and Tsuruta (2001)

Table 5-56 Planted area by each crop type [kha]

Crop type	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Vegetables	620.1	564.4	524.9	476.3	465.4	453.4	448.9	424.9	419.8	412.5	405.0	396.8
Paddy rice (for grain)	2,055.0	2,106.0	1,763.0	1,702.0	1,625.0	1,597.0	1,505.0	1,462.0	1,403.0	1,355.0	1,344.0	1,359.0
Fruit	346.3	314.9	286.2	265.4	246.9	237.0	230.2	211.0	207.5	203.9	200.3	196.2
Tea	58.5	53.7	50.4	48.7	46.8	45.4	44.0	39.1	38.0	36.9	36.0	35.1
Potatoes	115.8	104.4	94.6	86.9	82.5	79.7	77.4	71.9	70.9	71.4	71.2	70.9
Pulse	256.6	155.5	191.8	193.9	189.0	178.5	187.6	183.3	184.0	188.3	192.5	190.5
Feed crops	1,096.0	1,013.0	1,026.0	1,030.0	1,012.0	1,012.0	1,072.0	1,052.6	1,102.5	1,130.0	1,121.2	1,074.4
for Pasture land	646.7	660.7	644.7	630.6	616.7	611.1	606.5	595.2	593.5	591.4	589.1	585.9
Sweet potato	60.6	49.4	43.4	40.8	39.7	38.6	36.6	33.1	32.4	32.3	32.0	31.8
Wheat	366.4	210.2	236.6	268.3	265.7	269.5	274.4	276.2	283.0	290.6	295.7	296.8
Coarse cereal (incl. buckwheat)	29.6	23.4	38.4	45.9	49.7	62.9	59.7	68.3	67.2	67.3	68.8	70.8
Mulberries	59.5	26.3	5.9	3.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
Industrial crops	142.9	124.5	116.3	110.3	104.8	98.5	98.8	97.9	99.9	99.0	93.4	91.0
Tobacco	30.0	26.4	24.0	19.1	15.0	8.9	8.3	6.1	5.7	3.6	3.5	3.4
Upland rice	18.9	11.6	7.1	4.5	2.9	1.7	1.2	0.6	0.6	0.5	0.4	0.3
Total	5,256.2	4,783.7	4,408.5	4,295.1	4,147.4	4,085.0	4,046.1	3,928.9	3,916.4	3,893.3	3,866.0	3,819.0

Reference: Potatoes: *Vegetable Production and Shipment Statistics*, Tobacco: Survey of Japan Tobacco Inc.,
Mulberries: MAFF Survey, Other crops: *Statistics of Cultivated and Planted Area*
(Note: "Industrial crops" is subtracted the area of "Tobacco" from estimated value from total area of tea, rape, sugar beet and sugarcane. The values of "Vegetable" before FY2017 excluded the value of "Potatoes". The values of "Vegetable", "Fruit", "Pulse", "Feed crops" and "Coarse cereal" in FY2017 are estimated by using the last five years average proportion of sum of planted areas for object crops in each crop group to the statistic because of the abolition of statistical survey for planted area of these crop groups.)

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the emission factors, uncertainty (113%) estimated in the reference of EFs, Akiyama et al. (2006 b), was applied. For activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be 113%.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

d) Category-specific QA/QC and Verification

Same as Sheep, Swine, Buffalo, Goats & Horses (3.A.2., 3.A.3., 3.A.4.-) in Enteric Fermentation. See section 5.2.2. d).

Comparison with Japan's EF and the default EF in the IPCC Guidelines is described in the section 'Emission factors' above.

e) Category-specific Recalculations

Since nitrogen fertilizer demand from FY2017 to FY2023 was revised, the emissions from FY2017 to FY2023 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

5.5.1.2. Organic N Fertilizers (3.D.1.b.)

a) Category Description

This section provides the estimation methods for N_2O emissions by application of organic fertilizer (manure from livestock and other, and compost).

b) Methodological Issues

- ***Estimation Method***

Emissions of N_2O have been calculated by Tier2 method in accordance with decision tree of the *2006 IPCC Guidelines* (Vol.4, p.11.9, Fig.11.2).

$$E = \sum_i (F_{ONi} \times EF_{1i}) \times 44/28$$

E : N_2O emissions from the organic fertilizers applied to agricultural soils [kg-N_2O]
F_{ONi} : Nitrogen amount of organic fertilizer applied to agricultural soil for crop type i [kg-N]
EF_{1i} : N_2O emission factor of organic fertilizer for crop type i [kg-N_2O-N/kg-N]
i : Crop types

- ***Emission Factors***

Emission factors for N_2O associated with the application of synthetic fertilizers without nitrification inhibitor and organic fertilizers were defined as the same value as the emission factors for Inorganic N Fertilizers (3.D.1.a.), because there was no significant difference between emission factors of synthetic fertilizers and organic fertilizers for rice and tea.

For other crops, emission factor was calculated as the weighted average of the emission factors for two soil types (Andsol and Non-Andosol) without synthetic N fertilizers from Akiyama et al. (2023) by type of organic fertilizer.

For livestock manure, the emission factor for cattle was defined as the weighted average of that for compost and slurry, and the emission factors for swine and poultry were defined as the value for their compost. For other livestock, the default values in the *2019 Refinement* were used.

For sewage sludge and other organic fertilizers (human waste, composting sub-material, etc.), the emission factors for non-manure organic fertilizers were adopted. Most of other organic fertilizers are generally low in CN ratio and higher in N_2O emission factors (comparable to or higher than EF for poultry manure) than livestock manure, such as for cattle, which is relatively high in CN ratio. Note that the default values in the *2019 Refinement* take many data into account for livestock manure and considered not to be applicable for use.

Table 5-57 Emission factors for organic fertilizers

Organic Fertilizer	EF [%]	References
Weighted average of cattle compost and slurry	0.39	Akiyama et al. (2023)
Swine compost	0.70	
Poultry compost	0.83	
Other livestock	0.60	*2019 Refinement*
Sewage sludge	1.16	Akiyama et al. (2023)
Other organic fertilizers (human waste, composting sub-material, etc.)		

- ***Activity Data***

For activity data (total amount of nitrogen contained in the organic fertilizers), the following nitrogen was calculated on the basis of formula described in the *2006 IPCC Guidelines* (Vol.4, p11.12, Equation 11.3).

$$F_{ON} = F_{AM} + F_{SEW} + F_{FU} + F_{COMPsub} + F_{OOA}$$

F_{ON}	: Nitrogen amount in organic fertilizers applied to soil [kg-N]
F_{AM}	: Nitrogen amount in livestock manure applied to soil [kg-N]
F_{SEW}	: Nitrogen amount in sewage sludge applied to soil [kg-N]
F_{FU}	: Nitrogen amount in human waste applied to soil [kg-N]
$F_{COMPsub}$	: Nitrogen amount in composting sub-material applied to soil (rice straw, rice husk, wheat straw) [kg-N]
F_{OOA}	: Nitrogen amount in other organic fertilizers applied to soil (fish residue, soybean oil residue, canola oil residue, etc.) [kg-N]

- ***Nitrogen amount in livestock manure applied to soil (F_{AM})***

Amount of nitrogen in livestock manure applied to agricultural soil (F_{AM}) of each livestock was calculated by subtracting the amount of nitrogen included in grazing livestock excretion(F_{PRP}), nitrogen discharged into public sewage (F_{PSW}) nitrogen in livestock manure volatilized as N_2O (excluding grazing livestock) (F_{N2O}), nitrogen in manure volatilized as NH_3 and NO_X (excluding grazing livestock) ($F_{NH3+NOx}$), nitrogen not applied to soil due to disposal as industrial waste, discharge to river after purification and other reasons ($F_{disposal}$) from the total nitrogen in livestock manure ($F_{Total\text{-}AW}$) by each livestock.

$$F_{AM} = F_{Total\text{-}AW} - F_{PRP} - F_{PSW} - F_{N_2O} - F_{NH_3+NOx} - F_{disposal}$$

F_{AM}	: Nitrogen amount in livestock manure applied to soil [kg-N]
$F_{Total\text{-}AW}$	: Total amount of nitrogen excreted by livestock [kg-N]
F_{PRP}	: Amount of nitrogen included in grazing livestock excretion [kg-N]
F_{PSW}	: Amount of nitrogen discharged into public sewage [kg-N]
F_{N_2O}	: Nitrogen in livestock manure volatilized as N_2O (excluding N from grazing livestock) [kg-N]
F_{NH_3+NOx}	: Nitrogen in manure volatilized as NH_3 and NO_X (excluding N from grazing) [kg-NH_3-N + NO_X-N]
$F_{disposal}$	: Nitrogen not applied to farm field due to disposal as industrial waste, discharge to river after purification and other reasons [kg-N]

For the amount of nitrogen included in grazing livestock excretion (F_{PRP}) amount of nitrogen discharged into public sewage (F_{PSW}) and nitrogen in livestock manure volatilized as N_2O (excluding N from grazing livestock excretion) (F_{N2O}), the amount calculated in 3.B. Manure management were used.

Nitrogen not to applied to farm field ($F_{disposal}$) was calculated by using the percentage of non-agricultural utilization in the *survey of current status for livestock manure management system and others 2019* (MAFF, 2021) and *Survey of actual conditions for livestock manure management system and others, 2024,* (MAFF, 2025).

Table 5-58 Nitrogen amount in livestock manure applied to agricultural soil (F_{AM}) [t-N]

Item	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Total nitrogen amount in animal waste ($F_{Total\text{-}AW}$)	683,190	642,484	604,830	565,954	549,834	519,131	509,970	523,897	522,980	513,437	508,465	503,696
Nigrtogen amount in excretion from grazing livestock and for public sewage ($F_{PRPI}+F_{PRP}$)	12,987	12,836	12,024	11,615	11,319	10,564	10,102	9,793	9,995	10,720	11,166	11,451
Amount of N_2O-N released from manure (excluing excretion from grazing livestock and for public sewage) (F_{N2O})	5,977	5,663	5,636	6,251	6,783	6,318	6,078	5,945	5,768	5,556	5,330	5,129
Amount of NH_3-N and NOx-N released from manure (excluing excretion from grazing livestock and for public sewage) ($F_{NH3}+F_{Nox}$)	236,054	219,528	202,664	184,081	177,539	166,018	163,441	166,734	166,101	161,500	160,570	159,557
Nitrogen amount not to applied to farm field ($F_{disposal}$)	40,822	35,395	36,226	46,146	55,654	52,447	50,728	55,021	55,803	57,136	58,368	60,079
Nitrogen amount in livestock manure applied to agricultural soil (F_{AM})	387,350	369,061	348,280	317,862	298,539	283,783	279,621	286,404	285,313	278,526	273,031	267,481

➢ *Nitrogen amount in sewage sludge applied to soil (F_{SEW})*

Nitrogen amount in sewage sludge applied to soil (F_{SEW}) was calculated by multiplying amount of sludge described in the *Yearbook of Fertilizer Statistics (Pocket Edition)* before FY2017 and the data surveyed by Plant Products Safety Division, MAFF since FY2017 by nitrogen contents established using data provided by Japan Sewage Works Association.

➢ *Nitrogen amount in human wastes applied to soil (F_{FU})*

Nitrogen amount of human waste (F_{FU}) was calculated from the amount of human waste-derived nitrogen calculated with the data of *Waste Treatment in Japan*.

➢ *Nitrogen amount in composting sub-material applied to soil ($F_{COMPsub}$)*

For composting sub-material, data of "composting" and "barn bedding" of rice straw, rice chaff and wheat straw calculated from each prefecture data were used. For nitrogen content rate of rice straw, rice chaff and wheat straw, values described in 5.5.1.4. “Crop Residue” below were used (Table 5-66).

➢ *Nitrogen amount in other organic fertilizers applied to soil (F_{OOA})*

Nitrogen amount in other organic fertilizers (fish residue, soybean oil residue, canola oil residue, etc.) applied to soil (F_{OOA}) was calculated by multiplying amount of other organic fertilizer described in the *Yearbook of Fertilizer Statistics (Pocket Edition)* before FY2017 and the data surveyed by Plant Products Safety Division, MAFF since FY2017 by nitrogen contents established using data provided in the *Yearbook of Fertilizer Statistics (Pocket Edition)*.

Table 5-59 Amount of sludge and other organic fertilizer [kt]

Item	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Animal derived fertilizers	384.1	389.4	341.0	262.7	268.3	298.3	300.6	261.2	210.4	240.8	166.6	166.6
Fish residue	111.5	88.6	89.0	73.9	62.2	60.0	52.9	47.6	32.8	40.2	32.2	32.2
Bone meal	113.1	134.2	112.8	11.4	16.7	16.2	20.0	15.5	13.7	14.5	14.3	14.3
Other animal derived	159.5	166.6	139.2	177.5	189.4	222.1	227.7	198.1	163.9	186.1	120.1	120.1
Plant derived fertilizers	635.9	725.7	982.4	494.8	1,064.3	1,203.7	1,852.7	728.3	725.4	388.6	321.7	321.7
Soybean oil residue	3.5	4.7	28.9	1.1	209.5	167.7	477.0	74.0	69.8	1.3	66.0	66.0
Canola oil residue	451.0	437.2	620.7	241.0	221.4	288.4	474.8	131.4	141.3	88.9	86.9	86.9
Other plant derived	181.4	283.8	332.8	252.7	633.5	747.6	900.9	522.9	514.4	298.5	168.9	168.9
Sludge	787.3	935.2	817.7	1,287.4	1,395.6	1,355.5	1,395.7	1,261.5	1,237.9	1,272.1	1,236.1	1,236.1

Reference: *Yearbook of Fertilizer Statistics (Pocket Edition)* before FY2017
The data surveyed by Plant Products Safety Division, MAFF since FY2017

Table 5-60 Nitrogen content rate of each organic fertilizer

Organic fertilizer	Nitrogen content
Fish residue	8.0%
Bone meal	4.1%
Other animal matters	7.5%
Soybean oil residue	7.5%
Canola oil residue	5.1%
Other vegetable matter	4.6%
Sludge	2.7%

Reference: Other than sludge: Yearbook of Fertilizer Statistics (Pocket Edition)
Sludge: Established from Japan Sewage Works Association data

Table 5-61 Nitrogen amount in organic fertilizers applied to agricultural soil [t-N]

Item	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
From livestock manure (F_{AM})	387,350	369,061	348,280	317,862	298,539	283,783	279,621	286,404	285,313	278,526	273,031	267,481
From sewage sludge (F_{SEW})	21,257	25,250	22,078	34,760	37,682	36,599	37,685	34,059	33,423	34,345	33,374	33,374
From human waste (F_{FU})	10,394	4,747	2,116	874	427	286	231	197	200	181	132	105
From composting sub-material ($F_{COMPsub}$)	18,316	15,514	11,485	11,217	8,864	8,879	6,816	6,601	6,259	5,454	5,233	5,218
From other organic fertilizers (F_{OOA})	57,128	60,790	71,314	43,685	76,006	83,796	123,560	55,602	51,581	36,129	29,312	29,312
Total (Nitrogen amount applied to agricultural soil as organic N fertilizer) (F_{ON})	494,445	475,361	455,273	408,399	421,519	413,343	447,913	382,863	376,776	354,636	341,082	335,490

➢ *Estimation for nitrogen amount of organic fertilizer applied to agricultural soil for crop type i*

Nitrogen amount of organic fertilizer applied to agricultural soil for crop type *i* (F_{ONi}) by type of organic fertilizer is calculated by multiplying the total nitrogen amount in organic fertilizers applied to agricultural soil by type of organic fertilizer above (F) by the proportion of nitrogen amount to be applied to crop type *i* for the nitrogen to be applied to total crop (proportion of fertilizer application). The proportion of fertilizer application was calculated by dividing the product of nitrogen amount of organic fertilizer application per unit area of crop field for crop type *i* and the cultivation area for crop type *i* by the grand total of all products for all crop types.

$$F_i = F \times \frac{(RA_i \times RF_i / 10)}{\sum (RA_i \times RF_i / 10)}$$

F_i : Nitrogen amount of organic fertilizer applied to agricultural soil for crop type *i* [t-N] by type of organic fertilizer
F : Total nitrogen amount in organic fertilizers applied to agricultural soil [t-N] by type of organic fertilizer
RA_i : Area planted of crop type *i* [ha]
RF_i : Nitrogen amount of organic fertilizer per area of crop field for crop type *i* [kg-N/10a]

For nitrogen amount in organic fertilizer applied per unit area for tea, as same as the synthetic fertilizers, the amounts of nitrogen applied to tea fields (the total of synthetic and organic) in FY1993, FY1998, and FY2002 investigated and summarized by Nonaka (2005) and the ratio of synthetic fertilizer and organic fertilizer applied to tea according to Tsuruta (2001) were used to estimate the amounts of organic fertilizer applied and time-series data were prepared (see Table 5-62). Organic fertilizer application amount per unit area by each crop type except tea is based on the data on the survey in 2000 as same as synthetic fertilizer. The value of upland rice was substituted by the value of paddy rice. Cultivated area by each crop type is same as synthetic fertilizers.

Table 5-62 Amount of nitrogen applied as organic fertilizers per area (tea) [kg-N/10a]

Item	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
N amount in organic fertilizers application per area (tea)	20.77	19.92	17.44	16.24	16.24	16.24	16.24	16.24	16.24	16.24	16.24	16.24

Reference: Nonaka (2005), Tsuruta (2001)

Table 5-63 Amount of nitrogen applied as organic fertilizers per area by each crop type (except tea)

Crop type	Amount of application [kg-N/10a]
Vegetables	23.62
Paddy rice	3.2
Fruit	10.90
Potatoes	7.94
Pulse	6.24
Feed crops	10.00
Sweet potato	8.85
Wheat	5.70
Coarse cereal (including Buckwheat)	1.81
Mulberries	0.00
Industrial crops	3.96
Tobacco	11.41

Reference: Tsuruta (2001)

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the emission factors of rice and tea, uncertainty (196%, 122%) estimated in the reference of EFs, Akiyama et al. (2006 b), and for the emission factor of cattle compost, swine compost, poultry compost, sewage sludge, and other organic fertilizers, uncertainty (-100%~315%, -97%~250%, -89%~317%, -65%~161%, -65%~161%) estimated by the percentile presented in Akiyama et al. (2023) were applied. For emission factor of compost of other livestock, default value (83%) from the *2019 Refinement*. For activity data for livestock manure, uncertainty (30%) estimated by substitutions in the *Livestock Statistics* and *Survey of current status for livestock manure management system and others 2019*. For uncertainty of activity data for others, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution ratio. As a result, the uncertainties of the emissions were determined to be -42%~110%.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

d) Category-specific QA/QC and Verification

Same as Sheep, Swine, Buffalo, Goats & Horses (3.A.2., 3.A.3., 3.A.4.-) in Enteric Fermentation. See section 5.2.2. d).

e) Category-specific Recalculations

Since the population of dairy cattle by calving in *Record of Dairy Herd Performance Test*, averaged age in days of shipment in *The report of the fact-finding survey for pig farming*, egg production and feed intake per day for hen, and crop residues for composting sub-materials for FY2023 were updated, the emissions from livestock manure, composting sub-materials, and other organic fertilizers for FY2023 were recalculated. The area of orchard for FY2022 and FY2023 were revised, and therefore the emissions from organic N fertilizer for FY2022 and FY2023 were recalculated. The amount of animal and plant derived fertilizer distributed for FY2022 and FY2023 was updated and revised, and therefore emissions from organic fertilizers for FY2022 to FY2023 were recalculated. Since the *Survey of actual conditions for livestock manure management system and others, 2024* (MAFF, 2025) was applied, the emissions from livestock manure from FY2020 were recalculated. The emissions from livestock manure for the whole time-series were recalculated, due to the revision of application of the *Japanese Feeding Standard for Beef Cattle*. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

5.5.1.3. Urine and Dung Deposited by Grazing Animals (3.D.1.c.)

a) Category Description

This section provides the estimation methods for N_2O emissions from urine and dung deposited by grazing animals.

b) Methodological Issues

The method for calculating CH_4 and N_2O emissions from urine and dung deposited by grazing animals is described in 5.3.1 "Livestock Waste Management: Cattle, Swine and Poultry (Hen and Broiler) (3.B.1., 3.B.3., 3.B.4.)" and 5.3.2. "Buffalo, Sheep, Goats, Horses, Rabbit and Mink (3.B.2., 3.B.4.-)".

5.5.1.4. Crop Residues (3.D.1.d.)

a) Category Description

This section provides the estimation methods for N_2O emissions by crop residue plowed into soil.

b) Methodological Issues

- ***Estimation Method***

Basically, the N_2O emissions were calculated by using the *2006 IPCC Guidelines*. For emission factors, default EF described in the *2019 Refinement* were used. However, activity data for some crops (rice, tea, vegetables, sugarcane and sugar beet) were estimated by country-specific method which is considered to be capable for estimating emissions more accurately than the method provided in the *2006 IPCC Guidelines*.

$$E = EF \times A_i \times 44 / 28$$

E	: N_2O emissions from crop residue [kg-N_2O]
EF	: N_2O emission factor for crop residue [kg-N_2O-N/kg-N]
A_i	: Nitrogen amount in crop i residue plowed into soils [kg-N]

- ***Emission Factors***

0.006 [kg-N_2O-N/kg-N] (Disaggregated (Wet climates), the *2019 Refinement*)

- ***Activity Data***

➢ ***Rice***

For the amount of rice crop residue of above-ground biomass plowed into soil, the data for rice straw and rice chaff plowed into soil calculated from each prefecture data was used. The nitrogen content of rice was calculated by multiplying the aforementioned data by nitrogen content in crop residue (kg-N/t) calculated from Date (1988). In addition, below-ground was calculated from yield, dry matter fraction of harvested crop, ratio of below-ground residues to yield, N content of below-ground residues. For the ratio of below-ground residues to yield ($Frac_{BGR\text{-}Y}$), 27% indicated by Ogawa et al. (1988) was used. For dry matter fraction of harvested product (*DRY*), 0.89 of default value indicated in the *2019*

Refinement was used.

$$A_{Rice} = Residue \times N_{AG} + Y \times DRY \times Frac_{BGR\text{-}Y} \times N_{BG}$$

A_{Rice} : Nitrogen amount in crop residue plowed into soils [t-N] (Rice)
Residue : Amount of crop residue plowed into soils (rice straw and chaff) [t]
N_{AG} : N contents of above-ground residues (rice straw and chaff) [%: kg-N/kg]
Y : Yield of rice [t]
DRY : Dry matter fraction of harvested product
$Frac_{BGR\text{-}Y}$: Ratio of below-ground residues to yield of crop T [%]
N_{BG} : N contents of below-ground residues [%: kg-N/kg]

➢ *Tea*

For tea, "Leaf fall" and "Autumn pruning" were targeted as the residues which return into soils annually. In addition, as residues return into soil once in several years, "Medium pruning", which prunes the part of 30-50 cm from the ground and carried out once in about five years, was targeted. For the "Medium pruning", it is assumed that it is carried out one fifth of the total area of tea fields every year, and all of tea field will be renewal in five years. The residues' nitrogen contents were calculated by multiplying by nitrogen contents per unit area of "Leaf fall", "Autumn pruning" and "Medium pruning" by crop field areas. The crop field areas used for this were the data indicated in the *Statistics of Cultivated and Planted Area* by MAFF.

$$A_{Tea} = (A_{AP} + A_{LF} + A_{MP}/5) \times 10 \times Area$$

A_{Tea} : Nitrogen amount in crop residue plowed into soils [kg-N] (Tea)
A_{AP} : Nitrogen amount included in residue by autumn pruning [kg-N/10a]
A_{LF} : Nitrogen amount included in residue by leaf fall [kg-N/10a]
A_{MP} : Nitrogen amount included in the residue by medium pruning [kg-N/10a]
Area : Area planted of tea [ha]

Table 5-64 Amount of nitrogen content included in tea residue of branch pruning

Kind of branch pruning		Amount of Nitrogen content [kg-N/10a]	Reference
Autumn pruning	Annual	7.7	Hoshina et al. (1982), Kinoshita and Tsuji (2005), Tachibana et al. (1996)
Medium pruning	Once in five years	19.4	Ohta et al. (1996)
Leaf fall	Annual	11.5	Hoshina et al. (1982)

➢ *Vegetables, sugarcane and sugar beet*

The amount of nitrogen in each crop residue plowed into soil were calculated by multiplying nitrogen content in residue per crop yield calculated from Matsumoto (2000) by annual crop yield (by *Statistics of Cultivated and Planted Area* or *Vegetable Production and Shipment Statistics*) by the fraction of above-ground residue removed and fraction burnt on field (after consideration of Combustion Factor).

For the amount of nitrogen in crop residue plowed into soil, the data of the *Document of Kagoshima prefectural Institute for Agricultural Development* was used for sugarcane, and the data of *Hokkaido Fertiliser Recommendations 2010* was used for sugar beets, potato, Japanese radish and onion, and the data of Owa (1996) was used for Chinese cabbage and lettuce.

When any crop has no available data with respect to nitrogen content included in crop residue per crop yield, the value for a similar type of crop was used. The same values were adopted for all fiscal years.

$$A_{Vegetable} = Y \times (1 - Frac_{Remove} - Frac_{burnt} \times CF) \times N_R$$

$A_{Vegetable}$: Nitrogen amount in crop residue plowed into soils (Vegetables, Sugarcane, Sugarbeet) [t-N]
Y : Yield [t]
$Frac_{Remove}$: Fraction of above-ground residue removed [%]
$Frac_{burnt}$: Fraction burnt on field [%]
CF : Combustion factor
N_R : Nitrogen contents in crop residue [%: kg-N/kg]

Table 5-65 Fraction of above-ground residue removed ($Frac_{Remove}$), Fraction burnt on field ($Frac_{burnt}$), Combustion factor (CF), and Ratio of below-ground residues to above-ground biomass ($RS_{(T)}$) for main crops

Crop type	Fraction of above-ground residue removed ($Frac_{Remove}$)	Fraction burnt on field ($Frac_{burnt}$)	Combustion factor (CF)	Raito of above-ground residues ($RS_{(T)}$)
Vegetables and sugar beet	47%	7%	0.85[4)]	—
Tubers and roots, other crops (buckwheat, tobacco, etc.)	47% [1)]	7% [1)]	0.85[4)]	Tubers and roots: 0.20 Other crops: 0.22 [8)]
Sugarcane	47% [1)]	7% [1)]	0.80[5)]	—
Green manure crops	0% [2)]	0% [2)]	—	Perennial grasses:0.80 Sorghum: 0.24 [9)]
Feed crops	100% [3)]	0% [3)]	—	
Wheat, barley, rye and oats	See Table 5-67	See Table 5-67	0.90 [6)]	Wheat: 0.24 [56)] Barley: 0.22 Rye: 0.25 [10)] Oats: 0.25
Pulse	13%	12%	0.85[7)]	0.19 [7)]
Maize	47% [1)]	7% [1)]	0.80	Maize: 0.22

Reference: $Frac_{Remove}$, $Frac_{burnt}$: *Survey of Greenhouse Gas Emissions from Soils and Soil Carbon Sequestration*
CF, $RS_{(T)}$: The *2019 Refinement*
Note:1) Value of vegetables, 2) All residues are plowed into soil, 3) All above-ground biomass removed as for feed, 4) Value of vegetables, 5) Value of maize and/or sugarcane, 6) Value of wheat, 7) Value of Soybean, 8) Value of generic grains, 9) Average value between maize and oats, 10) Substituted by oats

Table 5-66 N contents of above- and below-ground residues (N_{AG}, N_{BG}) for main crops

Crop type	N contents of above-ground residues (N_{AG})	N contents of below-ground residues (N_{BG})	Note
Rice (above ground)	Straw: 0.541% a) Chaff: 0.423% a)	—	Wet weight
Rice (below ground)	—	0.9% 1)	Dry weight
Vegetables	Japanese radish: 0.093% b), c) Radish: 0.086% e) Burdock: 0.584% e) Chinese cabbage: 0.071% c) Cabbage: 0.183% e) Spinach: 0.106% e) Lettuce: 0.164% c) Welsh onion: 0.086% e) Onion: 0.019% b), c) Cucumber: 0.248% e) Eggplant: 0.235% e) Green beans: 0.605% e) Melon, Watermelon: 0.240% e)		Wet weight
Sugar beet	0.095% b), c)		
Sugarcane	0.548% d)		Dry weight
Green manure crops and Feed crops	Perennial grasses: 1.5% z) Sorghum: 0.7% z)	Perennial grasses:1.2% z) Sorghum: 0.6% z)	
Wheat	0.43% e)	0.9% 2)	
Barley	Two-row: 2.14% e) Six-row: 0.31% e)	1.4% z)	
Rye	0.50% z)	1.1% z)	
Oats	0.70% z)	0.8% z)	
Maize	1.64% e)	0.7% z)	
Soybean	0.65% e)	0.8% z)	
Adzuki beans	0.84% e)	1.0% 3)	
Potatoes	2.42% e)	1.4% z)	

Reference: a) Date (1988)
b) Hokkaido Government, Department of Agriculture (2010)
c) Owa (1996)
d) Document of Kagoshima prefectural Institute for Agricultural Development
e) Matsumoto (2000)
z) The *2019 Refinement*

Note:1) Substituted by wheat in the *2006 IPCC Guidelines*
2) Value of wheat in the *2006 IPCC Guidelines*
3) Substituted by value of dry bean in the *2006 IPCC Guidelines*

- ***Feed and green manure crops, wheat, barley, orts, rye, maize, pulse, tubers and roots (e.g. potato, sweet potato), and other crops (e.g. buckwheat, tobacco)***

Activity data were calculated by the method shown in the following equation in accordance with the *2006 IPCC Guidelines*. For parameters, values in Table 5-65 and Table 5-66 were used. The proportion removed from field and burned in field for wheat, barley, rye and oats were determined on the basis of data of crop area by treating method for wheat straw surveyed by MAFF as shown in the Table 5-67. Since the survey data are not available in and before FY2006, the values for FY2007 were applied to these years. Fraction renewed of field ($Frac_{Renew}$) was determined for feed crops as 3% by expert judgment, taking into account variable survey results. For other crops, it was calculated as 100% renewed.

$$A = \sum_T \left\{ \begin{array}{c} \left(Area_{(T)} - Area_{burnt(T)} \times CF\right) \times Frac_{Renew(T)} \times \\ \left[AG_{DM(T)} \times N_{AG(T)} \times \left(1 - Frac_{Remove(T)}\right) + \left(AG_{DM(T)} \times 1000 + Crop_{(T)}\right) \times R_{BG-BIO(T)} \times N_{BG(T)}\right] \end{array} \right\}$$

$$Area_{burnt(T)} = Area_{(T)} \times Frac_{burnt(T)}$$

A : Nitrogen amount in crop residue plowed into soils [t-N]

$Area_{(T)}$: Area planted of crop T [ha]
$Area_{burnt(T)}$: Area burnt of crop T [ha]
CF : Combustion factor
$Frac_{Renew(T)}$: Fraction renewed of field of crop T [%]
$AG_{DM(T)}$: Dry matter of above-ground residues of crop T [Mg/ha]
$N_{AG(T)}$: N contents of above-ground residues of crop T [%]
$Frac_{Remove(T)}$: Fraction removed from field of crop T [%]
$Crop_{(T)}$: Dry matter in yield of crop T [kg/ha]
$R_{BG\text{-}BIO(T)}$: Ratio of below-ground residues to above-ground biomass of crop T [%]
$N_{BG(T)}$: N contents of below-ground residues of crop T [%]
$Frac_{burnt(T)}$: Fraction burnt on field of crop T [%]

Table 5-67 Proportion removed from field and burned in field for wheat, barley, rye and oats [%]

Item	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Proportion removed from field	32.1	32.1	32.1	32.1	37.8	41.0	37.9	37.2	36.3	39.8	39.9	41.6
Proportion burned in field	13.5	13.5	13.5	13.5	10.6	8.8	8.0	7.6	8.5	8.0	7.2	5.7

Note: Calculated from each prefecture data

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For uncertainty of the emission factor, default values (-70% to +200%) described in the *2006 IPCC Guidelines* were applied. For activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be -70% to +200%.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

d) Category-specific QA/QC and Verification

Same as Sheep, Swine, Buffalo, Goats & Horses (3.A.2., 3.A.3., 3.A.4.-) in Enteric Fermentation. See section 5.2.2. d).

At the Breakout Group on Agriculture of the Committee for GHG Emissions Estimation Method in 2012, nitrogen content for rice were checked in detail. As a result, the group decided to use data by Date (1988), which were separated into rice straw and chaff and were considered as the most appropriate to represent Japan's actual circumstances because the data are intermediate among the various regional data in Japan.

e) Category-specific Recalculations

Since the amount of rice chaff plowing for FY2023 was updated/revised, the emissions for FY2023 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

Discussion whether it will be possible to establish country-specific emission factors for Japan has been conducted.

5.5.1.5. Mineralization/Immobilization Associated with Loss/Gain of Soil Organic Matter (3.D.1.e.)

a) Category Description

This section estimates N_2O emissions by nitrogen mineralization in loss of carbon oxidized by organic matter in mineral soil.

b) Methodological Issues

- ***Estimation Method***

Based on Equation 11.1 and Equation 11.8 described in section 11.2.1. in Vol.4 of the *2006 IPCC Guidelines*, N_2O emission factor per unit area [kg-N_2O-N/ha] is set for calculation. The N_2O emission factors are country-specific values by region by land use type. Activity data are the area of cropland remaining cropland and grassland remaining grassland in mineral soil.

$$N_2O\text{-}N_{direct\_N_{Mineral_{i,j}}} = EF_{N2O\_N_{i,j}} \times A_{i,j}$$

$N_2O\text{-}N_{direct\text{-}NMineral_{i,j}}$	: Direct N_2O emissions from N mineralization as a result of loss of organic matter in mineral soil [kg-N_2O-N]
EF	: N_2O emission per area derived from loss of organic matter [kg-N_2O-N/ha]
A	: Mineral soil area with soil carbon loss as a result of loss of soil organic matter [ha]
i	: Land use type of land (paddy fields, upland fields, grass land)
j	: Regions (Hokkaido, Tohoku, Kanto, Hokuriku, Tokai/Kinki, Chugoku/Shikoku, Kyushu/Okinawa)

- ***Emission Factors***

The emission factor is established by Shirato et al. (2021). The details of the estimation are shown in LULUCF sector (6.14.b)).

Table 5-68 N_2O emission factor by mineralization for paddy field, common upland field and grassland by each region [kg N_2O-N/ha/yr]

Region	Paddy field	Upland field	Grassland
Hokkaido	0.244	0.210	0.206
Tohoku	0.269	0.189	0.187
Kanto	0.291	0.166	0.178
Hokuriku	0.265	0.167	0.199
Tokai and Kinki	0.284	0.172	0.195
Chugoku and Shikoku	0.307	0.200	0.191
Kyusyu and Okinawa	0.310	0.197	0.173

Reference: Shirato et al. (2021)

- ***Activity Data***

The area of plowed mineral soil was established by subtracting the area of organic soils (peat soil and muck soil) in paddy fields common upland fields and grassland by region in Japan from the cultivated areas of paddy fields and common upland fields, obtained from the *Statistics of Cultivated and Planted Area* (MAFF). Lands of mineral soil converted to paddy field, upland field and grassland are estimated in LULUCF sector. For detail, see estimation method described in LULUCF sector (6.6.1 b) 2) “Activity Data” below).

Table 5-69 Intended areas of mineral soil in Agriculture sector [kha]

Item	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Intended paddy field	2,630	2,572	2,499	2,417	2,358	2,321	2,300	2,222	2,205	2,189	2,169	2,149
Hokkaido	190	189	187	180	178	178	178	176	176	176	176	175
Tohoku	575	580	577	564	557	541	535	520	517	514	508	504
Kanto	485	476	465	445	429	422	418	403	399	396	393	390
Hokuriku	317	305	296	288	282	279	278	273	272	271	270	268
Tokaiand Kinki	366	351	337	325	313	309	305	293	291	288	285	282
Chugoku and Shikoku	338	323	303	291	282	277	274	262	259	255	252	248
Kyusyu and Okinawa	360	348	334	324	317	315	313	296	292	289	285	282
Intended upland field	1,163	1,115	1,100	1,105	1,124	1,122	1,115	1,089	1,084	1,080	1,075	1,071
Hokkaido	389	367	371	380	394	396	398	402	402	402	402	402
Tohoku	135	132	129	129	131	129	128	124	123	123	122	123
Kanto	291	286	287	284	282	278	273	260	258	256	254	252
Hokuriku	23	21	21	22	24	25	25	25	24	24	24	24
Tokaiand Kinki	55	53	53	56	58	60	60	59	59	59	59	58
Chugoku and Shikoku	59	56	50	50	53	53	52	49	48	47	46	45
Kyusyu and Okinawa	211	201	189	184	182	180	178	170	169	168	167	166
Intended grassland	3.93	9.02	11.78	13.37	14.47	22.54	21.07	14.26	14.23	14.20	14.19	14.14
Hokkaido	3.82	8.60	11.11	12.52	12.81	14.68	18.23	13.25	13.23	13.21	13.22	13.21
Tohoku	0.11	0.40	0.54	0.64	1.16	5.29	1.91	0.66	0.66	0.65	0.64	0.63
Kanto	0.003	0.009	0.03	0.04	0.10	0.54	0.19	0.09	0.09	0.09	0.09	0.09
Hokuriku	0.004	0.006	0.01	0.01	0.03	0.14	0.05	0.02	0.02	0.02	0.02	0.02
Tokaiand Kinki	0.0003	0.00007	0.004	0.010	0.03	0.15	0.05	0.02	0.02	0.02	0.02	0.02
Chugoku and Shikoku	0	0	0.006	0.007	0.03	0.18	0.07	0.03	0.03	0.03	0.03	0.03
Kyusyu and Okinawa	0	0.01	0.08	0.15	0.31	1.57	0.56	0.19	0.18	0.18	0.16	0.14

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the emission factors, uncertainty (paddy field 2.4%, upland field 2.9%) was estimated from standard deviation described in the reference of EFs, Shirato et al. (2021) was applied. For activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be 2.4%.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

d) Category-specific QA/QC and Verification

Same as Sheep, Swine, Buffalo, Goats & Horses (3.A.2., 3.A.3., 3.A.4.-) in Enteric Fermentation. See section 5.2.2. d).

e) Category-specific Recalculations

Since the mineral soil area associated with land use conversion in LULUCF sector was changed, the emissions for the whole time-series were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

5.5.1.6. Cultivation of Organic Soils (3.D.1.f.)

a) Category Description

In Japan, organic soil mainly occurs in Hokkaido. In Japanese GHG inventory, two categories of soil

type, “muck soil” and “peat soil”, are treated as organic soils. In Japan, the creation of farmland on organic soils was mostly completed by the 1970s, and in general farmers till land that has had soil dressing.

b) Methodological Issues

- ***Estimation Method***

Emissions of N_2O from the plowing of organic soil were calculated by multiplying the area of the plowed organic soil of paddy field, upland field, and grassland by the emission factor in accordance with the *2006 IPCC Guidelines*.

$$E = EF \times A \times 44 / 28$$

E	: N_2O emission associated with the plowing of organic soils [kg-N_2O]
EF	: N_2O emission factor for plowing of organic soils [kg-N_2O-N/ha]
A	: Area of plowed organic soils [ha]

- ***Emission Factors***

For paddy field cultivation in organic soils, it is known that N_2O emission in paddy field is lower than the one in upland field. In Japan, Nagata and Sameshima (2006) observed N_2O emissions for paddy field of organic soil in Hokkaido, but the observations included emissions from applied nitrogen. Therefore, country-specific emission factor is determined to be 0.30 [kg-N_2O-N/ha/year] by deducting emission for applied fertilizer (estimated from country-specific emission factor of fertilizers (0.31% [% : kg-N_2O-N/kg-N]) indicated in Table 5-51 above).

For upland field and grassland (pastureland) cultivation, default values of 13 [kg-N_2O-N/kg-N] and 8.2 [kg-N_2O-N/kg-N] indicated in the *2019 Refinement* were used respectively.

- ***Activity Data***

The area of organic soil was obtained from the value calculated in LULUCF sector. For 1992, 2001 and 2010 when area data by soil type is available, the proportion of soil categorized in organic soil was estimated from area data by soil types, land categories and prefectures, and the proportion was multiplied by area by land categories and prefectures to obtain organic soil area. For other years, organic soil area was estimated by adjusting constant rate of converted land area to the area in 1992, 2001 and 2010.

Plowed area of organic soil includes all areas of organic soil for rice field and upland field and the renewed pasture lands, while organic soils for orchard, grazed meadow and wild land are not included. This is because orchard, grazed meadow and wild land are not plowed. (see 6.7.1. Grassland remaining Grassland)

The renewal of grassland is the maintenance work with re-sowing and re-plowing which is done once in several years. Annual plowed grassland area of organic soil is calculated by multiplying the annual renewal ratios by organic soil areas of grassland. For annual renewal ratio of grassland, a report of a study result by Hatano (2017) was utilized. The result by Hatano mentioned annual renewal ratios of grassland for categorized two areas, “Hokkaido” and “other areas” from 2006 to 2015. Averaged annual renewal ratios from 2006 to 2010 for each area (Hokkaido: 3.0%, other area: 1.3%) were substituted for the ratios before FY2006 and since FY2016.

Table 5-70 Annual renewal ratio of grassland

Fiscal year	Before 2006	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	Since 2016
Hokkaido	3.0%	2.5%	2.8%	3.0%	3.7%	2.9%	3.5%	3.6%	3.3%	3.9%	4.1%	3.0%
Other area	1.3%	1.0%	1.2%	1.0%	1.4%	2.1%	3.8%	15.7%	9.6%	5.2%	3.5%	1.3%

Reference: Hatano (2017)

Table 5-71 Intended areas of organic soil in the agriculture sector [kha]

Item	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Intended paddy field	131.6	129.8	129.1	127.3	125.3	125.1	125.2	125.2	125.1	125.0	125.0	125.0
Intended upland field	16.4	16.7	17.0	16.9	16.8	16.6	16.5	16.4	16.3	16.2	16.2	16.2
Intended grassland (Hokkaido)	1.1	1.2	1.2	1.2	1.1	1.3	1.6	1.2	1.2	1.2	1.2	1.2
Intended grassland (other area)	0.005	0.004	0.003	0.003	0.004	0.018	0.006	0.002	0.002	0.002	0.002	0.002

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For uncertainty of the emission factor, default values (-75% to +200%) described in the *2006 IPCC Guidelines* were applied. For activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be -75% to +200%.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Annex 4.

The country-specific emission factor (CSEF), 0.30 [kg-N_2O-N/ha/yr], from paddy fields with organic soil is set based on the actual measurement values of N_2O emissions from the paddy fields with peat soil in Hokkaido (Nagata and Sameshima, 2006). N_2O emissions from the paddy fields with peat soil were measured on 8 observation points and the range of emission measurement values were -0.28 to 1.27 [kgN_2O-N/ha/yr]. For setting the CSEF, emissions from fertilization were deducted because fertilizers were applied on those observation points. Emission estimation values of N_2O from fertilization to the paddy fields were in the range between 0.11 to 0.29 [kgN_2O-N/ha/yr]. The N_2O emission factor from the paddy fields with peat soil, therefore, is calculated as 0.30 [kg-N_2O-N/ha/yr].

The default emission factor for upland fields 13 [kg-N_2O-N/ha/yr] (the *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*: Wetlands, Chapter 2, Table 2.5.) is in the range between 2.87 to 13.60 [kg-N_2O-N/ha/yr] which were the values from the measurements conducted in 9 observation points of upland fields with peat soil (Nagata and Sameshima, 2006).

e) Category-specific Recalculations

Since the organic soil area associated with land use conversion in LULUCF sector was changed, the emissions of FY1990, FY1991, and from FY2011 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

5.5.2. Indirect N_2O Emissions from Managed Soils (3.D.2.)

Nitrogen compounds such as ammonia, that volatilize and are released into the atmosphere from synthetic fertilizers applied to agricultural soils, organic fertilizers applied to agricultural soils and the grazing livestock manure applied to soil are deposited on soil as the results of various actions, including turbulent diffusion, molecular diffusion, effect of electrostatic forces, chemical reactions, plant respiration, and being washed out of the air by rain. In this section, the amount of N_2O generated by microbe activity on the deposited nitrogen compounds was calculated.

N_2O is generated by the action of microbes on nitrogen that leaches or runs off as nitrate from synthetic fertilizers, organic fertilizers, etc.

5.5.2.1. Atmospheric Deposition (3.D.2.a.)

a) Category Description

This section provides the estimation methods for N_2O indirect emissions caused by atmospheric deposition of nitrogen compounds volatilized as NH_3 and NOx from synthetic fertilizers applied to soil, organic fertilizers applied to soil, and the grazing livestock manure applied to soil.

b) Methodological Issues

- ***Estimation Method***

N_2O emissions have been calculated in accordance with decision tree of the *2019 Refinement* (Vol. 4, Page 11.23, Fig11.3).

$$E = EF \times A \times 44 / 28$$

E	: N_2O emissions from atmospheric deposition [kg-N_2O]
EF	: N_2O emission factor for atmospheric deposition [kg-N_2O-N/ kg-NH_3-N+NO_X-N volatilized]
A	: Total nitrogen amount volatilized as NH_3 and NOx from synthetic fertilizers, organic fertilizers, and deposition by grazing livestock [kg-NH_3-N+NO_x-N]

- ***Emission Factors***

0.014 [kg-N_2O-N/kg-NH_3-N & NO_X-N volatilized] (the *2019 Refinement,* Vol.4 Table11.3).

- ***Activity Data***

As described in the following equation, the activity data are composed of the "nitrogen amount volatilized as NH_3 and NOx from synthetic fertilizers" applied to soil by type of fertilizer, organic fertilizers applied to soil, and the excretion deposited by grazing livestock. The "nitrogen amount volatilized NH_3 and NOx in process of livestock manure management" are reported in 3.B.5.

$$A = \sum_t (F_{SNt} \times Frac_{GASFt}) + [\ (F_{ON} + F_{PRP}) \times Frac_{GASM3}]$$

A	: Total N amount volatilized as NH_3 and NOx from synthetic fertilizers, organic fertilizers, and excretion by grazing livestock [kg-NH_3-N+NO_x-N]
F_{SNt}	: N amount for synthetic fertilizers t applied to agricultural soil [kg-N]
$Frac_{GASFt}$	: Fraction of volatilization as NH_3 and NOx from synthetic fertilizer applied to agricultural soil [(kg-NH_3-N + NO_X-N)/kg-N]
F_{ON}	: N amount for organic N fertilizers applied to agricultural soil [kg-N]
F_{PRP}	: N amount in urine and dung deposited by grazing livestock [kg-N]
$Frac_{GASM3}$	: Fraction of volatilization as NH_3 and NOx from applied organic N fertilizer (F_{ON}) and of urine and dung N deposited by grazing animals (F_{PRP}) [(kg-NH_3-N + NO_X-N)/kg-N]

➢ ***N amount volatilized as NH_3 and NOx from synthetic fertilizers applied to soil ($F_{SN} \times Frac_{GASF}$)***

For N amount of synthetic fertilizer applied to agricultural soil (F_{SNt}), the demand for nitrogenous fertilizer described in *Yearbook of Fertilizer Statistics (Pocket Edition)* before FY2017 and the data surveyed by Agricultural Technology Promotion Division, MAFF since FY2017 was used for estimation. To estimate the value of synthetic fertilizer applied to agricultural soil (F_{SNt}), amount of synthetic fertilizer applied to forest were subtracted from this demand for nitrogenous fertilizer (Table 5-72). The default values, indicated in Table 5-73, given in the *2019 Refinement* were used for the fraction of volatilization ($Frac_{GASFt}$). Fractions of N volatilized from each type of fertilizer are provided in the *2019 Refinement*, although they are not disaggregated in the *2006 IPCC Guidelines*. Using the default EFs from the *2019 Refinement* leads to estimates that reflect the circumstances of Japan more accurately because those EFs reflect the types of fertilizer used.

Table 5-72 Amount of synthetic fertilizer applied to agricultural soil by type (excluding forest application)
[t-N]

Type	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Urea-based	115,620	107,917	106,712	125,170	117,267	136,391	136,622	99,818	82,724	68,077	94,326	94,326
Ammonium-based	465,738	393,888	363,180	286,181	245,364	239,123	208,505	227,440	305,524	270,107	176,873	176,873
Ammonium-nitrate-based	8,010	7,090	3,947	2,207	989	1,105	713	1,143	1,756	2,494	558	558
Other	22,300	18,374	13,338	57,410	45,778	33,105	26,325	26,438	27,444	36,130	6,322	6,322

Reference: Yearbook of Fertilizer Statistics (Pocket Edition) before FY2017
The data surveyed by Agricultural Technology Promotion Division, MAFF since FY2017

Table 5-73 Fraction of nitrogen volatilized from synthetic fertilizers and organic fertilizers as ammonia or nitrogen oxides [kg-NH_3-N + NO_X-N/kg-N]

	Type	Value
$Frac_{GASF}$	Urea	0.15
	Ammonium-based	0.08
	Ammonium-nitrate-based	0.05
	For other type of N fertilizer	0.11
$Frac_{GASM}$	All organic N fertilizer	0.21

Reference: the *2019 Refinement*, Vol. 4, Table 11.3

➢ ***N amount volatilized as NH_3 and NOx from organic fertilizers applied to agricultural soil and from excretion by grazing livestock ($(F_{ON} + F_{PRP}) \times Frac_{GASM3}$)***

For nitrogen amount in organic N fertilizers applied to agricultural soil (F_{ON}), the data described in the "Organic N Fertilizers (3.D.1.b.)" were used. For the nitrogen amount in excretion from grazing livestock (F_{PRP}), the calculated data in 3.B. were used. For fraction of nitrogen volatilized as NH_3 and NOx ($Frac_{GASM3}$), default value ($Frac_{GASM}$ = 0.21) of the *2019 Refinement* indicated in Table 5-73 above was used.

Table 5-74 Amount of nitrogen that volatilizes as ammonia and nitrogen oxides from synthetic fertilizers, livestock manure, and human waste [t (NH_3-N+NOx-N)]

Item	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
From synthetic N fertilizers applied to soil ($F_{SN} \times Frac_{GASF}$)	57,455	50,074	46,726	48,095	42,304	43,285	40,105	36,133	39,957	35,919	29,022	29,022
From organaic N fertilizers ($F_{ON} \times Frac_{GASM3}$)	103,833	99,826	95,607	85,764	88,519	86,802	94,062	80,401	79,123	74,473	71,627	70,459
From excretion from grazing livestock ($F_{PRP} \times Frac_{GASM4}$)	2,727	2,696	2,506	2,334	2,210	2,052	1,955	1,869	1,908	2,057	2,148	2,204
Total (nitrogen amount volatilized as ammonia and nitrogen oxides (A)	164,016	152,596	144,839	136,193	133,034	132,139	136,122	118,403	120,988	112,449	102,798	101,685

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For uncertainty of the emission factor, uncertainty (-106% to +447%) was calculated by synthesis of defaults of each parameter described in the *2006 IPCC Guidelines*. For activity data, 9% for population of broiler given in the *Livestock Statistics* was applied as substitution. As a result, the uncertainties of the emissions were determined to be -106% to +447%.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

d) Category-specific QA/QC and Verification

Same as Sheep, Swine, Buffalo, Goats & Horses (3.A.2., 3.A.3., 3.A.4.-) in Enteric Fermentation. See section 5.2.2. d).

e) Category-specific Recalculations

Since the demand of nitrogen fertilizer from FY2017 to FY2023 was revised, the emissions from inorganic fertilizers from FY2017 to FY2023 were recalculated. Since the population of dairy cattle by calving in *Record of Dairy Herd Performance Test*, averaged age in days of shipment in *The report of the fact-finding survey for pig farming*, egg production and feed intake per day for hen, and crop residues for composting sub-materials for FY2023 were updated, the emissions from organic N fertilizers and that from excretion from grazing livestock for FY2023 were recalculated. Since the area of orchard for FY2022, and FY2023 and the distribution amount of animal and plant derived fertilizer from FY2022 and FY2023 were updated and revised, the emissions from organic fertilizers from FY2022 and FY2023 were recalculated. Since the *Survey of actual conditions for livestock manure management system and others, 2024* (MAFF, 2025) was applied, the emissions from livestock manure from FY2020 were recalculated. Due to the revision of application of the *Japanese Feeding Standards for Beef Cattle*, the emissions from organic fertilizers and grazing livestock for all fiscal years were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

Discussion for the establishment of country-specific emission factors and the ratios of volatile nitrogen compounds has been conducted.

5.5.2.2. Nitrogen Leaching and Run-off (3.D.2.b.)

a) Category Description

This section provides the estimation methods for N_2O emissions from Nitrogen Leaching and Run-off.

b) Methodological Issues

- ***Estimation Method***

N_2O emissions were calculated according to the decision tree in the *2019 Refinement* (Vol. 4, Page 11.23, Fig11.3), by multiplying default emission factors by the amount of nitrogen that leached and run-off.

$E = EF \times A \times 44 / 28$

E	: N_2O emissions from N leaching and run-off [kg-N_2O]
EF	: N_2O emission factor for N leaching and run-off [kg-N_2O-N/kg-N]
A	: Total nitrogen amount for N leaching and run-off from synthetic fertilizers, organic fertilizers, etc. [kg-N]

- ***Emission Factors***

0.011 [kg-N_2O-N/kg-N] (default value, the *2019 Refinement*, Vol. 4, Table11.3).

- ***Activity Data***

As described in the formula below, activity data was composed of each nitrogen amount of leaching and run-off by synthetic fertilizers, organic fertilizers, excretion deposited by grazing livestock, crop residue, and carbon loss by mineralization. Each AD was calculated by multiplying the default value of fraction of leaching and run-off ($Frac_{LEACH}$, 0.24 [kg-N/kg-N]) given in the *2019 Refinement* by the amount of nitrogen calculated in 3.D.1.a. to 3.D.1.e. above. For $Frac_{LEACH}$, the *2019 Refinement* value was used because it was established from a larger data set provided by research covering wide ranges of climate zone, crop types, livestock species and types of fertilizers, thus it is more accurate than that from the *2006 IPCC Guidelines*.

$$A = (F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM}) \times Frac_{LEACH}$$

A	: Total nitrogen amount for N leaching and run-off from synthetic fertilizers, organic fertilizers, etc. [kg-N]
F_{SN}	: Nitrogen amount in synthetic fertilizers applied to agricultural soil [kg-N]
F_{ON}	: Nitrogen amount in organic N fertilizers applied to agricultural soil [kg-N]
F_{PRP}	: Nitrogen amount in urine and dung deposited by grazing livestock [kg-N]
F_{CR}	: Nitrogen amount in crop residue plowed into soil [kg-N]
F_{SOM}	: Nitrogen amount in mineralization in loss of carbon oxidized by organic matter in mineral soil [kg-N]
$Frac_{LEACH}$	: Fraction of nitrogen leaching and run-off in each activity [kg-N/kg-N]

Table 5-75 Total nitrogen amount for N leaching and run-off from synthetic fertilizers, organic fertilizers, etc. [t (NH_3-N+NO_X-N)]

Item	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
From synthetic N fertilizers applied to soil (F_{SN}×$Frac_{LEACH}$)	146,800	126,545	116,922	113,032	98,255	98,334	89,319	85,161	100,187	90,434	66,739	66,739
From organaic N fertilizers (F_{ON}×$Frac_{LEACH}$)	118,667	114,087	109,266	98,016	101,165	99,202	107,499	91,887	90,426	85,113	81,860	80,518
From excretion from grazing livestock (F_{PRP}×$Frac_{LEACH}$)	3,117	3,081	2,864	2,667	2,526	2,345	2,235	2,136	2,181	2,350	2,455	2,519
From crop residue (F_{CR}×$Frac_{LEACH}$)	36,041	35,620	37,982	34,989	30,032	30,451	29,358	27,792	27,965	27,122	26,464	25,864
From mineralization (F_{SOM}×$Frac_{LEACH}$)	66,321	64,680	62,933	61,186	60,039	59,281	58,757	56,770	56,348	55,960	55,471	55,018
Total (nitrogen amount by leaching and run-off) (A)	370,947	344,012	329,967	309,890	292,017	289,612	287,168	263,746	277,107	260,979	232,989	230,658

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For uncertainty of the emission factor, uncertainty (-115% to +287%) was calculated by synthesis of defaults of each parameter described in the *2006 IPCC Guidelines*. For activity data, 9% was applied as same as “Atmospheric Deposition” above. As a result, the uncertainties of the emissions were determined to be -115% to +287%.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

d) Category-specific QA/QC and Verification

Same as Sheep, Swine, Buffalo, Goats & Horses (3.A.2., 3.A.3., 3.A.4.-) in Enteric Fermentation. See section 5.2.2. d).

e) Category-specific Recalculations

Since the demand of nitrogen fertilizer from FY2017 to FY2023 was revised, the emissions from inorganic fertilizers since FY2017 to FY2023 were recalculated. Since the population of dairy cattle by calving in *Record of Dairy Herd Performance Test*, averaged age in days of shipment in *The report of the fact-finding survey for pig farming*, egg production and feed intake per day for hen, crop residues for composting sub-materials, and the amount of rice straw and rice chaff plowed into soil for FY2023 were updated, the emissions from organic N fertilizers, excretion from grazing livestock, and crop residue for FY2023were recalculated. Since the area of orchard for FY2022, and FY2023 and the distribution amount of animal and plant derived fertilizer for FY2022 and FY2023 were updated and revised, the emissions from organic fertilizers for FY2022 and FY2023 were recalculated. Due to the revision of application of the *Japanese Feeding Standards for Beef Cattle*, the emissions from organic fertilizers and grazing livestock for all fiscal years were recalculated. Since the amount of rice chaff plowing for FY2023 was updated/revised, the emissions from crop residues for FY2023 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

Discussion for the establishment of country-specific emission factors and the fraction of nitrogen leaching and run-off has been conducted.

5.6. Prescribed Burning of Savannahs (3.E.)

This source is given in the *2006 IPCC Guidelines* as “being for the purpose of managing pastureland in sub-tropical zones”. There is no equivalent activity in Japan, and this source has been reported as “NO”.

5.7. Field Burning of Agricultural Residues (3.F.)

a) Category Description

Incomplete burning of crop residues in field releases CH_4 and N_2O into the atmosphere. CH_4 and N_2O emissions from this source are calculated and reported in this category.

CH_4 and N_2O emissions from Field Burning of Agricultural Residues in FY2024 are 26.1 kt-CO_2 eq. and 7.2 kt-CO_2 eq., comprising 0.002% and 0.001% of total emissions (excluding LULUCF), respectively. The value represents a decrease by 66.6% and 68.5% for CH_4 and N_2O from FY1990, respectively.

Table 5-76 CH_4 and N_2O emissions from field burning of agriculture residues (3.F.)

Gas	Item		Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
CH_4	3.F.1. Cereals	Wheet	kt-CH_4	0.46	0.22	0.33	0.42	0.23	0.26	0.28	0.26	0.33	0.28	0.28	0.21
		Barley		0.12	0.07	0.07	0.06	0.05	0.04	0.04	0.04	0.05	0.05	0.04	0.03
		Maize		0.06	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03
		Rice		1.71	1.79	1.21	0.90	0.61	0.66	0.49	0.45	0.42	0.35	0.36	0.36
		Other cereals		0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	3.F.2. Pulses	Soybeans		0.11	0.05	0.10	0.10	0.10	0.09	0.11	0.10	0.11	0.11	0.12	0.12
		Other pulses		0.05	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	3.F.3. Tubers and roots	Potatoes		0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		Sugarbeet		0.04	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.03	0.04
		Other tubers and roots		0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
	3.F.4.	Sugarcane		0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	3.F.5. Other	Vegetables		0.10	0.09	0.09	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06
		Other crops		0.03	0.03	0.02	0.01	0.01	0.01	0.01	0.005	0.005	0.004	0.004	0.003
	Total		kt-CH_4	2.78	2.47	2.01	1.76	1.22	1.29	1.16	1.08	1.14	1.02	1.01	0.93
			kt-CO_2 eq.	77.9	69.1	56.2	49.2	34.3	36.0	32.5	30.3	31.9	28.4	28.4	26.1
N_2O	3.F.1. Cereals	Wheet	kt-N_2O	0.0120	0.0057	0.0087	0.0109	0.0059	0.0066	0.0073	0.0067	0.0085	0.0074	0.0072	0.0054
		Barley		0.0031	0.0019	0.0019	0.0016	0.0012	0.0011	0.0010	0.0011	0.0013	0.0012	0.0011	0.0007
		Maize		0.0016	0.0012	0.0011	0.0010	0.0009	0.0009	0.0009	0.0009	0.0008	0.0008	0.0008	0.0008
		Rice		0.0581	0.0607	0.0410	0.0306	0.0206	0.0222	0.0166	0.0152	0.0143	0.0119	0.0123	0.0123
		Other cereals		0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0003	0.0003	0.0003	0.0002	0.0003
	3.F.2. Pulses	Soybeans		0.0027	0.0014	0.0026	0.0027	0.0027	0.0024	0.0028	0.0027	0.0029	0.0029	0.0031	0.0030
		Other pulses		0.0013	0.0010	0.0008	0.0007	0.0006	0.0006	0.0006	0.0005	0.0004	0.0005	0.0004	0.0004
	3.F.3. Tubers and roots	Potatoes		0.0009	0.0008	0.0007	0.0007	0.0006	0.0006	0.0006	0.0005	0.0005	0.0005	0.0005	0.0005
		Sugarbeet		0.0011	0.0010	0.0010	0.0011	0.0008	0.0009	0.0010	0.0010	0.0011	0.0009	0.0009	0.0009
		Other tubers and roots		0.0007	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0003	0.0003	0.0003	0.0003	0.0003
	3.F.4.	Sugarcane		0.0008	0.0007	0.0006	0.0005	0.0006	0.0005	0.0005	0.0006	0.0006	0.0005	0.0005	0.0006
	3.F.5. Other	Vegetables		0.0026	0.0024	0.0022	0.0020	0.0018	0.0018	0.0018	0.0017	0.0018	0.0017	0.0017	0.0016
		Other crops		0.0009	0.0007	0.0005	0.0004	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001
	Total		kt-N_2O	0.086	0.078	0.062	0.053	0.037	0.039	0.034	0.032	0.033	0.029	0.029	0.027
			kt-CO_2 eq.	22.74	20.73	16.35	13.98	9.69	10.22	9.01	8.39	8.72	7.72	7.74	7.16
Total of all gases			kt-CO_2 eq.	100.68	89.81	72.57	63.20	43.96	46.21	41.49	38.74	40.61	36.15	36.15	33.22

b) Methodological Issues

- ***Estimation Method***

CH_4 and N_2O emissions were calculated by using the method indicated in the *2006 IPCC Guidelines.*

$$E = A \times M_B \times C_f \times G_{ef} \times 10^{-3}$$

E : CH_4 and N_2O emissions from field burning of agriculture residues [t-CH_4 or t-N_2O]
A : Area burnt [ha]
M_B : Mass of fuel available for combustion [t/ha]
C_f : Combustion factor
G_{ef} : Emission factor [g-CH_4/kg or g-N_2O/kg]

- ***Emission Factors***

For rice straw, which has the highest CH_4 and N_2O emissions among the others in the category of field burning of agriculture residues, the emission factor was defined as the average of the values reported in Miura and Kanno (1997) and Hayashi et al. (2014). For other crops, the default value in *2006 IPCC Guidelines* was used.

Table 5-77 Emission factors for field burning

	CH_4 [g-CH_4/kg (dry weight)]	N_2O [g-N_2O/kg (dry weight)]	References
Rice straw	2.36	0.08	Average of Miura and Kanno (1997) and Hayashi et al. (2014)
Other crops	2.7	0.07	*2006 IPCC Guidelines*, Vol 4, Table 2.5

- ***Activity Data***

Parameters used in estimation are indicated in the Table 5-78 below. For proportion of burned residue and combustion factor, same values in Crop Residues (3.D.1.d.) were used. The proportion burned in field for wheat, barley, rye and oats were the same values as shown in Table 5-67.

Table 5-78 Proportion of burned residue on agricultural field, and Combustion factor

Crop	Proportion of burned residue	Combustion Factor (C_f)
Rice	—	0.80
Pulse	12% [1)]	0.85
Vegetable, Sugarbeet, Tuber crops (e.g. potato), Buckwheat, Canola seed, Konjac, Rush grass, Tabacco	7% [2)]	0.85
Maize, Sugarcane	7% [2)]	0.80
Wheat, Barley, Ray, Oats	See Table 5-67	0.90 [3)]

Reference: Proportion burned: *Survey of Greenhouse Gas Emissions from Soils and Soil Carbon Sequestration*
C_f: *2019 Refinement* Vol.4, Table 2.4
Note: 1) value of pulse, 2) value of vegetable, 3) value of wheat

For rice, amount of rice straw and rice chaff burned on crop field is surveyed by MAFF (Table 5-79). The amounts of burning residue of other crops were estimated by area data described in the *Crop Statistics* or the *Vegetable Production and Shipment Statistics*. The dry matter fraction (0.89) from the *2006 IPCC Guidelines* was used for converting the amount of residue in wet basis into that in dry basis.

Table 5-79 Amount of rice straw and rice chaff burned in crop field (Wet) [kt]

Item	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Rice straw	438.2	536.9	429.1	276.6	149.3	183.4	144.2	129.7	115.6	91.2	82.2	82.2
Rice chaff	581.3	528.3	291.3	260.3	212.9	206.6	147.5	137.1	135.1	118.0	133.8	133.8
Total	1,019.5	1,065.2	720.4	536.9	362.2	390.0	291.7	266.8	250.8	209.3	216.0	216.0

Reference: Calculated from each prefecture data

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For uncertainty of the emission factor, uncertainties (CH_4: 296%, N_2O: 300%) were calculated by synthesis of defaults of each parameter described in the *2006 IPCC Guidelines*. For activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be 296% for CH_4 and 300% for N_2O.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

d) Category-specific QA/QC and Verification

Same as Sheep, Swine, Buffalo, Goats & Horses (3.A.2., 3.A.3., 3.A.4.-) in Enteric Fermentation. See section 5.2.2. d).

e) Category-specific Recalculations

Since the amount of rice chaff burned for FY2023 was revised, the emissions for FY2023 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

5.8. Liming (3.G.)

a) Category Description

CO_2 are released into the air by application of limestone ($CaCO_3$) fertilizer and/or dolomite ($CaMg(CO_3)_2$) fertilizer via hydrogen carbonate ions (HCO_3^-) which is released in soil water. This category deals with CO_2 emissions from their agricultural lime application.

CO_2 emissions from this category in FY2024 were 205 kt-CO_2, comprising 0.02% of total emissions (excluding LULUCF). The value represents a decrease by 62.7% from FY1990.

Table 5-80 CO_2 emissions from agricultural lime application (3.G.)

Gas	Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
CO_2	3.G-Limestone	kt-CO_2	550	303	332	231	242	379	258	223	219	201	204	204
	3.G-Dolomite		0.3	0.5	0.5	0.6	1.0	1.1	0.8	0.8	2.0	1.9	1.4	1.4
	Total	kt-CO_2	550	304	333	231	243	380	259	224	221	203	205	205

b) Methodological Issues

- ***Estimation Method***

The Tier 1 method is used in accordance with the decision tree described in the *2006 IPCC Guidelines* (Vol.4, page 11.27, Figure 11.4).

$$E = (M_{Limestone} \times EF_{Limestone} + M_{Dolomite} \times EF_{Dolomite}) \times 44/12$$

E : Annual CO_2 emissions from agricultural lime application [t-CO_2]
$M_{Limestone}$: Annual amount of calcic limestone [t]
$EF_{Limestone}$: Emission factor of calcic limestone [t-C/t]
$M_{Dolomite}$: Annual amount of dolomite [t]
$EF_{Dolomite}$: Emission factor of dolomite [t-C/t]

- ***Emission Factors***

Limestone ($CaCO_3$): 0.12 [t-C/t] (default value, *2006 IPCC Guidelines*, Vol.4, page 11.29).

Dolomite ($CaMg(CO_3)_2$): 0.13 [t-C/t] (default value, *2006 IPCC Guidelines*, Vol.4, page 11.29).

- ***Activity Data***

The activity data were calculated by adding up lime production and import quantities as listed in *the Yearbook of Fertilizer Statistics (Pocket Edition)* published by the Association of Agriculture and Forestry Statistics before FY2017 and the data surveyed by Plant Products Safety Division, MAFF since FY2017. Based on expert judgment, all of the "Calcium carbonate fertilizer" and 70% of each of "Fossil seashell fertilizer", "Crushed limestone" and "Seashell fertilizer" and "Powdered fossil seashell" listed in the Yearbook were classified as calcic limestone ($CaCO_3$), and all of the "Magnesium carbonate fertilizer" and 74% of "Mixed magnesium fertilizer" as dolomite ($CaMg(CO_3)_2$).

Table 5-81 Amount of limestone and dolomite applied to agricultural soils [kt]

Item	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Applied Limestone	1,250	689	755	524	550	860	586	508	497	457	463	463
Applied Dolomite	0.7	1.1	1.1	1.4	2.0	2.2	1.7	1.8	4.3	4.1	2.8	2.8

Reference: Estimated from the data described in *Yearbook of Fertilizer Statistics (Pocket Edition)* and Plant Products Safety Division, MAFF

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For uncertainty of the emission factor, default values (50%) described in the *2006 IPCC Guidelines* was applied. For activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be 50%.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

d) Category-specific QA/QC and Verification

Same as Sheep, Swine, Buffalo, Goats & Horses (3.A.2., 3.A.3., 3.A.4.-) in Enteric Fermentation. See section 5.2.2. d).

e) Category-specific Recalculations

Since the amount of applied limestone and dolomite for FY2023 were updated, the emissions for FY2023 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

5.9. Urea Application (3.H.)

a) Category Description

CO_2 are released into the air by application of urea ($(NH_2)_2CO$) fertilizer via hydrogen carbonate ions (HCO_3^-) which is released in soil water. This category deals with estimation and reporting for this CO_2 emissions.

CO_2 emissions from this category in FY2024 were 148 kt-CO_2, comprising 0.01% of national total emissions (excluding LULUCF). The value represents a decrease by 18.4% from FY1990.

Table 5-82 CO_2 emissions from urea fertilizer (3.H.)

Gas	Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
CO_2	3.H. Urea fertilization	kt-CO_2	182	170	168	197	184	214	215	157	130	107	148	148

b) Methodological Issues

- ***Estimation Method***

The Tier 1 method is used in accordance with the decision tree described in the *2006 IPCC Guidelines* (Vol.4, p.11.33, Fig.11.5).

$E = (M \times EF) \times 44/12$

E	: Annual CO_2 emissions from urea application [t-CO_2]
M	: Annual amount of urea application [t]
EF	: Emission factor for urea application [t-C/t]

- ***Emission Factors***

0.20 [t-C/t] (default value, *2006 IPCC Guidelines*, Vol.4, page 11.34).

- ***Activity Data***

For the amount of urea applied, "total demand of urea fertilizer" in Japan described in *the Yearbook of Fertilizer Statistics (Pocket Edition)* published by the Association of Agriculture and Forestry Statistics before FY2017 and the data surveyed by Agricultural Technology Promotion Division, MAFF since FY2017 is used.

Table 5-83 Total demand for urea fertilizer in Japan [kt]

Item	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Amount of imported urea fertilizer	248	231	229	268	251	292	293	214	177	146	202	202

Reference: *Yearbook of Fertilizer Statistics (Pocket Edition)* before FY2017
The data surveyed by Agricultural Technology Promotion Division, MAFF since FY2017

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For uncertainty of the emission factor, default value (50%) described in the *2006 IPCC Guidelines* was applied. For activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be 50%.

- ***Time-series Consistency***

Emissions are estimated by using consistent estimation methods and data sources.

d) Category-specific QA/QC and Verification

Same as Sheep, Swine, Buffalo, Goats & Horses (3.A.2., 3.A.3., 3.A.4.-) in Enteric Fermentation. See section 5.2.2. d).

e) Category-specific Recalculations

Since the demand of urea fertilizer and the amount for fertilizer in domestic production of urea from FY2017 to FY2023 was updated, the emissions from FY2017 to FY2023 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

5.10. Other Carbon-containing Fertilizers (3.I.)

Since there are no other sources to be reported in this category, this category is reported as "NO".

5.11. Other (3.J.)

Since there are no other sources as "Other", this category is reported as "NO".

References

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Chapter 6. Land Use, Land-Use Change and Forestry (CRT sector 4)

6.1. Overview of Sector

The land use, land-use change, and forestry (LULUCF) sector deals with greenhouse gas (GHG) emissions and removals resulting from land use such as forestry activities and its land-use change. GHG emissions and removals in this sector consist of carbon stock changes in five carbon pools (aboveground biomass, belowground biomass, dead wood, litter, and soil) in each land-use category, such as forest land (4.A.), cropland (4.B.), grassland (4.C.), wetlands (4.D.), settlements (4.E.) and other land (4.F.) which are divided in accordance with the *2006 IPCC Guidelines'* land-use classification, and carbon stock changes in harvested wood products (HWP) pool in forest land (4.G.). It also consists of N_2O emissions from N fertilization (4.(I)), CH_4 and N_2O emissions from drainage and other management of organic soils (4.(II)), N_2O emissions from nitrogen mineralization resulting from change of land use or management of mineral soils (4.(III)), and emissions of CH_4 and N_2O etc. from biomass burning (4.(IV)) in each land-use category (except N_2O emissions from 4.(I) and 4.(II) in cropland and grassland as well as from 4.(III) in cropland remaining cropland and grassland remaining grassland, which are reported in the Agriculture sector). Methodological tiers used in this sector are shown in Table 6-1. In this chapter, above- and below-ground biomass are collectively referred as "living biomass", and dead wood and litter are also referred as "dead organic matter".

This sector includes both sources and sinks; however, it has been continuously a net sink since FY1990 in Japan. Net removals in FY2024 were 49,421 kt-CO_2 eq; which accounts for 4.7% of the total national emissions (excluding LULUCF). The net removals in FY2024 also represent a decrease of 35.5% compared to FY1990 and a decrease of 1.9% compared to the previous year. Net removals in Japan had been increasing from FY1990 to FY2003, but have been on a long-term decreasing trend since FY2004. The key drivers for the rise in removals from FY1990 to FY2003 were increase of removals in forest land and decrease of emissions due to the decrease in areas of conversion from forest land. The decreasing trends in net removals since FY2004 are mainly caused by the decrease of removals in forest land.

Table 6-1 Methodological tiers used in the LULUCF sector

GHG source and sink category	CO_2		CH_4		N_2O	
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
A. Forest land	T2,T3	CS,D	T1	D	T1,T2	CS,D
B. Cropland	T1,T2,T3	CS,D	T1	D	T1,T2	CS,D
C. Grassland	T1,T2,T3	CS,D	T1	D	T1,T2	CS,D
D. Wetlands	T1,T2,T3	CS,D	-	-	-	-
E. Settlements	T1,T2	CS,D	T2	CS,D	T1,T2	CS,D
F. Other land	T2	CS,D	-	-	T1	D
G. Harvested wood products	T2,T3	CS,D				
H. Other	CS	CS				

Note: D: IPCC default, T1: IPCC Tier1, T2: IPCC Tier2, T3: IPCC Tier3, CS: country-specific method or emission factor

Japan's national land is an archipelago consisting of Hokkaido, Honshu, Shikoku, Kyushu and other islands, and lies off the east coast of the Eurasian Continent. The archipelago is formed into a crescent shape extending from northeast to southwest. Its northernmost point is located at about 45 degrees north latitude, and its southernmost point is located at about 20 degrees north latitude. Most of Japan's national

land is located in the temperate humid climate zone. Some islands in the southern part of Japan belong to the subtropical climate zone, and the northern part of Japan is located in the cool-temperate climate zone.

6.2. Land-use Definitions and the Land Representation Approaches Used and Their Correspondence to the LULUCF Categories

6.2.1. Method of Determining the Area of Each Land-Use Category

All of the land area of Japan is allocated to one of the 6 land-use categories in accordance with the *2006 IPCC Guidelines.* The allocation is on the basis of the criteria and definitions in existing statistics in Japan as shown in Table 6-2. Land which is not classified into the five land-use categories (forest land, cropland, grassland, wetlands and settlements) is defined as "other land", and its area is determined by deducting the total area of the five land-use categories from the total national land area.

Table 6-2 Criteria for IPCC land-use category allocation and data sources and methods for determining land areas

IPCC land-use category	Criteria for land-use category allocation	Data sources and methods for determining land areas
Forest land	Forests under Forest Law Article 5 and 7.2 (excluding agricultural woodlands and urban forests)	Forests with standing trees (intensively managed forests, semi-natural forests), forests with less standing trees and bamboo in the forests which are included in the regional forests plan according to the *Forestry Status Survey* [-FY2004] and the *National Forest Resources Database* (NFRDB) [FY2005-] (Forestry Agency).[1]
Cropland	Rice fields, upland fields, orchards and dilapidated farmland	Rice fields, upland fields and orchard according to *Statistics of Cultivated and Planted Area* by the MAFF. Dilapidated farmland according to *Census of Agriculture and Forestry* (MAFF) and *Survey on the Occurrence and Resolution of Dilapidated Farmland* (MAFF), etc.
Grassland	Pasture land, grazed meadow land, and wild land[2] (not included in pasture land and grazed meadow land)	Pasture land according to *Statistics of Cultivated and Planted Area* (MAFF), grazed meadow land (excluding when it is included in forest land) according to *Census of Agriculture and Forestry* (MAFF), and wild land according to *Land Use Status Survey* (MLIT).
Wetlands	Lands covered with water (such as dams), rivers, and waterways. Mangroves (not included in forest land) and seagrass meadows and macroalgal beds	Lands covered with water, rivers, and waterways according to *Land Use Status Survey, Survey of Forestry regions* (MLIT). Areas of mangroves, seagrass meadows and macroalgal beds are identified with other surveys and statistical data (see section 6.7.1. b)2) for the details). However, since this area is not part of the total land area of the country, it is treated as land area outside of the national land area.
Settlements	Urban areas that do not constitute forest land, cropland, grassland or wetlands. Urban green areas, including urban forests, consist of both green spaces conserved by zoning and urban green facilities.	Settlements are roads, residential land, school reservations, park and green areas, road sites, environmental facility sites, golf courses, ski courses and other recreation sites identified in *Land Use Status Survey* and other surveys by the MLIT. The included figures for urban green areas are taken from the surveys on urban green facilities conducted by the MLIT. (Details are shown in Table 6-59).
Other land	Any land that does not belong to the above land-use categories.	Determined by subtracting the total area belonging to the above five land-use categories from the total area of national land according to *Statistical Reports on the Land Area by Prefectures and Municipalities in Japan* by the Geospatial Information Authority of Japan.

Note: MAFF: Ministry of Agriculture, Forestry and Fisheries; MLIT: Ministry of Land, Infrastructure, Transport and Tourism

[1] The *Forestry Status Survey* and the *National Forest Resources Database* (NFRDB) use the same definitions and survey methods for forests, and these two databases have time-series consistency.

[2] Its present status is mainly wild grassland (including perennial pasture land, degenerated pasture land, and areas abandoned after cultivation and becoming wild). The item of "wild land" was changed to "wild land, etc" including

The summed area of all land-use categories is not used as the total land area because it is difficult to cover all the land areas in "other land" through existing data sources.

The area of each land-use category in FY2024 obtained by the methods shown in Table 6-2 is as follows; approximately 24.96 million ha for forest land, 3.94 million ha for cropland, 0.9 million ha for grassland, 1.35 million ha for wetlands, 3.89 million ha for settlements, and 2.75 million ha for other land. Note that each land-use category has its own subcategories. See the section on each land-use category for a description of the subcategories and their definitions. The frequency of statistical surveys used and other information are shown in Table 6-3.

Table 6-3 Statistics used for area estimation

Name of the statistics / census	Survey method	Survey due date	Frequency	Presiding ministry
Forest Status Survey	Complete count survey	March 31st	Every 5 years	Forestry Agency
National Forest Resources Database (NFRDB)[3]	Complete count survey	April 1st	Every year	Forestry Agency
Statistics of Cultivated and Planted Area (Survey of cropland area)	Ground measurement survey (sample)	July 15th	Every year	MAFF
Census of Agriculture	Complete count survey	February 1st	Every 5 years	MAFF
Survey on the status of occurrence and elimination of dilapidated cropland	Complete count survey	December 31st	Every year	MAFF
Land Use Status Survey	Complete count survey	October 1st	Every year	MLIT
Statistical Reports on the Land Area by Prefectures and Municipalities in Japan	Complete count survey	October 1st	Every year	GSI

Note: GSI: Geographical Survey Institute

Japan's total land area as of FY2024, from the *Statistical Reports on the Land Area by Prefectures and Municipalities in Japan* (GSI), is about 37.8 million ha, an increase of 0.06% (approximately 24 kha) compared to FY1990 due to the reclamation by drainage and landfilling of sea areas. It is recommended to "ensure that the national land area is consistent across the inventory time-series "in Section 3.3, Chapter 3, Volume 6 of *the 2006 IPCC Guidelines*." However, in Japan, the national land area itself fluctuates from year to year and thus keeping the same total land area through the entire time-series would result in reporting inaccurate information. Therefore, Japan reports that the sum of all land-use categories for each year is equal to the total national land area for each year which have been identified by the statistical source, thereby accurately reflecting the actual changes in the total land area of Japan. The Guidelines also state that "Ensure that the national land area is consistent across the inventory time-series; otherwise stock changes will reflect false C increases or decreases due to a change in total land area accounted for when using a stock change emissions estimation method." In practice, the increase in area due to reclamation, etc. in the relevant year is not directly allocated to forest land or other land-use areas, but is included in "other land" and the carbon stock is calculated according to the status of conversion from the following year. In addition, in the calculation of "other land" that has been increased including by reclamation, it is

grazed meadow land, so the areas of wild land from 2011 onward were calculated excluding grazed meadow land of the "*Census of Agriculture and Forestry*".

[3] The *National Forest Resource Database* maintains and manages administrative information such as forest registers and forest planning maps, and location information such as Orthophoto and satellite information such as Landsat TM and SPOT images.

assumed that no carbon losses or gains occur in the conversion of sea areas to other land, and no change in carbon stocks is reported. Therefore, even when the time-series consistency of the total land area is not maintained as in Japan, over- or under-estimation of emissions and removals do not occur because the carbon stock changes are not directly estimated using area caused from land area change as activity data.

Emissions and removals from mangroves and seagrass meadows and macroalgal beds located in intertidal zone are included in the estimation and are reported under the wetlands category. However, the area is excluded from both the wetlands category area and land-use conversion matrix, because the area is slightly outside the national "land" area which is determined by the high tide line.

6.2.2. Method of Estimating the Area Converted from Other Land Uses

Each land-use category is further classified into "land remaining in the same land-use category" and "land converted to a new land-use category" depending on its history of land-use conversion. To classify into these two subcategories, a default period of 20 years is applied as the threshold to distinguish the occurrences of land-use conversion in accordance with the *2006 IPCC Guidelines*. The transition period was set at 40 years for the estimation of carbon stock changes in mineral soils from the conversion between forest land and grassland/cropland, however, the emissions and removals from the land where 21 years have passed after conversions are reported under the land remaining in the same land-use categories.

Each area converted from other land use is estimated by conversion ratio from satellite image interpretation as well as by the data of converted area and current area from existing statistics. Table 6-4 shows the survey methods and due dates of major land area statistics. Approach 2 was used for representing land-use areas using the information on changes between land-use categories as well as each land-use area mentioned in the previous section.

Table 6-4 Statistics used for estimating area of land-use conversions

Name of the statistics / survey	Survey contents	Survey due date	Survey frequency	Presiding ministry
Survey of land use change status by remote sensing image interpretation (survey to determine areas converted between forest land and non-forest land)	Identifying non-forest land converted to forest land and forest land converted to non-forest land by image interpretation	December 31st	Survey was conducted in 1989 and every year since 2005 (2 years to complete one cycle)	Forestry Agency
Statistics of Cultivated and Planted Area (Survey of Expansion area and Abandoned area of cropland)	Circulation survey (using documents from relevant agencies and aerial photographs, etc.) including the reason for movement and the area of each land category (Areas by the reasons for movement were not obtained from 2017 onwards)	July 15th	Every year since 1956	MAFF
A Move and Conversion of Cropland	Survey on the area of converted cropland and grassland by means of the notified area	December 31st	Every year since 1961	MAFF
Administrative Statistics of Creation of Agricultural Land	Project based area (area of land established of cropland and grassland)	March 31st	Survey was conducted in each year from 1971 to 2002	MAFF

a) Identification of the Area of Conversion Between Forest Land and Non-Forest Land (converted Area from 1990 onwards)

This section deals how to determine the area converted between forest land and non-forest land from 1990 onwards. With the *Survey of land use change status by remote sensing image interpretation* shown in Table 6-4, land-use changes between forest land and non-forest land were estimated by interpreting aerial orthophotos and satellite images. This survey was used because the forest register, which is used as the basic data of forest area, doesn't track the land-use conversion between forest land and non-forest land.

1) Methodologies and estimation procedures

i. Plot design and interpretation procedure

[Plot setting]: Approximately 1.5 million plots were set up in a grid pattern at 500m intervals across the country.

[Image used for interpretation]: Orthophoto taken at the end of 1989 (hereinafter referred to as "1989 aerial photo") and satellite images of SPOT (hereinafter referred to as "satellite image") (all images taken at approximately two-year intervals since 2005). Details of the images used are shown in Table 6-5.

[Coverage of interpretation]: The entire country is divided into two parts, and half of the total plots are interpreted in turns each year, alternating between the two parts. It takes two years to complete a cycle of image interpretation for the whole country.

[Interpretation methods]:

1. Plots where changes of forest cover occurred are detected by comparing 1989 aerial photo and the most recent satellite images. Changes from non-forest land to forest land due to human-induced afforestation practices are categorized as "land converted to forest land (or land subject to AR activities)" and those from forest land to non-forest land are categorized as "land converted from forest land (or land subject to D activities)" (Hayashi et al. 2008). The land units are evaluated in spatial assessment units (0.3 ha in area and 20 m in width) considering the numerical definition of forest (Table 6-16), and the land-use status before or after conversion for each plot is also identified.
2. The number of points when the changes were occurred was determined using 1989 aerial photos and satellite images taken at approximately two-year intervals since 2005. Each time this procedure is performed, the results of previous interpretation are corrected.
3. Plots which were difficult to interpret for some reason were excluded from available sample plots.

ii. Procedures for calculating the occurrence rate of conversion between forest land and non-forest land

1. For plots identified as having changed between 1990 and 2005, the cumulative occurrence rate from the beginning of 1990 to the end of 2005 was calculated by dividing the number of total occurrence plots by the number of total available sample plots. In the estimation of "land converted to forest land (or land subject to AR activities)," the cumulative occurrence rate was divided by 16 to obtain the occurrence rate for the single year from 1990 to 2005, assuming

that those changes occurred linearly from 1990 to 2005. In the estimation of "land converted from forest land (or land subject to D activity)," the cumulative occurrence rate from 1990 to 2005 was allocated for each year according to the conversion rate in the *Area of forest land conversion* statistics. Respective occurrence rates for 2005 are alternatively used for those for 2006.

2. For the occurrence from 2007 onward, the number of occurrences between two images photographed in two-year intervals were divided by two to obtain the number of occurrences for single year. Since one interpretation cycle is completed every two years, two sets of number of occurrences for single year are summed up and then divided by the total number of available sample plots to obtain occurrence rate in each single year. In the first half year of the cycle, the results of the second half year of the previous cycle are used to cover the entire land area.

iii. Calculation of area converted between forest land and non-forest land

The area converted between forest land and non-forest land was calculated by multiplying the national land area by the occurrence rates of conversions between forest land and non-forest land in each single year with the procedure mentioned above. The changes in areas estimated from the above-mentioned procedure was used as the activity data for a single Fiscal year.

As shown in Section 6.2.1. , the land area in Japan has been gradually increasing due to land reclamation, etc. However, the newly expanded land area is not included in this land-use change survey because it is considered that afforestation and deforestation activities have hardly occurred on the reclaimed coastal areas. Therefore, the land area in 2005, when the land-use change survey started, was used as the fixed land area for the entire time series in the calculation for multiplying the land area by the rate of land-use change. The converted areas between forest land and non-forest land were obtained by land-use categories of before and after conversion.

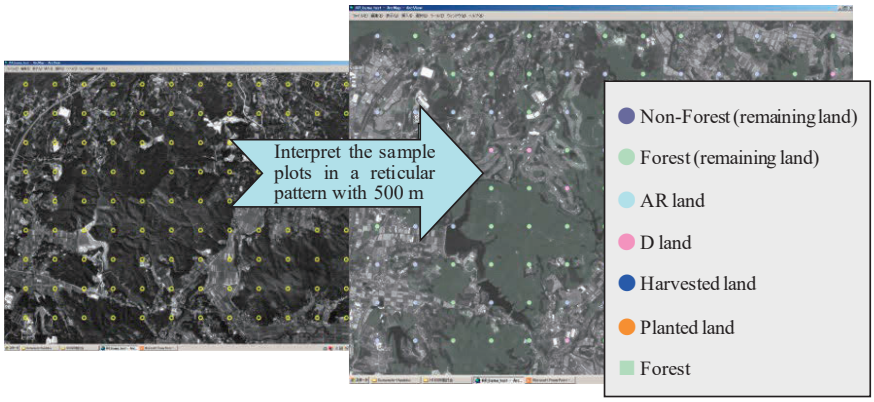

Figure 6-1 Identification of conversion between forest land and non-forest land by interpreting remote sensing images

2) Data used

The data used to identify conversion between forest land and non-forest land are as follows.

Table 6-5 Data used to identify conversion between forest land and non-forest land

Data sources	Resolution [m]	Data format
Orthophoto aerial photograph (1989)	1	Raster
SPOT5/HRV-P (2005, 2007, 2009-2014)	2.5	Raster
SPOT6/7/HRV-P (2015-2024)	1.5	Raster

b) Identification of the Area of Conversion between Non-Forest Lands

Land-use conversion between non-forest lands was estimated using the statistics and surveys shown in Table 6-4. See the details in "Activity Data" under each land-use section.

6.2.3. Land-Use Conversion Matrix

Land-use conversion matrix has been produced annually since the beginning of FY1990 to date, for six land-use categories whose areas are identified. Land-use conversion that occurred in FY1990 and in FY2024 are shown in the following Table 6-6 and Table 6-7, respectively. In addition, land-use conversion matrix produced by accumulating areas of conversion between each land-use category, from the beginning of FY1990 to the end of FY2024, is shown in Table 6-8.

Table 6-6 Land-use conversion matrix for Japan in FY1990 [kha]

at the beginning \ at the end	Forest land	Cropland	Grassland	Wetlands	Settlements	Other land	Total
Forest land	24,945.80	2.63	3.38	0.33	14.55	3.60	24,970.29
Cropland	3.11	4,758.67	1.91	0.03	23.19	2.36	4,789.27
Grassland	0.27	0.01	1,023.11	0.00	1.36	0.15	1,024.91
Wetlands	NO	0.20	0.26	1,309.55	IE	IE	1,310.01
Settlements	0.54	IE	NO	0.00	3,160.14	IE	3,160.69
Other land	0.54	2.33	2.94	0.09	0.76	2,511.88	2,518.55
Total	24,950.27	4,763.84	1,031.60	1,310.00	3,200.00	2,518.00	37,773.71

Table 6-7 Land-use conversion matrix for Japan in FY2024 [kha]

at the beginning \ at the end	Forest land	Cropland	Grassland	Wetlands	Settlements	Other land	Total
Forest land	24,945.80	2.63	3.38	0.33	14.55	3.60	24,970.29
Cropland	3.11	4,758.67	1.91	0.03	23.19	2.36	4,789.27
Grassland	0.27	0.01	1,023.11	0.00	1.36	0.15	1,024.91
Wetlands	NO	0.20	0.26	1,309.55	IE	IE	1,310.01
Settlements	0.54	IE	NO	0.00	3,160.14	IE	3,160.69
Other land	0.54	2.33	2.94	0.09	0.76	2,511.88	2,518.55
Total	24,950.27	4,763.84	1,031.60	1,310.00	3,200.00	2,518.00	37,773.71

Table 6-8 Land-use conversion matrix of Japan for FY1990-FY2024 [kha]

at the beginning of FY1990 \ at the end of FY2024	Forest land	Cropland	Grassland	Wetlands	Settlements	Other land	Total
Forest land	24,861.89	23.64	23.43	16.72	241.27	54.61	25,221.56
Cropland	38.99	3,811.42	36.52	1.39	477.09	67.71	4,433.11
Grassland	12.04	1.79	802.97	0.24	57.98	9.94	884.95
Wetlands	0.11	0.87	0.64	1,326.90	IE	IE	1,328.52
Settlements	26.09	IE	NO	0.08	3,091.69	IE	3,117.86
Other land	22.71	104.55	32.37	4.67	25.97	2,621.29	2,811.56
Total	24,961.83	3,942.26	895.93	1,350.00	3,894.00	2,753.55	37,797.56
Net change of each land-use category (FY1990-FY2024)	-259.73	-490.85	10.97	21.48	776.14	-58.01	-

Note: The areas described as "IE" are included in "Other land remaining other land" which could be used for adjustment with total area of national land.

6.3. Country-specific Approaches

6.3.1. Parameters for Estimating Carbon Stock Changes Due to Land-use Conversions

The parameters used for estimating carbon stock changes due to land-use conversions are shown here.

Table 6-9 Biomass or carbon stocks in living biomass before and immediately after land-use conversion

Land-use category			Biomass stocks or carbon stocks	Methodology for setting parameters and data source used
Before conversion	Forest land		157.5 [t-d.m./ha] (FY2024)	The values of biomass stocks in forest land prior to conversion were based on the average carbon stock per unit area of forests with standing trees at the beginning of the period. The values for FY1990-FY2007 are substituted by the average value for FY2008- FY2012. (See Table 6-10 for values for each fiscal year in the time series.)
	Cropland	Cropland (Average)	1.7 [t-C/ha]	Average value of below-listed rice and upland fields from FY 1990 to FY2017 (Weighted average value of area in rice and upland fields is used for the value at each year.) The amount of dry matter of crop residues plowed into rice and upland fields is estimated by utilizing the activity data in the agriculture sector (3.D.a.4.)
		Rice field	2.0 [t-C/ha]	Average carbon content of crop residues plowed into rice fields from FY1990 to FY2017.
		Upland field	1.3 [t-C/ha]	Weighted average carbon content of crop residues plowed into upland fields from FY1990 to FY2017, calculated by crop cultivation area for each type of crop.
		Orchard	-	It is not indicated since carbon stock change after conversion is calculated collectively in the calculation of the “orchard” in cropland remaining cropland. See 6.5.1. b)1) for the parameter of “orchard remaining orchard”.
	Grassland		13.5 [t-d.m./ha]	Default value (Table 6.4: “warm temperate wet”, Vol. 4 of the *2006 IPCC Guidelines*). This default value applied for all types of grassland based on Tier 1 as land conversions to/from grassland are non-key category.
	Wetlands, settlements and other land		0 [t-d.m./ha]	Assumed to be “0”.
Immediately after conversion	All land uses		0 [t-d.m./ha]	Assumed to be “0”.

Table 6-10 Biomass stocks in forest land before land-use conversion

Land-use category	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Forest land (before conversion)	t-d.m./ha	93.1	93.1	93.1	93.1	93.1	93.9	94.0	153.7	154.9	155.8	156.6	157.5

Table 6-11 Annual increments in living biomass after land-use conversion

Land-use category			Annual increments	Methodology for setting parameters and data source used
After conversion	Forest land		3.0 [t-C/ha/yr]	To estimate the average annual growth of forests within 20 years after conversion, average growth increments per unit area for 3 years (FY2008-FY2010) including year of FY2009, which is 20 years after the start of AR activity under the Kyoto Protocol, is applied.
	Cropland	Cropland (average)	1.7 [t-C/ha/yr]	Assumed that carbon stock after conversion reaches the value in Table 6-9 in one year.
		Rice field	2.0 [t-C/ha/yr]	Assumed that carbon stock after conversion reaches the value in Table 6-9 in one year.
		Upland field	1.3 [t-C/ha/yr]	Assumed that carbon stock after conversion reaches the value in Table 6-9 in one year.
		Orchard	-	It is not indicated since carbon stock change after conversion is calculated collectively in the calculation of the "orchard" in cropland remaining cropland.
	Grassland		2.7 [t-d.m./ha/yr]	Assumed that carbon stock after conversion reaches the default value (Table 6.4: 13.5 at "warm temperate wet", Vol. 4 of the *2006 IPCC Guidelines*) in 5 years.
	Wetlands, Settlements and other land		0 [t-C/ha/yr]	Assumed to be "0".

Table 6-12 Carbon stocks in dead wood before, immediately after and after land-use conversion

Land-use category		Carbon stocks	Methodology for setting parameters and data source used
Before conversion	Forest land	7.5 [t-C/ha]	Average value of carbon stocks in dead wood of all forests calculated using the results of the Forest Soil Inventory Survey (Kawanishi et al. (2024)).
	Cropland, grassland, wetlands, settlements, other land	0 [t-C/ha]	Default value (Section 5.3.2 etc. in Vol. 4 of the *2006 IPCC Guidelines*, Tier 1)
Immediately after conversion	All land uses	0 [t-C/ha]	Default value (Section 5.3.2 etc. in Vol. 4 of the *2006 IPCC Guidelines*, Tier 1)
After conversion	Forest land	6.5 [t-C/ha]	Predicted carbon stocks in 40 years after afforestation, based on the regression equation using the results of a domestic survey of the amount of dead wood in afforested areas after land-use conversion, starting from 0 accumulation in year 0. The annual carbon stock change is 0.16 t-C/ha/yr.
	Cropland, grassland, wetlands, other land	0 [t-C/ha]	Default value (Section 5.3.2 etc. in Vol. 4 of the *2006 IPCC Guidelines*, Tier 1)
	Settlements	0 [t-C/ha]	Default value (Section 8.3.2 in Vol. 4 of the *2006 IPCC Guidelines*, Tier 1) If land is converted to urban green facilities, it is not indicated since it is included in the estimation of stock changes in living biomass.

Table 6-13 Carbon stocks or annual changes in litter before, immediately after and after land-use conversion

Land-use category		Carbon stocks or annual change	Methodology for setting parameters and data source used
Before conversion	Forest land	4.9 [t-C/ha]	Average value calculated using the results of the *Forest Soil Inventory Survey* (Ugawa et al., 2012).
	Cropland, grassland, wetlands, settlements, and other land	0 [t-C/ha]	Default value (Section 5.3.2 etc. in Vol. 4 of the *2006 IPCC Guidelines*, Tier 1)
Immediately after conversion	All land uses	0 [t-C/ha]	Default value (Section 5.3.2 etc. in Vol. 4 of the *2006 IPCC Guidelines*, Tier 1)
After conversion	Forest land	6.67 [t-C/ha]	Average carbon stocks in litter based on a domestic survey of the amounts of litter in afforested areas, starting from 0 accumulation in year 0 after land-use conversion. The measured data after 21 years from land-use conversions, which are observed to reach almost stable state of litter stock, are used.
	Cropland, grassland, wetlands, settlements and other land	0 [t-C/ha]	Default value (Section 5.3.2 etc. in Vol. 4 of the *2006 IPCC Guidelines*, Tier 1)

Table 6-14 Carbon stocks in mineral soils before and after land-use conversion

Land-use category			Carbon stocks or annual change	Transition period (years)	Stock change factor	Methodology for setting parameters and data source used
Before conversion	Forest land		76.0 [t-C/ha]			Average soil carbon stocks of all forests in Japan (Yamashita et al., 2022)
	Cropland	Rice field	70.5 [t-C/ha]			Average soil carbon stocks of each land use in Japan. Estimated from the soil group data which is based on soil surveys from 2015 to 2018 used in Matsui et al.(2021). Soil carbon stocks of each land-use type is divided by the area in 2018 of respective land-use type. Organic soils are excluded.
		Upland field	90.8 [t-C/ha]			
		Orchard	79.1 [t-C/ha]			
		Cropland (average)	77.2 [t-C/ha]			
	Grassland (pasture land)		120.7 [t-C/ha]			
	Cropland and Grassland (average)		83.0 [t-C/ha]			
After conversion	Forest land (from cropland or grassland)		0.44 [t-C/ha]	40	1.21	County specific transition period (40 years) and country-specific stock change factor of 1.21 were set by a domestic research project[1)] as Tier 2 factor for conversion from cropland and grassland to forest land. The annual carbon stock change was calculated as (83 x 1.21-83) / 40 = 0.44 t-C/ha/yr, based on the average soil carbon stocks of the initial cropland and grassland values.
	Forest land (from other than cropland or grassland)		1.5 [t-C/ha/yr]	40	-	Set by the Committee for the GHG Emissions Estimation Methods in FY2022 based on the results of the above-mentioned research project.
	Rice field (from forest land)		1.33 [t-C/ha/yr]	20	1.35	Default stock change factor of 1.35 for rice field in the *2019 Refinement* and default transition period (20 years) were used. Annual change is calculated based on the average carbon stocks of the forest land and the initial values.
	Upland field and Orchard (from forest land)		-0.44 [t-C/ha/yr]	40	0.77	Country-specific transition period (40 years) and country-specific stock change factor of 0.77 were set by the above-mentioned research project as Tier 2 factor for conversion from forest land to cropland. Annual carbon stock change is calculated using the average carbon stocks of the forest land as the initial value.
	Grassland (pasture land) (from forest land)		-0.54 [t-C/ha/yr]	20	0.858	Country-specific transition period (equivalent to default transition period 20 years) and country-specific stock change factor of 0.858 were set by the above-mentioned research project, as Tier 2 factor for conversion from forest land to grassland, according to Koga et al. (2020). Annual carbon stock change is calculated using the average carbon stocks of the forest land as the initial value.
	Settlements		28.1 [t-C/ha]	20		Average soil carbon stocks of settlements at 20 years after land-use conversion, as determined by Tonosaki et al. (2022)
	Other land (excluding natural disasters)		20.1 [t-C/ha]	20		Simple average of soil carbon stocks of lands immediately after development obtained by sample survey results, as mentioned in Tonosaki et al. (2022) Determined by the Committee for the GHG Emissions Estimation Methods in FY2022.

Note: 1) Research project conducted under the Environment Research and Technology Development Fund of the MOE (MOE: Ministry of Environment)
[2-1601] Evaluation Study on the Soil Carbon Changes through the Land Use Changes between Forest Land and Cropland and its Application to GHG Inventory
[2-1909] Assessment of Soil Carbon Stock Changes due to Land Use Changes and Its Application to National Greenhouse Gas Inventories

6.3.2. Information on Approaches Used for Natural Disturbances

Japan does not separately address emissions and subsequent removals from natural disturbances. All emissions and subsequent removals from any of disturbance events are included in the calculation of the LULUCF sector.

6.3.3. Information on Approaches Used for Reporting Harvested Wood Products

Japan uses production approach for reporting harvested wood products.

6.4. Forest Land (4.A.)

Forests to be calculated under this category of Japan's inventory are the forests that are subject to forest planning under Articles 5 and 7.2 of the Forest Law as shown in Table 6-2, which is the same scope as the forests subject to reporting in the Global Forest Resources Assessment (FRA) that Japan submits to FAO. Therefore, all forests subject to the calculation are treated as "managed forests", which are divided by the management entity into "National forests" as defined in Article 7.2 and "Private forests (forests other than National forests)" as defined in Article 5 of the Forest Law. Forest category consists of 4 subcategories, which are intensively managed forests, semi-natural forests, bamboo, and forests with less standing trees, as shown in Table 6-15. Intensively managed forests are planted forests, while semi-natural forests are naturally regenerated forests, and both are further collectively referred to as "Forests with standing trees". The definition of forests in Japan is based on the *KP Supplements* is specified numerically as shown in Table 6-16, and forests with standing trees meet the minimum values in the Table. Forests with standing trees are further divided into Ikusei-rin forests and Tennensei-rin forests depending on forest management types. Table 6-17 shows the correspondence of these above to the subcategories under this category. In inventory reporting, "intensively managed forests in Ikusei-rin forests" are referred to as "intensively managed forests", and "semi-natural forests in Ikusei-rin forests" and "Tennensei-rin forests" are collectively referred to as "semi-natural forests".

Note that there are a small number of forests that are not covered by the forest planning, and these forests are excluded from "managed forests" and are mainly included in the area of "Other land use (4.F.)" for reporting and carbon stock changes are not reported.

Table 6-15 Definitions of forest subcategories

Subcategory		Definition
Forests with standing trees		Forests that do not fall under "forests with less standing trees", where the crown cover of standing trees is 30% or more (including young stands with the degree of stocks of 3 or more even though the tree crown cover is less than 30%). Even if the crown cover of standing trees is less than 30%, forests with a total crown cover of both standing trees and bamboo of 30% or more, while dominated by standing trees, are included in this subcategory.
	Intensively managed forests	Forests established by artificial regeneration such as tree planting and seeding, where the volume (or number) of standing trees of tree species subject to the artificial regeneration account for 50% or more.
	Semi-natural forests	Forests with standing trees which are not classified as "intensively managed forests".
Forests with less standing trees		Forests with a total crown cover of both standing trees and bamboo of less than 30%.
Bamboo		Forests that do not fall under "forests with standing trees", where the crown cover of bamboo (excluding bamboo grasses) is 30% or more. Even if the crown cover of bamboo is less than 30%, forests with a total crown cover of both standing trees and bamboo of 30% or more, while dominated by bamboo, are included in this subcategory.

Reference: *Forest Resources Status Survey* (Forestry Agency), partially modified.
Note: The degree of stocks is the ratio of actual tree volume to expected tree volume in a given forest area, multiplied by 10.

Table 6-16 Numerical definition of Forest in Japan

Elements	Numerical definition of forests in Japan
Minimum area	0.3 [ha]
Minimum tree crown coverage	30 [%]
Minimum tree height	5 [m]
Minimum forest width	20 [m]

Table 6-17 Correspondence and definitions of subcategories by reporting and by management type

Subcategories by reporting	Subcategories by management type	
Intensively managed forest	Ikusei-rin forest	Ikusei-tansou-rin forest; Forests where practices for establishment and maintenance of single-storied forests have been carried out after clear-cutting. Ikusei-fukusou-rin forest; Forests where practices for establishment and maintenance of multi-storied forests have been carried out after selective cutting.
Semi-natural forest		
	Tennensei-rin forest	Forests where practices for establishment and maintenance of forests mainly through the use of natural forces are carried out.

Japan's forest land area in FY2024 was about 24.96 million ha, representing about 66.0% of the total national land area. The net removal in this category in FY2024 was 57,025 kt-CO_2 (GHG emissions other than changes in carbon stocks are not included). This represents a decrease of 1.3% compared to the previous year, and a decrease of 41.5% compared to the FY1990 value, and it has been on a decreasing trend in the long term.

Table 6-18 Emissions and removals in forest land resulting from carbon stock changes

Category	Carbon pool	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
4.A. Forest land	Total	kt-CO_2	-97,557	-103,380	-103,830	-106,059	-89,490	-83,598	-73,785	-65,849	-63,592	-59,761	-57,765	-57,025
	Living biomass	kt-CO_2	-88,232	-93,014	-93,810	-96,075	-80,325	-75,437	-66,277	-59,579	-57,613	-54,029	-52,264	-51,685
	Dead wood	kt-CO_2	-264	-1,075	-1,628	-2,680	-3,539	-3,784	-3,941	-4,407	-4,446	-4,510	-4,558	-4,640
	Litter	kt-CO_2	-2,638	-1,994	-1,432	-996	-322	27	229	474	518	564	596	602
	Mineral soil	kt-CO_2	-6,423	-7,297	-6,961	-6,308	-5,305	-4,403	-3,796	-2,337	-2,051	-1,786	-1,538	-1,302
	Organic soil	kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.A.1. Forest land remaining Forest land	Total	kt-CO_2	-87,981	-99,209	-101,155	-104,105	-88,105	-82,321	-72,635	-65,040	-62,859	-59,104	-57,188	-56,526
	Living biomass	kt-CO_2	-82,158	-90,352	-92,092	-94,820	-79,412	-74,587	-65,508	-59,023	-57,104	-53,569	-51,854	-51,323
	Dead wood	kt-CO_2	66	-930	-1,534	-2,611	-3,488	-3,738	-3,898	-4,377	-4,419	-4,485	-4,536	-4,620
	Litter	kt-CO_2	-1,960	-1,697	-1,239	-853	-218	123	316	536	575	615	641	642
	Mineral soil	kt-CO_2	-3,928	-6,230	-6,290	-5,821	-4,987	-4,119	-3,544	-2,176	-1,910	-1,666	-1,439	-1,225
	Organic soil	kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.A.2. Land converted to Forest land	Total	kt-CO_2	-9,577	-4,171	-2,675	-1,954	-1,385	-1,276	-1,151	-809	-733	-656	-578	-499
	Living biomass	kt-CO_2	-6,074	-2,662	-1,718	-1,255	-913	-850	-769	-556	-509	-460	-411	-362
	Dead wood	kt-CO_2	-330	-145	-94	-70	-51	-47	-42	-30	-28	-25	-22	-20
	Litter	kt-CO_2	-677	-297	-192	-143	-104	-96	-87	-62	-57	-51	-46	-40
	Mineral soil	kt-CO_2	-2,495	-1,067	-671	-487	-317	-284	-252	-161	-141	-120	-99	-77
	Organic soil	kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Table 6-19 Areas of Forest land

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Forest land remaining Forest land	kha	24,950	24,897	24,876	24,992	24,966	25,173	24,906	24,985	24,971	24,970	24,946	24,962
Intensively managed forests	kha	10,288	10,356	10,331	10,337	10,285	10,241	10,202	10,100	10,076	10,060	10,050	10,040
Semi-natural forests	kha	13,354	13,220	13,195	13,316	13,361	13,369	13,401	13,465	13,474	13,479	13,485	13,490
Forests with less standing trees	kha	1,159	1,171	1,197	1,186	1,162	1,401	1,150	1,251	1,248	1,257	1,242	1,256
Bamboo	kha	149	150	153	154	159	162	153	169	173	174	170	175

Reference: *Forest Status Survey, NFRDB* (Forestry Agency)

6.4.1. Forest Land Remaining Forest Land (4.A.1.)

a) Category Description

This subcategory deals with carbon stock changes in forest land remaining forest land, which has remained forested without conversion for more than 20 years. The net removals in this subcategory in FY2024 were 56,526 kt-CO_2 (GHG emissions other than changes in carbon stocks are not included). This represents a decrease of 35.8% compared to FY1990 and a decrease of 1.2% compared to the previous year. It had been on an increasing trend from FY1990 to FY2004, but has been decreasing since FY2005. The increase in net removals in the first half of the reporting period is mainly due to the growth in intensively managed forests, and the decrease in net removals in the second half of the period is mainly due to progression in the maturation of those intensively managed forests.

As for a factor influencing changes in the forest growth, the maturity of the forest is considered in Japan. Large-scale development of planted forests was carried out in Japan in the 1960s, but since then the area of planted forest development has decreased. These large-scale planted forests had contributed to the increase in removals until around FY2004, but the removals began to decrease from around FY2005 due to progression in the maturation. The distribution of age class structure of the intensively managed forests has since shifted further to the elderly side, with these planted forests over 51 years old accounting for 64% of the total intensively managed forest area at the end of FY2021 (Figure 6-2).

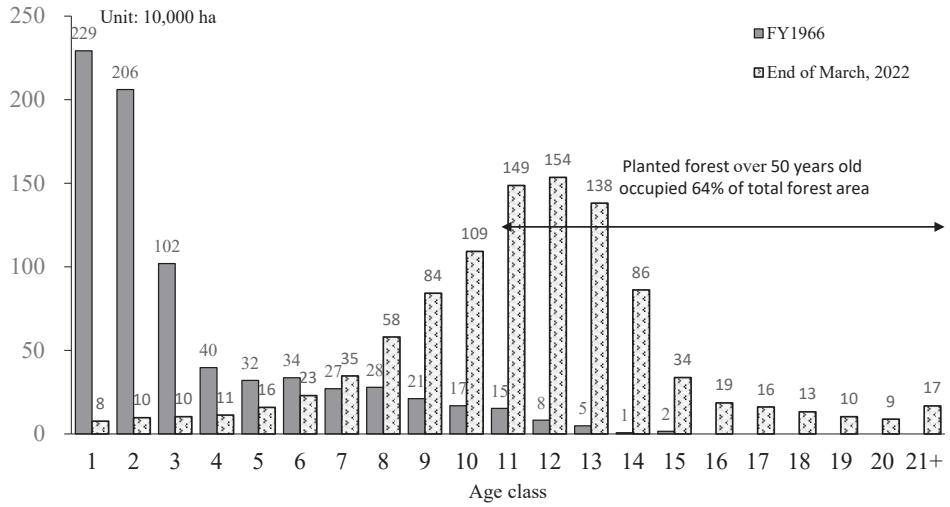

Figure 6-2 The distributions of age class structure of intensively managed forests

Sources: *State of Forest Resources* (March 31, 2022) (Forestry Agency); *Forest Resources of Japan* (April 1968) (Forestry Agency)
Note: Age-classes are divided by 5 year-period steps. "Age-class 1" includes the 1st to 5th year after plantation with the year of plantation counted as the 1st year.

Recently, domestic wood supply has been on an increasing trend. The changes in the supply of domestically produced wood since 1990 are shown in Figure 6-3. The supply of domestic wood had been declining from FY1990 to FY2002, but since then, it has turned to an increasing trend and has been continuously increasing. As mentioned above on the trend of growing stocks of forests, the forest resources in Japan have become enriched to be able to meet the demand for wood supply since those forests planted in the 1960s have grown enough to be harvested from around 2000, and the use as woody biomass in power generation facilities has increased in recent years, both of which have affected the increase in wood supply from FY2003.

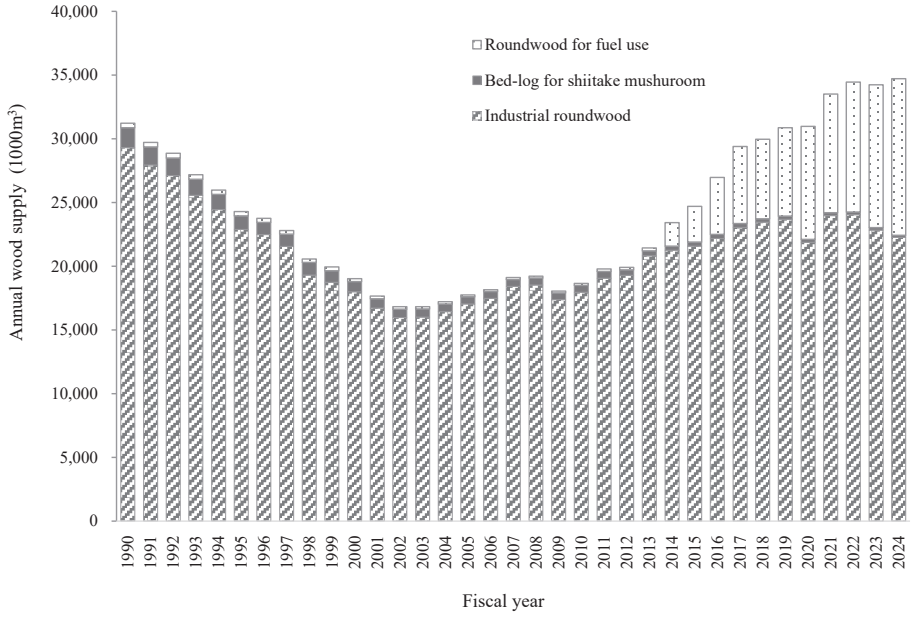

Figure 6-3 Changes in the supply of domestic wood (except logging residue)

Source: *Wood supply and demand chart* (FY2024) (Forestry Agency)
Note: The supply of wood is provided in the roundwood basis

b) Methodological Issues

1) Carbon stock changes in living biomass in forest land remaining forest land

- ***Estimation Method***

➢ ***Carbon stock changes in living biomass in intensively managed forests, semi-natural forests and forests with less standing trees***

The Tier 2 stock-difference method is used for the estimation in the subcategories. Since the NFRDB collectively deals with carbon stock changes in living biomass in "forest land remaining forest land" and "land converted to forest land", it is difficult to separate those in "forest land remaining forest land" from the total. Therefore, carbon stock changes in "forest land remaining forest land" (ΔC_{FF_LB}) are obtained by subtracting those amount in "land converted to forest land" (ΔC_{LF_LB}) calculated by estimation from the amount of carbon stock change in the entire forest land (ΔC_{F_LB}). Assuming that all the land-use conversion to forest land occurred in intensively managed forests, all the carbon stock changes in "land converted to forest land" are subtracted from those in "Intensively managed forest". See section 6.4.2. b)1) for the method of estimating the amount of carbon stock changes in "land converted to forest land".

$$\Delta C_{FF\_LB} = \Delta C_{F\_LB} - \Delta C_{LF\_LB}$$

$$\Delta C_{F\_LB} = \left(C_{F\_LB_{t2}} - C_{F\_LB_{t1}}\right)/(t_2 - t_1)$$

ΔC_{FF_LB} : Annual change in carbon stocks in living biomass in forest land remaining forest land [t-C/yr]
ΔC_{F_LB} : Annual change in carbon stocks in living biomass in entire forest land [t-C/yr]
ΔC_{LF_LB} : Annual change in carbon stocks in living biomass in the land converted to forest land [t-C/yr]
t_1, t_2 : Time points of carbon stock measurement
$C_{F\_LB\ t1}$: Total carbon stock in living biomass in forest land calculated at time t_1 [t-C]
$C_{F\_LB\ t2}$: Total carbon stock in living biomass in forest land calculated at time t_2 [t-C]

$$C_{F\_LB} = \sum_j \left\{V_j \times D_j \times BEF_j \times \left(1 + R_j\right) \times CF\right\}$$

C_{F_LB} : Carbon stock in living biomass in entire forest land[t-C]
V : Merchantable volume [m^3]
D : Wood density [t-d.m./m^3]
BEF : Biomass expansion factor for conversion of merchantable volume
R : Root-to-shoot ratio
CF : Carbon fraction of dry matter [t-C/t-d.m.]
j : Tree species (Private forests or National forests in the case of forests with less standing trees)

$$V_j = \sum_m \left(A_{m,j} \times v_{m,j}\right)$$

V : Merchantable volume [m^3]
A : Area [ha]
v : Merchantable volume per unit area [m^3/ha]
m : Age class or forest age

j : Tree species

➢ ***Carbon stock changes in living biomass in bamboo***

Carbon stock changes in living biomass in Bamboo are reported as "NA" because annual growth and death of bamboo trunk in established bamboo forests are considered as equivalent. Bamboo does not have a vascular cambium, therefore, it reaches the limit of growth in the first year of the emergence and then does not exhibit secondary growth, and as such, in bamboo forests that have reached a certain density, the amount of emerging bamboo is said to be equal to the amount of those dying. The result of FAO's survey (2007) of bamboo resource status in 2000 and 2005 in several countries in Asia and Africa also showed that the carbon stock per unit area for the 5 years from 2000 to 2005 remained almost unchanged.

● ***Parameters***

➢ ***Volume per unit area***

The merchantable volume per unit area (*v*) is set based on the "Yield tables" developed for each tree species in Private and National forests, as shown in Table 6-20. "Yield tables" provide stand growth under standard forest practices including thinning for each region, tree species and site class, and also provide estimates of the volume per unit area with respect to the forest ages. The "New yield tables" prepared in 2006, which had previously been used to estimate the volume of intensively managed forests in private forests, were reviewed and updated to the "2021 Yield Tables" (Forestry Agency) to better reflect the current state of the forests, which are used from the current (2023) submission. While the "New yield tables" were based on the results of field survey conducted in FY2003-FY2005, the "2021 Yield Tables" use data from field survey conducted in FY2014-FY2016 and the *National Forest Inventory survey* in FY2014-FY2018, in addition to the data used to develop the "New yield tables."

"2021 Yield Tables" are applied to estimate the volumes per unit area of Japanese cedar, Hinoki cypress and Japanese larch in private forests, which are representative tree species of intensively managed forests in Japan. These three tree species cover 82% of intensively managed forests of private forests in terms of areas. Regional differences were considered in the development of the "2021 Yield Tables"; the tables were developed for 7 regions for Japanese cedar, 4 regions for Hinoki cypress and 2 regions for Japanese larch.

Table 6-20 Yield tables used to estimate merchantable volume

<table>
<tr><th colspan="3" rowspan="2">Tree species</th><th colspan="2">Yield tables in use</th></tr>
<tr><th>Private forest</th><th>National forest</th></tr>
<tr><td rowspan="3">Intensively managed forests</td><td rowspan="2">Conifer</td><td>Japanese cedar, Hinoki cypress, Japanese larch</td><td>2021 Yield Tables (From the 2023 submission)</td><td rowspan="4">Yield tables developed by Regional Forest Offices, Forest Agency</td></tr>
<tr><td>Other conifer</td><td rowspan="3">Yield tables developed by prefectures</td></tr>
<tr><td colspan="2">Broad leaf</td></tr>
<tr><td colspan="3">Semi-natural forests</td></tr>
</table>

➢ ***Parameters for estimating carbon stock in living biomass (biomass expansion factor and root-to-shoot ratio, wood density and carbon fraction of dry matter)***

The biomass expansion factors (*BEF*) [above-ground biomass/below-ground biomass], root-to-shoot ratios (*R*) and wood density (*D*) were set based on the results of biomass surveys on major tree species, and existing research reports which were developed by the Forestry and Forest Products Research Institute (Table 6-21).

BEFs were set for two age class categories (20 years and below / 21 years and above) and for each tree species, because *BEFs* were found to differ between young forests and mature forests. On the other hand, *R* and *D* values were set by tree species only, because no clear correlation was found between these values and forest ages. For forests with less standing trees, information on tree species and age composition was not available. Therefore, a weighted average of each parameter, weighted by tree species and area composition of all forests with standing trees, was used separately for private and national forests.

Carbon fractions (*CF*) of dry matter were set separately for conifer trees and broad leaf trees based on Japan's research results, and the average value of 0.50 was used for the forests with less standing trees.

Table 6-21 Parameters for estimations of Living Biomass for each tree species

		BEF [-]		R	D	CF	Note
		≦20	＞20	[-]	[t-d.m./m^3]	[t-C/t-d.m.]	
Forests with standing trees (Conifer trees)	Japanese cedar	1.57	1.23	0.25	0.31	0.51	
	Hinoki cypress	1.55	1.24	0.26	0.41		
	Sawara cypress	1.55	1.24	0.26	0.29		
	Japanese red pine	1.63	1.23	0.26	0.45		
	Japanese black pine	1.39	1.36	0.34	0.46		
	Hiba arborvitae	2.38	1.41	0.20	0.41		
	Japanese larch	1.50	1.15	0.29	0.40		
	Momi fir	1.40	1.40	0.40	0.42		
	Sakhalin fir	1.88	1.38	0.21	0.32		
	Japanese hemlock	1.40	1.40	0.40	0.46		
	Yezo spruce	2.18	1.48	0.23	0.36		
	Sakhalin spruce	2.17	1.67	0.21	0.36		
	Japanese umbrella pine	1.39	1.23	0.20	0.46		
	Japanese yew	1.39	1.23	0.20	0.45		
	Ginkgo	1.50	1.15	0.20	0.45		
	Exotic conifer trees	1.41	1.41	0.17	0.32		
	Other conifer trees	2.55	1.32	0.34	0.35		Applied to Hokkaido, Aomori, Iwate, Miyagi, Akita, Yamagata, Fukushima, Tochigi, Gunma, Saitama, Niigata, Toyama, Yamanashi, Nagano, Gifu and Shizuoka prefectures
		1.39	1.36	0.34	0.46		Applied to Okinawa prefecture
		1.40	1.40	0.40	0.42		Applied to prefectures other than above
Forests with standing trees (Broad leaf trees)	Japanese beech	1.58	1.32	0.26	0.57	0.48	
	Oak (evergreen tree)	1.52	1.33	0.26	0.65		
	Japanese chestnut	1.33	1.18	0.26	0.42		
	Japanese chestnut oak	1.36	1.32	0.26	0.67		
	Oak (deciduous tree)	1.40	1.26	0.26	0.62		
	Japanese poplar	1.33	1.18	0.26	0.29		
	Alder	1.33	1.25	0.26	0.45		
	Japanese elm	1.33	1.18	0.26	0.49		
	Japanese zelkova	1.58	1.28	0.26	0.61		
	Cercidiphyllum	1.33	1.18	0.26	0.45		
	Japanese big-leaf magnolia	1.33	1.18	0.26	0.39		
	Maple tree	1.33	1.18	0.26	0.52		
	Amur cork	1.33	1.18	0.26	0.34		
	Linden	1.33	1.18	0.26	0.37		
	Kalopanax	1.33	1.18	0.26	0.40		
	Paulownia	1.33	1.18	0.26	0.23		
	Exotic broad leaf trees	1.41	1.41	0.16	0.66		
	Japanese birch	1.31	1.20	0.26	0.47		
	Other broad leaf trees	1.37	1.37	0.26	0.47		Applied to Chiba, Tokyo, Kochi, Fukuoka, Nagasaki, Kagoshima, and Okinawa prefectures
		1.52	1.33	0.26	0.65		Applied to Mie, Wakayama, Oita, Kumamoto, Miyazaki, and Saga prefectures
		1.40	1.26	0.26	0.62		Applied to prefectures other than above
Forests with less standing trees	Private forests	1.27		0.26	0.48	0.50	
	National forests	1.30		0.26	0.47		

Note: BEF: Biomass expansion factor (20 = forest age); R: Root-to-shoot ratio; D: Wood density; CF: Carbon Fraction

- ***Activity Data***

➢ ***Forest area***

Forest areas by species and forest age in intensively managed forests, semi-natural forests, forests with less standing trees and bamboo under the forest planning system were obtained from the *Forest Status*

Survey until FY2004 and has been obtained from the NFRDB, which was developed and is being maintained by the Forestry Agency based on the forest register information etc., since FY2005 and onward. Data for FY1991-FY1994, FY1996-FY2001, and FY2003-FY2004 were estimated by linear interpolation, as no data was available for those periods. In addition, area data of Sakhalin fir, Yezo spruce, Japanese chestnut oak and Oak (deciduous tree) before FY1990 are not available individually; therefore, these data were estimated from "other conifer" and "other broad leaf" area divided by the area ratio in FY1995. The forest registers are prepared according to the procedure in Figure 6-4 and are updated by prefectures for private forests and by the Regional Forest Offices of the Forestry Agency for national forests. When the forest registers are updated, changes to the forest register information for multiple years may be reflected at once.

Table 6-22 Classifications in Forest Status Survey (before 2004) and NFRDB (after 2005)

Conifer trees		Broad leaf trees	
Before 2004	After 2005	Before 2004	After 2005
Japanese cedar	Japanese cedar	Japanese chestnut oak	Japanese chestnut oak
Hinoki cypress	Hinoki cypress	Oak (deciduous tree)	Oak (deciduous tree)
Pine	Japanese red pine	Other broad leaf	Japanese beech
	Japanese black pine		Oak (evergreen tree)
Japanese larch	Japanese larch		Japanese chestnut
Sakhalin fir	Sakhalin fir		Japanese poplar
Yezo spruce	Yezo spruce		Alder
	Sakhalin spruce		Japanese elm
Other conifer	Sawara cypress		Japanese zelkova
	Hiba arborvitae		Cercidiphyllum
	Momi fir		Japanese big-leaf magnolia
	Japanese hemlock		Maple tree
	Japanese umbrella pine		Amur cork
	Japanese yew		Linden
	Ginkgo		Kalopanax
	Exotic conifer trees		Paulownia
	Other needle leaf		Japanese birch
			Exotic broad leaf trees
			Other broad leaf

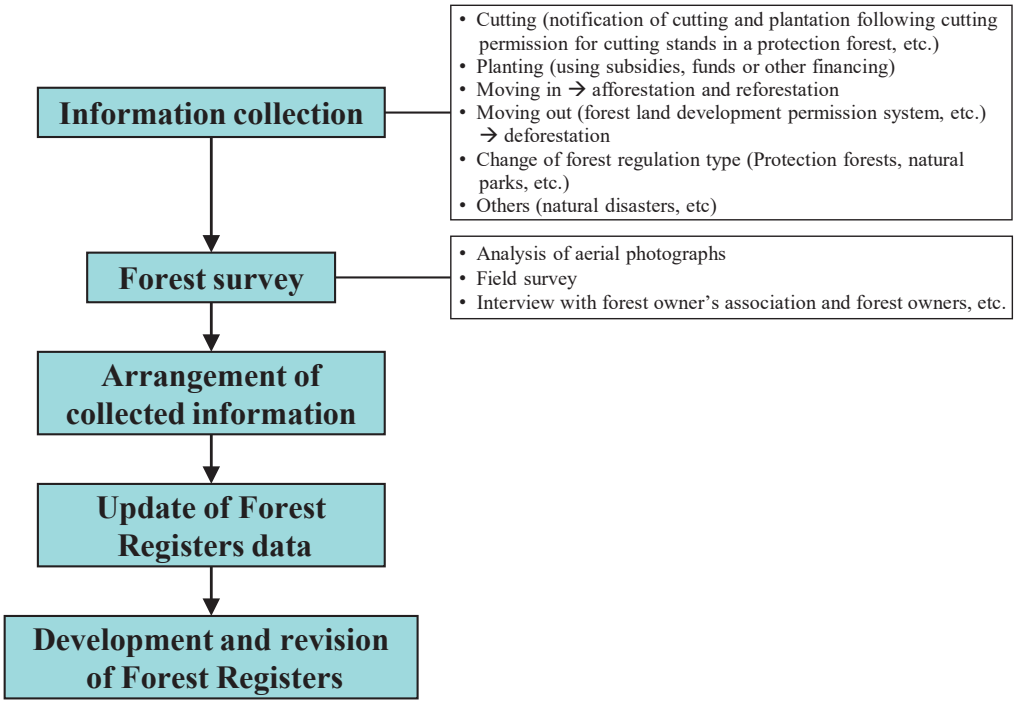

Figure 6-4 Procedures for developing and updating Forest Registers

2) Carbon stock changes in dead organic matter and soils in Forest land remaining Forest land

- ***Estimation Method***

➢ ***Carbon stock changes in dead organic matter and mineral soils in forests with standing trees***

In accordance with the decision tree provided in the *2006 IPCC Guidelines*, these pools are estimated by the Tier 3 method. Average carbon stock changes per unit area of dead wood, litter and mineral soils in forests with standing trees are calculated by prefecture, forest type (classified by dominant tree species), forest management type and age class or forest age using the CENTURY-jfos model.

The carbon stock changes in carbon pools of dead wood, litter and mineral soils of all forests with standing trees are summed up for each pool by multiplying each of the calculated average carbon stock changes per unit area by the land area of each tree species, forest management type, age class or age of the forest. The carbon stock changes in pools of dead wood, litter and mineral soils in "Forest land remaining Forest land (forests with standing trees)" are obtained by subtracting those amounts in "land converted to forest land (forests with standing trees)" from the amounts of all forests with standing trees estimated above. See section 6.4.2. b)2) for the method of estimating the amount of carbon stocks in "land converted to forest land."

$$\Delta C(l)_{FF} = \Delta C(l)_{F} - \Delta C(l)_{LF}$$

$$\Delta C(l)_{F} = \sum_{n,k,m,j} \{A_{n,k,m,j} \times p(l)_{n,k,m,j}\}$$

$\Delta C(l)_{FF}$: Annual carbon stock changes in a carbon pool *l*, in forest land remaining forest land (forests with standing trees) [t-C/yr]

$\Delta C(l)_{F}$: Annual carbon stock changes in a carbon pool *l*, in entire forest land (forests with standing trees) [t-C/yr]

$\Delta C(l)_{LF}$	: Annual carbon stock changes in a carbon pool *l,* in the land converted to forest land (forests with standing trees) [t-C/yr]
A	: Area [ha]
P(l)	: Average carbon stock changes per unit area in a carbon pool *l* [t-C/ha/yr]
l	: Type of carbon pool (dead wood, litter, mineral soils)
n	: Prefecture (47 prefectures)
k	: Type of forest management (intensively managed forests in Ikusei-rin forests, semi-natural forests in Ikusei-rin forests, Tennensei-rin forests)
m	: Age class or forest age (1-19 age class or 1-100 age)
j	: Tree species (Japanese Cedar, Hinoki Cypress, Pine species, Japanese Larch, Sakhalin Fir, Sakhalin Spruce, other conifer trees and broad leaf trees)

➢ ***Carbon stock changes in dead organic matter and mineral soils in forests with less standing trees and bamboo***

With respect to forests with less standing trees and Bamboo, carbon stock changes in dead organic matter and mineral soils are reported as "NA" because gains and losses of carbon stocks in the dead organic matter and mineral soils are equivalent on a long-term basis (FRA, 2010).

➢ ***CO_2 emissions from organic soils caused by cultivation and drainage***

Since it is unlikely in Japan that the treatment of drainage would be taken and then to plant trees on land with organic soil not suitable for growing forestry tree species, it was assumed that organic soils do not exist in intensively managed forests, "Semi-natural forests in Ikusei-rin forests", forests with less standing trees and bamboo, but exist only in "Tennensei-rin forests". Moreover, when we consulted with forest experts, they said they had never heard of such cases in Japan. In addition, there are many cases where areas with organic soils have a precious natural environment, and the change of the land configuration or characteristics are being regulated in these places by law and regulations. Given the above, it was concluded that drainage in forest land with organic soils is not implemented in Japan[4]; therefore, the emissions for this category are reported as "NO", since emissions from organic soils under the estimation methodology of Tier 1 or Tier 2 are estimated only when drainage is implemented in accordance with the *2006 IPCC Guidelines*.

● ***Parameters***

➢ ***Overview and adjustments of the CENTURY-jfos model***

CENTURY-jfos model is a soil carbon cycle model based on the CENTURY model developed by Colorado State University in the United States. It was modified to conduct calculation by each tree species in each prefecture to be applicable to Japanese forests. The model consists of two sub-models; forest growth model and soil organic matter (SOM) decomposition model. Dead organic matter outputted by the forest growth model is transferred to the SOM decomposition model, and carbon stock changes in the pools of dead wood, litter and mineral soil are calculated there. When adjusting the model, it was assumed that forests have continuously existed and have been used for a long time without undergoing conversion from/to other land use, and their soil carbon stocks have reached a nearly steady

[4] Drainage in organic soils in forest was discussed and concluded by breakout group on LULUCF under the Committee for the GHG Estimation Methods in FY2012 and FY2013.
Issue 6, FY2012：https://www.env.go.jp/content/900444857.pdf
Issue 2, FY2013：https://www.env.go.jp/content/900444882.pdf

state.

- ***Data used for the model***

The mesh climate data of Japan (average temperature and precipitation from 1981 to 2010) (Japan Meteorological Agency, 2012) were used for setting climate conditions. NFRDB (geographical forest distribution) and national-scale soil organic carbon map (Yamashita et al. 2022) were used for calculating soil carbon stocks (30cm soil depth). The "2021 Yield Tables" (Forest Agency) and the data of *National Forest Inventory Survey* (Forest Agency) were used for adjusting the forest growth model.

- ***Adjustments of the forest growth model***

Forest growth model for each tree species was adjusted based on the relationship between forest age and stock volume. The relationships for Japanese cedar, Hinoki cypress and Japanese larch were obtained from "2021 Yield Table" (Forest Agency), and those for other tree species including broadleaf tree species were obtained from the *National Forest Inventory Survey* (Forest Agency). Since "2021 Yield Table" incorporates the effects of natural mortality and thinning, the model was adjusted accordingly. The natural mortality rate of the trunks in intensively managed forests was set to 0.3%/yr, based on data from the test site of the Forest and Forest Products Research Institute (Nishizono et al. 2023). The thinning rate in the intensively managed forests was set at 1.1%/yr, which corresponds to a thinning rate of approximately 20% per 20 years. The trunk mortality rate for natural forests, which are rarely harvested, was assumed to be 0.8%/yr. The amount of litterfall was adjusted to average 2.2-2.3 t-C/ha/yr for coniferous forests and 2.5 t-C/ha/yr for broadleaf forests up to 60 years of forest age, based on literature information.

- ***Adjustments of the SOM decomposition model and estimation of carbon stock changes***

Before conducting the simulation, spin-up of 6,000 years was conducted with the assumption of cutting rotation age of 50 years for broadleaf forests. Then the coefficient of the decomposition rate of the persistent fraction of soil organic matter in the model was modified so that the soil carbon stocks calculated by the model are aligned with the soil carbon stocks in 30cm depth for each prefecture and each tree species. The parameters were determined in accordance with the CENTURY model manual (Metherell et al. 1993).

Using the adjusted model, the average annual carbon stock changes per unit area were calculated for each age class 1-19 (100 years), by forest management type and by tree species for each carbon pool.

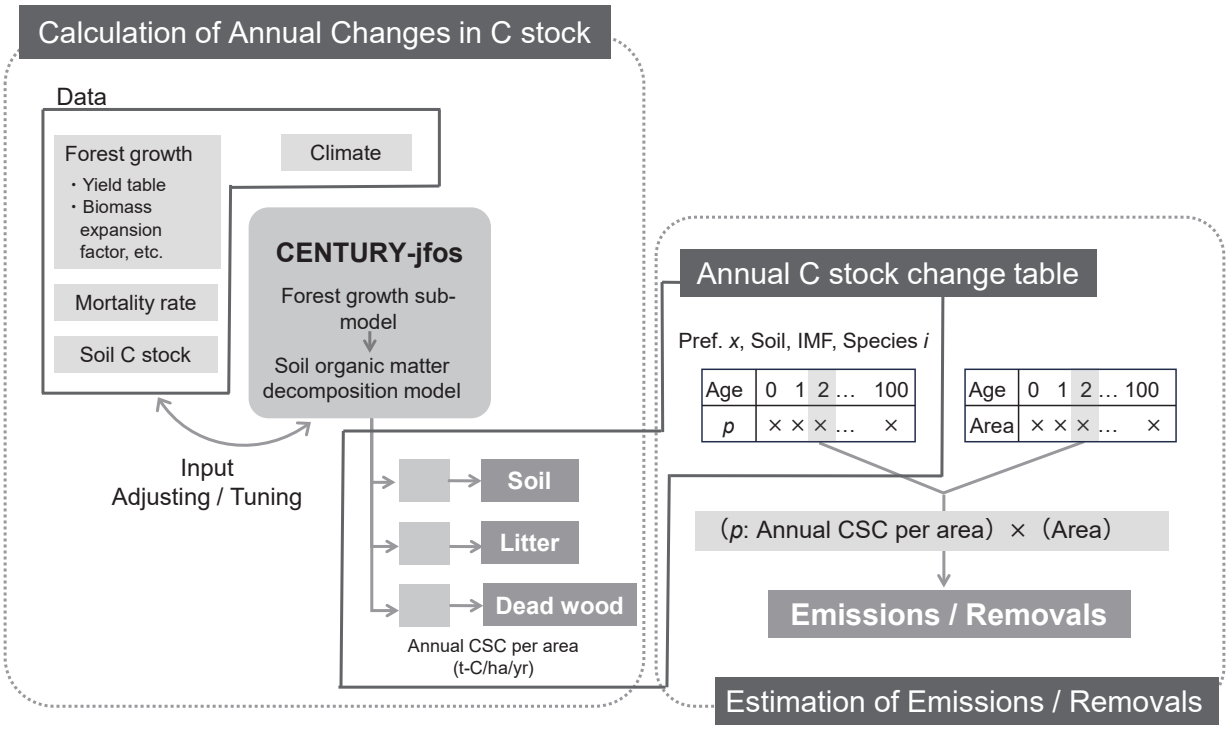

Figure 6-5 Estimation of emissions/removals in dead wood, litter and soils carbon pool

- ***Activity Data***

➢ ***Area of mineral soils***

Forest area data by forest management type, tree species and age provided by the NFRDB were used as activity data to be multiplied by the annual carbon stock changes per unit area calculated by the CENTURY-jfos model.

➢ ***Area of organic soils***

Areas of organic soils in forest land were estimated by means of soil maps and status of distribution of organic soils in each prefecture. Furthermore, organic soils exist only in semi-natural forests in Japan; hence, all areas of organic soils are reported in semi-natural forests, and areas of organic soils in intensively managed forests, forests with less standing trees and bamboo are reported as "NO".

Table 6-23 Area of organic soils in forest land

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Forest land	kha	66.2	65.5	65.4	66.0	66.2	66.3	66.4	66.7	66.8	66.8	66.8	66.9
Intensively managed forests	kha	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Semi-natural forests	kha	66.2	65.5	65.4	66.0	66.2	66.3	66.4	66.7	66.8	66.8	66.8	66.9
Forests with less standing trees	kha	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Bamboo	kha	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainties of the parameters and activity data for living biomass were individually assessed on the basis of field study results, expert judgment, or the default values provided in the *2006 IPCC Guidelines*. The uncertainty estimates for dead organic matter and soil were assessed by calculating the variance of outputs from the CENTURY-jfos model. As a result, the uncertainty estimate was 9% for the total

removals by forest land remaining forest land. Uncertainty estimates regarding the major parameters in this category are shown in Table 6-24.

Table 6-24 Uncertainty estimates regarding major parameters in the forest land category

			Uncertainty estimates [%]	Country specific (CS) or default(D)	Remarks
Forest land area			5.9	CS	Estimated based on uncertainty estimates of land areas in the NFRDB. Used 5.9% without distinguishing tree species.
Volume of timber per area			12.3	CS	Estimated based on analysis of comparison between yield table and measured data.
Biomass Expansion Factor	Japanese cedar	≦20	3.5	CS	Estimated based on measured values.
		＞20	1.1	CS	
	Hinoki cypress	≦20	3.2	CS	
		＞20	1.6	CS	
	Oak (deciduous tree)	≦20	8.6	CS	
		＞20	2.1	CS	
Wood density	Japanese cedar		2.5	CS	
	Hinoki cypress		1.7	CS	
	Oak (deciduous tree)		1.6	CS	
Carbon fraction of dry matter	All tree species		6.0	D	Estimated taking into account the *2006 IPCC Guidelines* default value.
Dead wood	All forests		22.1	CS	Result of uncertainty analysis of CENTURY-jfos model.
Litter			51.0		
Soils			19.9		

- ***Time-series Consistency***

There were no data for forest areas from FY1991 to FY1994, from FY1996 to FY2001, and from FY2003 to FY2004. Therefore, the time-series consistency was ensured by estimating these forest areas by means of interpolation.

The time-series consistency in the estimations of carbon stock changes in living biomass, dead wood, litter and mineral soils of forests with standing trees were ensured using consistent methodologies, yield tables, and parameters for the whole time-series in each carbon pool.

d) Category-specific QA/QC and Verification

General inventory QC procedures have been conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission and removal factors and the archiving of reference materials. QA/QC activities are summarized in Annex 4.

e) Category-specific Recalculations

- ***Correction in accordance with revision of the area of land converted to forest land***

Areas of intensively managed forests in forest land remaining forest land was recalculated to be consistent with the revision of interpretations of the "*Survey of land use change status by satellite image interpretation*" which are used as original data for determining areas of forests converted from other land

use. Following the revision, carbon stock changes in living biomass, dead organic matter and mineral soils in this category were recalculated for all years. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

We have revealed our plan to revise the method for estimating carbon stock in living biomass from the current indirect measurement approach based on yield table information developed for each region, tree species, and site productivity, to direct measurement approach based on periodic systematic sampling surveys conducted under the NFI, *National Forest Inventory Survey* (Forest Agency). The detailed methodology for estimating carbon stock changes using NFI data will be developed over the coming year.

6.4.2. Land Converted to Forest Land (4.A.2.)

a) Category Description

This subcategory deals with the carbon stock changes in forest land converted from other land-use categories within 20 years. The net removals in this subcategory in FY2024 were 499 kt-CO_2 (GHG emissions other than changes in carbon stock are not included). This represents a decrease of 94.8% compared to FY1990 and a decrease of 13.6% compared to the previous year. Removals since 1990 have been on a consistent decreasing trend.

b) Methodological Issues

1) Carbon stock change in Living Biomass in land converted to forest land

- ***Estimation Method***

The Tier 2 method which is estimated by summing the loss of carbon stock due to conversion ($\Delta C_{LB\_conversion\_to\_F}$) using Equation 2.16 from the *2006 IPCC Guidelines* (Vol. 4, Section 2.3.1.2) and the change of carbon stock accumulated after conversion ($\Delta C_{LF\_LB\_SC}$) was used for the annual carbon stock change in land converted to forest land (ΔC_{LF_LB}). Moreover, it was assumed that all land-use conversion occurred in intensively managed forests. And the ΔC_{LF_LB} value was reported for each land-use category before conversion and for each subcategory basis in cropland.

$$\Delta C_{LF\_LB} = \Delta C_{LB\_conversion\_to\_F} + \Delta C_{LF\_LB\_SC}$$

$$\Delta C_{LB\_conversion\_to\_F} = \sum_i \{\Delta A_i \times (B_a \times CF_a - B_{b_i} \times CF_{bi})\}$$

$$\Delta C_{LF\_LB\_SC} = \Delta A_{LF} \times IEF_{AR}$$

ΔC_{LF_LB}	: Annual carbon stock change in land converted to forest land [t-C/yr]
$\Delta C_{LB\_conversion\_to\_F}$	: Annual carbon stock loss in the previous land use due to conversion [t-C/yr]
$\Delta C_{LF\_LB\_SC}$	: Annual increase in Carbon stocks due to biomass growth on the converted forest land within 20 years from conversion [t-C/yr]
i	: Land-use category before conversion
ΔA_i	: Annual land area that has been converted from land-use type i to forest land [ha/yr]
B_a	: Dry matter weight biomass per unit area immediately after conversion to forest [t-d.m./yr]
$B_{b,i}$	: Dry matter biomass weight per unit area before conversion from land-use type i to forestland [t-d.m./yr]
CF_a	: Carbon fraction of dry matter after conversion (forest land) [t-C/t-d.m.]
CF_{bi}	: Carbon fraction of dry matter in land-use type before conversion [t-C/t-d.m.]

ΔA_{LF} : Area of converted forest land within 20 years [ha]
IEF_{AR} : Average carbon stock gain per unit area due to AR activities (equal to the implied removal factor) [t-C/ha/yr]. See Table 6-11.

- ***Parameters***

➢ ***Parameters for estimating living biomass stocks***

- ***Per unit area removals used in the estimation after conversion (IEF_{AR})***

Annual increase in biomass carbon stocks due to biomass growth in "land converted to forest land" used the value of the carbon stock gain per unit area caused from AR activities (Table 6-11) which is estimated in the forest land subjected to AR activities under Article 3, paragraph 3, of the Kyoto Protocol, since it can be considered that growth in "land converted to forest land" is similar to that in the land subjected to AR activities.

- ***Biomass stock or carbon stock in each land-use category (B_a)***

The parameter in cropland (rice fields and upland fields) and grassland before conversion, shown in Table 6-9, is used. For conversions from wetlands, settlements and other land, carbon stock losses in living biomass are assumed as 0, the carbon losses are reported as "NA".

- ***Carbon fraction of dry matter (CF)***

For carbon fraction of dry matter of forest, average value of broad leaf trees and conifer trees (0.50 t-C/t-d.m.) was applied. For that of grassland, the default value for herbaceous biomass (0.47 t-C/t-d.m.) was applied in accordance with the *2006 IPCC Guidelines*.

- ***Activity Data***

The areas of "land converted to forest land" within 20 years were calculated by summing the annually converted areas during the past 20 years. The estimation methods for total converted areas and for annually converted areas from each land-use category are described below. Since the transition period in the calculation of changes in soil carbon stocks is set at 40 years, the area converted to forest land is estimated from the year 1951.

➢ ***Total area of land converted to forest land***

- ***From FY2005 onwards***

The annual area of land converted to forest land from each land-use was estimated using the satellite image interpretation as mentioned in 6.6.2. a).

- ***From FY1990 to FY2004***

The annual areas of each land use converted to forest land from FY1990 to FY2004 are calculated by averaging the total AR area of FY 2005, obtained from interpretating aerial orthophotos taken at the end of FY1989 and satellite images taken in 2005, and allocating it to each year from FY1990 to FY2004.

- ***From FY1970 to FY1989***

The annual areas of land converted to forest land are calculated using forest area and deforestation area obtained from statistics provided by the *Census of agriculture and Forestry* (MAFF). The procedure of the calculation method is as follows.

1. Changes in forest area in 10 years (A_{t2}-A_{t1}) from FY1970 to FY1980 and FY1980 to FY1990 and deforested area in 10 years (ΔA_{D10}) are calculated using the forest areas obtained from the statistics

in FY1970, FY1980 and FY1990.

2. Total areas of land converted to forest land in the same 10 years' periods (ΔA_{LF10}) are calculated by summing of those areas calculated in Step 1 ($\Delta A_{LF10}=(A_{t2}+\Delta A_{D10})-A_{t1}=(A_{t2}-A_{t1})+\Delta A_{D10}$).

3. The values from Step 2 are allocated to each year according to the area of afforested land based on the statistical values which are from "the *Statistics of Cultivated and Planted Area* (MAFF)".

- ***From FY1951 to FY1969***

The annual areas of land converted to forest land are calculated to maintain consistency between the change in total forest area and deforestation area, as was done for the period 1971-1989 using forest area (1951, 1954, 1957, 1965, 1970) obtained from statistics provided by the *Census of Agriculture and Forestry* and *Statistical Tables of the Ministry of Agriculture and Forestry* (MAFF) and the deforested area estimated from the area under cultivation in the *Statistics of Cultivated and Planted Area*.

➢ ***Areas of cropland and grassland converted to forest land among the total areas***

- ***From FY2005 onwards***

The areas of cropland or grassland converted to forest land since FY2005 were respectively estimated by multiplying the percentage of the number of plots interpreted as conversion from cropland or grassland to forest land in the total number of AR plots. As subcategories of cropland, the areas of cropland converted to forest land from FY 2005 to 2016 is further divided into "rice fields converted to forest land", "upland fields converted to forest land" and "orchards converted to forest land" using area data obtained by statistics, obtained in the same way as below [from 1951 to 2004]. Since the subcategory of cleared and abandoned land is not available in the *Statistics of Cultivated and Planted Area* after FY2017, the data is divided into fields based on the percentage of cropland from rice fields and fields in *A Move and Conversion of Cropland* and proportionally divided into upland fields and orchards based on the current area.

- ***From FY1951 to FY2004***

The areas of cropland converted to forest land were determined by utilizing the areas of forested cropland reported in the Statistics of Cultivated and Planted Area. As its subcategories, the areas of cropland converted to forest land are categorized to rice fields converted to forest land, upland fields converted to forest land and orchards converted to forest land. The areas of rice fields converted to forest land are determined by utilizing the areas of forested by planting on rice fields provided by the Statistics of Cultivated and Planted Area. The areas of upland fields and orchards converted to forest land are estimated by taking into account the area data of annual agricultural land creation at each land-use subcategory obtained by Administrative Statistics of Creation of Agricultural Land for the period of 1971-2002, For other periods, the estimates were prorated using existing area ratios of upland fields, orchards and pasture land provided in the Statistics of Cultivated and Planted Area.

The areas of grassland converted to forest land are calculated by summing the areas of forested by planting on pasture land estimated from the data mentioned above and those of forested by planting on grazed meadow reported in *A Move and Conversion of Cropland* (MAFF).

➢ ***Areas of Wetlands, Settlements or Other land converted to Forest land***

- ***From FY2005 onwards***

The areas of wetlands, settlements or other land converted to forest land since FY2005 were respectively estimated by multiplying the percentage of the number of plots interpreted as conversion from each land

use to forest land in the total number of AR plots.

- ***From FY1951 to FY2004***

Since the areas of wetlands, settlements, and other land converted to forest land cannot be obtained directly from statistics for the years before FY2004, they are estimated by subtracting the summed areas of cropland converted to forest land and grassland converted to forest land from the total area of land converted to forest land, and by multiplying the difference by ratios of areas of wetlands, settlements, and other land converted to forest land, which are estimated based on trend of results of AR identification in 2007. The allocation ratio was fixed at wetlands: settlements: other land = 0: 1: 1.

Table 6-25 Area of land converted to forest land (intensively managed forests) within the past 1 year

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Land converted to Forest land	kha	4.46	4.46	4.46	4.46	3.17	1.01	1.08	0.05	0.04	0.04	0.05	0.05
Cropland converted to Forest land	kha	3.11	1.28	1.05	2.69	1.79	0.59	0.31	0.01	0.03	0.03	0.02	0.02
Rice field	kha	0.92	0.47	0.41	0.81	0.76	0.22	0.10	0.01	0.01	0.01	0.01	0.01
Upland field	kha	1.20	0.52	0.20	1.47	0.81	0.30	0.17	0.01	0.01	0.01	0.01	0.01
Orchards	kha	0.99	0.30	0.44	0.42	0.22	0.08	0.04	0.00	0.00	0.00	0.00	0.00
Grassland converted to Forest land	kha	0.27	0.25	0.30	0.80	0.75	0.28	0.59	0.04	NO	NO	0.03	0.03
Wetlands converted to Forest land	kha	NO	NO	NO	0.00	NO	0.01	NO	NO	NO	NO	NO	NO
Settlements converted to Forest land	kha	0.54	1.47	1.55	0.78	0.51	0.09	0.11	NO	NO	NO	NO	NO
Other land converted to Forest land	kha	0.54	1.47	1.55	0.19	0.13	0.04	0.07	NO	0.01	0.01	NO	NO

Table 6-26 Area of Land converted to forest land (intensively managed forests) (areas within the past 20 years and areas for 21 to 40 years after conversion)

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Area within the past 20 years after conver	kha	553.9	243.1	157.2	116.9	85.4	78.2	71.3	50.7	46.2	41.8	37.4	33.0
Cropland converted to Forest land	kha	123.6	60.2	43.1	34.2	31.2	28.2	26.4	21.1	20.2	19.4	18.8	18.3
Grassland converted to Forest land	kha	17.6	9.1	6.5	5.8	7.9	9.2	9.6	9.1	9.0	8.7	8.5	8.4
Wetlands converted to Forest land	kha	NO	NO	NO	NO	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Settlements converted to Forest land	kha	206.3	86.9	53.8	38.7	24.6	22.0	19.3	11.9	10.2	8.5	6.7	4.8
Wetlands converted to Forest land	kha	206.3	86.9	53.8	38.2	21.7	18.7	15.9	8.4	6.8	5.1	3.3	1.4
Area 21-40 years after conversion	kha	439.8	724.0	781.1	729.1	555.8	321.6	243.2	157.1	146.3	137.1	129.8	123.3
Cropland converted to Forest land	kha	201.8	270.0	286.8	235.8	123.6	75.9	60.2	43.1	40.6	38.3	36.0	34.0
Grassland converted to Forest land	kha	16.7	26.4	30.0	27.9	17.6	11.4	9.1	6.5	6.1	5.8	5.7	5.4
Settlements and other land converted	kha	221.3	427.6	464.4	465.4	414.5	234.3	173.9	107.5	99.7	93.0	88.1	83.9

2) Carbon stock changes in dead organic matter and soils in land converted to forest land

- ***Estimation Method***

➢ ***Carbon stock changes in dead organic matter in forests with standing trees***

Carbon stock changes in dead wood and litter were calculated under the assumption that these carbon stocks change linearly in each transition period from those in land-use categories other than forest land (0 t-C/ha) to those in forest land, calculating the rate of change per year [t-C/ha/yr], and multiplying it by the area of activity as shown in the following equation. Even if the transition period is 40 years for dead wood, the area of activity should be the area converted in the last 20 years, since under that category, lands up to 20 years after conversion are subject to reporting. Lands that have been converted for more than 21 years up to 40 years are reported under the category of "forest land remaining forest land" .

$$\Delta C(l)_{LF} = \sum_i \left\{ \Delta A_{LF_i} \times (C(l)_{FT} - C(l)_i)/T(l) \right\}$$

$\Delta C(l)_{LF}$: Annual carbon stock changes in a carbon pool l in land-use category i converted to forest land (forests with standing trees) [t-C/yr]

ΔA_{LFi}	: Area of land-use category *i* being converted to forest land (forests with standing trees) within the past 20 years [ha]
$C(l)_{FT}$	: Average carbon stocks in a carbon pool *l* per unit area in forest at the end of the transition period [t-C/ha]
$C(l)_i$	: Average carbon stocks in a carbon pool *l* per unit area in land-use category *i* before conversion [t-C/ha]
$T(l)$	: Transition period (40 years for dead wood, 20 years for litter)
l	: Type of carbon pool (dead wood, litter)
i	: Land-use category before conversion

➢ ***Carbon stock changes in mineral soils of forests with standing trees***

Carbon stock changes in mineral soils were calculated by multiplying the annual change, calculated using the method shown in Table 6-14, by the forest area converted from other land-uses within the past 20 years. The amount of annual change depends on the land use prior to the conversion.

➢ ***CO_2 emissions from organic soils due to cultivation and drainage***

Emissions from organic soils in this category were reported as "NO" in the same manner as forest land remaining forest land.

- ***Parameters***

➢ ***Parameters for estimating carbon stock changes in dead organic matter and soils***

Parameters for each carbon pool in Table 6-12 (dead wood), Table 6-13 (litter) and Table 6-14 (mineral soils) were used, in particular, for the categories cropland, grassland, wetlands, settlements and other land before conversion and for the category forest land after conversion.

- ***Activity Data***

➢ ***Total areas of land converted to forest land***

Areas of land converted to forest land within the past 20 years shown in Table 6-26

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainties of the parameters and activity data for living biomass, dead organic matter, and soil were individually assessed on the basis of field study results, expert judgment, or the default values provided in the *2006 IPCC Guidelines*. As a result, the uncertainty estimate was 9% for the entire removal from land converted to forest land.

- ***Time-series Consistency***

Time-series consistency for this subcategory is ensured.

d) Category-specific QA/QC and Verification

Same as Forestland Remaining Forestland (4.A.1.). See section 6.4.1 d).

e) Category-specific Recalculations

- ***Correction in accordance with revision of the area converted to forest land***

As it was mentioned in 6.4.1. e), areas of land converted to forest land due to the correction of the area

were recalculated. Accordingly, carbon stock changes in living biomass, dead organic matter and mineral soils in this category were recalculated for all years. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

In conjunction with the planned improvement for the calculation under forest land remaining forest land, some improvements are also planned in this category.

6.5. Cropland (4.B.)

This category covers lands on which annual and perennial crops, as well as land temporarily left fallow or has become degraded due to the abandonment of cultivation. In Japan's national inventory, cropland is classified into subcategories (land-use types) of rice fields, upland fields, orchards and dilapidated farmland.

Three main types of carbon stock changes occur on cropland:

i) Carbon stock changes occurring from ongoing agricultural practices on land that continues to be used as cropland (e.g., organic matter inputs, tillage, growth of trees, pruning/harvesting).

ii) Carbon gains and losses resulting from conversions among subcategories within cropland each other.

iii) Carbon losses resulting from cropland conversion to other land-use categories, and carbon gains resulting from conversion from other land-use categories into cropland.

In Japan's estimation framework, the treatment of carbon stock changes in living biomass on cropland is shown in Table 6-27. First, increases due to growth and decreases due to harvesting or mortality for annual crop and increase due to growth and decreases due to harvesting, pruning and mortality for perennial crop under (i) are considered to offset each other, and so assumed that the carbon stock per area for the same crop type are stable over time. Therefore, this reported as "NA" in accordance with the *2006 IPCC Guidelines*, Vol. 4, Section 5.2.1.1.

Next, regarding (ii) internal conversions within cropland, for rice fields and upland fields neither carbon losses nor gains due to such internal conversions are estimated. For orchards, the net change in area—whether due to internal conversion within cropland or land use conversion to other land uses—is identified, and all associated carbon stock changes are estimated collectively under "6.5.1. Cropland Remaining Cropland (4.B.1)." However, carbon gains associated with tree growth following conversion into orchards are implicitly included in total carbon stock changes in orchard.

Finally, with respect to (iii) conversion to other land uses, carbon losses are reported under the land-use category to which the land has been converted. Carbon gains after conversion from other land uses into cropland are reported under "6.5.2. Land Converted to Cropland (4.B.2)" for rice fields and upland fields.

Table 6-27 Reporting status of living biomass in cropland subcategories

		i) Agricultural activities	ii) Conversions within agricultural land (from/to)			iii) Conversions between agricultural land and other land use (from/to)
			Rice fields	Upland fields	Orchards	
Rice fields	loss	NA		NE	NE	Land-use category after conversion
	gain	NA		NE	NE	4.B.2
Upland fields	loss	NA	NE		NE	Land-use category after conversion
	gain	NA	NE		NE	4.B.2
Orchards	loss	NA	4.B.1	4.B.1		4.B.1
	gain	NA	4.B.1	4.B.1		4.B.1

For carbon stock changes in mineral soils due to organic matter inputs and tillage, the estimation model used incorporates the history of land-use conversions from non-cropland and internal conversions within its scenarios. Therefore, all such carbon stock changes are calculated collectively under "Cropland Remaining Cropland (4.B.1)" for each subcategory.

For dilapidated farmland, carbon stock changes are considered to be zero for all carbon pools because no direct human-induced management activities are carried out, and they are reported as "NA." accordingly.

In FY2024, Japan's cropland area was about 3.94 million ha, which is equivalent to about 10.4% of the national land. The area of organic soil in cropland is about 0.17 million ha. The emissions from this category in FY2024 were 4,241 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 41.8% compared to FY1990 and a decrease of 6.0% compared to the previous year.

Table 6-28 Emissions and removals in cropland resulting from carbon stock changes

Category	Carbon pool	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
4.B. Cropland	Total	kt-CO_2	7,286	3,777	3,456	2,307	5,760	4,546	5,344	3,895	4,228	5,093	4,513	4,241
	Living biomass	kt-CO_2	700	347	183	206	282	190	241	326	509	514	236	243
	Dead wood	kt-CO_2	72	19	7	15	21	14	13	13	33	33	9	9
	Litter	kt-CO_2	47	13	4	10	14	9	9	9	22	22	6	6
	Mineral soil	kt-CO_2	5,222	2,169	2,049	879	4,263	3,159	3,906	2,376	2,495	3,355	3,095	2,816
	Organic soil	kt-CO_2	1,244	1,228	1,214	1,197	1,180	1,175	1,174	1,172	1,170	1,168	1,167	1,166
4.B.1. Cropland remaining Cropland	Total	kt-CO_2	6,660	3,562	3,356	2,133	5,551	4,433	5,215	3,721	3,806	4,662	4,377	4,104
	Living biomass	kt-CO_2	280	245	157	121	154	144	179	231	202	200	180	189
	Dead wood	kt-CO_2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Litter	kt-CO_2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mineral soil	kt-CO_2	5,222	2,169	2,049	879	4,263	3,159	3,906	2,376	2,495	3,355	3,095	2,816
	Organic soil	kt-CO_2	1,158	1,147	1,150	1,133	1,134	1,131	1,130	1,115	1,110	1,107	1,102	1,099
4.B.2. Land converted to Cropland	Total	kt-CO_2	626	215	100	175	209	112	129	173	422	431	136	137
	Living biomass	kt-CO_2	421	102	25	85	128	46	63	95	307	314	56	54
	Dead wood	kt-CO_2	72	19	7	15	21	14	13	13	33	33	9	9
	Litter	kt-CO_2	47	13	4	10	14	9	9	9	22	22	6	6
	Mineral soil	kt-CO_2	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	Organic soil	kt-CO_2	86	81	64	64	46	44	44	57	59	61	65	67

Table 6-29 Areas of cropland

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Cropland	kha	4,764	4,582	4,430	4,333	4,268	4,199	4,173	4,060	4,015	3,987	3,965	3,942
Rice fields	kha	2,846	2,745	2,641	2,556	2,496	2,465	2,446	2,380	2,366	2,352	2,335	2,319
Upland fields	kha	1,275	1,225	1,188	1,173	1,169	1,161	1,151	1,130	1,126	1,123	1,120	1,118
Orchards	kha	475	408	357	332	311	300	292	268	263	259	253	249
Dilapidated farmland	kha	167	204	244	272	292	273	284	282	260	253	257	257

6.5.1. Cropland Remaining Cropland (4.B.1.)

a) Category Description

This category covers carbon stock changes associated with change in orchard area for living biomass, all carbon stock changes in mineral soils including those resulting from "land converted to Cropland", and carbon losses from tillage or drainage of organic soils in cropland remaining cropland. The emissions from this subcategory in FY2024 were 4,104 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 38.4% compared to FY1990 and a decrease of 6.2% compared to the previous year. The trends in emissions and removals in this category are driven by carbon stock changes in mineral soils. CO_2 emissions from mineral soil pool in FY2024 were 2,816 kt-CO_2; a 46.1% decrease compared to FY1990 and a 9.0% decrease compared to the previous year.

The trend on emissions in time-series for mineral soils started from a decreasing trend of emissions from FY1990 to FY2003, turned to continuously increasing trend of emissions from FY2004 to FY2008, which is the peak of emissions for whole time series, and shown a declining trend of emissions again since then. It is considered that the time-series variability is mainly caused by annual variability of carbon input amount into mineral soils (especially, carbon input of composted farm-yard manure) and annual fluctuation of temperature that affects decomposition of the carbon input. Among the three subcategories of cropland (rice field, upland field and orchard), the annual fluctuations have been largely affected by the trends in upland fields, especially occurred in Hokkaido prefecture, which holds more than 25% of upland field in Japan. This is because that the amount of emissions are calculated by multiplying the carbon stock change factor by the area of prefecture, so even if the fluctuation of the carbon stock change factor is small, it will be amplified when there is a fluctuation in a prefecture with a large area.

In addition, estimation of carbon stock changes in mineral soils by biochar amendments in cropland have been included. The amount of reduction in emissions by the effect of carbon stored by biochar amendment in FY2024 is 3.62 kt-CO_2. This value potentially includes biochar amendments in pasture lands under the Grassland category in addition to those in rice fields, upland fields, and orchards under the Cropland category.

b) Methodological Issues

1) Carbon stock changes in living biomass in "cropland remaining cropland"

- ***Estimation Method***

➢ ***Carbon stock changes in living biomass in orchards***

Carbon stock changes in living biomass in orchard are estimated by applying the Tier 2 estimation

method of the stock-difference method described in section 5.2.1.1 in Vol. 4 of the *2006 IPCC Guidelines*.

The carbon stocks in living biomass in orchard are calculated by multiplying area of each orchard tree type by dry matter biomass weight per tree, standard planting density, and carbon fraction of dry matter. The carbon stock changes associated with the changes in area are fully calculated in this estimation.

$$\Delta C_{C\_LB} = C_{t+1} - C_t$$

$$C_t = \sum_j \left(A_{t,j} \times D_j \times W_j\right) \times \frac{10}{1000} \times CF$$

Note: 10/1000 is for unit conversion

$\Delta C_{C\ LB}$: Carbon stock change in living biomass in Orchards [t-C/yr]
C_t : Total Carbon stock in living biomass at time *t* [t-C]
A_t : Cultivation area of orchards at time *t* [ha]
D : Planting density [tree/10a]
W : Dry matter weight of biomass per tree [kg/tree]
CF : Carbon fraction of dry matter [t-C/t-d.m.]
j : Type of orchard tree

- ***Parameters***

➢ ***Parameters for estimating the living biomass carbon stock of orchard trees***

Country specific parameters of the planting density, dry matter biomass weight per tree, and root-to-shoot ratio by orchard tree species were set for major orchard trees based on domestic research reports and expert judgment (in the Committee for the GHG emission estimation methods in FY2014).

The dry matter biomass weight per unit area and the root-to-shoot ratio for each major orchard trees are presented in the table below. The country specific carbon fraction of dry matter of forest (broad leaf: 0.48 t-C/t-d.m.) was applied as the carbon fraction of dry matter of orchard trees.

Table 6-30 Parameters for estimating the living biomass carbon stock of orchard trees

Orchard Species	Biomass per Unit Area (t-d.m./ha)	root-to-shoot ratio
Mikan(Mandarin)	20	5:4
Other Citrus	Substituted with Mikan	
Apple	24	2:1
Persimmon	10	3:2
Chestnunut	8	5:3
Grape	10	2:1
Japanese apricot	15	7:3
Jananese Pear	20	3:2
Peach	20	3:2
European Pear	Substituted with Japaneese Pear	
Loquat	Substituted with Mikan	
Japanese Plum	Substituted with Peach	
Cherry	Substituted with Apple	
Kiwi Fruit	Substituted with Grape	
Tea	48	2:1

- ***Activity Data***

➢ ***Area for orchard***

The cultivation areas for 15 major orchard trees were identified by *the Statistics of Cultivated and Planted Area* and for fruit trees other than 15 major orchard trees were identified by *Survey on Productive Movement of Local Fruits*. Even when the survey is conducted only in the main producing prefectures for major orchard trees, all the area of the orchard trees at each prefecture are assumed in line with the method to assume the national total area in the statistics or using interpolation. As the area of "newly-established" and "deserted" is not identified by orchard type in this statistic, only the apparent amount of change after land-use conversion is used as activity data. Therefore, this value includes area of orchard land converted from other land use.

2) Carbon stock changes in dead organic matter in cropland remaining cropland

- ***Estimation Method***

Carbon stock changes in dead organic matter are estimated as zero by applying the Tier 1 method, assuming that the carbon stocks are not changed, according to section 5.2.2.1 in Vol. 4 of the *2006 IPCC Guidelines*. Thus, the carbon stock changes are reported as "NA".

3) Carbon stock changes in soils in cropland remaining cropland

For mineral soils, the estimations are conducted separately to agricultural land (Rice fields, Upland fields, Orchards) and non-agricultural land (dilapidated farmland). Carbon stock changes in agricultural land consist on carbon stock changes due to normal practices in farming as well as carbon accumulation by biochar amendment. For organic soils, the emission associated with cultivation of organic soils (on-site) and the emission due to water-soluble carbon loss from drained organic soils (off-site) in rice fields and upland fields in agricultural land were estimated.

- ***Estimation Method***

➢ ***Carbon stock changes in mineral soils***

- ***Carbon stock changes in mineral soils in agricultural land (rice fields, upland fields and orchard)***

Japan uses a Tier 3 method, the Rothamsted Carbon Model (Roth C), to estimate soil organic carbon stock changes in agriculture land (cropland and managed grassland) over time.

As shown in Figure 6-6, amounts of soil carbon [t C/ha (for each 100m x 100m mesh)] by each of the five compartments with different rates of carbon decomposition are calculated monthly, using inputs from weather data (monthly average temperature, precipitation, and open-pan evaporation), soil property data (soil clay content, depth of surface soil, carbon content at the starting year, and bulk density), land-use data, and carbon input from plant residue (including crop residue and green manure) and composted farm-yard manure (hereafter manure). The annual soil carbon stock changes [t-C/ha/yr] for each mesh were calculated by taking the difference between the annual total carbon of all compartment for all months in this year and those in the previous year. In order to classify the report category of the GHG inventory, the average amount of soil carbon stock changes per unit area by each subcategory and by each prefecture [t-C/ha/yr] were estimated by identifying the land use in subcategory for each mesh and by superimposing the map with the prefectural administrative boundaries on the mesh data. The total carbon stock changes in agriculture land [t-C/year] were calculated by

multiplying the carbon stock change parameter obtained from the model by the mineral soil area of each prefecture level obtained from statistics.

$$\Delta C_{C\_ms} = \sum_{i,j} \left(\Delta SOC_{i,j} \times A_{i,j} \right)$$

ΔC_{C_ms} : Carbon stock changes in mineral soils in agricultural land [t-C/yr]
$\Delta SOC_{i,j}$: Carbon stock changes in mineral soils per unit area [t-C/ha/yr] by subcategory *j* and by prefecture *i*, estimated from the Roth C model
A : Area of cropland with mineral soils obtained from statistics [ha]
i : Prefecture
j : Type of land-use subcategory in cropland (rice fields, upland fields and orchard)

In the model calculation, land unit which was recorded once as cropland since FY1970 was regarded as cropland and used for calculation; the result of the calculation includes all croplands, regardless of whether converted or not.

- ***Carbon sequestration associated with biochar amendment in mineral soils***

Amount of carbon stored in mineral soils associated with biochar amendment to cropland is estimated using Equation 2.25A provided in Vol. 4 of the *2019 Refinement*. This estimation covers hard charcoal, soft charcoal, bamboo charcoal, fine coal and sawdust coal, which are domestically produced using domestic woods.

Since information on past land-use changes at the application sites as well as data on biochar amendment rate by land-use subcategory, could not be obtained, all results were reported collectively in mineral soils in cropland remaining cropland. The estimation equation is as follows:

$$\Delta BC_{C\_ms} = \sum_{p} \left(BC_{TOT_p} \times F_{C_p} \times F_{perm_p} \right)$$

ΔBC_{C_ms} : Amount of carbon stored in mineral soils land associated with biochar amendment to agricultural land , tonnes [t-C/yr]
BC_{TOTp} : Mass of biochar applied into mineral soil during the inventory year for each biochar production type *p* [t-d.m./yr]
F_{Cp} : Organic carbon content of biochar for *p* [t-C/t-d.m.]
F_{perm} : Fraction of biochar carbon for biochar *p* remaining (unmineralized) after 100 years [t-C/t-C]
p : Biochar type (hard charcoal, soft charcoal, bamboo charcoal, fine coal and sawdust coal)

- ***Carbon Stock Changes in Mineral soils in dilapidated farmland***

As it is described in the carbon stock changes in the biomass pool, carbon stock changes due to direct human management were considered zero in the dilapidated farmland area and so reported as “NA”.

➢ ***CO_2 emissions from organic soils caused by cultivation and drainage***

- ***On-site CO_2 emissions from organic soils in rice fields and upland fields caused by cultivation and drainage***

On-site CO_2 emissions from organic soils in rice fields and upland fields were estimated by applying Tier 1 or Tier 2 estimation method described in section 5.2.3.1 in Vol. 4 of the *2006 IPCC Guidelines*. Tier 2 method was applied to land-use subcategories for which country-specific emission factors were available.

$$L_{C\_os} = \sum_{j,z} \left(A_{j,z} \times EF_{j,z} \right)$$

L_{C_os} : Loss of Carbon in organic soils [t-C/yr]
$A_{j,z}$: Area of organic soils in subcategory *j* in Climate zone *z* [ha]
$EF_{j,z}$: CO_2 emission factor in subcategory *j* in Climate zone *z* [t-C/ha/yr]
j : Type of land-use subcategory in cropland (rice fields, upland fields)
z : Climate zone (Cold temperate zone, warm temperate zone)

- ***Off-site CO_2 emissions via waterborne carbon losses from drained inland organic soils in rice fields and upland fields***

Off- site CO_2 emissions via waterborne carbon losses from drained inland organic soils in rice fields and upland fields were estimated by applying Tier 1 estimation method described in 2.2.1.2 section in the *Wetlands Guidelin*es. The estimation equation is as follows. See section 6.13. b) for the methodology of methane emission.

$$CO_2\text{-}C_{DOC_{C\_os}} = \sum_{j} \left(A_j \times EF_{DOC} \right)$$

$$EF_{DOC} = DOC_{FLUX_{NATURAL}} \times (1 + \Delta DOC_{DRAINAGE}) \times F_{rac_{DOC-CO_2}}$$

$CO_2\text{-}C_{DOCC\_os}$: Annual off-site CO_2-C emissions due to DOC loss from drained organic soils [t-C/yr]
A_j : Land area of drained organic soils in land-use subcategory *j* [ha]
j : Subcategory in cropland (rice fields, upland fields)
EF_{DOC} : Emission factors for annual CO_2 emissions due to DOC loss from drained organic soils [t-C/ha/yr]
$DOC_{FLUX_{NATURAL}}$: Flux of DOC from natural (undrained) organic soil [t-C/ha/yr]
$\Delta DOC_{DRAINAGE}$: Proportional increase in DOC flux from drained sites relative to undrained sites
$Frac_{DOC\text{-}CO2}$: Conversion factor for proportion of DOC converted to CO_2 following export from site

- ***CO_2 emissions from organic soils caused by cultivation and drainage in orchard and dilapidated farmland***

There are few organic soils area in orchard, and it is common to grow orchard trees by either a method of cultivation by clean cultivation system or a method of cultivation by sod culture without tillage and drainage of soils are not also implemented in dilapidated farmland. So, since no emissions occur in these inactive areas the emissions were reported as "NO" in accordance with the *2006 IPCC Guidelines*.

- ***Parameters***

➢ ***Key assumption and parameters necessary for Roth C model estimating carbon stock changes in mineral soils in agricultural land (rice fields, upland fields and orchard)***

- ***Application of Roth C model for agricultural land in Japan***

Roth C is a soil carbon dynamic model validated using long-term field experiments (Coleman and Jenkinson, 1996). The model had been tested against long-term experimental data sets in Japanese agricultural lands and some modifications were made after that in order to apply the model to Japanese agricultural conditions. It was found that the original model could be applied for non-volcanic upland soils without any modification or calibration (Shirato and Taniyama, 2003), however, for Andosols, the decomposition rate constant of the HUM (humified organic matter) pool of Roth C was reduced because

the presence of Al-humus complexes enhances its stability and resistance to decomposition (Shirato *et al.* 2004). And, for paddy soils, the decomposition rate constants of all four active C pools was reduced on the basis of differences in organic matter decomposition rates between upland and paddy (submerged in the rice growing season) soil conditions (Shirato and Yokozawa, 2005).

- ***Input data for Roth C model estimation***

Weather data with 1km mesh resolution, soil property and land-use data obtained by 100m mesh were used. The statistical data and the questionnaire survey by prefecture were used for amount of carbon input from plant residue and manure. The input amount of plant residue was calculated in each crop by multiplying the crop yield by the ratio of residue generation and the ratio of plow-into soils. Since the amount of plant residue is related to the amount of crops rather than the amount of harvest, it is not considered that reflecting the annual fluctuation of the amount of harvest leads to accurate estimation. So, we decided to use the average yield (for rice fields, the average value of yield of rice calculated by the MAFF was used, and for upland fields and orchard, the average values of actual yield from 1970 to 2017 were used) for each year. The residue generation ratio is set by a same value all over the country for each crop from the literature values. And the ratio of plow-into soils were determined by the actual treatment ratio of plowing from the annual questionnaire survey. For rice, annual values are used for each region and for other crops, unified values for the entire period are used. For the manure input, the amount of manure application in the item of "production cost of rice" in the *Statistics on Farm Management* is used for rice and the amount of manure application estimated by the questionnaire survey are used for crops other than rice (upland crops, vegetables, fruit trees, tea, feedstuff, pasture grass). However, since surveys are conducted over the course of several years except for rice fields, the values for the years when results of the survey are not compiled are complemented by interpolation or extrapolation, and if the number of samples is too small to assure representativeness, those data are used after statistical processing, such as exclusion from the usage for estimation.

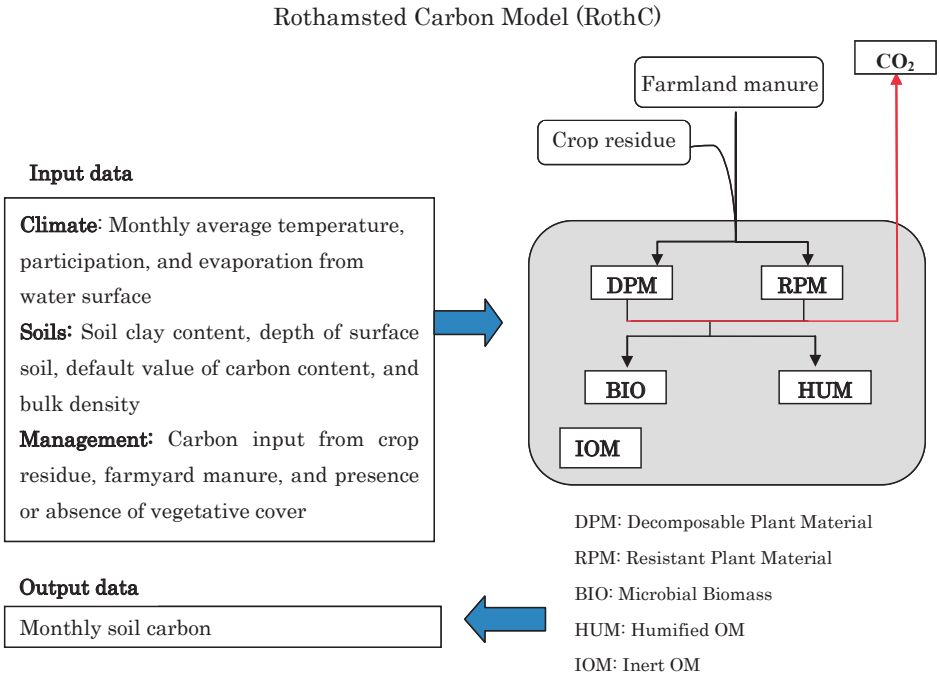

Figure 6-6 Roth C model

- ***Parameters for estimating carbon sequestration associated with biochar amendment (organic carbon content and fraction of carbon remaining after 100 years)***

The country-specific estimation parameters for organic carbon content and the fraction of carbon remaining after 100 years for soft charcoal, bamboo charcoal, and fine coal were developed through a national research project[5] (Kurimoto et al., 2024).

For classifying pyrolysis temperature ranges in the inventory, the distribution of pyrolysis temperatures in commercial biochar, which are reported as the production data for specialty forestry products in *Special Forest Products Production Statistical Survey* of the Ministry of Agriculture, Forestry and Fisheries'.

For hard charcoal and sawdust coal, the default value for organic carbon content associated with the thermal decomposition process of wood, 0.77 t-C/t-d.m, provided in Table 4Ap.1, Appendix4, vol.4 of the *2019 Refinement* is applied. Regarding the fraction of carbon remaining after 100 years, the value corresponding to a pyrolysis temperature of ≥600 °C, 0.89 t-C/t-C, is adopted from the default values presented in Table 4Ap.2, Appendix4, vol.4 of the same Guidelines, reflecting the pyrolysis temperatures commonly used in Japan.

Table 6-31 Organic carbon content and fraction of carbon remaining after 100 years by biochar type

Type of biochar	Organic carbon content [t-C/t-dm]	Fraction of carbon remaining after 100 years [t-C/t-C]	Reference
Soft charcoal	0.90	0.86	Kurimoto et al., 2024, pyrolysis temperature of ≥450 °C
Bamboo charcoal	0.83	0.85	Kurimoto et al., 2024, all range of pyrolysis temperature
Fine coal	0.76	0.84	Kurimoto et al., 2024, pyrolysis temperature of ≥450 °C
Hard charcoal / sawdust coal	0.77	0.89	Default value, pyrolysis temperature of ≥600 °C, Table 4A p.1 / Table4A p.2, Appendix4, vol.4 of the *2019 refinement*

- ***CO_2 emission factors from organic soils (on-site)***

The following CO_2 emission factors from organic soils in rice fields and upland fields were applied to the estimation.

Table 6-32 Carbon emission factors resulting from cultivation of organic soils

Type of land use	Climate zone	Emission factors [t-C/ha/yr]	Reference
Rice fields	Cold temperate	1.55	Measured data[1)]
	Warm temperate	1.55	Data measured for cold temperate was applied.[2)]
Upland fields	Cold temperate	4.18	Measured data
	Warm temperate	10.0	Default value (*2006 IPCC Guidelines,* Vol.4, Table 5.6)

Note: Some areas of Japan belong to the subtropical climate zone, but the data used for the calculation shows that the cultivated area of organic soils in those agricultural areas is reported as "NO", so the carbon emission factor for the subtropical zone is not used in the calculation.
1)Measured data of rice field was set as if emission in waterlogging period was zero (0).
2)The emission factor of rice field in warm temperate was excluded in default values in *the 2006 IPCC Guidelines*; hence, the country-specific factor in cold temperate was applied as substitute.

[5] the Commissioned Project 'Enhancing Carbon Sequestration Capacity in Agricultural Soils through Biochar Development' (Grant Number JP J008722)

➢ ***Parameters for calculating CO_2 emissions from organic soils (off-site)***

Tier 1 default parameters described in the *Wetlands Guidelines* were applied to the estimation.

Table 6-33 Parameters for calculating CO_2 emissions from organic soils (off-site)

Climate zone	$DOC_{FLUX\_NATURAL}$ [t-C/ha/yr]	$DOC_{DRAINAGE}$	$Frac_{DOC\text{-}CO2}$	EF_{DOC} [t-C/ha/yr]
Temperate	0.21	0.60	0.9	0.31

Reference: The *Wetlands Guidelines*: Table 2.2

● ***Activity Data***

➢ ***Area of mineral soils***

Areas of mineral soils in cropland which are multiplied by carbon stock changes per unit area calculated by Roth C model were estimated from the reported area in the *Statistics of Cultivated and Planted Area*, divided as rice field (only the area with rice really planted), upland field (including the area divided into rice field with other crops planted and with no crops) and orchards; and the areas of organic soils in each divided area (Table 6-34) is subtracted. Since the model calculation includes the agricultural land converted from other land use, the area of the agricultural land (mineral soils) converted from other land use are also included for activity data.

➢ ***Amount of biochar applied into mineral soils in cropland***

The amount of biochar applied to the mineral soils in cropland, was calculated by multiplying the amount of wood charcoal production for agriculture use, by the proportion of biochar applied to cropland, and the ratio of area of mineral soils to the total.

As for the amount of wood charcoal production for agriculture use, the values classified as “agricultural use” obtained from *Statistical Survey on production of Special Forest Products* (MAFF), were applied. In addition, complete time series data were made using interpolation and allocation methods (If only the total value is available, allocation is conducted using the proportion of a certain wood charcoal in a certain year) due to lack of data for some years. Moreover, since wood charcoal were also used for “feed and other uses”, the amount of biochar amendments applied to cropland were calculated by subtracting wood charcoal production for “feed and other uses”, from the amount of wood charcoal production for “agricultural use”. Based on experts’ comments, the proportion of biochar applied to cropland was estimated as 95%. In addition, since it is difficult to obtain the amount of biochar production applied to mineral soils and organic soils in cropland separately, it is assumed that the same proportion (amount of biochar applied to cropland per unit area) of biochar production applied to all cropland. Therefore, the amount of biochar production applied to mineral soils were calculated based on the percentage of the mineral soils to the total area. Furthermore, when calculating the percentage of mineral soils to the total area, that of pasture land is considered since biochar amendments to pasture lands are potentially included in the total amendment.

However, since there is no default fraction of biochar C remaining after 100 years for organic soil in the *2019 Refinement* and data and information are not also available in Japan, carbon stock change associated with biochar amendments to organic soil in cropland was not subject to estimation.

➢ ***Area of organic soils***

For the area of organic soils in subcategories of agricultural land, in the year when the soil area data by soil group is obtained, the proportion of soil classified as organic soil is calculated from the soil area

data by soil group by prefecture and is multiplied by each area by prefecture (in 1992, 2001 and 2010). In other years, area of organic soils is calculated by adding or subtracting on or from the starting value at each fixed point in 1992, 2001, and 2010, using a certain rate for organic soils in the expanded / converted area. When the land is converted from other land use due to the expansion of agricultural land, the ratio of organic soil in the land-use category before conversion is basically used. However, regarding the conversion from wetlands, which covering reclaimed land from shallow water body, the ratio of organic soil was set to 0% (reported as "NO") because organic soil did not exist in the soil map around the reclaimed land in the reclaimed land corresponding to this activity. In the case of conversion from agricultural land, the ratio of the changed area of the organic soil area to the changed total area that occurred during each survey year (1992-2001 or 2001-2010) is basically used. However, for land-use conversion before 1992, the organic soil ratio of each subcategory at the time of the 1992 survey is used, and for conversion after 1992, the value from 1992 to 2001 is used, and for conversion after 2001 onwards, the values from 2001 to 2010 are used.

Table 6-34 shows the total areas of organic soils (total organic soil area of cropland remaining cropland and land converted to cropland) by subcategories in cropland in Japan calculated by the method above. The CRT of the LULUCF sector requires the total area of organic soils to be reported regardless of cultivation or drainage as shown in Table 6-34, but the values used for activity data for emission estimation are the actual areas where those activities are conducted. The values of the areas of organic soils reported in the CRT Table in the Agricultural sector is the actually cultivated areas out of the total organic soils in the agricultural land. So, the values of the areas in the Agricultural sector were different from these in this table below (see section 5.5.1.6).

Table 6-34 Areas of organic soils in cropland

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Cropland	kha	169.7	168.3	168.5	167.4	166.0	165.8	166.0	167.6	167.8	168.0	168.3	168.6
Rice fields	kha	131.6	129.8	129.1	127.3	125.3	125.1	125.2	125.2	125.1	125.0	125.0	125.0
Upland fields	kha	16.4	16.7	17.0	16.9	16.8	16.6	16.5	16.4	16.3	16.2	16.2	16.2
Orchards	kha	1.3	1.0	0.5	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Dilapidated farmland	kha	20.4	20.8	22.0	22.8	23.6	23.8	24.0	25.7	26.0	26.4	26.8	27.1

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainty assessment for the parameters and the activity data in biomass in orchards was conducted in accordance with the uncertainties of existing statistics and the default values provided in the *2006 IPCC Guidelines*. For the uncertainties of carbon stock changes in mineral soil estimated by Roth C model, the comparison of simulation results and observed values, when both input values and current measurement values of mineral soils are available, revealed that the uncertainty due to model structure was estimated about 10%. The uncertainty caused by input values has not been quantified yet and remains as an issue to be solved. For the uncertainties of change in mineral soil organic carbon stocks from biochar amendments, the uncertainties of statistical data and default values given in the *2019 Refinement* are used. For the uncertainties of organic soil, the uncertainties of statistical data and default values given in the *2006 IPCC Guidelines* are used. As a result, the uncertainty was estimated as 25% for the entire emission from the cropland remaining cropland.

- ***Time-series Consistency***

Time-series consistency for this category is ensured.

d) Category-specific QA/QC and Verification

Same as Forestland Remaining Forestland (4.A.1.). See section 6.4.1 d).

Although calibration for Roth C model has not been carried out, it was confirmed that the simulation results of Roth C have matched well with the observed data using the three modified versions of the Roth C model classified by land uses and soil types (Paddy soils, Andosols and non-Andosols). Verification and modification of plot scale were done with measured data.

Experiment fields are classified by soil characteristics into Paddy soils group, Andosols group and non-Andosols group. These 3 soil types are considered to be covered with all soil type. For detailed information, see references; Shirato (2006), Shirato and Taniyama (2003), Shirato et al. (2004), Shirato and Yokozawa (2005), Takata et al. (2011), Shirato (2011) listed in this chapter.

e) Category-specific Recalculations

- ***Correction in accordance with revision of the area converted from forest land***

Due to a revision of the interpretations of the *Land Use Change Survey by Satellite Interpretation*, the area of cropland converted from forest land was recalculated, and the areas of cropland remaining cropland were recalculated for all years. With this recalculation, carbon stock changes in mineral soils and CO_2 emissions from organic soils were recalculated for all years.

- ***Correction of input data used for Roth C model calculation***

Due to revision of the aggregation of the amount of manure application data used in the Roth C model, carbon stock changes in mineral soils per unit area were recalculated from FY2021 onwards. With this recalculation, the carbon stock changes in mineral soils were recalculated from FY 2021 onwards.

- ***Correction in the cultivation areas of orchard trees***

Due to a correction in some cultivation areas of orchard trees since 2021, the area of the orchard trees and the carbon stock changes in living biomass from FY2021onwards were recalculated.

- ***Correction of parameter values used to estimate carbon sequestration associated with biochar amendment***

Due to the revision of values for organic carbon content and the fraction of carbon remaining after 100 years for some biochar types, the amount of carbon sequestered by biochar amendment in mineral soils were recalculated for all years.

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

6.5.2. Land Converted to Cropland (4.B.2.)

a) Category Description

This subcategory deals with the carbon stock changes which occurred in the lands that were converted from other land-use categories to cropland within the past 20 years. Total area of land converted to cropland within the past 20 years by FY2024 is 89.1 kha, which represents 0.2% of the national total area.

The emissions from this subcategory in FY2024 were 137 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 78.1% compared to FY1990 and an increase of 0.5% compared to the previous year. Changes in emissions from land converted to croplands are mainly driven by changes in the area converted from forestland with high carbon stock to cropland.

b) Methodological Issues

1) Carbon stock changes in living biomass in land converted to cropland

- ***Estimation Method***

The Tier 2 method which is estimation by summing the loss of carbon stock due to conversion ($\Delta C_{LB\_conversion\_to\_C}$) and the change of carbon stock accumulated after conversion ($\Delta C_{LC\_LB\_SC}$) was used for the annual carbon stock change in land converted to cropland (ΔC_{LC_LB}), using Equation 2.16 from the *2006 IPCC Guidelines* (Vol. 4, Section 2.3.1.2). And the country specific value of the amount of biomass accumulation is used for forest land converted to cropland. The Tier 1 method using default values is applied for land uses other than forest land converted to cropland.

$$\Delta C_{LC\_LB} = \Delta C_{LB\_conversion\_to\_C} + \Delta C_{LC\_LB\_SC}$$

$$\Delta C_{LB\_conversion\_to\_C} = \sum_i \left\{ \Delta A_i \times \left(B_a \times CF_a - B_{b_i} \times CF_{b_i} \right) \right\}$$

$$\Delta C_{LC\_LB\_SC} = \sum_j \left(\Delta A_j \times C_j \right)$$

ΔC_{LC_LB}	: Annual carbon stock change in the converted land [t-C/yr]
$\Delta C_{LB\_conversion\_to\_C}$	: Annual carbon stock change at the time of land-use conversion [t-C/yr]
$\Delta C_{LC\_LB\_SC}$	: Annual carbon stock change accumulated due to biomass growth in the converted land after conversion [t-C/yr]
i	: Land use before conversion
ΔA_i	: Area converted from land-use type i to cropland for the current year [ha/yr]
B_a	: Dry matter biomass weight per unit area immediately following conversion to cropland [t-d.m./ha/yr]
B_{bi}	: Dry matter biomass weight per unit area before conversion from land-use type i to cropland [t-d.m./ha/yr]
CF_a	: Carbon fraction of dry matter after conversion [t-C/t-d.m.]
CF_{bi}	: Carbon fraction of dry matter in land-use type i before conversion [t-C/t-d.m.]
ΔA_j	: Area converted to subcategory j in cropland for the current year [ha/yr]
C_j	: Change of dry matter biomass weight per unit area accumulated after conversion [t-d.m./ha/yr], seeTable 6-11.
j	: Land use in cropland subcategory after conversion (rice fields, upland fields)

Note: Carbon stock changes accumulated after conversion in Orchards are estimated collectively in cropland remaining cropland.

- ***Parameters***

➢ ***Biomass stock in each land-use category***

Table 6-9 is used for the estimation of biomass stock changes upon land-use conversion and Table 6-11 is used for subsequent changes in biomass stock due to biomass growth in the converted land. The carbon stock changes accumulated due to biomass growth after conversion in rice fields and upland fields equal to the amount of carbon stock acquired in one year after conversion (Table 6-11), so the same value was used assuming that the amount of carbon stock of annual crops set in Table 6-9 would be reached in one year.

The amount of crop residue which was used to estimate N_2O emissions from crop residues plowed into agricultural soil after harvesting in the Agriculture sector (3.D.a.4) was used for the amount of carbon stock in rice fields and upland fields in this Table 6-9. In addition, since the amount of crop residues plowed into cropland differs depending on the type of crop, the carbon content of the crop residues plowed into cropland per unit cultivation area was weighted average according to the annual cultivation area. And the average value from FY1990 to FY2017 was calculated using the weighted average value each year calculated above and was applied as parameter uniformly over the whole years (Table 6-9).

➢ ***Carbon fraction of dry matter***

For carbon fraction of dry matter of forest, average value of broad leaf trees and conifer trees (0.50 t-C/t-d.m.) was applied. The default value (0.47 t-C/t-d.m. for herbaceous biomass in grassland and 0.5 t-C/t-d.m. for the others) was applied for other than forest in accordance with the *2006 IPCC Guidelines*.

- ***Activity Data***

For the calculation of the carbon stock changes of living biomass in land converted to cropland, the annual area converted to cropland was used.

➢ ***Areas of forest land converted to other land-use categories***

- ***From FY2005 onwards***

Survey of land-use change status by satellite image interpretation described in section 6.2.2. a) was used to estimate areas converted from forest land to cropland. Regarding the land converted to cropland, statistical area data was used.

- ***From FY1990 to FY2004***

In the period from FY1990 to FY2004, annual conversion areas from forest land to other land-use categories were estimated dividing the total D areas occurred from FY1990 to FY2005 by the ratio of annual forest conversion areas for this period based on the Forest Agency's record. To estimate areas of forest land converted to each land-use category, the ratios of conversions by land-use categories based on the same Forestry Agency's records as above mentioned was used. This record only covers private forest, but the conversion from private forests to other land-use categories accounts for 90% of the total areas of conversion from forest land. Thus, the record above is assumed as the value for total forest.

- ***From FY1975 to FY1989***

With respect to the areas before 1989, since D survey is not conducted in this period, the areas were

obtained from statistics provided by the *Census of Agriculture and Forestry* and the Forestry Agency's records, but the areas obtained from the surveys on D areas were larger than those from statistics. Hence, the total areas converted from forest land are estimated by setting an adjustment factor (1.5) from the ratio between the D areas since FY1990 and the areas converted from forests provided by and the Forestry Agency's records, and multiplying the areas converted from forests since FY1975 by the adjustment factor.

- ***From FY1951 to FY1974***

The area was estimated by considering a certain percentage (1975-1984 average percentage) of the newly expanded cultivation area of rice fields and upland fields obtained in the *Statistics of Cultivated Land and Planted Area* as cropland area converted from forests.

➢ ***Areas of conversion from land-use categories other than forest land***

The areas of land converted from land-use categories other than forest land to cropland are determined by applying expansion area values provided by the *Statistics of Cultivated and Planted Area*. The converted areas from arable land are divided into upland fields, orchards, and pasture land proportionately by means of the current situation and other statistical data. The areas of rice fields, upland fields, and orchards are allocated to cropland, while the area of pasture land is allocated to grassland. In addition, settlements converted to cropland are reported as "IE" because the areas are included in other land remaining other land.

Table 6-35 Area of land converted to cropland within the past 1 year

Subcategory		Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Land converted to Cropland		kha	5.17	3.55	2.73	1.99	0.82	6.11	3.68	6.83	6.02	5.26	7.11	7.80
	Forest land converted to Cropland	kha	2.63	0.71	0.24	0.55	0.78	0.49	0.49	0.48	1.22	1.22	0.34	0.34
	Grassland converted to Cropland	kha	0.009	0.083	0.041	0.060	0.001	0.001	0.007	0.007	0.008	0.007	0.006	0.010
	Wetlands converted to Cropland	kha	0.20	0.03	0.06	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Settlements converted to Cropland	kha	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	Other land converted to Cropland	kha	2.33	2.73	2.39	1.38	0.04	5.62	3.18	6.35	4.79	4.03	6.76	7.45
Land-use classification after conversion	Rice fields	kha	0.22	1.21	1.37	0.32	0.17	4.29	2.02	3.71	3.46	2.83	4.09	4.04
	Upland fields	kha	4.67	2.26	1.31	1.30	0.51	1.45	1.32	2.52	2.07	1.98	2.46	3.08
	Orchards	kha	0.28	0.08	0.05	0.37	0.14	0.37	0.33	0.60	0.48	0.45	0.56	0.68

2) Carbon stock change in dead organic matter in land converted to cropland

● ***Estimation Method***

Carbon stock changes in dead organic matter in forest land converted to cropland were estimated by applying Tier 2 estimation method using forest-wide averages calculated using the results of the *Forest Soil Inventory Survey* (Kawanishi et al., 2024). All carbon stocks in dead organic matter in the subcategory are assumed oxidized and emitted as CO_2 within the year of conversion in accordance with the description in section 5.3.2.1 in Vol. 4 of the *2006 IPCC Guidelines*. In addition, as described in the Parameters section below, carbon stocks of dead organic matter in cropland are assumed to be zero.

$$\Delta C_{DOM} = \sum_i \{(C_{after,i} - C_{before,i}) \times \Delta A\}$$

ΔC_{DOM} : Carbon stock changes in dead organic matter in the converted land [t-C/yr]
$C_{after,i}$: Average carbon stock per unit area in dead wood or litter after conversion [t-C/ha]
Note: carbon stocks after conversion are assumed as "0" (zero).
$C_{before,i}$: Average carbon stock per unit area in dead wood or litter before conversion [t-C/ha]

ΔA : Area of converted land within the year of conversion [ha/yr]
i : type of dead organic matter (dead wood, litter)

- ***Parameters***

Average carbon stocks in dead wood and litter in forest land before conversion are shown in Table 6-12 and Table 6-13. With regard to grassland converted to cropland, carbon stocks of dead wood and litter carbon pools were assumed to be minor and the stock changes could be ignored, and were set to zero. With regard to wetlands and settlements converted to cropland, these were also reported as "NA", since it is assumed that carbon stock changes are from zero to zero, supposing that basically no such carbon pools exist in reclaimed wetland and that carbon stocks in dead organic matter in settlements before conversion could be negligible. Other land converted to cropland, which is estimated to be cropland restoration, was set to zero, because dead wood and litter in non-forest land are assumed as zero based on the Tier 1 method described in the *2006 IPCC Guidelines*.

In addition, it is assumed that carbon stocks become zero immediately after land-use conversion, and will not be accumulated thereafter.

- ***Activity Data***

Annually converted areas from forest land to cropland are used for estimating carbon stock changes in dead organic matter in land converted to cropland (Table 6-35).

3) Carbon stock changes in soils in land converted to cropland

- ***Estimation Method***

➢ ***Carbon stock changes in mineral soils***

Carbon stock changes in mineral soils in "Land converted to Cropland" is reported under "Cropland remaining cropland" collectively as described in 6.5.1. b) 3). Therefore, carbon stock changes in mineral soils in cropland converted from other land-use categories was reported as "IE".

➢ ***CO_2 emissions from organic soils caused by cultivation and drainage***

CO_2 emissions from organic soils were estimated in rice field and upland field converted from other land-use categories caused by cultivation (on-site) and from water soluble carbon loss from drained organic soils (off-site). For detailed information on the emission factors and activity data, see section 6.5.1. Note that no distinction is made here between land use prior to conversion, which is reported collectively in "agricultural land converted from grassland".

- ***Activity Data***

➢ ***Area of mineral soils***

The methodology for estimating the area of mineral soils in land converted to cropland was based on the 20-year cumulative total of the area converted in a single year used in the biomass calculation. The transition period for changes in soil carbon stocks on Uplands and Orchards in cropland converted from forest land is 40 years, and the area subject to such changes is also estimated. But as mentioned above, changes in carbon stocks are included in the model calculations for whole cropland reported under cropland remaining cropland.

Table 6-36 Area of land converted to cropland within the past 20 years after conversion and 21 to 40 years after conversion

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Area within the past 20 years after conversion	kha	230.9	164.9	98.6	70.4	46.7	47.3	48.1	68.5	73.4	77.6	83.6	89.1
Forest land converted to Cropland	kha	119.8	84.9	48.7	24.8	12.8	10.7	10.1	10.3	11.4	12.5	12.6	12.8
Rice fields	kha	22.8	13.2	0.8	0.4	0.6	0.9	1.2	2.1	2.7	3.3	3.4	3.6
Upland fields	kha	65.3	57.1	41.3	22.7	10.9	8.3	7.4	6.6	6.9	7.3	7.3	7.3
Orchards	kha	31.6	14.7	6.6	1.7	1.3	1.5	1.5	1.7	1.8	1.9	1.9	1.9
Grassland converted to Cropland	kha	34.1	16.6	2.1	1.8	1.7	1.2	0.7	0.4	0.4	0.3	0.2	0.2
Wetlands converted to Cropland	kha	10.4	2.5	1.1	0.7	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.5
Settlements converted to Cropland	kha	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Other land converted to Cropland	kha	66.7	60.8	46.7	43.2	31.5	34.9	36.8	57.3	61.2	64.4	70.3	75.6
Area 21-40 years after conversion	kha	233.2	174.8	161.5	138.3	97.0	79.3	71.8	47.9	43.4	37.8	33.2	28.1
Forest land converted to Upland fields	kha	105.1	49.8	48.1	61.1	65.3	60.2	57.1	41.3	38.2	34.3	30.3	26.0
Forest land converted to Orchards	kha	128.1	124.9	113.4	77.2	31.6	19.2	14.7	6.6	5.2	3.4	2.9	2.1

➢ ***Area of organic soils***

The methodology for estimating the area of organic soils in land converted to cropland is as same as that in cropland remaining cropland (4.B.1.) explained in section 6.5.1. b) 3).

c) Uncertainty Assessment and Time-series Consistency

● ***Uncertainty Assessment***

Uncertainties of the parameters and the activity data for living biomass, dead organic matter were individually assessed on the basis of field study results, expert judgment, or the default values provided in the *2006 IPCC Guidelines*. The uncertainty was estimated as 12% for the entire emission from the land converted to cropland.

● ***Time-series Consistency***

The methods to estimate the area of forest land converted to other land-use categories are different between before FY1989 and after FY1990, however, the values before 1989 are adjusted using the ratio of the area before 1989 to the areas after 1990 as described in section 6.5.2. b) 1). Thus, the time-series consistency for this subcategory is basically ensured.

d) Category-specific QA/QC and Verification

Same as Forestland Remaining Forestland (4.A.1.). See section 6.4.1 d).

e) Category-specific Recalculations

● ***Correction in accordance with revision of the area converted from forest land***

Due to a revision of the interpretations of the *Land Use Change Survey by Satellite Interpretation*, the area of cropland converted from forest was recalculated and carbon stock changes in living biomass, dead organic matter and CO_2 emissions from organic soils in this category were recalculated for all years. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

6.6. Grassland (4.C.)

Grassland is generally covered with perennial pasture and is used mainly for harvesting fodder or grazing. In FY2024, Japan's grassland area was about 0.9 million ha, which is equivalent to about 2.4% of the national land. The area of organic soil in the grassland is about 0.052 million ha. The emissions from carbon stock changes in this category in FY2024 were 577 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 41.9% compared to FY1990 and a decrease of 9.1% compared to the previous year.

Table 6-37 Emissions and removals from grassland resulting from carbon stock changes

Category	Carbon pool	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
4.C. Grassland	Total	kt-CO_2	995	-215	-890	-868	323	105	1,573	195	120	674	635	577
	Living biomass	kt-CO_2	288	-11	-38	31	166	119	76	16	119	119	45	45
	Dead wood	kt-CO_2	93	14	4	13	34	24	16	5	16	16	8	8
	Litter	kt-CO_2	61	9	2	8	22	16	10	3	10	10	6	6
	Mineral soil	kt-CO_2	526	-255	-887	-949	73	-86	1,433	142	-53	502	548	491
	Organic soil	kt-CO_2	27	28	29	28	27	31	38	28	28	28	28	28
4.C.1. Grassland remaining Grassland	Total	kt-CO_2	539	-236	-865	-926	96	-58	1,468	169	-26	529	575	517
	Living biomass	kt-CO_2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Dead wood	kt-CO_2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Litter	kt-CO_2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mineral soil	kt-CO_2	526	-255	-887	-949	73	-86	1,433	142	-53	502	548	491
	Organic soil	kt-CO_2	13	18	22	23	24	28	35	26	27	27	26	26
4.C.2. Land converted to Grassland	Total	kt-CO_2	456	21	-26	57	226	162	105	26	146	146	60	60
	Living biomass	kt-CO_2	288	-11	-38	31	166	119	76	16	119	119	45	45
	Dead wood	kt-CO_2	93	14	4	13	34	24	16	5	16	16	8	8
	Litter	kt-CO_2	61	9	2	8	22	16	10	3	10	10	6	6
	Mineral soil	kt-CO_2	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO	IE,NO
	Organic soil	kt-CO_2	14.1	9.2	6.3	5.1	3.3	3.1	3.1	1.3	1.1	1.1	1.1	1.1

Table 6-38 Areas of grassland

Subcategory		Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Grassland		kha	1,031.6	1,021.6	1,011.6	1,007.2	993.2	951.1	956.5	905.2	903.5	901.4	899.1	895.9
	Pasture land	kha	646.7	660.7	644.7	630.6	616.7	611.1	606.5	595.2	593.5	591.4	589.1	585.9
	Grazed meadow	kha	105.0	100.9	96.8	96.5	96.4	96.3	96.3	96.2	96.1	96.0	95.9	95.8
	Wild land	kha	280.0	260.0	270.0	280.0	280.0	243.7	253.7	213.8	213.9	214.0	214.1	214.2

6.6.1. Grassland Remaining Grassland (4.C.1.)

a) Category Description

In this category carbon stock changes in grassland remaining grassland more than 20 years are reported, divided into three subcategories: "pasture land", "grazed meadow" and "wild land".

The emissions from carbon stock changes in this category in FY2024 were 517 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 4.0% compared to FY1990 value and a decrease of 10.0% compared to the previous year. Regarding the trend of emissions and removals, a peak of removals was occurred in FY2003, then the amount of removals has been on a decrease and hit a peak of emissions in FY2014. The amount of emissions has been on a decreasing trend since then. This high variability was considered mainly caused by annual changes of amount of carbon input into soils and annual fluctuation of temperature, as it is described in the estimation of mineral soil pools in cropland. The amount of manure application had been on an increasing trend in the 1990s and has been decreasing since 2000. In addition, recently there have been

no cold year; the relatively mild weather might facilitate more organic matter decomposition. Thus, it is considered that these factors are mainly contribute to the trend.

With respect to living biomass, carbon stock changes in pasture land and grazed meadow are assumed to be in a steady state and reported as "NA" in accordance with the Tier 1 estimation method in section 6.2.1.1 in the *2006 IPCC Guidelines*.

Carbon stock changes in dead organic matter in pasture land and grazed meadow are estimated as zero (0) by applying the Tier 1 method described in section 6.2.2.1 in the *2006 IPCC Guidelines*, which assumes that the carbon stocks are not changed. Thus, the carbon stock changes are reported as "NA".

In regard to carbon stock changes in mineral soils, the carbon stock changes in pasture land were estimated by applying the Tier 3 method using Roth C model same as cropland remaining cropland. Grazed meadows were non-degraded and sustainably managed grassland, but without significant management improvements. Therefore, the default value of the carbon stock change factor for "Nominally managed (non-degraded)" in table 6.2 of the *2006 IPCC Guidelines*, which was "1.0", was applied to grazed meadows. In this case, soil carbon stocks were not changed over time; therefore, the soil carbon stock changes in grazed meadows were reported as "NA". On-site CO_2 emissions resulting from cultivation and drainage of organic soils and off-site CO_2 emissions via waterborne carbon losses from drained inland organic soils in pasture land were estimated by applying Tier 1 method.

CO_2 emission from organic soils in grazed meadow was reported as "NO" because the cultivation and drainage resulting from renewal of grazed meadow are not implemented.

Carbon stock changes in all carbon pools in wild land are reported as "NA" because anthropogenic management is not implemented to the wild land in general.

b) Methodological Issues

1) Carbon stock changes in soils in grassland remaining grassland

- ***Estimation Method***

➢ ***Estimation of carbon stock changes in mineral soils***

Carbon stock changes in mineral soils in pasture land were estimated using the Tier 3 modeling method same as the one used for cropland remaining cropland (4.B.1.) in 6.5.1. b) 3).

➢ ***Estimation of on-site CO_2 emissions resulting from cultivation in organic soils***

CO_2 emissions from organic soils in pasture land were estimated by applying the Tier 1 estimation method described in section 6.2.3.1 in Vol. 4 of the *2006 IPCC Guidelines*. The estimation method is the same as the one used for cropland remaining cropland (4.B.1.).

➢ ***Estimation of off-site CO_2 emissions via waterborne carbon losses from drained inland organic soils***

Off-site CO_2 emissions via waterborne carbon losses from drained inland organic soils were estimated by applying Tier 1 estimation method described in section 2.2.1.2 in the *Wetlands Guidelines.* The estimation method is the same as the one used for cropland remaining cropland (4.B.1.).

- ***Parameters***

➢ ***Assumption for the Roth C model and parameters for estimating mineral soils***

The parameters used are omitted because they are the same as cropland remaining cropland (4.B.1.).

➢ ***Parameters for estimation of CO_2 emissions from organic soils***

Because there is little research data on CO_2 emission factor that is suitable for grassland in Japan, the default value provided in *the Wetlands Guidelines* (Table 2.1, deep-drained, nutrient-rich, 6.1 t-C/ha/year) which is considered to be most appropriate for the emission factor under the distribution of pasture land and current management system in Japan, was applied. As for off-site CO_2 emissions, the same parameters as cropland remaining cropland (4.B.1.) were used.

- ***Activity Data***

➢ ***Area of mineral soils***

The area of mineral soils applied for Roth C model is calculated by subtracting area of organic soils in pasture land from total area of pasture land reported in the *Statistics of Cultivated and Planted Area*.

➢ ***Area of organic soils***

Areas of organic soils in pasture land remaining pasture land and in pasture land converted from other land use were obtained by applying the method same as section 6.5.1. b) 3). The activity data (the actual area for conducting cultivation and drainage) was calculated by multiplying renewal ratio of pasture land by the area of organic soils in pasture land. For the renewal ratio of pasture land, the values (Hokkaido and other than Hokkaido) published in the report of "Survey on actual situation of grassland management for feed" (Hatano, 2017) which investigated the management status of pastures were applied (see section 5.5.1.6. in Chapter 5). Moreover, about renewal ratio of pasture land before FY2005, the average value between FY2006 and FY2010 (for Hokkaido: 3.0%, for other than Hokkaido: 1.3%) was applied because the survey has not been implemented. Also, since there are no survey values for FY2016 and for FY2017, the average values from FY2006 to FY2010 were used as well. The area of organic soil in grazed meadow and in wild land in FY2009 were calculated by multiplying the area of grazed meadow (*Census of agriculture and Forestry*) and wild land (*Land Use Status Survey*) in FY2009, by ratio of organic soil area obtained from GIS (Geographic information system) data analysis results in FY2009. The area of organic soil before FY2009 and after FY2009 were calculated by adding organic soil area in grazed meadow and wild land converted other land use to FY2009, and by subtracting organic soil area in land converted from grazed meadow and wild land from FY2009.

In addition, as described in section 6.5.1. , since the area of organic soil reported in the Agriculture sector does not include areas of organic soil in grazed meadow and in wild land, the area of organic soil reported in LULUCF sector is different to the value reported in the Agriculture sector.

Table 6-39 Area of organic soils in grassland

Subcategory		Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Grassland		kha	56.3	56.3	57.9	58.1	57.5	55.7	56.0	53.9	53.9	53.8	53.8	53.8
	Pasture land	kha	38.6	39.5	40.6	40.4	39.8	39.7	39.6	39.4	39.3	39.3	39.2	39.2
	Grazed meadow	kha	4.6	4.6	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5	4.5
	Wild land	kha	13.2	12.2	12.7	13.2	13.2	11.4	11.9	10.0	10.0	10.1	10.1	10.1

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

Uncertainties of carbon stock change in mineral soil are the same as cropland remaining cropland (4.B.1); therefore, the description is omitted. Uncertainties of existing statistical data and the default values provided in the *Wetlands Guidelines* were applied to estimate CO_2 emissions from organic soil. As a result, the uncertainty was estimated as 10% of the total emissions grassland remaining grassland.

- ***Time-series Consistency***

Time-series consistency for this category is ensured.

d) Category-specific QA/QC and Verification

Same as Forestland Remaining Forestland (4.A.1.). See section 6.4.1 d).

e) Category-specific Recalculations

- ***Correction of input data used for Roth C model calculation***

Due to revision of the aggregation of the amount of manure application data used in the Roth C model, carbon stock changes in mineral soils per unit area were recalculated from FY2021 onwards. With this recalculation, the carbon stock changes in mineral soils were recalculated from FY 2021 onwards.

- ***Correction in accordance with revision of the area converted from forest land***

Due to a revision of the interpretations of the *Land Use Change Survey by Satellite Interpretation*, the area of grassland converted from forest was recalculated, areas of grassland remaining grassland were recalculated for all years. With this recalculation, carbon stock change in mineral soils and CO_2 emissions from organic soils were recalculated for all years.

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

6.6.2. Land Converted to Grassland (4.C.2.)

a) Category Description

This subcategory deals with the carbon stock changes, which occurred in the lands that were converted from other land-use categories to grassland within the past 20 years. The emissions from carbon stock changes in this category in FY2024 were 60.1 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 86.8% compared to FY1990 and a decrease of 0.2% compared to the previous year.

b) Methodological Issues

1) Carbon stock changes in living biomass in land converted to grassland

- ***Estimation Method***

The Tier 2 method using Equation 2.16 from the *2006 IPCC Guidelines* (Vol. 4, Section 2.3.1.2), as

well as cropland converted from other land uses, was applied to estimate forest land and cropland (rice fields) converted to grassland (pasture lands) using country specific amount of biomass accumulation. The Tier 1 method was used for land uses other than forest land and cropland (rice fields) using default value. The equations are given in section 6.5.2. b)1). While the annually converted areas were used for estimating the loss of living biomass upon land-use conversion, the biomass growth after land-use conversion was estimated by summing the converted areas for the latest five years, assuming that it takes five years after conversion to reach a steady state with a constant growing rate.

- ***Parameters***

➢ ***Biomass stock in each land-use category***

The values shown in Table 6-9 Table 6-10, and Table 6-11 are used for the estimation of biomass stock changes upon land-use conversion and subsequent changes in biomass stock due to biomass growth in converted land.

➢ ***Carbon fraction of dry matter***

Average value of broad leaf trees and conifer trees (0.50 t-C/t-d.m.) was applied as the carbon fraction of dry matter of forest. The default value (0.47 t-C/t-d.m. for herbaceous biomass in grassland and 0.5 t-C/t-d.m. for the others) was applied for other than forest in accordance with the *2006 IPCC Guidelines.*

- ***Activity Data***

For the estimation of carbon stock change in living biomass in grassland converted from other land-use categories, the annually converted areas were used for estimating the loss (Table 6-40) and the areas of summing the converted areas for the latest five years are used for estimating the biomass growth after land-use conversion (Table 6-41).

➢ ***Area converted from forestland***

As described in 6.5.2. b)1), the methodology of "Areas of forest land converted to other land-use categories" is applied.

➢ ***Area converted from other than forest land***

As shown in Table 6-2, grassland is treated as a part of arable land in statistics of Japan. Therefore, the procedure to obtain the area of the grassland converted from other land-use categories is as described in 6.5.2. b)1). Areas of settlements converted to grassland are reported as "NO" because land-use conversion from settlements to grassland does not occur.

Table 6-40 Area of land converted to grassland within the past 1 year

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Land converted to Grassland	kha	8.5	3.3	2.6	2.4	2.0	1.3	1.1	2.0	2.0	1.9	2.0	2.7
Forest land converted to Grassland	kha	3.4	0.5	0.1	0.5	1.2	0.9	0.6	0.2	0.6	0.6	0.3	0.3
Cropland converted to Grassland	kha	1.9	1.0	1.5	1.7	0.7	0.3	0.4	0.5	0.6	0.6	0.5	0.9
Wetlands converted to Grassland	kha	0.3	0.02	0.05	NO	NO	NO	NO	NO	NO	NO	NO	NO
Settlements converted to Grassland	kha	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other land converted to Grassland	kha	2.94	1.75	0.93	0.24	0.00	0.15	0.13	1.22	0.83	0.76	1.22	1.53

Table 6-41 Area of land converted to grassland within the past 5 years

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Land converted to Grassland	kha	63.8	22.2	15.5	12.9	10.5	7.1	5.7	9.1	9.7	10.0	9.9	10.6
Forest land converted to Grassland	kha	24.2	5.0	1.7	1.0	5.4	4.3	3.3	1.8	1.8	1.9	1.8	1.9
Cropland converted to Grassland	kha	15.3	6.3	8.3	8.6	4.6	2.6	1.9	2.4	2.4	2.5	2.6	3.1
Wetlands converted to Grassland	kha	0.7	0.1	0.1	NO	0.2	NO	NO	NO	NO	NO	NO	NO
Settlements converted to Grassland	kha	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other land converted to Grassland	kha	23.6	10.8	5.4	3.3	0.2	0.2	0.5	4.9	5.5	5.6	5.5	5.6

2) Carbon stock change in dead organic matter in land converted to grassland

- ***Estimation Method***

In this category, carbon stock changes in dead organic matter in forest land converted to grassland were estimated. The Tier 2 estimation method was applied to the subcategory using country specific values of the carbon stocks before and after conversion . It should be noted that the carbon stocks of dead organic matter after conversion to grassland are assumed as zero (Tier 1 method in the *2006 IPCC Guidelines,* Vol.4, section 6.3.2), because there are no quantitative data of them, although a subtle but certain amount of carbon stocks does generally exist on the soil surface. As described in section 6.5.2. b)2), cropland converted to grassland were reported as "NA" since the carbon stocks before and after conversion were assumed as zero. As for wetlands and other land converted to grassland, they include only reclamation and restoration. Thus, they were reported as "NA"[6], for the same reasons as described in section 6.5.2. b)2).

- ***Parameters***

The average carbon stocks in dead wood and litter in forest land before conversion are shown in Table 6-12 and Table 6-13. The average carbon stocks in these categories from FY1990 to FY2004 are not estimated; therefore, those in FY2005 are substituted for them. In addition, it is assumed that they become zero immediately after conversion, and are not accumulated after conversion. All carbon stocks in dead organic matter in the subcategory are assumed oxidized and emitted as CO_2 within the year of conversion in accordance with the description in section 6.3.2.2 in the *2006 IPCC Guidelines*.

- ***Activity Data***

The area of land converted to grassland during the past 20 years is used.

Table 6-42 Areas of land converted to grassland within the past 20 years

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Land converted to Grassland	kha	492.1	315.1	191.6	114.4	61.1	48.6	44.5	38.2	38.1	37.0	36.5	36.3
Forest land converted to Grassland	kha	219.3	141.7	84.3	32.0	13.2	10.9	11.5	11.5	12.0	12.4	12.6	12.7
Cropland converted to Grassland	kha	84.4	55.2	44.7	38.4	27.8	24.6	23.5	17.5	16.8	15.4	14.1	13.2
Wetlands converted to Grassland	kha	2.3	2.2	1.7	0.9	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.2
Settlements converted to Grassland	kha	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other land converted to Grassland	kha	186.1	116.0	60.8	43.0	19.7	12.7	9.4	8.9	9.1	9.0	9.6	10.2

3) Carbon stock change in soils in land converted to grassland

- ***Estimation Method***

Carbon stock changes in mineral soils in pasture land was estimated by applying the Tier 3 estimation

[6] Cropland in the Japanese statistics includes pasture land which falls into grassland.

method same as the one for Cropland remaining Cropland (4.B.1.) in section 6.5.1. b)3). For the estimation, land which was once pasture land since 1970's was regarded as pastures land and used for calculation; the result of the calculation includes all grassland, regardless of land-use conversion. Therefore, carbon stock changes in mineral soils are reported regardless of whether or not land-use conversion has been occurred and carbon stock changes in mineral soils in pasture land converted from other land use was reported as "IE" since it was included in carbon stock changes in mineral soils in pasture land remaining pasture land. CO_2 emissions (on-site and off-site) from organic soils were estimated in pastures land converted from other land use using the same method as in cropland converted from other land use. For detailed information on the emission factors and activity data, see section 6.5.1. b)3).

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

Uncertainties of the parameters and the activity data for living biomass, dead organic matter, and soil were individually assessed on the basis of field study results, expert judgment, or the default values provided in the *2006 IPCC Guidelines*. The uncertainty was estimated as 21% for the entire removal from the land converted to grassland.

- ***Time-series Consistency***

Although the methods to estimate the area of forest land converted to other land use are different between FY1990-2004 and post FY2005, as described in section 6.5.2. , time-series consistency for this subcategory is basically ensured.

d) Category-specific QA/QC and Verification

Same as Forestland Remaining Forestland (4.A.1.). See section 6.4.1 d).

e) Category-specific Recalculations

- ***Correction in accordance with revision of the area converted from forest land***

Due to a revision of the interpretations of the *Land Use Change Survey by Satellite Interpretation*, the area of grassland converted from forest was recalculated, carbon stock changes in living biomass, dead organic matter and CO_2 emissions from organic soils in this category were recalculated for all years.

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

- ***Method of obtaining data of the areas of cropland converted from other land-use categories to grassland***

The method used to obtain data on the area converted to grassland needs to be improved. For example, currently, the area of lands converted from forest land to grassland is estimated by multiplying the summed areas of forest land converted to cropland and grassland by the ratio of grazing land to the summed area. However, this estimation method may not represent the actual status of these areas. Therefore, the validity of the estimation method needs to be reviewed, and, if necessary, a new method of obtaining the area data should be developed.

- ***Method of obtaining data of the area of cropland converted to grassland***

The area of Cropland converted to Grassland cannot be obtained from statistics except for the land-use conversion from cropland (rice field) to grassland (pasture land). For this reason, the estimates of the carbon stock changes in this land-use category may not fully reflect the actual conditions. Therefore, the methods used to detect the following area data need to be developed.

- from upland field / orchard to pasture land
- from rice field / upland field / orchard to grazed meadow

- ***Estimation method of soil carbon stock change upon land-use conversion from other land to cropland***

The estimation method will be revised when new data and information are obtained.

6.7. Wetlands (4.D.)

Wetlands include land managed for peat extraction and land defined as lands that are covered or saturated by water throughout or part of the year. The CRT requires reporting in three subcategories; peat land for peat extraction, flooded land, and other wetlands. Japan reports carbon stock changes in mangroves and seagrass meadows and macroalgal beds in coastal wetlands under other wetlands. However, area of the habitat is not included in the wetland area reported under this category because it is outside the high tide line and not included in the total national land area (Table 6-44).

In FY2024, Japan's wetland area was about 1.35 million ha, which is equivalent to about 3.6% of the national land. The removals from this category in FY2024 were 317 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 29.6% compared to FY1990 and an increase of 6.8% compared to the previous year. It should be noted that about 0.15 million ha are reported as coastal wetland in FY2024, and all CO_2 removals in wetlands remaining wetlands under this category are from coastal wetlands.

Table 6-43 Emissions and removals in wetlands resulting from carbon stock changes

Category	Carbon pool	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
4.D. Wetlands	Total	kt-CO_2	-450	-188	-64	-346	-271	-336	-291	-314	-292	-301	-297	-317
	Living biomass	kt-CO_2	55	207	259	26	75	17	49	28	14	14	4	5
	Dead wood	kt-CO_2	9	34	42	4	12	3	8	3	1	1	0	0
	Litter	kt-CO_2	6	22	28	3	8	2	5	2	1	1	0	0
	Mineral soil	kt-CO_2	-520	-451	-393	-379	-366	-358	-352	-346	-308	-317	-302	-322
	Organic soil	kt-CO_2	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO
4.D.1. Wetlands remaining Wetlands	Total	kt-CO_2	-521	-452	-394	-380	-366	-358	-352	-347	-309	-318	-303	-323
	Living biomass	kt-CO_2	-0.5	-0.6	-0.6	-0.7	-0.2	-0.7	0.0	-0.7	-0.7	-0.7	-0.7	-0.6
	Dead wood	kt-CO_2	-0.08	-0.09	-0.10	-0.12	-0.04	-0.11	-0.01	-0.11	-0.11	-0.11	-0.11	-0.10
	Litter	kt-CO_2	-0.005	-0.006	-0.007	-0.008	-0.003	-0.007	0.000	-0.007	-0.007	-0.007	-0.007	-0.007
	Mineral soil	kt-CO_2	-520	-451	-393	-379	-366	-358	-352	-346	-308	-317	-302	-322
	Organic soil	kt-CO_2	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO
4.D.2. Land converted to Wetlands	Total	kt-CO_2	70	264	330	34	95	22	62	34	17	17	6	6
	Living biomass	kt-CO_2	55	208	260	27	75	18	49	29	15	15	5	5
	Dead wood	kt-CO_2	9	34	42	4	12	3	8	3	1	1	0	0
	Litter	kt-CO_2	6	22	28	3	8	2	5	2	1	1	0	0
	Mineral soil	kt-CO_2	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE
	Organic soil	kt-CO_2	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO	NA,NE,NO

Table 6-44 Areas of wetlands

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Wetlands	kha	1,310	1,320	1,350	1,340	1,330	1,340	1,340	1,350	1,350	1,350	1,350	1,350
Land managed for peat extraction	kha	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Flooded land	kha	1,310	1,320	1,350	1,340	1,330	1,340	1,340	1,350	1,350	1,350	1,350	1,350
Other wetlands (coastal wetlands)	kha	328.4	278.4	233.7	210.3	187.0	172.9	163.6	153.6	142.8	142.8	142.9	146.5
Mangroves	kha	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Seagrass meadows and macroalgal beds	kha	328.1	278.1	233.4	210.0	186.7	172.6	163.3	153.2	142.4	142.4	142.6	146.2

6.7.1. Wetlands Remaining Wetlands (4.D.1.)

a) Category Description

This subcategory deals with carbon stock changes in wetlands which have remained as wetlands more than 20 years. “Wetlands remaining wetlands” refers to wetlands that have not undergone conversion from other land-use categories. This category also includes blue carbon ecosystems in coastal wetlands that have expanded, either through human activities or through natural processes.

For emissions from organic soils in peat land for peat extraction, as a result of the domestic survey, it is found out that although small amount of peat extraction is carried out in Japan, estimating emissions with high accuracy is difficult. Therefore, based on the amount of emissions expected, carbon stock changes in organic soils that are managed for peat extraction are reported as “NE” in line with the insignificant threshold provided by the *MPGs.* “Flooded land remaining flooded land” is not calculated at the present time as this is treated in an appendix in the *2006 IPCC Guidelines* and reported as “NE”. The carbon stock changes for mangroves in coastal wetlands and seagrass meadows and macroalgal beds are covered under “Other wetlands remaining other wetlands”. There are about 0.9 kha of mangroves in Okinawa prefecture and Kagoshima prefecture, out of which mangroves (about 0.3 kha) not included in “4.A. Forest Land”, are reported here. For seagrass meadows and macroalgal beds, long-term (more than 100 years) storage of organic carbon through the four processes is estimated, where the carbon of which was originally stored by uptake of CO_2 in the ocean through photosynthesis. Since the major carbon sequestration occurs in soils through the processes such as sedimentation and burial, the total amount of carbon sequestered through the four processes is reported under the mineral soil carbon pool of “other wetlands remaining other wetlands”. Furthermore, the living biomass and the dead organic matter carbon pools are reported as “NA” because these carbon pools themselves do not contribute long-term carbon sequestration since the increase and decrease in the carbon stocks are balanced. CO_2 removals associated with carbon sequestration from coastal wetlands is shown in the table below.

Table 6-45 Emissions and removals in coastal wetlands resulting from carbon stock changes

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Other wetlands (coastal wetlands)	kt-CO_2	-520.7	-451.7	-393.7	-380.3	-366.1	-358.5	-352.3	-347.2	-309.0	-317.6	-302.8	-323.1
Mangroves	kt-CO_2	-1.8	-1.9	-2.1	-2.3	-1.8	-2.3	-1.6	-2.4	-2.3	-2.3	-2.3	-2.3
Seagrass meadows and macroalgal beds	kt-CO_2	-518.9	-449.7	-391.6	-378.0	-364.4	-356.2	-350.7	-344.8	-306.6	-315.3	-300.4	-320.7

b) Methodological Issues

1) Emission from peats extraction

For adaptation of standard for small emission, the following estimation was implemented. A result of domestic survey, peats are extracted in Japan, but accurate emissions are not able to estimate. A rough calculation of emission from peat extraction was made both at “on-site” and “off-site” with the Tier1

methodology in Chapter 7 of the *2006 IPCC Guidelines*. The peat extraction is carried out mainly in Hokkaido area, where is located in the northernmost part of Japan. So that we applied climatic zone as "Boreal and Temperate" and its soil condition as "Nutrient-Poor" under expert judgment in our preliminary calculation. To calculate on-site CO_2 emissions, we use the value, about "150 ha" for peat extraction area that from private company of peat extraction. And we also use the default values of EF, 0.2 t-C/ha (Boreal and Temperate, Nutrient- Poor on Table 7.4, Chp.7, Vol.4, 2006 *IPCC Guidelines*), and the result of this calculation is approximately 0.1 kt-CO_2. To calculate off-site CO_2 emissions, we use the value from National production data, which is available since 2003, ranged from 17 to 34 kt-d.m.. And we also use the default value of carbon fractions, 0.45 t-C/t-d.m. (Boreal and Temperate, Nutrient- Poor on Table 7.5, Chp.7, Vol.4, 2006 *IPCC Guidelines*). So the result of this calculation is ranged from 30 to 50 kt-CO_2. Furthermore, N_2O emissions from peat extraction are not conducted, as the estimation is necessary only for "Nutrient–Rich" area in Tier 1 method. As a result of these calculations, the emissions from peat extraction are regarded as "NE" due to the insignificant level of emissions. This value is below the threshold of *MPGs* and country specific standard of 90 kt-CO_2 (this value is 0.1 % of the removals in LULUCF sector in 2005). Please refer to Annex 6, for details.

2) Carbon stock changes in mangroves

i. Carbon stock changes in living biomass in mangroves

- ***Estimation Method***

Carbon stock changes in living biomass in mangroves are estimated using the Tier 1 gain-loss method provided in the *Wetlands Guidelines*. Since data on stock volume and harvested volume in mangroves were not available, it assumed that carbon stocks in land remaining mangroves have been stable, and the default value of the *Wetlands Guidelines* were used to set the average living biomass stocks of mangroves. Based on this, a) the gains in living biomass carbon stock associated with the increase in area of mangroves and b) carbon losses in living biomass associated with decrease in area of mangroves were estimated. The change of area of mangroves was estimated by each community level.

- ***Parameters***

➢ ***Average living biomass stock and biomass growth***

For the above-ground living biomass stock, the above-/ below-ground living biomass ratio (R), and the carbon fraction factor (CF), the default values in the *Wetlands Guidelines* are used (Table 6-46). For annual above-ground biomass growth associated with the expansion of mangrove areas, it is assumed that the living biomass stock increases linearly and reaches the average steady-state biomass stock within 20-year transition period, which is commonly applied in IPCC Guidelines, since the default value in the *Wetlands Guidelines* would otherwise imply an unrealistically short growth period of 4 years.

Table 6-46 Parameters of living biomass in mangroves

Parameter	Value	Reference
Amount of above ground living biomass stock	75 [t-d.m./ha]	Table 4.3, subtropical, *Wetlands Guidelines*
Above ground biomass growth	3.75 [t-d.m./ha/yr]	It is assumed that above ground living biomass grows to reach 75 t-d.m./ha in 20 years.
Above and below ground living biomass ratio (R)	0.96	Table 4.5, subtropical, *Wetlands Guidelines*
Carbon fraction factor (CF)	0.451 [t-C/t-d.m.]	Table 4.2, *Wetlands Guidelines*

- ***Activity Data***

The increase in living biomass is estimated using the area that expanded over the past 20 years, while the decrease in living biomass is estimated using the area that declined in the relevant year. These areas are derived by combining various domestic survey datasets (Table 6-47) and compiling annual gross increases and decreases in area for each mangrove community. For years without survey data, community-level areas are linearly interpolated.

Most mangroves are designated as protected areas in Japan, and land-use changes such as conversion to settlements or cropland have generally not occurred. However, decreases in mangrove area may occur due to the cutting of mangrove trees that have become excessively over grown as a result of direct or indirect human induced activities, or due to environmental changes such as sediment accumulation or disturbances.

Mangroves reported under this category are those not included in "4.A. Forest land" (i.e., non-forest mangroves). These areas were identified through an overlap assessment with forest area data, which showed that the proportion of non-forest mangroves has remained nearly constant – about 36% of the total mangroves – throughout the time series since 1990. Accordingly, 36 % of the total mangrove activity data and the carbon stock changes in each carbon pool are reported under the "Wetlands" category.

Table 6-47 Reference used to estimate the area of mangroves

Year	Reference
1961 and 2007	*Transition of mangrove*, Okinawa Prefecture
1973	*Research about Mangrove I. Mangrove Distribution in Japan,* Nakasuga, et al., Japanese Journal of Ecology, 24(4)
1977, 1993-1995 and 2001	*Investigation of Mangrove Distribution in Okinawa for Coastal Ecosystem and Monitor the Sea Level Rise*, International Society for Mangrove Ecosystems, 2003
2019	*Explore the Mangrove in Kagoshima and Okinawa*, ManGlobal

ii. Carbon stock changes in dead organic matter in mangroves

- ***Estimation Method***

Carbon stock changes in the dead organic matter pool of mangroves were estimated using the Tier 1 gain-loss method provided in the *Wetlands Guidelines*. Generally, it is considered that dead organic matter in mangroves continues to accumulate without reaching saturation. However, since no data are available on the accumulation ratio of dead organic matter in observations in mangroves, the amount of dead organic matter in "mangroves remaining mangroves" was assumed to be in a steady state, and the average stock of dead organic matter for mangroves was estimated. Based on this assumption, a) when mangrove area increases, the dead organic matter stock is assumed to increase linearly and reach the average steady-state stock within 20 years, consistent with the assumption applied to living biomass, and (b) when mangrove area decreases, the carbon loss is calculated by assuming that the entire existing dead organic matter stock is lost in the year the area of mangrove is lost.

- ***Parameters***

The default values of carbon stocks in mangroves for dead wood (10.7 t-C/ha) and litter (0.7 t-C/ha) provided in Table 4.7 in the *Wetlands Guidelines* were used.

- ***Activity Data***

The increase in mangrove area over the past 20 years and the decrease in area in the relevant year, as described in the section 2) i) above, are used.

iii. Carbon stock changes in soil in mangroves

- ***Estimation Method***

Carbon stock changes in mineral soils of mangroves are estimated using the gain-loss method.

For soil carbon gains, the *Wetlands Guidelines* (Section 4.2.3.3) provides annual default value as removal factor for increases in soil carbon stocks associated with revegetation and creation of mangrove, and indicate that soil carbon continues to accumulate until it reaches levels comparable to natural mangroves or undrained soils. Since inputs to soil in mangroves are generally considered to exceed outputs, it was assumed that soil carbon stocks continue to increase across all mangrove areas - not only those that have clearly expanded since the year of data available (i.e around 1960). Accordingly, soil carbon gains are calculated by applying the default values as removal factor to the total mangrove area.

For soil carbon losses, emissions are estimated only when soil excavation occurred, by assuming that all soil carbon accumulated since mangrove establishment is lost. This type of events has been occurred in two mangrove habitats so far. In contrast, when decreases in mangrove area are caused by biomass cutting, environmental changes such as sediment deposition, or disturbances leading to fallen trees or vegetation loss, soil carbon losses are assumed not to occur because no excavation is occurred in these cases.

- ***Parameters***

Since Japan's mangrove habitat is located in a relatively cooler region compared to other mangrove habitats in the world, the removal factor applicable for Japan is considered to be smaller than the tropical and subtropical average. The minimum value of the default removal factor range, 1.3 t-C/ha/yr on Table 4.12 in the *Wetlands Guidelines,* is applied.

For estimating loss of carbon in soils, the period from the year the mangroves had planted to the year dredging began in the relevant mangrove habitats were multiplied by the removal factor above described, and then estimated the accumulated amount soil carbon for the places where the excavated area estimation is available where dredging took place after 1990.

- ***Activity Data***

The total mangrove area for each year was used to estimate the increase in soil carbon which was described in section 2) i) above.

For the estimation of soil carbon losses, the decreased area due to dredging was determined using the dredged areas of Ishikawa River (Masuno, et al. (2012)) and the Hiyagon wetlands (based on materials from the Okinawa General Bureau, Cabinet Office).

3) Carbon stock changes in seagrass meadows and macroalgal beds

i. Carbon sequestration from seagrass meadows and macroalgal beds

- **Estimation Method**

➢ **Scope of estimation**

Recent studies (e.g. Krause-Jensen and Duarte 2016) show that seagrass meadows as well as macroalgal (seaweed) beds effectively sequestrate carbon in marine sediments and deep ocean for long time. Japan has developed country specific ecosystem model (Tier 3) on estimating long-term carbon sequestration (over 100 years[7]) through seagrass meadows and macroalgal beds considering these recent scientific knowledges in Japan. Therefore, the estimation covers not only newly planting or creating activities of seagrass meadows described in the *Wetland Guidelines*, but also all activities related to carbon sequestration from existing managed seagrass meadows and macroalgal beds in coastal areas.

In Japan, entire costal ecosystems are treated as managed, and carbon sequestration from entire seagrass meadows and macroalgal beds, including natural seagrass meadows and macroalgal beds, are covered in the estimation. This definition is based on considering juristic coastal management in Japan as well as the fact that coastal areas including seagrass meadows and macroalgal beds frequently influenced by human induced activities and/or effects. In Japan, the Government shall formulate a basic plan with regard to the oceans (*Basic Plan on Ocean Policy*), in order to promote measures with regard to the oceans comprehensively and systematically. This basic plan ensures government jurisdictional authority for all coastal line in the territorial sea. Based on a *Basic Policy for Coastal Conservation* due to Coast act of Japan, *Basic Plan for Coastal Conservation* are formulated in all coastal zones covering all coastal line in Japan aiming to implement comprehensive coastal area management and conservation which covers conservation of natural environment including tidal marsh, seagrass meadows and macroalgal beds.

➢ **Ecosystem model on estimating long-term carbon sequestration through seagrass meadows and macroalgal beds (Tier 3)**

Long-term carbon sequestration through seagrass meadows and macroalgal beds in Japan is assessed in line with the methodology has developed in a national research project (hereafter "MAFF research project") implemented for 2020-2024[8]. This methodology assesses four carbon sequestration processes 1) buried in seagrass meadows and macroalgal beds, 2) exported to deep sea, 3) exported as POC and buried outside of seagrass meadows and macroalgal beds, and 4) exported as RDOC (see details in the box below). The sequestered organic carbon is estimated using coefficient of long-term sequestration rate of annual net primary production by seagrass meadows and macroalgal beds in each process. Some components of this methodology have been published as scientific articles, but not all components have been published as a paper yet. However, the methodology and the parameters of this model had discussed regularly in a domestic committee of this research with the third-party experts (as QA process)

[7] There is no official guidance to define how many years are required to assess long-term carbon sequestration in the IPCC guidelines. Japan applies "100 years" as its definition follows a suggestion from Joint Group of Experts on the Scientific Aspects of Marine Environment Protection (GESAMP) in 2019 "carbon sequestration is defined as the secure storage of carbon-containing molecules for >100 years outside the atmosphere'.

[8] Project JPJ008722 commissioned by the Ministry of Agriculture, Forestry and Fisheries of Japan

in order to prepare reasonable estimation method. A methodological guidance of this methodology for domestic users is publicly available (Japanese only at this moment)[9].

Carbon sequestration process through seagrass meadows and macroalgal beds

1) Buried in seagrass meadows: long-term sequestration process in which dead seagrass and macroalgal is buried in the underlying sediments.

2) Exported to deep sea: long-term sequestration process in which floating macroalgal that are torn off by waves and flow offshore lose buoyancy and settle into the deep sea.

3) Exported as POC and buried outside of seagrass meadows and macroalgal beds: long-term sequestration process in which dead seagrass and macroalgal and its fragment become Refractory Particle Organic Carbon (RPOC) and buried in shelf.

4) Exported as DOC: long-term sequestration process in which Refractory Dissolved Organic Carbon (RDOC) released by seagrass and macroalgal is stored in seawater for a long period of time.

Reference: *Guidebook for the estimation of CO_2 sequestration by seagrass and macroalgal beds* (in Japanese) (Japan Fisheries Research and Education Agency)

➢ *Estimation equation*

Annual CO_2 sequestration amount through seagrass meadows and macroalgal beds is estimated by CO_2 removal coefficient represented as annual CO_2 sequestration amount per unit of area prepared in each sea-area and in each seagrass and macroalgal type, and the area of each seagrass meadows and macroalgal beds. The removal coefficients are established from net primary production (NPP) per unit of area for each seagrass/macroalgal type in each sea-area and long-term carbon sequestration rates of the four sequestration processes (r1 – r4). NPP is estimated by maximum amount of seagrass meadows /macroalgal beds (B_{max}) which is easier for monitoring and a predetermined conversion factor of P/B_{max}. Then, carbon fraction and a conversion factor from carbon to CO_2 and an ecosystem conversion factor (used for adjusting amount of seagrass/macroalgal at site level) are applied to deliver CO_2 removal coefficient.

$$CO_{2\,sq.\_sgsw} = \sum_{i,j} \left(RF_{i,j} \times Area_{i,j}/100 \right)$$

$$RF_{i,j} = RF'_{i,j} \times CF \times E \times 44/12$$

$$RF'_{i,j} = \left(\frac{P}{Bmax}\right)_{i,j} \times Bmax_{i,j} \times r2_{i,j} + \left(\frac{P}{Bmax}\right)_{i,j} \times Bmax_{i,j} \times r3_{i,j} + \left(\frac{P}{Bmax}\right)_{i,j} \times Bmax_{i,j} \times r1_{i,j} \times \left(1 - r2_{i,j} - r3_{i,j}\right) + Bmax_{i,j} \times r4_{i,j}$$

[9] https://www.fra.go.jp/home/kenkyushokai/press/pr2023/20231101_kaisou.html

$$= Bmax_{i,j} \times \left[\left(\frac{P}{Bmax} \right)_{i,j} \times \{ r1_{i,j} \times (r2_{i,j} + r3_{i,j})(1 - r1_{i,j}) \} + r4_{i,j} \right]$$

$CO_{2s.q._{sgsw}}$: Annual CO_2 sequestration through seagrass meadows and macroalgal beds [t-CO_2 /yr]

$Area_{i,j}$: Area of sea-area *i*, type of seagrass / macroalgae *j* [ha]

$RF_{i,j}$: CO_2 removal coefficient for sea-area *i*, type of seagrass / macroalgae *j* (annual CO_2 sequestration amount per unit of area) [g-CO_2 /m/yr]

$RF'_{i,j}$: Organic carbon annual sequestration coefficient per unit of area for sea-area *i*, type of seagrass / macroalgae *j* [g /m^2/yr]

$P/Bmax_{i,j}$: Ratio of production to maximum weight of seagrass/ macroalgae of sea-area *i*, type of seagrass / macroalgae *j* [(g/m^2/yr) / (g/m^2)]

$Bmax_{i,j}$: Maximum weight of seagrass/ macroalgae of sea-area *i*, type of seagrass / macroalgae *j* [g/m^2]

$r1_{i,j}$: Long-term sequestration rate of RPOC export for sea-area *i*, type of seagrass / macroalgae *j*.
Note: As this rate includes buried in algal beds and deep-sea export, these two rates are excluded from the RPOC export rate.

$r2_{i,j}$: Long-term sequestration rate of buried in algal beds for sea area *i*, type of seagrass / macroalgae *j*

$r3_{i,j}$: Long-term sequestration rate of deep sea export for sea-area *i*, type of seagrass / macroalgae *j*

$r4_{i,j}$: Long-term sequestration rate of RDOC sequestration for sea-area *i*, type of seagrass / macroalgae *j*
Note: Including coefficient for calculating RDOC residuals

CF : Carbon fraction

E : Ecosystem conversion factor (E=1)

i : Sea-area

j : Type of seagrass and macroalgal

➢ *Categorization of seagrass meadows and macroalgal beds*

There are about 15 to 20 species of seagrass and about 1,500 species of macroalgal. These are classified into broad categories considering similarity of CO_2 sequestration process. We used 16 natural seagrass meadows and macroalgal beds types for estimation. The long-term sequestration processes covered in each type are shown in the table below. As species compositions are different in each sea-area, nine sea-area classification is established. These classifications were suggested by the MAFF research project.

Table 6-48 Types of seagrass /macroalgal habitat and the relevant carbon sequestration processess

Type of seagrass and macroalgal			Main species	Long-term carbon sequestration processes			
				Buried in seagrass meadows	Deep-sea export	RPOC export	RDOC export
Seagrass meadows		1 Eelgrass type	*Zostera marina, Zostera caespitosa, Zostera japonica*	x	x	x	x
		2 Long eelgrass type	*Zostera caulescens*	x	x	x	x
		3 Surfgrass type	*Phyllospadix iwatensis, Phyllospadix japonicus* Makino		x	x	x
		4 Seagrass, subtropical small type	*Halophila* sp., *Halodule pinifolia, Zostera japonica* (subtropica type)	x	x	x	x
		5 Seagrass, subtropical medium type	*Thalassia hemprichii, Cymodocea serrulata*	x	x	x	x
		6 Seagrass, subtropical large type	*Enhalus acoroides*	x	x	x	x
Macroalgal beds	Kelps	7 Kelp type	*Saccharina japonica, Laminaria religiosa. Kjellmaniella crassifolia*		x	x	x
		8 Long Kelp type	*Laminaria longissima, Costaria costata, Alaria* sp.		x	x	x
	Eisenia and *Ecklonia*	9 *Eisenia*-kelp type	*Eisenia bicyclis* (Arame), *Eisenia nipponica*		x	x	x
		10 *Ecklonia*-kelp type	*Ecklonia cava* (Kajime), *Ecklonia kurome*		x	x	x
		11 *Undaria*-kelp type	*Undaria pinnatifida* (Wakame), *Undaria undarioides* (Hirome)		x	x	x
	Sargassum spp.	12 Temperate *Sargassum* spp.	*Sargassum horneri* (Akamoku), *Sargassum fulvellum, Sargassum*	x	x	x	x
		13 Subtropical *Sargassum* spp.	*Sargassum ilicifolium, Sargassum myriocystum, Hormophysa cuneiformis*		x	x	x
	Small algae	14 Small green algae	*Monostroma nitidum,Ulva pertusa, Codium fragile*		x	x	x
		15 Small red algae	*Gelidium elegans,Chondrus ocellatus* Holmes, *Neopyropia yezoensis*		x	x	x
		16 Small brown algae	*Dictyota dichotoma, Fucus distichus, Dictyopteris latiuscula*		x	x	x

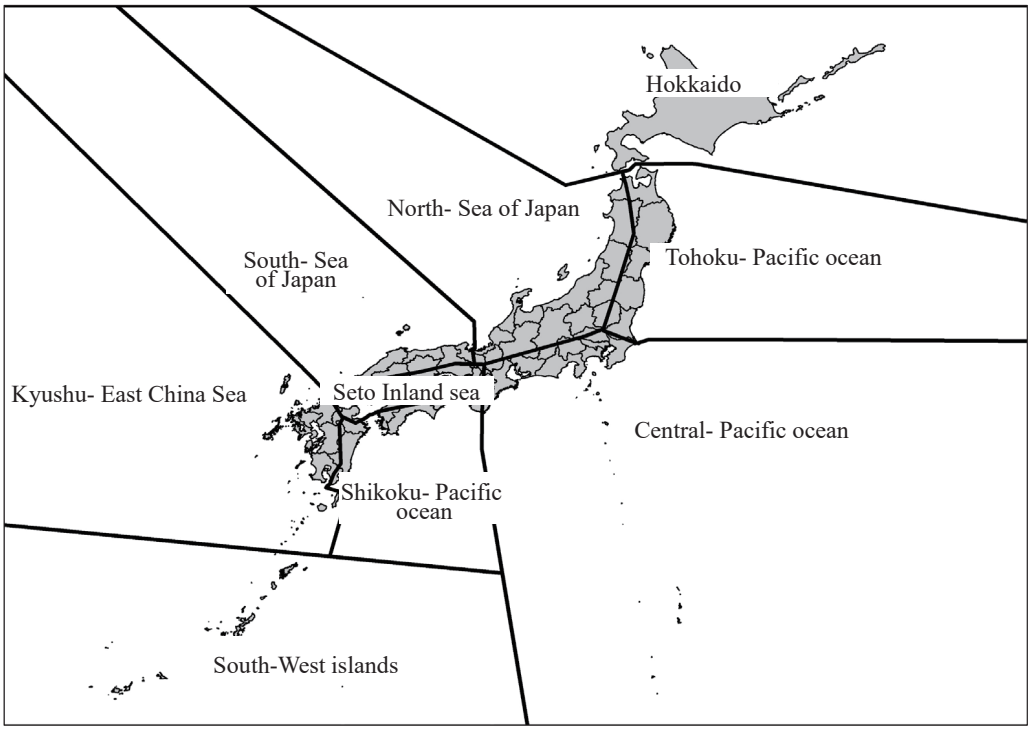

Figure 6-7 Nine sea-areas used for estimation of carbon sequestration from seagrass meadows and macroalgal beds

Reference: *Guidebook for the estimation of CO_2 sequestration by seagrass and macroalgal beds* (Japan Fisheries Research and Education Agency)

- ***Parameters***

  - ***Maximum weight of seagrass/ macroalgae (B_{max})***

    Maximum amount of seagrass and macroalgal habitat per area (B_{max}) were derived from the monitored data from the MAFF research project and these were applied as fixed values for all time-series.

  - ***Ratio of production to maximum weight of seagrass/ macroalgae (P/B_{max})***

    P/B_{max} was established by comprehensive literature review implemented in the MAFF research project. The original data used and the values applied for each vegetation type are as shown in the table below.

Table 6-49 P/B_{max} value by Vegetation type and references used

Vegetation Type		P/B_{max}	References
1 Eelgrass type		2.6	Duarte and Chiscano 1999, Kokubu and Yamada 2015*, Watanabe et al., 2005, Uede 2007*, Abe et al. 2012*
2 Long eelgrass type		2.4	Nakaoka et al. 2003
3 Surfgrass type		2.8	Muraoka 2003*, Hasegawa et al. 2005
4 Seagrass, subtropical – small type		4.5	Lee 1997, Duarte and Chiscano 1999
5 Seagrass, subtropical – medium type		3	Duarte and Chiscano 1999
6 Seagrass, subtropical large type		1.9	Duarte and Chiscano 1999
7 Kelp type		1.9	Musashi et al. 1993*, Nabata and Sakai 1996*, Nakawaki et al. 2001*
8 Long Kelp type		2.3	FRA 2025*
9 *Eisenia* -kelp type	*Eisenia bicyclis*	1.2	Yoshida 1970*, Kamohara et al. 2009*
	Eisenia nipponica	2.4	
10 *Ecklonia* -kelp type	*Ecklonia cava kurome*	1.9	Yatsuya et al. 2014*, Yoshida et al. 2020*
	Ecklonia cava	1.1	Yokohama et al. 1987, Tominaga et al. 2004*, Komazawa et al. 2017*
11 *Undaria* -kelp type		1.3	Nakai et al.1993*
12 Temperate sargassum spp.		1.3	Taniguchi and Yamada 1978*, Taniguchi and Yamada 1988*, Murase 2000*, Tsuda and Akaike 2001*, Kobayashi 2001*, Nakabayashi and Taniguchi 2002*, Agatsuma et al. 2002, Muraoka 2003*, Yatsuya et al. 2005, Yatsuya et al. 2007*, Yoshida et al. 2011, Yoshida and Shimabukuro 2013, Terawaki et al. 2015*
13 Subtropical sargassum spp.		1.2	Yoshida et al. 2013*, Murase et al. 2017*
14 Small green algae		2.5	Fuji and Kawamura 1970, Sfriso et al. 1993, Honda 2000*
15 Small red algae		1.3	Honda et al. 2000*, Kaneko and Yoneda 2010*
16 Small brown algae		1.1	Kaneko and Yoneda 2010*

Note: * in Japanese

  - ***Long-term sequestration rate***

    "r2" for buried in algal bed was established by the result of analysis about carbon accumulation ratio of sediment soil core (Miyajima et al., 2022). In this analysis, 1m depth was used in order to be consistent with the default soil depth suggested by the *Wetland Guidelines*, which is almost equivalent to 2,000 years scale of accumulation of sediment in surrounding seas of Japan.

    "r3" for deep-sea export was established based on the existing studies about the ratio of reaching deep-sea from floating seagrass and macroalgal, from the ratio of reaching deep-sea amount and floating seagrass and macroalgal amount in sea around Japan (Abo et al. 2019, Kuwae et al. 2019, Taniguchi et al. 2022).

    "r1" for RPOC export was established from 100-year remaining ratio of organic carbon computed by a decomposition model with input of active values obtained from decomposition experiment for various seagrass and macroalgal types implemented in the MAFF research project (MAFF / Japan Fisheries Research and Education Agency, 2025), because there were no existing studies targeting long-term

carbon sequestration of this process. As this value implicitly includes the sequestered carbon for "r2" and "r3", the RPOC export was calculated excluding the elements covered by "r2" and "r3".

"r4" for RDOC export was established from the methodology of multiplying "existing amount of seagrass and macroalgal habitat", "release rate of DOC" and "RDOC%" suggested by Watanabe et al. (2020). "RDOC%" was established from 100-year remaining ratio of organic carbon computed by a decomposition model with input of active values obtained from decomposition experiment for various seagrass and macroalgal types implemented in the MAFF research project (MAFF / Japan Fisheries Research and Education Agency, 2025). Only "r4" is directly applied to amount of seagrass and macroalgal habitat instead of NPP.

➢ ***Carbon fraction (CF)***

Carbon fraction used for converting the dry matter weight to organic carbon weight for seagrass meadows and macroalgal beds is set as 30%. This was calculated based on a MAFF research project.

The removal coefficient integrated the parameter above is shown in the table below.

Table 6-50 Removal coefficient by sea-area and types of seagrass /macroalgal habitat [g-CO_2/m^2/yr]

Type of seagrass and macroalgal		Hokkaido	Tohoku-Pacific Ocean	North-Sea of Japan	South-Sea of Japan	Central-Pacific Ocean	Seto Inland sea	Shikoku-Pacific Ocean	Kyushu-East China sea	South-West Islands
1	Eelgrass type	490.39	224.11	593.2	381.56	593.2	232.1	381.56	280.52	
2	Long eelgrass type	847.77	212.74	847.77	847.77	847.77				
3	Surfgrass type	2039.74	1780.41	713.21	713.21	535.52				
4	Seagrass, subtropical – small type									108.79
5	Seagrass, subtropical – medium type									305.91
6	Seagrass, subtropical large type									336.35
7	Kelp type	164.18	468.66	468.66						
8	Long Kelp type	110.7								
9	*Eisenia* -kelp type		274.72		127.16	423.02		162.69	127.16	
10	*Ecklonia* -kelp type		61.55	15.54	151.57	49.39	126.08	25.24	20.28	
11	*Undaria* -kelp type	58.48	116.28	58.48	25.7	23.71	47.49	12.23	15.83	
12	Temperate sargassum spp.	312.03	158.86	60.5	219.24	31.56	155.21	27.33	105.50	
13	Subtropical sargassum spp.							128.51	21.31	41.97
14	Small green algae	4.16	9.95	5.54	7.05	6.05	9.7	1.89	4.16	17.76
15	Small red algae	112.69	7.91	11.68	63.91	1.19	19.9	30.51	14.88	9.35
16	Small brown algae	52.38	22.90	56.94	17.57	1.52	30.24	22.76	15.98	4.36

Reference: Guidebook for the estimation of CO_2 sequestration by seagrass and macroalgal beds (Japan Fisheries Research and Education Agency)

● ***Activity Data***

The activity data are defined as the areas of seagrass meadows and macroalgal beds by sea-area classification and vegetation type, consistent with the classification used for removal factors as activity data.

- ***From 2018 onwards***

A spatial distribution model for seagrass meadows and macroalgal beds developed by Port and Airport Research Institute (Moki et al. 2023) is applied. This model estimates the annual distribution area of seagrass meadows and macroalgal beds using environmental data for each year, such as topographic data, sea bottom sediment, chlorophyll a concentration and see surface temperature, based on the reference area for the period 2018-2020, as well as the following algorithm. The analysis covers costal sea area across Japan at water depths ranging from 0-50 m, with a spatial resolution of 250 m.

$$E_e = E_p \cdot \frac{D_y}{D_b}$$

E_e : Estimated area of seagrass meadows and macroalgal bed for each year (by sea-area and types of seagrass /macroalgal habitat) [ha]
E_p : Initial vegetated area of seagrass meadows and macroalgal beds obtained through MAFF research project in baseline period (2018–2020) [ha]
D_y : Number of habitable meshes estimated using environmental data each year
D_b : Number of habitable meshes estimated in the baseline period

The criteria for evaluating changes in area are as follows:

Dy < Db: Vegetated area is shrunk compared to the initial vegetated area in baseline period (2018-2020)

Dy = Db: Vegetated area is unchanged

Dy > Db: Vegetated area is expanded compared to the initial vegetated area in baseline period (2018-2020)

Habitable potential is determined based on light availability and water temperature. Light transmittance is calculated using water depth and chlorophyll a concentration, and growth is considered impossible when light intensity fell below a predefined threshold. Regarding water temperature, the seagrass meadow and macroalgal bed distribution data obtained from the MAFF research project were cross-referenced with monthly water temperature data for the period 2018-2020. This process identified the minimum and maximum water temperatures suitable for growth for each sea area and species. If the monthly water temperature for a specific year fell outside this range, it was determined to be unsuitable for maintaining growth.

- ***From 1990 to 2017***

The time series of areas from 1990 to 2017 were constructed using several data sources and methodologies summarized in the table below since the equivalent accuracy environmental data are not available. The MOE survey data for 1990 and 1999 had different categorization of sea-areas and categorization of seagrass and macroalgal types from those used in the model mentioned above. Therefore, experts implemented assessment and developed method to construct time series area estimation considering the ecosystems of seagrass and macroalgal appropriate for proportional allocation.

Table 6-51 Data and methods used for estimating area of seagrass meadows and macroalgal beds

Fiscal year	Reference
1990	Coastal Survey of the 4th National survey on Natural Environment[1)], MOE
1991-1998	Linear interpolation of the 1990 and 1999 data implemented in each sea-area and each type of seagrass meadows and macroalgal beds
1999	Coastal Survey of the 5th National survey on Natural Environment[1)], MOE
2000-2017	Linear interpolation of the 1999 and 2018 data implemented in each sea-area and each type of seagrass meadows and macroalgal beds
2018-2024	Spatial distribution model for seagrass meadows and macroalgal beds Initial area: Seagrass meadow and macroalgal bed area obtained by the MAFF research project in the baseline period (2018–2020) Data sources for environment data: Chlorophyll a concentration and water temperature: GCOM-C, the earth observation satellite of JAXA Topographic data are from Research and review committee on large-scale earthquakes in the Sea of Japan (MLIT), Global tsunami Terrain Mode, Expert committee on earthquake disaster of subduction zone earthquake around Japan trench and Chishima trench (Cabinet Office), and Review Committee on Nankai Trough Mega-Earthquake Model (Cabinet Office) Sea floor sediment: dbSEABED (INSTAAR), Digital mesh data for sediment of the Northwest Pacific (second edition) (Japan Hydrographic Association)

Note: 1) Values for 1990 and 1999 were estimated at the time of the 2024submission by backward extrapolation based on the rate of the changes observed between 2018 and 2019 since data for the Southwest Islands were unavailable.

Table 6-52 Area of seagrass meadows and macroalgal beds by the type

Type of seagrass and macroalgal	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
1 Eelgrass type	kha	26.4	22.6	20.0	22.2	24.5	25.8	26.7	27.8	23.9	25.5	24.9	25.3
2 Long eelgrass type	kha	10.2	7.6	5.2	3.8	2.4	1.5	0.9	0.1	0.1	0.04	0.02	0.02
3 Surfgrass type	kha	5.4	4.4	3.8	4.5	5.2	5.6	5.8	6.3	5.5	5.7	4.9	5.9
4 Seagrass, subtropical small type	kha	0.9	0.8	0.7	0.7	0.7	0.7	0.7	0.6	0.5	0.6	0.5	0.6
5 Seagrass, subtropical medium type	kha	4.7	4.4	4.2	3.9	3.7	3.5	3.4	3.3	3.3	3.2	3.1	3.1
6 Seagrass, subtropical large type	kha	0.07	0.07	0.06	0.05	0.05	0.04	0.04	0.03	0.03	0.02	0.02	0.02
7 Kelp type	kha	5.2	13.3	19.3	16.5	13.8	12.2	11.1	9.4	8.7	8.4	8.6	8.9
8 Long Kelp type	kha	1.1	3.6	5.5	4.8	4.1	3.6	3.4	2.4	1.6	2.3	1.5	2.1
9 *Eisenia* -kelp type	kha	61.6	39.1	20.2	15.9	11.6	9.1	7.4	5.5	5.2	5.1	5.2	5.1
10 *Ecklonia* -kelp type	kha	34.5	27.5	21.2	18.2	15.2	13.4	12.2	12.8	11.1	11.0	11.1	11.6
11 *Undaria* -kelp type	kha	27.5	23.4	19.4	15.8	12.3	10.1	8.7	6.9	6.6	6.5	6.6	6.8
12 Temperate Sargassum spp.	kha	85.6	73.3	61.9	54.2	46.5	41.9	38.8	35.1	34.2	33.3	34.8	34.1
13 Subtropical *Sargassum* spp.	kha	12.6	11.6	10.6	9.6	8.5	7.9	7.5	7.6	7.8	6.9	7.7	7.9
14 Small green algae	kha	10.4	10.3	10.1	9.3	8.6	8.2	7.9	7.0	6.6	7.0	6.2	7.2
15 Small red algae	kha	23.2	20.2	17.4	14.7	12.0	10.4	9.4	7.8	7.5	7.5	7.3	7.7
16 Small brown algae	kha	18.8	16.0	14.0	15.8	17.5	18.6	19.3	20.7	19.9	19.4	19.9	19.9
Total	kha	328.1	278.1	233.4	210.0	186.7	172.6	163.3	153.2	142.4	142.4	142.6	146.2

ii. Carbon stock change due to extraction of seagrass meadows and macroalgal beds

- ***Estimation Method***

Carbon stock changes due to extraction of seagrass meadows and macroalgal beds are considered along with Tier 1 of "Extraction" in *Wetland Guidelines*. Under Tier 1, changes in carbon stock in biomass is assumed to be zero for coastal wetlands without perennial biomass and in dead organic matter in seagrass meadows. Thus, biomass and dead organic matter carbon pools are reported as "NO" for extraction.

For soil organic carbon, the Tier 1 methodology assumes that the soil (1 m depth) is removed and disposed of under aerobic conditions where the carbon stock is emitted as CO_2 during the year of the extraction. Japan reports this as "NO" for historical time series, because the relevant activities have unlikely occurred in Japan (see explanation of Activity data). But these emissions will be calculated if such activity will occur on a large scale in the future.

- ***Activity Data***

Extraction activity in channel is implemented in port areas in Japan. But channels in port areas generally

do not have enough light at their floor required for photosynthesis due to its deep-water depth and high turbidity. Japan also found that quite a few areas of loss of seagrass meadows or macroalgal beds in the past have occurred in channels. Considering these facts, we conclude that extraction of seagrass meadows and macroalgal beds due to channel digging in port areas as well as extraction in other managed area do not affect to CO_2 emissions based on expert judgement (in the Committee for the GHG emission estimation methods in FY2023).

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

Uncertainties of the parameters of mangroves for living biomass, dead organic matter, and soil are individually assessed on the basis of the default values provided in the W*etlands Guidelines* and uncertainties of the activity data are 10% for the general total inspection. Uncertainties of the parameters of seagrass meadows and macroalgal beds were 17% from the standard error of the result of observation in the MAFF research project. Uncertainties of the activity data were 8% from annual variability of the result of observation in the MAFF research project. The uncertainty is estimated as 19% of the total emissions from the wetlands remaining wetlands for year which emissions are calculated.

- ***Time-series Consistency***

Although some different statistics are used to estimate the area of mangroves, data continuity is checked and time-series consistency for this subcategory is basically ensured. For the estimation of seagrass and macroalgal, the same methodology and parameters are used for a whole time series. The reasonable time-series of area is constructed using several data sources based on the support of experts of seagrass and macroalgal. These processes ensure time-series consistency in seagrass and macroalgal CO_2 emissions and removals estimation.

d) Category-specific QA/QC and Verification

Same as Forestland Remaining Forestland (4.A.1.). See section 6.4.1 d).

e) Category-specific Recalculations

- ***Updates of environmental data used for area estimation***

In addition to updating the environmental data (GCOM-C) used to estimate the areas of seagrass meadows and macroalgal beds, the light transmittance calculation algorithm was revised, and the minimum viable water temperature and the optimal water temperature range for each species by sea area (regional variation) were added, the area of seagrass meadows and macroalgal bed since 2000 have been revised. Accordingly, the removals in the seagrass meadows and macroalgal beds after 2000 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

Further improvements in carbon stock change estimation in coastal wetlands are planned.

For example, B_{max} could change over time reflecting the circumstance of their habitat and so may be revised in the future if future monitoring or refinement work of the past observation will provide updated numbers considered better reflection of reality.

6.7.2. Land converted to Wetlands (4.D.2.)

a) Category Description

This subcategory deals with the carbon stock changes which occurred in the land that was converted from other land-use categories to wetlands, particularly to flooded land (i.e., dams) within the past 20 years. The emissions from this subcategory in FY2024 were 6 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.), this represents a decrease of 91.5% compared to FY1990 and an increase of 0.5% compared to the previous year.

b) Methodological Issues

1) Carbon stock change in Living biomass in "Land converted to Wetlands"

- ***Estimation Method***

The Tier 2 method was applied for estimating carbon stock changes in the land converted to wetlands (flooded land), as the same as land converted to cropland, which is estimated by country-specific amount of biomass stock with the equation 2.16 in section 2.3.1.2 in Vol.4 of the *2006 IPCC Guidelines*. The equations are given in section 6.5.2. b)1).

- ***Parameters***

➢ ***Biomass stock in each Land-Use Category***

The values shown in Table 6-9, Table 6-10 and Table 6-11 are used for the estimation of biomass stock changes resulting from land-use conversion and subsequent changes in biomass stock due to biomass growth in converted land.

➢ ***Carbon Fraction of Dry Matter***

For carbon fraction of dry matter of forest, average value of broad leaf trees and conifer trees (0.50 t-C/t-d.m.) was applied. The default value (0.47 t-C/t-d.m. for herbaceous biomass in grassland and 0.5 t-C/t-d.m. for the others) was applied for other than forest in accordance with the *2006 IPCC Guidelines*.

- ***Activity Data (Area)***

➢ ***Areas of land converted to wetlands (reservoirs)***

Areas of land converted to wetlands (dammed reservoirs) were estimated based on the area of reservoirs converted from forest land and the ratio of forest land among the area of land-use categories before conversion. The area of forest land converted to wetlands was calculated by the method described in section 6.5.2. b)1). With respect to areas of each land-use type before conversion to reservoir, percentages of each land area converted to reservoir from agricultural land (cropland and grassland), settlements and other land were estimated based on the numbers of dwellings and agricultural land which were submerged into some large-scale reservoir. Breakdown of wetland areas converted from agricultural land into from cropland and grassland was determined based on the ratio of current area the same manner of other land-use categories. The differences between the areas of wetlands converted from forest land, cropland, grassland, and settlements and the total conversion area to reservoir were regarded as other land converted to wetlands.

Table 6-53 Area of land annually converted to wetlands within the past 1 year

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Land converted to Wetlands	kha	0.45	1.69	2.12	0.22	0.61	0.14	0.39	0.14	0.07	0.07	0.03	0.03
Forest land converted to Wetlands	kha	0.33	1.23	1.53	0.16	0.44	0.10	0.28	0.10	0.05	0.05	0.02	0.02
Cropland converted to Wetlands	kha	0.030	0.100	0.133	0.015	0.038	0.008	0.025	NO	NO	NO	NO	NO
Rice field	kha	0.007	0.023	0.089	0.013	0.023	0.004	0.015	NO	NO	NO	NO	NO
Upland fields	kha	0.012	0.049	0.014	0.002	0.012	0.004	0.007	NO	NO	NO	NO	NO
Orchards	kha	0.010	0.028	0.031	0.0004	0.003	0.001	0.002	NO	NO	NO	NO	NO
grassland converted to Wetlands	kha	0.003	0.023	0.021	0.001	0.006	0.002	0.004	NO	NO	NO	NO	NO
Settlements converted to Wetlands	kha	0.0016	0.0060	0.0075	0.0008	0.0022	0.0005	0.0014	0.0005	0.0003	0.0003	0.0001	0.0001
Other land converted to Wetlands	kha	0.09	0.34	0.42	0.04	0.12	0.03	0.08	0.04	0.02	0.02	0.01	0.01

2) Carbon Stock Change in Dead Organic Matter in "Land converted to Wetlands"

Carbon stock changes in dead organic matter and litter in forest land converted to wetlands were estimated in this category.

- ***Estimation Method***

The Tier 2 method was applied as described in section 6.5.2. b)2).

- ***Parameters***

➢ ***Carbon Stocks in Dead Organic Matter***

The average carbon stocks in dead wood and litter in forest land before conversion are shown in Table 6-12 and Table 6-13. It is assumed that they become zero immediately after conversion, and are not accumulated after conversion.

- ***Activity Data (Area)***

➢ ***Area of forest land converted to wetlands***

The area of land that was converted to wetlands during the past 1 year was used. The areas are shown in Table 6-54.

Table 6-54 Area of land converted to wetlands within the past 20 years

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Land converted to Wetlands	kha	27.9	24.6	26.8	21.9	20.2	18.7	16.9	7.9	6.1	5.6	5.3	4.9
Forest land converted to Wetlands	kha	19.8	17.8	19.4	15.9	14.6	13.5	12.2	5.7	4.4	4.1	3.8	3.6
Cropland converted to Wetlands	kha	1.8	1.5	1.7	1.4	1.3	1.2	1.0	0.5	0.3	0.3	0.3	0.3
Grassland converted to Wetlands	kha	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.0	0.0
Settlements converted to Wetlands	kha	0.10	0.09	0.10	0.08	0.07	0.07	0.06	0.03	0.02	0.02	0.02	0.02
Other land converted to Wetlands	kha	5.8	4.9	5.4	4.4	4.0	3.7	3.4	1.6	1.3	1.2	1.1	1.0

3) Carbon stock Change in soils in land converted to wetlands

- ***Estimation Method***

➢ ***Carbon stock changes in soils in forest land converted to wetlands***

They were reported as "NA", because their soils were supposed to become anaerobic condition after the areas came to be reservoirs (dams); hence CO_2 emissions resulting from organic matter decomposition is considered to be very small.

➢ ***Carbon stock changes in soils in land other than forest land converted to wetlands***

Since methodology is not provided by the *2006 IPCC Guidelines* and due to lack of data, carbon stock changes in soils in wetlands (flooded land) converted from land use other than forest land were not estimated. Therefore, the carbon stock changes in soils were reported as "NE".

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

Uncertainties of the parameters and the activity data for living biomass, dead organic matter, and soil were individually assessed on the basis of field study results, expert judgment, or the default values provided in the *2006 IPCC Guidelines*. The uncertainty was estimated as 23% of the total emissions from the land converted to wetlands for year which emissions are calculated.

- ***Time-series Consistency***

Although the methods to estimate the area of forest land converted to other land use are different between FY1990-2004 and post FY2005, as described in section 6.5.2. b)1), time-series consistency for this subcategory is basically ensured.

d) Category-specific QA/QC and Verification

Same as Forestland Remaining Forestland (4.A.1.). See section 6.4.1 d).

e) Category-specific Recalculations

- ***Correction in accordance with revision of area of land converted from forest***

Since the revision of the interpretations of the *Land Use Change Survey by Satellite Interpretation*, which is used for estimating each land are converted from forest, the areas of wetlands converted from forest land were recalculated, carbon stock changes in living biomass and dead organic matter after FY2005 in this category were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

- ***Validity of the assumption used in the method of estimating the area of wetlands***

Under the present estimation method, wetlands are assumed to consist of “water surfaces”, “rivers” and “canals”, as defined in the national land-use classification, and the whole area is estimated by summing the areas covered by these three land types. However, this estimation method may fail to cover the entire wetland area. The validity of the assumption used in the estimation method is now under revision.

- ***Estimation method of the storage reservoirs***

Preparatory work to apply the estimation method for GHG emissions from storage reservoirs in the *2019 Refinement* had started.

6.8. Settlements (4.E.)

Settlements are defined as all developed land, including transportation infrastructure and human habitats that do not fall under any of the land-use categories of forest land (4.A.), cropland (4.B.), grassland (4.C.), and wetland (4.D.). In settlements, carbon sequestered by trees existing in urban green areas such as urban parks, are estimated. Urban green areas are divided into two categories; “green spaces

conserved by zoning[10]" for which conservation measures are taken and permanent protection is ensured, and "urban green facilities[11]" established as urban parks and others, and the amount of carbon stock changes is calculated for each green area. In addition, the method of classifying the area of the settlements and the subcategories of the report shall be as follows.

Settlements are divided into "Settlements remaining settlements" and "Land converted to settlements." The cumulative area of settlements converted from other land-use categories to settlements within the past 20 years is defined as "Land converted to settlements" based on the default setting of the *IPCC Guidelines*, and "Settlements remaining settlements" is reported as all settlements minus "Land converted to settlements."

"Settlements remaining settlements" is divided into three subcategories corresponding to the calculation of carbon stock change: "green spaces conserved by zoning," "urban green facilities," and "other settlements." "Other settlements" includes all land that is not classified as "green spaces conserved by zoning" or "urban green facilities." In urban green areas, the active growing period (AGP) is applied, and therefore the activity data area that are subject to carbon stock change calculations is used as the area for this category. Urban green area exceeded the AGP and where no carbon stock changes are considered to occur is included in "other settlements." Note that carbon stock changes from trees growing in the yards of private residences in "Other remaining other" is reported as "NA", based on the Tier 1 assumption of no change in carbon stocks.

Since a small portion of "urban green facilities" is created on the land converted to settlements, the area of "urban green facilities under Settlements remaining settlements" can include the area of "urban green facilities converted from other land uses," so technically, there is double counting between the area of "urban green facilities" and that of "Land converted to settlements." However, since some area of all settlements is rounded to the nearest 10,000 ha due to the source statistics, when uncertainty is considered, this level of double counting does not affect the accuracy of the overall area. Also, "urban green facilities" existing in "Land converted to settlements" is treated in the calculation of emissions and removals as "IE," and therefore, no substantial problem has occurred. In the "Land converted to settlements", only the amount of carbon stock loss associated with the loss in the original land use was accounted for, and the amount of carbon stock increase associated with the growth in the land converted to urban green facilities was calculated collectively under the "Settlements remaining Settlements". The area of each subcategory is shown in Table 6-55.

In FY2024, Japan's settlement area was about 3.89 million ha, equivalent to about 10.3% of the national land. The emissions from carbon stock changes in this category in FY2024 were 3,308 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 67.7% compared to FY1990 and an increase of 5.1% compared to the previous year.

[10] Green spaces conserved by zoning are green areas which are conserved through land-use regulation with land-ownership still maintained. Of these areas, the Special Greenery Conservation Zones are stipulated in Article 12 of the Urban Green Area Law, and are designated as green area such as forestlands, grasslands, and swamp areas that form a favorable natural environment alone or in combination with their surroundings within an urban planning area. Of these areas, those that exclude waterfront areas are classified under this subcategory.

[11] Urban Green Facilities refer to green areas which are managed with the acquisition of title to the green areas. Specifically, they include urban parks, green areas on roads, green areas at ports, green areas around sewage treatment facilities, , green areas along rivers and erosion control sites, green areas around government buildings and green areas around public rental housing, TSUNAG-Certified Green Spaces (TSUNAG: Certification System for Securing Quantity and Quality Urban Green Space).

Table 6-55 Each area in the subcategory of settlements

Category			Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Settlements (a)			kha	3,200	3,428	3,594	3,698	3,779	3,806	3,833	3,896	3,895	3,895	3,895	3,894
	Settlements remaining Settlements (a-b)		kha	2,296.3	2,635.4	2,872.6	3,068.9	3,283.4	3,404.6	3,466.1	3,562.0	3,559.5	3,556.0	3,546.5	3,537.1
		Green spaces conserved by zoning(c)	kha	1.8	3.6	3.6	4.1	4.1	4.4	4.6	4.7	4.7	3.2	3.1	3.0
		Urban green facilities (d)	kha	82.4	105.5	122.4	136.3	139.6	134.7	126.9	114.2	111.3	106.9	102.7	97.9
		Other (a-b-c-d)	kha	2,212.1	2,526.4	2,746.6	2,928.5	3,139.7	3,265.5	3,334.6	3,443.1	3,443.4	3,445.9	3,440.7	3,436.1
	Land converted to Settlements (b)		kha	903.7	792.6	721.4	629.1	495.6	401.4	366.9	334.0	335.5	339.0	348.5	356.9

Table 6-56 Emissions and removals in settlements resulting from carbon stock changes

Category	Carbon pool	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
4.E. Settlements	Total	kt-CO_2	10,248	7,955	6,038	4,734	4,026	3,098	3,074	3,660	3,207	3,324	3,147	3,308
	Living Biomass	kt-CO_2	1,865	850	-273	-697	-328	-423	-185	662	249	315	80	133
	Dead Wood	kt-CO_2	400	278	140	112	182	157	186	182	136	136	104	104
	Litter	kt-CO_2	249	167	74	54	99	84	103	101	72	72	52	52
	Mineral soil	kt-CO_2	7,590	6,550	6,008	5,183	3,996	3,213	2,907	2,648	2,682	2,734	2,843	2,950
	Organic soil	kt-CO_2	144	109	90	82	77	67	64	67	69	68	69	69
4.E.1. Settlements remaining Settlements	Total	kt-CO_2	-1,013	-1,353	-1,636	-1,852	-1,893	-1,848	-1,788	-1,649	-1,608	-1,529	-1,469	-1,400
	Living Biomass	kt-CO_2	-747	-1,032	-1,262	-1,448	-1,495	-1,469	-1,418	-1,314	-1,282	-1,214	-1,165	-1,108
	Dead Wood	kt-CO_2	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA	IE,NA
	Litter	kt-CO_2	-12	-15	-18	-19	-20	-19	-19	-17	-17	-17	-16	-16
	Mineral soil	kt-CO_2	-254	-306	-357	-384	-378	-360	-351	-317	-309	-298	-289	-276
	Organic soil	kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.E.2. Land converted to Settlements	Total	kt-CO_2	11,261	9,308	7,675	6,586	5,918	4,946	4,863	5,309	4,815	4,853	4,617	4,708
	Living Biomass	kt-CO_2	2,611	1,882	989	751	1,166	1,046	1,233	1,977	1,531	1,528	1,244	1,241
	Dead Wood	kt-CO_2	400	278	140	112	182	157	186	182	136	136	104	104
	Litter	kt-CO_2	261	182	91	73	119	103	121	119	89	89	68	68
	Mineral soil	kt-CO_2	7,845	6,856	6,365	5,568	4,374	3,573	3,258	2,965	2,991	3,032	3,131	3,226
	Organic soil	kt-CO_2	144	109	90	82	77	67	64	67	69	68	69	69

6.8.1. Settlements Remaining Settlements (4.E.1.)

a) Category Description

This subcategory deals with carbon stock changes in all urban green areas. The net removals in this subcategory in FY2024 was 1,400 kt-CO_2; this represents an increase of 38.2% compared to FY1990 and a decrease of 4.7% compared to the previous year.

b) Methodological Issues

1) Carbon Stock Changes in Living Biomass in "Settlements remaining Settlements"

- ***Estimation Method***

The calculation of carbon stock change in living biomass in urban green areas was performed for tall trees[12] only, using the gain-loss method of Equation 2.7 described in the section 2.3.1.1, Vol.4 of the *2006 IPCC Guidelines*. For the calculation of carbon stock increase due to growth ($\Delta C_{S\_LB\_G}$), based on the characteristics of urban green areas and available activity data, the Tier 2a crown cover area method is used for green spaces conserved by zoning, and Tier 2b individual plant growth method is used for

[12] Tall trees are consistent with the definition in "Standards for the quality and size of planted trees for the public (draft). "Standards for the quality and size of planted trees for the public (draft)" was decided by the Ministry of Land, Infrastructure, Transport and Tourism in order to promote proper enforcement of projects such as greening in public spaces. Tall tree is defined in the standards as tree which reaches 3 ~ 5 m in height.

urban green facilities, as described in the section 8.2.1.1, Vol.4 of the *2006 IPCC Guidelines*. In addition, AGP was set based on the results of measured surveys in Japan in accordance with the description in the section 8.2.1.2, Vol.4 of the *2006 IPCC Guidelines*. For trees older than AGP, it was conservatively assumed that gains and losses were the same and no carbon stock change was calculated, while up to AGP, only gains were calculated and losses ($\Delta C_{S\_LB\_L}$) were assumed to be zero.

➢ ***Tier 2a: Green spaces conserved by zoning***

$$\Delta C_{Sa\_LB} = \Delta C_{Sa\_LB\_G} - \Delta C_{Sa\_LB\_L}$$

$$\Delta C_{Sa\_LB\_G} = A_{Sa\_AGP} \times PW \times CRWs$$

ΔC_{Sa_LB}	: Changes in carbon stocks in living biomass in green spaces conserved by zoning [t-C/yr]
$\Delta C_{Sa\_LB\_G}$	: Gains in carbon stocks due to growth in living biomass in green spaces conserved by zoning [t-C/yr]
$\Delta C_{Sa\_LB\_L}$	: Losses in carbon stocks due to losses in living biomass in green spaces conserved by zoning [t-C/yr]. Note: assumed as "0" (zero) because AGP is set
A_{Sa_AGP}	: Area of green spaces conserved by zoning younger than or equal to AGP years since designation (activity data area) [ha]
PW	: Rate of forested area (rate of forested area per green spaces conserved by zoning). Note: assumed as 100%
CRW	: Annual living biomass growth per forested area [t-C/ha crown cover/yr]

➢ ***Tier 2b: Urban green facilities***

$$\Delta C_{Sb\_LB} = \sum_i \left(\Delta C_{Sb\_LB\_G_i} - \Delta C_{Sb\_LB\_L_i}\right)$$

$$\Delta C_{Sb\_LB\_G_i} = \sum_j NT_{Sb\_AGP_{i,j}} \times C_{Rate_{i,j}}$$

ΔC_{Sb_LB}	: Changes in carbon stocks in living biomass in urban green facilities [t-C/yr]
$\Delta C_{Sb\_LB\_Gi}$	: Gains in carbon stocks due to growth in living biomass in urban green facilities *i* [t-C/yr]
$\Delta C_{Sb\_LB\_Li}$	: Losses in carbon stocks due to losses in living biomass in urban green facilities *i* [t-C/yr]. Note: assumed as "0" (zero) because AGP is set
$C_{Ratei,j}$	: Annual living biomass growth in urban green facility *i* in climate type *j* per tree [t-C/tree/yr] See Table 6-57
$NT_{Sb\_AGPi,j}$	: Number of tall trees younger than or equal to AGP years (AGP tall tree count) in urban green facility *i* in climate type *j*
i	: Types of urban green facilities (urban parks, green areas on roads, green areas at ports, green areas around sewage treatment facilities, green areas along rivers and erosion control sites, green areas around government buildings, or green areas around public rental housing, TSUNAG-Certified Green Spaces)
j	: Climate type (Hokkaido, other than Hokkaido)

● ***Parameters***

➢ ***Tier 2a: Annual living biomass growth per crown cover area in green spaces conserved by zoning***

The default value (2.9 t-C/ha crown cover/yr) indicated in Table 8.1 in Vol.4 of the *2006 IPCC Guidelines* is taken for the annual rate of living biomass growth of trees per forested area in green spaces conserved by zoning.

➢ ***Rate of forested area in green spaces conserved by zoning***

The rate of forested area per green spaces conserved by zoning was assumed to be 100% considering

the planting status of the green area.

➢ ***Tier 2b: Annual living biomass growth per individual tree in urban green facilities***

The following steps are taken to calculate the annual living biomass growth rates per tree by the type of urban green facility, and used throughout the time series. Each value is shown in Table 6-57.

- ***Urban parks***

At first, a sample survey (for Hokkaido:176, for other than Hokkaido: 321, 497 in total) was conducted to determine the tree species composition of urban parks. The distribution ratio of tree types was calculated by using tree registers and plantation maps for all urban parks in Hokkaido and in other prefectures separately and for a total of 321 randomly extracted sites.

Next, annual living biomass growth by major tree species in Japan was determined as follows. The annual growth rates of living biomass for Japanese zelkova, ginkgo, bamboo-leaf oak and camphor tree, which are the main planted trees in Japan, are calculated by using the growth curve for each tree species (Matsue et al., 2009), which were developed based on the results of surveys conducted by the National Institute for Land and Infrastructure Management (NILIM) of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) and the average trunk diameter at breast height for each tree species (Parks and Green Spaces Division of the MLIT, 2005), which were determined from the results of surveys in urban parks. For the carbon fraction, the default value of 0.5 in Section 8.2.1.2 of Vol.4 of the *2006 IPCC Guidelines* is used.

At last, the annual living biomass growth of trees in urban parks was calculated by using the country-specific value for annual growth rate of living biomass per tree, which was developed by combining the default values (0.0033-0.0142 t-C/tree/yr) provided in the *2006 IPCC Guidelines* (Vol.4, Table 8.2) and the country specific annual growth rates of living biomass for the trees in Japan (0.0204 for Japanese zelkova, 0.0103 for ginkgo, 0.0095 for bamboo-leaf oak and 0.0122 t-C/tree/yr for camphor tree), and by taking into account the distribution ratio of tree species in sample urban parks obtained by the sample survey. The values were established separately for Hokkaido and areas other than Hokkaido.

- ***Green areas on roads***

At first, the distribution ratio of tree types in green areas on roads is taken from the Road Tree Planting Status Survey (The Street tree of Japan VI), which covered green areas on roads throughout Japan.

Then the annual living biomass growth in green areas on roads is calculated by using the country-specific value for annual growth rate of living biomass per tree, which was developed by taking a weighted average of the *2006 IPCC Guidelines'* default values and the annual growth rates of living biomass for the trees in Japan (4 species), which were also used for the urban parks, using the distribution ratio of tree species obtained in 1. The values were established separately for Hokkaido and areas other than Hokkaido.

- ***Urban parks, green areas at ports, green areas around sewage treatment facilities, green areas along rivers and erosion control sites, green areas around government buildings, and green areas around public rental housing, TSUNAG-Certified Green Spaces***

For the annual biomass growth of trees in these green areas, the same values as those for urban parks were applied, because the standard for planted trees, tree types and their distribution are applied in the same manner as in urban parks.

Table 6-57 Annual biomass growth rate per tree in urban green facilities

Climate category	Annual living biomass growth per tall tree [t-C/tree/yr]
Hokkaido	Other than green areas on roads: 0.0098 Green areas on roads: 0.0103
Areas other than Hokkaido	Other than green areas on roads: 0.0105 Green areas on roads: 0.0108

- ***Activity Data***

➢ ***Activity data area in green spaces conserved by zoning system***

For the activity data area for green spaces conserved by zoning, the AGP is defined as 30 years after designation as green spaces conserved by zoning, and the area of special greenery conservation zones and suburban greenery special conservation zones obtained through annual surveys[13] by the Ministry of Land, Infrastructure, Transport and Tourism, which are less than 30 years after designation, were extracted. Waterfront areas are excluded.

Table 6-58 Activity data areas of green spaces conserved by zoning (younger than or equal to 30 years after designation)

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Green spaces conserved by zoning	kha	1.8	3.6	3.6	4.1	4.1	4.4	4.6	4.7	4.7	3.2	3.1	3.0
Special greenery conservation zones	kha	0.6	0.9	1.2	1.8	1.9	1.9	2.1	2.2	2.2	2.1	2.0	2.0
Suburban green space conservation zones	kha	1.2	2.7	2.4	2.2	2.3	2.5	2.5	2.5	2.5	1.1	1.1	1.0

➢ ***Number of tall trees in urban green facilities***

The activity data for urban green facilities are defined as the number of tall trees up to the AGP. For urban green facilities other than green area on roads, the total number of tall trees is estimated from the activity data area and the number of tall trees per unit area. Based on the field survey, the AGP for urban green facilities basically set at 30 years after the creation of the green area, and 50 years for unpruned wooded area[14] in large urban parks. The number of tall trees per area is calculated separately for Hokkaido and areas other than Hokkaido based on the data obtained from the sample survey as described in Table 6-60, and then used as fixed values for all time-series.

The activity data area of unpruned wooded areas in urban parks within 31-50 years after maintenance is calculated by multiplying the ratio of unpruned area by the number of eligible urban parks, which only includes relatively large urban parks such as urban core parks and large-scale parks. The unpruned ratio is 55%, which is obtained from the results of the sample survey. For those areas in the years which the survey is not conducted were estimated by linear interpolation with statistical information.

For the green areas on roads, the number of tall trees planted in green areas on roads within 30 years after establishing green areas on roads is determined by using data from the *Road Tree Planting Status Survey* which had been implemented in FY1987, FY1992, FY2007 and onward. Years for which data

[13] The actual results of the survey are posted on the website of the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) below.

https://www.mlit.go.jp/toshi/park/toshi_parkgreen_tk_000081.html (the area of special greenery conservation zones and suburban greenery special conservation zones)

[14] Unpruned wooded area was defined as " wooded area excluding the inner 5 m area from the outer perimeter of the woodland affected by periodic pruning, etc.".

are not available were supplemented by interpolation. The activity data area of green areas on roads is obtained using model values (general roads: 0.006237 ha/tree, highways: 0.000830 ha/tree) set by a sample survey conducted in 2007 (95% level of significance). Model values is obtained by randomly selecting road green space and dividing the area of the land by the number of tall trees planted on the land. For years after 1961 and before 1987 for which data are unavailable, values are estimated based on road extension and rate of greenery.

Table 6-59 Survey to determine the activity data area (by MLIT)

Type of urban facility	Data type	Name of Survey and Year of Implementation
Urban parks	Service area for each urban park	Urban Parks Status Survey (conducted since FY1960)
Green areas at ports	Service area by facility	Complete census (conducted every year since FY2008)
Green areas around sewage treatment facilities	Green area by facility	Survey on carbon dioxide absorption at Sewage Treatment Facility Status Survey (conducted every year since FY2009)
Green areas along river and erosion control sites	Planted land area by facility	Survey on carbon dioxide absorption in river works (conducted every year since FY2008)
Green areas around government buildings	Total land area and building area by facility	Complete census (conducted every year since FY2008)
TSUNAG-Certified Green Spaces	Green area by facility, excluding wall greening areas where tall trees cannot be planted.	Green area Certification System for Securing Quantity and Quality Urban Green Space (certificated in FY2024)

Table 6-60 Estimation method for the number of tall trees per unit area in urban green facilities

Type of urban facility	Estimation method number of tall trees per area
Urban parks	The number of tall trees per area is calculated based on the number of tall trees and the land areas of sample urban parks. Sample number was intended to satisfy the significance level of 95%. The number of tall trees per area in urban parks is calculated by using data from tree registers and planting maps for randomly extracted 176 sample urban parks in Hokkaido and 321 sample urban parks in the other prefectures. Samples were acquired from a wide range of urban parks, from large to small.
Green areas at ports	The number of tall trees per area in green areas at ports is assumed to be the same as in urban parks because the standard of planted trees, tree types and their distribution are applied in the same manner as in urban parks.
Green areas around sewage treatment facilities	The number of tall trees per area for green areas around sewage treatment facilities was established by using data on the number of tall trees and greening areas measured in 59 green areas.
Green areas along rivers and erosion control sites	For green areas along rivers and erosion control sites, the number of tall trees was measured in approximately 95% of this green area. Based on these data, the number of planted trees per area was estimated in order to simplify the estimation of the number of tall trees in all green areas.
Green areas around government buildings	For green areas around government buildings, the number of tall trees per area was estimated by dividing the number of tall trees by the “total land area – building area” (these data were based on 30 facilities where planting maps were available). The common value is used for all prefectures, since the sample data were not sufficient enough to set values for Hokkaido and the other prefectures, separately.
Green areas around public rental housing	For green areas around public rental housing, the number of tall trees per area was estimated for 33 facilities, where planting maps were available, by dividing the number of tall trees by the area “total land area – building area”. The common value is used for all prefectures, since the sample data were not sufficient enough to set values for Hokkaido and the other prefectures, respectively.
TSUNAG-Certified Green Spaces	For Evaluation and Certification System for Securing Quality Green Space, the number of tall trees per unit area was determined based on the number of tall trees and the greening area of 18 facilities potentially eligible under the same scheme. The common value is used for all prefectures, in the absence of construction in Hokkaido.

Table 6-61 Number of tall trees per area

Type of urban facility	Unit	Number of tall tree per area	
		Hokkaido	Areas other than Hokkaido
Urban parks	tree/ha	329.5	222.3
Green areas at ports	tree/ha	329.5	222.3
Green areas around sewage treatment facilities	tree/ha	129.8	429.2
Green areas along rivers and erosion control sites	tree/ha	1470.8	339.0
Green areas around government buildings	tree/ha	108.8	108.8
Green areas around public rental housings	tree/ha	219.9	219.9
TSUNAG-Certified Green Spaces	tree/ha	302.8	302.8

Table 6-62 Summary of Activity data of tall trees in each urban green facilities (Upper rows: area, lower rows: number of tall trees)

Item	Activity data	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Urban green facilities total	Activity areas	kha	82.4	105.5	122.4	136.3	139.6	134.7	126.9	114.2	111.3	106.9	102.7	97.9
Urban parks	Activity areas	kha	53.6	64.7	75.6	82.6	83.3	80.4	79.2	73.8	72.9	71.0	69.3	67.0
less than 30 years after establishing	Activity areas	kha	53.0	63.3	73.2	78.2	76.7	72.7	70.7	63.3	61.7	59.4	57.4	54.7
31-50 years after establishing(for large urban parks)	Activity areas	kha	0.6	1.4	2.4	4.3	6.6	7.8	8.5	10.5	11.2	11.6	11.9	12.3
	number of tall trees	1000 tree	12,520	15,075	17,660	19,317	19,517	18,857	18,560	17,270	17,041	16,618	16,221	15,678
Green area on roads	Activity areas	kha	23.7	34.1	38.3	44.3	46.8	45.2	38.8	32.1	30.5	28.3	26.2	23.9
	number of tall trees	1000 tree	4,979	8,844	11,623	14,321	15,227	15,234	14,240	12,988	12,464	11,628	10,892	10,078
Green areas at ports	Activity areas	kha	0.5	0.9	1.3	1.8	2.0	2.0	2.0	1.9	1.8	1.8	1.7	1.8
	number of tall trees	1000 tree	111	207	302	408	449	459	448	438	415	406	384	399
Green areas around sewage treatment facilities	Activity areas	kha	0.4	0.5	0.7	0.8	0.8	0.8	0.8	0.7	0.7	0.7	0.7	0.6
	number of tall trees	1000 tree	154	202	269	331	340	327	324	299	286	280	272	263
Green areas along river and erosion control sites	Activity areas	kha	0.8	1.0	1.4	1.7	1.9	1.9	1.9	1.7	1.7	1.7	1.6	1.6
	number of tall trees	1000 tree	451	561	818	954	1,063	1,041	1,013	942	934	919	885	846
Green areas around government buildings	Activity areas	kha	0.2	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3
	number of tall trees	1000 tree	27	35	42	45	45	43	41	41	40	37	36	34
green areas around public rental housing	Activity areas	kha	3.1	3.9	4.6	4.7	4.3	4.0	3.9	3.5	3.3	3.1	2.9	2.7
	number of tall trees	1000 tree	681	857	1,015	1,030	945	871	857	771	731	689	643	603
TSUNAG-Certified Green Spaces	Activity areas	kha	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.02
	number of tall trees	1000 tree	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	6

2) Carbon Stock Changes in dead wood and litter in "Settlements remaining Settlements"

- ***Estimation Method***

➢ ***Green spaces conserved by zoning***

In accordance with Tier 1 assumptions in the section 8.2.2.1, Vol.4 of the *2006 IPCC Guidelines*, the carbon stock change in dead wood and litter in green spaces conserved by zoning was assumed to remain unchanged and reported as "NA".

➢ ***Urban Green Facilities***

For litter, carbon stock changes only in branches and leaves dropped naturally from tall trees, only in urban parks and green areas at ports among urban green facilities are estimated. Carbon stock changes in litter in the subcategories other than urban parks and green areas at ports were reported as "NA" by applying Tier 1 because it is difficult to accurately estimate the carbon stock changes in fallen leaves, branches etc. that are taken off site by management such as cleaning etc.

For dead wood, the number of tall trees per land area used in the estimation of activity data for living

biomass includes trees which have died and have been complementary planted since the establishment of the park. Thus, the carbon stock changes in dead wood are thought to be included in the carbon stock changes in living biomass. Therefore, this category is reported as "IE".

To calculate the carbon stock change in litter, a country-specific method is applied for this estimation in accordance with the decision tree provided in the *2006 IPCC Guidelines*. The estimation method is described below.

$$\Delta C_{Sb\_Lit} = \sum_{i,j} \left(A_{Sb\_AGP_{i,j}} \times Lit_{i,j} \right)$$

ΔC_{Sb_Lit} : Carbon stock changes in litter in urban green facilities [t-C/yr]
$A_{Sb\_AGPi,j}$: Activity data area of urban green facility *i* in climate type *j* [ha]
$L_{it\ I,j}$: Carbon stock change in litter per area in urban green facility *i* in climate type *j* [t-C/ha/yr]
i : Type of urban green facilities (urban parks or green areas at ports)
j : Climate type (Hokkaido, areas other than Hokkaido)

- ***Parameters***

➢ ***Carbon stock changes in litter per area in urban green facilities (urban parks or green areas at ports)***

Carbon stock changes in litter per urban park area is calculated by using the following procedure.

1. The sample survey sites were selected according to differences in climatic zones, one in Hokkaido and one in non-Hokkaido prefecture, and the annual accumulation of litter (g/tree/yr) dropped naturally was measured for some tree types by using litter traps. Only those naturally falling to the ground surface were treated as litter in the measurements. The amount of litter (g/tree/yr) is sorted by tree species class described in table 8.2 of the *2006 IPCC Guidelines*, and the amount per tall tree is combined by taking into account the distribution ratio of tree species in urban parks. The values were established separately for Hokkaido and areas other than Hokkaido. As a result, the values are calculated as 1,469.36 g/tree/yr and 1,466.41 g/tree/yr, respectively. After conversion to carbon, the annual accumulation of litter per tree for Hokkaido and other prefectures was estimated to be 0.0006 t-C/tree/yr. (The carbon fraction in litter is assumed to be 0.4 t-C/t-d.m. which is a default value provided in the *2006 IPCC Guidelines* (Vol.4, p. 8.21)).

2. The ratio of litter moved off-site due to management including cleaning (54.4%) was taken into account. As shown in Table 6-61, the number of tall trees per area differs between Hokkaido and areas other than Hokkaido, carbon stock changes in litter per area have been calculated at 0.0882 t-C/ha/yr for Hokkaido and 0.0594 t-C/ha/yr for other prefectures.

3. The same values as those for urban parks were applied to green areas at ports, because the standard of planted trees, tree types and their distribution are applied in the same manner as in urban parks.

- ***Activity Data***

➢ ***Activity data area in urban green facilities (urban park and green areas at ports)***

Activity data in this category are the same as the Activity data area of urban parks and green areas at ports, as described in section 6.8.1. b)1).

3) Carbon Stock Changes in Soils in "Settlements remaining Settlements"

- ***Estimation Method***

➢ ***Green spaces conserved by zoning***

In accordance with Tier 1 assumptions in the section 8.2.3.1, Vol.4 of the *2006 IPCC Guidelines*, the carbon stock change in soils in the green spaces conserved by zoning was reported as "NA" since no carbon stock change was considered to have occurred due to there being no change in land-use patterns.

➢ ***Urban green facilities***

Among the urban green facilities, urban parks for which the carbon stock changes in soils per area were determined, and green areas at ports whose management practices are similar with those for urban parks, are the subject to estimation. For green facilities other than urban parks and green areas at ports, the patterns of carbon stock changes in soils are similar to those in urban parks, because planting, establishment and management practices are implemented in a similar way. The slopes on the expressway, where different plantation practices are applied, are assumed to be a sink, because field surveys have revealed that the carbon stocks keep increasing for at least 20 years after establishment.

However, it is difficult to accurately estimate the carbon stock changes in soils in these urban green facilities because of limited data. Therefore, as a conservative treatment, these sub-categories are not subject to reporting because they are not sources of GHGs.

In general, soils in urban green facilities are not classified as organic soils (peat soils and muck soils). Therefore, organic soils are reported as "NO".

Carbon stock changes in soils on settlements in newly established urban parks or green areas at ports are estimated based on Tier 2 (Country specific data are used) estimation method.

$$\Delta C_{Sb\_so} = \sum_i \left(A_{Sb\_AGP_i} \times So_i \right)$$

ΔC_{Sb_so} : Annual carbon stock changes in mineral soils in urban green facilities [t-C/yr]
A_{Sb_AGPi} : Activity data area of urban green facilities *i* [ha]
So_i : Annual carbon stock changes in mineral soils per area in urban green facilities *i* [t-C/ha/yr]
i : Type of urban green facilities (urban parks and green areas at ports)

- ***Parameters***

➢ ***Carbon stock change in mineral soils per area in urban green facilities (urban parks and green areas at ports)***

The carbon stock change in mineral soils per area in urban parks was calculated using the following procedure.

1. Soil carbon stocks (at 30 cm depth) were measured for areas with different types of vegetation cover in urban parks (planted: 31 areas, lawn: 29 areas, bare: 21 areas), which are located in Tokyo and were established in different years.

2. The soil carbon stocks of the area, where basically carbon is not supplied by plants (bare area), are assumed to be the same as soil carbon stocks of sites immediately after conversion. Based on the soil carbon stocks in the areas with different types of vegetation cover (planted, lawn and bare) in urban parks, which were established in different years, "carbon accumulation rates in planted areas" and

"carbon accumulation rates in lawn areas" are calculated:

- Carbon accumulation rates in planted areas = "Difference in soil carbon stocks between planted and bare areas" / "Average years after establishment of surveyed planted areas"
- Carbon accumulation rates in lawn areas = "Difference in soil carbon stocks between lawn and bare areas" / "Average years after establishment of surveyed lawn areas"

Since urban parks are generally established by turning entire sites into urban parks, soil carbon stocks within the site immediately after establishment are assumed to be uniform irrespective of previous types of vegetation cover. The soil carbon stocks of bare area are about 38 t-C/ha when converted from the sample data.

3. Changes in soil carbon stocks per area are determined by taking the weighted average based on the typical area ratio among planted, lawn and bare sites in urban parks. As a result, carbon stock changes in soils per area of urban parks and green areas at ports (integrated annual amount change during 0-20 years after establishment is 1.28t-C/ha/yr, integrated annual amount change during 21-30 years after establishment is 1.38t-C/ha/yr) are estimated. (Tonosaki et al., 2013, Parks, Green Spaces and Landscape Division, Ministry of Land, Infrastructure, Transport and Tourism, 2015).
4. This value is applicable to urban parks and green areas at ports which were established within 30 years.

- ***Activity Data***

➢ ***Activity data Area in urban green facilities (Urban parks and green areas at ports)***

Activity data on this category are the same as the activity data area of urban parks and green areas at ports, as described in section 6.8.1. b) 1).

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

The default values shown in the *2006 IPCC Guidelines* (Vol.4, page 8.10) were applied to the annual carbon stock changes for trees in green spaces conserved by zoning. Following the decision tree, the uncertainty was determined ±50% through application of the standard value shown in the *2006 IPCC Guidelines* (Vol.4, page 8.12). Moreover, for the uncertainty estimates for living biomass in green spaces conserved by zoning expert judgment (10%) is applied according to the decision tree for activity data, and became 51%.

Meanwhile, for the urban green facilities the uncertainty estimates for living biomass, dead organic matter and soil in urban parks, green areas on roads, green areas at ports, green areas around sewage treatment facilities, green areas along rivers and erosion control sites, green areas around government buildings and green areas around public rental housing are 17%, 106%, 38%.

As a result, the uncertainty estimate was 15% for the entire removal by settlements remaining settlements.

- ***Time-series Consistency***

Although the methods to estimate the area of forest land converted to other land use are different

between FY1990-2004 and post 2005, as described in section 6.5.2. b)1), time-series consistency for this subcategory is basically ensured.

d) Category-specific QA/QC and Verification

Same as Forest Land remaining Forest Land (4.A.1.). See section 6.4.1d).

e) Category-specific Recalculations

- ***Correction of activity data (area and number of tall trees) of urban green areas***

The correction of the activity data area and the number of tall trees was conducted on some urban green areas for all years. Due to this correction, carbon stock changes in living biomass, litter and mineral soils were recalculated for all years. See chapter 10 for impact on trend.

f) Category-specific Planned Improvements

- ***Growth rate of living biomass per unit of greening area in "green spaces conserved by zoning"***

The default values in the *2006 IPCC Guidelines* were applied to the living biomass growth rate per unit of greening area in green spaces conserved by zoning. However, the growth data needs to be further examined, and parameter that can be finally applied as the growth ratio should be determined. Therefore, based on the characteristics of greening activity, the most appropriate parameters need to be found.

- ***Validity of the assumption used in the method of estimating the area of Settlements***

The areas of forest land converted to settlements are presently assumed as "roads", "human habitats", "school reservations", "parks and green areas", "road sites", "environmental facility sites", "golf courses", "ski courses" and "other recreation sites" in the national land-use categorization; however, this assumption may fail to cover all the areas. Therefore, the validity of the assumption needs to be re-examined.

6.8.2. Land Converted to Settlements (4.E.2.)

a) Category Description

This subcategory deals with the carbon stock changes in lands converted to settlements, which were converted from other land-use categories to settlements within the past 20 years. However, the area of wetlands converted to settlements cannot be detected by the current method used for estimating land-use area. Thus, carbon stock changes in these carbon pools were reported as "NO".

The net emissions by this subcategory in FY2024 were 4,708 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 58.2% compared to FY1990 and an increase of 2.0% compared to the previous year. Emissions from land converted to settlements have been on a decreasing trend since 1993. These trends resulted from decreases in the annual changes of areas of land-use conversion area from forest land to settlements.

b) Methodological Issues

1) Carbon stock changes in Living Biomass in "Land converted to Settlements"

- ***Estimation Method***

Carbon stock changes in land converted to settlements, similar to land converted to cropland are estimated by using the Tier 2 estimation method with the country-specific biomass stocks, and equation 2.16 in section 2.3.1.2 in Vol. 4 of the *2006 IPCC Guidelines*. See the equation as in section 6.5.2. b)1). The carbon stock changes due to the growth in living biomass after conversion to settlements is collectively estimated in the category of "Settlements remaining Settlements".

- ***Parameters***

➢ ***Living biomass stocks for each land-use category***

Table 6-9, Table 6-10 and Table 6-11 show the living biomass stocks before and after conversion.

➢ ***Carbon fraction of dry matter***

For carbon fraction of dry matter of forest, average value of broad leaf trees and conifer trees (0.50 t-C/t-d.m.) was applied. The default value (0.47 t-C/t-d.m. for herbaceous biomass in grassland and 0.5 t-C/t-d.m. for the others) was applied for other than forest in accordance with the *2006 IPCC Guidelines*.

- ***Activity Data***

➢ ***Land areas converted to Settlements***

The areas converted to settlements from forest land, cropland and grassland are obtained. Since no data is available on the area converted to settlements from wetlands or other land, "IE" was allocated to those land-use categories. Instead, they are reported as "IE" since they are included in "Other land remaining Other land".

- ***Conversion from Forest land***

Areas of forest land converted to settlements were estimated as described in section 6.5.2. b).1).

- ***Conversion from Cropland***

For former rice fields, upland fields, and orchards (according to *Area Statistics for Cultivated and Commercially Planted Land*), the areas of land converted to factories, roads, housing, and forest roads are used.

- ***Conversion from Grassland***

Pasture land in land converted to factories, roads, housing, and forest roads in *Area Statistics for Cultivated and Commercially Planted Land* and grazed meadow land converted to settlements in *A Move and Conversion of Cropland* were subject to this category.

Table 6-63 Area of land converted to settlements within the past 1 year

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Land converted to Settlements	kha	39.9	33.4	22.6	13.0	13.4	14.7	18.0	23.2	22.1	20.4	24.6	23.3
Forest land converted to Settlements	kha	14.5	10.1	5.1	4.1	6.6	5.7	6.8	6.6	4.9	4.9	3.8	3.8
Cropland converted to Settlements	kha	23.2	20.1	14.3	7.4	5.8	7.3	9.0	14.6	14.6	13.2	18.4	16.7
Rice field converted to Settlements	kha	13.0	12.1	9.5	5.6	3.5	4.2	5.1	9.2	9.0	8.3	12.0	9.9
Upland field converted to Settlements	kha	5.6	5.1	1.5	1.4	1.8	2.4	3.1	4.3	4.6	4.0	5.2	5.6
Orchard converted to Settlements	kha	4.6	2.9	3.3	0.4	0.5	0.6	0.8	1.0	1.1	0.9	1.2	1.2
Grassland converted to Settlements	kha	1.4	2.5	2.3	0.8	0.7	1.2	1.2	1.9	2.4	2.3	2.4	2.6
Wetlands converted to Settlements	kha	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Other land converted to settlements	kha	0.8	0.7	0.9	0.8	0.3	0.5	1.1	0.1	0.1	NO	NO	0.2

2) Carbon Stock Change in Dead Organic Matter in "Land converted to Settlements"

In this category carbon stock changes in dead wood and litter in settlements converted from forest land, and those in litter in urban parks and green areas at ports established in land converted to settlements are estimated.

- ***Estimation Method***

The Tier 2 method was applied to the estimation in accordance with the method for conversion from other land use to cropland, as described in section 6.5.2. b)2).

- ***Parameters***

➢ ***Carbon stocks in dead organic matter in Forest land***

Average carbon stocks in dead wood and litter in forest land before conversion are shown in Table 6-12 and Table 6-13. In addition, it is assumed that they become zero immediately after conversion, and are not accumulated after conversion.

- ***Activity Data (Area)***

➢ ***Area of "Forest land converted to Settlements"***

The area of land that was converted from forest land to settlements within 1 year was used. For the areas, see Table 6-63.

3) Carbon stock change in mineral soils in Settlements converted from land use other than forest land

In this category, carbon stock change in forest land converted to settlements, cropland converted to settlements, and grass land converted to settlements were subject to estimation.

- ***Estimation Method***

Carbon stock changes in forest land converted to settlements, cropland converted to settlements, and grassland converted to settlements were estimated using the Tier 2 (use of country-specific data) method. Specifically, the amount of carbon stock before land-use conversion shown in Table 6-14 is calculated as changing linearly to the amount of soil carbon stock after land-use conversion (20.1 t-C/ha) over a transition period of 20 years and the amount of annual change for each land-use change was multiplied by the area of land converted to settlements within the past 20 years (Table 6-64).

Table 6-64 Area of land converted to settlements within the past 20 years

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Land converted to Settlements	kha	903.7	792.6	721.4	629.1	495.6	401.4	366.9	334.0	335.5	339.0	348.5	356.9
Forest land converted to Settlements	kha	275.8	281.3	259.6	218.2	149.3	116.0	107.8	106.3	106.6	109.0	110.5	111.9
Cropland converted to Settlements	kha	527.6	421.8	390.1	348.7	290.3	239.0	215.4	192.1	193.1	194.7	202.5	209.3
Grassland converted to Settlements	kha	52.3	44.5	42.0	38.0	34.1	30.4	28.4	24.3	25.3	25.5	26.5	27.6
Wetlands converted to Settlements	kha	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Other land converted to settlements	kha	48.0	45.1	29.7	24.2	21.9	15.9	15.3	11.3	10.5	9.8	9.1	8.0

4) CO_2 emissions from organic soils in "Land converted to Settlements"

- ***Estimation Method***

When land with organic soil is converted to settlements, it is common for the ground to be improved in accordance with the purpose of land use. However, it could not be denied that oxidation of organic soil occurred under construction work, for example, on road in soft ground being conducted on the premise of land subsidence. For CO_2 emissions from drainage of organic soils in land converted to settlements, according to the *Wetlands Guidelines*, CO_2 emissions from cultivation of organic soils (on-site emissions) and emissions from water-soluble carbon losses from drained organic solids (off-site emissions) in land converted to settlements are estimated. The estimation equation is the same as section 6.5.1.

- ***Parameters***

For CO_2 emissions from organic soils in settlements converted from other land-use categories, since specific default emission factors for settlements have not been provided in the *2006 IPCC Guidelines* and the *Wetlands Guidelines* and country specific factors based on actual condition in Japan is under investigation, it was assumed that settlements converted from other land use would occur mainly from rice fields, CO_2 emission factor from organic soil in rice field was applied. (see section 6.5.1.).

- ***Activity data***

The activity data was organic soils area in settlements within 20 years after conversion. The organic soil area obtained from other lands was estimated in the same way as described in section 6.5.1. This area was also used for estimating CH_4 and N_2O emissions reported in the CRT "Table 4(II)".

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainties of the parameters and activity data for living biomass and dead organic matter, and soil were individually assessed on the basis of field study results, expert judgment, or the default values provided in the *2006 IPCC Guidelines*. The uncertainty estimate was 43% for the entire emission from land converted to settlements.

- ***Time-series consistency***

Although the methods to estimate the area of forest land converted to other land use are different between FY1990-2004 and post FY2005, as described in section 6.5.2. b)1), time-series consistency for this subcategory is basically ensured.

d) Category-specific QA/QC and Verification

Same as Forest Land remaining Forest Land (4.A.1.). See section 6.4.1d).

e) Category-specific Recalculations

- ***Correction in areas converted from forest land***

Due to a revision of the interpretations of the *Land Use Change Survey by Satellite Interpretation* used for estimating the areas of settlements converted from forest land were recalculated, carbon stock changes in living biomass, dead organic matter, carbon stock change in mineral soil and CO_2 emissions from organic soils in this category were recalculated for all years. See chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

6.9. Other Land (4.F.)

Other land consists of land areas that are not included in the other five land-use categories. As concrete examples of other land, the *2006 IPCC Guidelines* indicates bare land, rock, ice, and all land areas that do not fall into any of the five categories. In FY2024, Japan's other land area was about 2.75 million ha, which is equivalent to about 7.3% of the national land. The classification of other land is shown in Table 6-65 below[15]. The emissions from this category in FY2024 were 646 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 71.2% compared to FY1990 value and a decrease of 0.4% compared to the previous year.

Table 6-65 Land included in the other land category

Items		Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Other land		kha	2,518.0	2,534.7	2,525.5	2,421.1	2,458.4	2,327.4	2,588.1	2,601.7	2,663.3	2,693.6	2,742.3	2,753.5
	Defense facility Site	kha	139.0	140.0	140.0	140.0	140.0	140.0	139.0	135.0	136.0	136.0	136.0	136.0
	Coast	kha	46.0	46.0	46.0	46.0	46.0	46.0	46.0	46.0	46.0	46.0	46.0	46.0
	Northern territories	kha	503.6	503.6	503.6	503.6	503.6	503.6	503.6	503.6	503.6	503.6	503.6	503.6
	Wasteland	kha	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Other	kha	1,829.4	1,845.1	1,835.9	1,731.5	1,768.8	1,637.8	1,899.5	1,917.1	1,977.7	2,007.9	2,056.7	2,067.9

[15] The *Defense of Japan* (Ministry of Defense) for "Defense Facility Site", the *Digital national land information* (MLIT) for "Coast" and *Land Survey of Prefectures, Shi, Ku, Machi and Mura* (GSI) for "Northern Territories"

Table 6-66 Emissions and removals resulting from carbon stock changes in other land

Category	Carbon pool	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
4.F. Other land	Total	kt-CO_2	2,247	1,980	1,631	1,079	882	719	697	621	543	514	649	646
	Living biomass	kt-CO_2	624	508	360	84	133	103	123	158	112	109	232	234
	Dead wood	kt-CO_2	99	80	56	9	21	15	18	14	10	10	20	20
	Litter	kt-CO_2	65	52	36	6	14	10	12	9	7	7	13	13
	Mineral soil	kt-CO_2	1,460	1,340	1,178	980	714	591	544	440	415	388	383	379
	Organic soil	kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.F.1. Other land remaining Other land	Total	kt-CO_2												
	Living biomass	kt-CO_2												
	Dead wood	kt-CO_2												
	Litter	kt-CO_2												
	Mineral soil	kt-CO_2												
	Organic soil	kt-CO_2												
4.F.2. Land converted to Other land	Total	kt-CO_2	2,247	1,980	1,631	1,079	882	719	697	621	543	514	649	646
	Living biomass	kt-CO_2	624	508	360	84	133	103	123	158	112	109	232	234
	Dead wood	kt-CO_2	99	80	56	9	21	15	18	14	10	10	20	20
	Litter	kt-CO_2	65	52	36	6	14	10	12	9	7	7	13	13
	Mineral soil	kt-CO_2	1460	1340	1178	980	714	591	544	440	415	388	383	379
	Organic soil	kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

6.9.1. Other Land Remaining Other Land (4.F.1.)

a) Category Description

Carbon stock changes in this subcategory are not considered in accordance with the *2006 IPCC Guidelines*.

Table 6-67 Areas of other land remaining other land more than 20 years

Category	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Other land remaining Other land	kha	2,304.2	2,349.9	2,370.6	2,290.9	2,357.0	2,228.6	2,496.6	2,526.1	2,590.9	2,624.3	2,674.2	2,687.8

b) Category-specific Recalculations

No recalculations are considered.

c) Category-specific Planned Improvements

No improvements are planned.

6.9.2. Land Converted to Other Land (4.F.2.)

a) Category Description

This subcategory deals with carbon stock changes in the land converted to other land within the past 20 years. The land area of this subcategory includes land converted for soil and stone mining, land damaged by natural disasters. “The land used for soil and stone mining activities” is the land which is artificially disturbed and the soil carbon in surface layer are removed and are considered not exist. Therefore, this categorization also takes the consistency of statistical division into consideration. By reading from satellite images to detect the land-use conversion, “the land used for soil and stone mining activities” is allocated under “Other land”.

The area of wetlands converted to other land and settlements converted to other land cannot be detected by the current method used for estimating land-use area. Thus, carbon stock changes in these carbon pools were reported as "NO".

b) Methodological Issues

1) Carbon stock change in Living Biomass in "Land converted to Other land"

- ***Estimation Method***

The Tier 2 method was applied to estimate the country specific living biomass stock in land converted to other land to use equation 2.16 on section 2.3.1.2, Vol.4 in the *2006 IPCC Guidelines* as described in other land use converted to cropland in section 6.5.2. b)1). Carbon stock changes due to biomass growth in other land were assumed as zero.

- ***Parameters***

➢ ***Biomass stock in each land-use category***

The values shown in Table 6-9, Table 6-10 and Table 6-11 are used for the estimation of biomass stock changes upon land-use conversion and subsequent changes in biomass stock due to biomass growth in converted land.

➢ ***Carbon fraction of dry matter***

For carbon fraction of dry matter of forest, average value of broad leaf trees and conifer trees (0.50 t-C/t-d.m.) was applied. The default value (0.47 t-C/t-d.m. for herbaceous biomass in grassland and 0.5 t-C/t-d.m. for the others) was applied for other than forest in accordance with *the 2006 IPCC Guidelines*.

- ***Activity Data***

➢ ***Area of land converted to other land***

Only the areas converted from forest land and cropland and grassland to other land are determined during the past 1 year.

- ***Conversion from Forest land***

See section 6.5.2. b) 1).

- ***Conversion from Cropland***

For former rice fields, upland fields, and orchards, the area classified as "other, natural disaster damage" is used according to *the Area Statistics for Cultivated and Commercially Planted Land*.

- ***Conversion from Grassland***

For former pasture land and grazed meadow land, the area of former pasture land classified as "other, natural disaster damage" (according to *the Area Statistics for Cultivated and Commercially Planted Land*) and the area of former grazed meadow land which is classified as "other, classification unknown" (*A Move and Conversion of Cropland*) are used.

Table 6-68 Area of land converted to other land within the past 1 year

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Land converted to Other land	kha	7.1	6.2	5.2	5.3	1.9	1.7	2.0	2.0	1.4	1.2	2.7	2.6
Forest land converted to Other land	kha	3.60	2.91	2.03	0.31	0.75	0.56	0.66	0.51	0.36	0.36	0.74	0.74
Cropland converted to Other land	kha	2.4	2.1	2.0	4.1	0.8	0.8	1.2	0.9	0.8	0.7	1.2	1.2
Rice field	kha	1.2	1.3	1.6	3.9	0.5	0.3	0.8	0.5	0.5	0.4	0.7	0.6
Upland field	kha	0.6	0.5	0.1	0.1	0.2	0.3	0.4	0.3	0.2	0.2	0.4	0.5
Orchard	kha	0.5	0.3	0.3	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Grassland converted to Other land	kha	0.2	0.2	0.2	0.1	0.1	0.2	0.1	0.5	0.2	0.1	0.6	0.6
Wetlands converted to Other land	kha	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Settlements converted to Other land	kha	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Non-land converted to Other land	kha	1.0	1.1	0.9	0.8	0.4	0.2	NO	0.1	NO	NO	0.2	0.1

2) Carbon Stock Changes in Dead Organic Matter in "Land converted to Other land"

- ***Estimation Method***

Carbon stock changes in dead organic matter in forest land converted to other land were estimated by applying the Tier 2 estimation method as described in section 6.5.2. b)2).

- ***Parameters***

➢ ***Carbon stocks in dead organic matter in "Other land converted from Forest land"***

The average carbon stocks in dead wood and litter in forest land before conversion are shown in Table 6-12 and Table 6-13. It is assumed that carbon stocks become zero immediately after conversion, and are not accumulated after conversion.

- ***Activity Data***

➢ ***Area of land converted from forest***

The values of annually converted area from forest land to other land during the past 1 year are used (Table 6-68).

3) Carbon Stock Changes in Soils in "Land converted to Other land"

In this category, carbon stock changes in mineral soils in forest land, cropland and grassland converted to other land were estimated

- ***Estimation Method***

Carbon stock changes in mineral soils in this category were estimated by applying the Tier 2 estimation method to use country specific data. For particular, carbon stock change per year described in Table 6-14 were multiplied by area of land converted to other land within the past 20 years (Table 6-69). Besides, land converted to other land by natural disturbance were excepted from the area of mineral soil in other land to use the estimation, since land converted to other land represented the artificial soil alteration by the establishments.

Table 6-69 Area of land converted to other land within the past 20 years

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Land converted to Other land	kha	213.8	184.8	154.9	130.2	101.4	98.8	91.5	75.5	72.4	69.3	68.0	65.7
Forest land converted to Other land	kha	102.4	97.2	85.5	65.0	43.0	33.6	28.4	17.3	15.5	13.7	12.8	11.9
Cropland converted to Other land	kha	56.8	41.6	37.1	38.0	33.3	46.5	45.1	41.8	41.2	40.6	41.0	40.0
Rice field	kha	32.4	20.7	20.0	22.2	21.6	35.7	35.0	32.3	32.2	31.8	32.0	31.2
Upland field	kha	14.7	12.0	8.8	8.3	7.0	7.0	6.7	7.1	7.1	7.0	7.1	7.0
Orchard	kha	9.7	9.0	8.3	7.5	4.7	3.9	3.4	2.4	1.8	1.8	1.8	1.8
Grassland converted to Other land	kha	5.6	5.0	4.2	4.3	3.8	3.8	3.7	6.0	6.0	5.8	6.2	6.5
Wetlands converted to Other land	kha	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Settlements converted to Other land	kha	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Non-land converted to Other land	kha	49.0	41.0	28.0	22.9	21.3	15.0	14.3	10.5	9.8	9.1	8.0	7.3

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainties of the parameters and the activity data for living biomass and dead organic matter were individually assessed on the basis of field study results, expert judgment, or the default values provided in the *2006 IPCC Guidelines*. The uncertainty was estimated as 53% for the entire emission from the land converted to other land.

- ***Time-series Consistency***

Although the methods to estimate the area of forest land converted to other land use are different between FY1990 - 2004 and post FY2005, as described in section 6.5.2. b)1), the time-series consistency for this subcategory is basically ensured.

d) Category-specific QA/QC and Verification

Same as Forest Land remaining Forest Land (4.A.1.). See section 6.4.1d).

e) Category-specific Recalculations

- ***Correction in accordance with revision of area of land converted from forest land***

Due to a revision of the interpretations of the *Land Use Change Survey by Satellite Interpretation* used for estimating each land are converted from forest, the areas of other land converted from forest were recalculated, carbon stock changes in living biomass, dead organic matter and carbon stock change in mineral soils and CO_2 emissions from organic soils in this category were recalculated for all years. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

- ***Breakdown analysis of Other land and reclassification into Other land-use categories***

A further breakdown analysis of the other land is required, since it may still include some areas that are supposed to be classified into other land-use categories even after the reallocation carried out in this year.

- ***Carbon stock changes in living biomass in "Land converted to Other land"***

The carbon stock changes in living biomass in land converted to other land were assumed to be zero because of a lack of reference information for other land. However, this assumption may differ from the actual situation. Therefore, the methods used to quantify the carbon stock are being examined.

6.10. Harvested Wood Products (4.G.)

The production approach is applied to the estimation of HWP in Japan, and thus the carbon stock changes associated with the use or disposal of domestic HWP are estimated.

The scope of the calculation covers semi-finished products such as “sawnwood”, “wooden board”, “plywood and LVL(laminated veneer lumber)”, and “paper and paperboard”, as well as “underground buried logs” derived from other industrial roundwood. “Sawnwood”, “wooden board”, and “plywood and LVL” shall be calculated and reported separately by end-use categories, namely “wood used for buildings” and “wood used for other than buildings”. “Underground buried logs” shall be reported under category “Other”. However, the current CRT format imposes restrictions on category structure and the addition of subcategories, making it unable to adequately reflect Japan's reporting categories. Therefore, reporting is adjusted as shown in the table below. Note that sawnwood and wood panel (wood board and plywood) used for other than buildings, which were previously reported under “3. Other” in the CRT until the 2025 submission, are now reported collectively under “1.c. Other solid wood products” in this report.

Table 6-70 Correspondence between Japan's Report and the CRT Report

<table>
<tr><td colspan="2" rowspan="2">NID Configuration
Section</td><td colspan="3">CRT Report</td></tr>
<tr><td colspan="2">Table 4.Gs1</td><td>Table 4.Gs2</td></tr>
<tr><td colspan="2"></td><td>4.G(X).1. Solid wood</td><td>Swanwood and Wood panels</td><td></td></tr>
<tr><td rowspan="3">6.10.1 Wood used for Buildings</td><td>Sawnwood</td><td>4.G(X).1.a. Sawnwood</td><td>Swanwood for buildings</td><td rowspan="3">(No report due to Tier 3 usage)</td></tr>
<tr><td>Wood board</td><td rowspan="2">4.G(X).1.b. Wood panels</td><td rowspan="2">Wooden board, Plywood and LVL for buildings</td></tr>
<tr><td>Plywood and LVL</td></tr>
<tr><td rowspan="3">6.10.2 Wood used for other than Buildings</td><td>Sawnwood</td><td rowspan="3">4.G(X).1.c. Other solid wood products</td><td rowspan="3">Swanwood, wooden board, Plywood and LVL for other than buildings</td><td>Sawnwood</td></tr>
<tr><td>Wood board</td><td rowspan="2">Wood panels</td></tr>
<tr><td>Plywood and LVL</td></tr>
<tr><td colspan="2" rowspan="3">6.10.3 Paper and paperboard</td><td>4.G(X).2. Paper and paperboard</td><td rowspan="3">Paper and paperboard</td><td></td></tr>
<tr><td>4.G(X).2.a. Other (please specify)</td><td></td></tr>
<tr><td>Paper and paperboard</td><td>Paper and paperboard</td><td>Paper and paperboard</td></tr>
<tr><td colspan="2" rowspan="2">6.10.4 Other</td><td>4.G(X).3. Other (please specify)</td><td>Other</td><td></td></tr>
<tr><td>Underground buried logs</td><td>Underground buried logs</td><td>Underground buried logs</td></tr>
</table>

Note (X): In Table 4.Gs1, these are categorized as Domestic Use(I) and Exports(II)

The net removals (carbon stock changes) in this category in FY2024 were 1,546 kt-CO_2; this represents an increase of 282.3% compared to FY1990 and a decrease of 12.9% compared to the previous year. The net removals in this category have been on an increasing trend since the 2000s due to an increase in the self-sufficiency rate of wood, except for the temporal drop reflecting the impact of the COVID-19 pandemic.

Table 6-71 CO_2 emissions and removals associated with carbon stock changes in the HWP pool

Category		Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Total		kt-CO_2	-404	1,205	1,768	611	-578	-516	-1,323	-1,537	-2,609	-2,249	-1,776	-1,546
Buildings	Total	kt-CO_2	-196	-642	0	-862	-2,032	-1,538	-2,241	-2,727	-3,127	-2,853	-2,952	-2,640
	Sawnwood	kt-CO_2	-2	-238	457	-77	-492	411	-235	-208	-520	-353	-762	-409
	Wooden board	kt-CO_2	-236	-453	-491	-518	-376	-457	-472	-507	-536	-515	-480	-448
	Plywood and LVL	kt-CO_2	42	49	34	-267	-1,163	-1,492	-1,533	-2,012	-2,071	-1,986	-1,709	-1,782
Wood used for other than buildings	Total	kt-CO_2	508	997	1,290	1,178	1,024	911	756	612	370	392	694	714
	Sawnwood	kt-CO_2	843	1,137	1,289	1,292	1,235	1,078	961	881	717	770	855	884
	Wooden board	kt-CO_2	-303	-188	-87	-57	91	86	98	163	174	170	164	154
	Plywood and LVL	kt-CO_2	-31	48	87	-58	-303	-253	-303	-432	-522	-548	-325	-324
Paper and paperboard		kt-CO_2	-712	853	480	296	432	119	176	594	164	229	499	394
Other	Underground buried logs	kt-CO_2	-4	-4	-2	-1	-2	-8	-14	-15	-16	-17	-17	-15

6.10.1. Wood Used for Buildings

a) Category Description

This category deals with annual carbon stock changes in sawnwood, wooden board, and plywood and LVL used for buildings in Japan. The net removals (carbon stock changes) in this subcategory in FY2024 were 2,640 kt-CO_2; this represents an increase of 1,245.2% compared to the FY1990 and a decrease of 10.6% compared to the previous year.

b) Methodological Issues

- ***Estimation Method***

In Japan, sawnwood, wooden board, and plywood and LVL are mainly used for buildings. Considering the fact that the statistics on buildings and related materials are compiled with a certain level of accuracy, the carbon stock changes in HWP pool of solid woods used for buildings are estimated using a country-specific method (Tier 3) that directly estimates the annual change in carbon stocks in year *i* based on inflows to and outflows from this pool during that year (year *i*). Inflow refers to the carbon stocks in sawnwood, wooden board, and plywood and LVL that are put into this HWP pool when buildings are constructed in year *i*, and outflow refers to the carbon stocks of those semi-finished wood products released from this HWP pool when the buildings are demolished in year *i*. It is assumed that all the carbon stored in the buildings is immediately oxidized when the buildings are demolished. The estimation equation is as follows:

$$\Delta C_{j,i} = Inflow_{j,i} - Outflow_{j,i}$$

$\Delta C_{j,i}$: Carbon stock change in HWP pool of subcategory *j* used for buildings during year *i* [t-C/year]
$Inflow_{j,i}$: Inflow to HWP pool of subcategory *j* used for buildings during year *i* [t-C/year]
$Outflow_{j,i}$: Outflow from HWP pool of subcategory *j* used for buildings during year *i* [t-C/year]
j : Subcategories (sawnwood, wooden board, plywood and LVL)
i : Year for calculation

The amount of wood input in the buildings was treated as its activities in the inflow, and the following methods were used for its calculation: for sawnwood and plywood up to 1997, multiplying constructed floor area by the wood input amount per unit floor area of buildings constructed; for plywood from 1998 onward and wooden board, estimating from production of semi-finished product, etc.

$$Inflow_{j,i} = V_{p_{j,i}} \times f_{DP_{j,i}} \times D_j \times CF_j$$

When using constructed floor area for the calculation, the following equation is used.

$$V_{p_{j,i}} = S_{P_{st,i}} \times v_{P_{j,st,i}}$$

$Inflow_{j,i}$	: Inflow to HWP pool of subcategory *j* used for buildings during year *i* [t-C/year]
$Vp_{j,i}$	: Wood input amount of subcategory *j* used for buildings during year *i* [m^3/year]
$S_{P\ st,i}$	: Constructed floor area by use (residential or nonresidential) and by structure type (*st*) in subcategory *j* during year *i* [m^2/year]
$v_{P\ j,st,i}$	: Wood input amount of subcategory *j* per unit floor area of building constructed (new construction or extension) by uses (residential or nonresidential) and by structure type (*st*) in year *i* [m^3/m^2]
$f_{DP\ j,i}$	: Ratio of domestic wood to total wood used for buildings of subcategory *j* in year *i* [%]
D_j	: Density of subcategory *j* (oven dry mass over air dry volume) [t-d.m./m^3]
CF_j	: Carbon fraction of subcategory *j* [t-C/t-d.m.]
j	: Subcategory (sawnwood, wooden board, plywood and LVL)
i	: Year for calculation
st	: Use (residential or nonresidential) and structure type of buildings

$$Outflow_{j,i} = S_{W_{st,i}} \times v_{W_{j,st,i}} \times f_{DW_{j,i}} \times D_j \times CF_j$$

$Outflow_{j,i}$	: Outflow from HWP pool of subcategory *j* used for buildings during year *i* [t-C/year]
$S_{W\ st,i}$	: Floor area of demolished buildings by use (residential or nonresidential) and by structure type (*st*) in year *i* [m^2/year]
$v_{Wj,st,i}$	: Wood input amount of subcategory *j* per unit floor area of demolished buildings in year *i* by use (residential or nonresidential) and by structure type (*st*) [m^3/m^2]
$f_{DWj,i}$	: Ratio of domestic wood to total wood used in demolished buildings of subcategory *j* during year *i* [%]
D_j	: Density of subcategory *j* (oven dry mass over air dry volume) [t-d.m./m^3]
CF_j	: Carbon fraction of subcategory *j* [t-C/t-d.m.]
j	: Subcategory (sawnwood, wooden board, plywood and LVL)
i	: Year for calculation
st	: Use (residential or nonresidential) and structure type of buildings

- ***Parameters***

➢ ***Wood input amount per unit floor area of buildings constructed ($v_{P\ j,st,i}$)***

- ***Sawnwood***

The amount of wood used per unit floor area was obtained from the *Survey on Actual Demand of Construction Labor and Materials* (MLIT). As for non-wooden buildings, since the data are missing from 1992 to 2020 in the statistics, the additional survey data for 2013 obtained by the Forest Agency of Japan were used for the year 2013 and the time series for 1992-2012 and 2014-2020 are estimated by linear interpolation. Furthermore, since the *Survey on Actual Demand of Construction Labor and Materials* is conducted every two years, data for intermediate years were estimated by linear interpolation.

- ***Plywood and LVL (up to 1997)***

The values obtained from the *Survey on Actual Demand of Construction Labor and Materials* (MLIT) were applied. Since the *Survey on Actual Demand of Construction Labor and Materials* is conducted every two years, data for intermediate years were estimated by linear interpolation.

➢ ***Ratio of domestic wood for construction ($f_{DP\,j,i}$)***

- ***Sawnwood***

The ratio of domestic wood for sawnwood was calculated by dividing the shipment quantity of domestic sawnwood for buildings, by the total amount of shipment quantity of sawnwood for buildings and imported sawnwood used for buildings. In addition, the ratio of the domestic wood is calculated separately for coniferous and non-coniferous wood based on their proportions of coniferous and non-coniferous wood in the raw material supply of sawnwood.

- ***Wooden board***

The ratio of domestic wood in the sales and consumption quantity of wooden board is a weighted average of the ratios of domestic wood for raw material; (i) logs, (ii) wood residue in mills, (iii) wood residue in forestry practices and (iv) scrap wood in particle board and fiberboard. The ratio of domestic wood for each raw material was estimated as follows: for (i) logs, it was estimated from quantity of wood used for wood chips (domestic and imported wood); for (ii) wood residue in mills, it was estimated from the ratio from domestic production of wood chips from wood chips from wood residue in mills and the shipment quantity of sawnwood (domestic and imported wood); for (iii) wood residue in forestry practices, it was assumed as 100%; and for (iv) scrap wood, the ratio of domestic wood for demolished buildings described below was applied.

- ***Plywood and LVL (up to 1997)***

The ratio of domestic wood in plywood used for constructed buildings was calculated by dividing the production of plywood from domestic wood by the sum of plywood production and imports. The production of plywood from domestic wood was calculated based on the ratio of domestic wood in the total plywood material input.

- ***Plywood and LVL (from 1998 onward)***

For plywood, the ratio of domestic wood in veneer consumption for plywood was used; for LVL, the ratio of domestic wood in LVL production for construction was used.

➢ ***The amount of wood input per unit floor area of demolished buildings ($v_{P\,j,st,i}$) and the ratio of domestic wood for demolished buildings ($f_{Dw\,j,i}$)***

The amount of wood input per unit floor area of demolished buildings ($v_{W\,j,st,i}$) and the ratio of domestic wood for demolished buildings ($f_{DW\,j,i}$) were calculated as the weighted average of the ratio of floor area built in year n ($S_{W\,st,I\,(n)}$) of the demolished floor area in year i ($S_{W\,st,i}$), respectively to reflect the wood input amount per unit demolished floor area ($v_{P\,j,st,i}$) or the ratio of domestic wood for buildings ($f_{DP\,j,i}$) in subcategory j, as shown in the equations below.

$$v_{W\,j,st,i} = \sum_n \left(\frac{S_{w\,,st,i\,(n)}}{S_{w\,st,i}} \times v_{P\,j,s,t,i\,(n)} \right)$$

$$f_{DW\,j,i} = \sum_n \left(\frac{S_{w\,st,i\,(n)}}{S_{w\,st,i}} \times f_{DP\,j,i\,(n)} \right)$$

Note that if the wood input amount per unit floor area of buildings constructed ($v_{P\,j,st,i}$) was not used to calculate the wood input amount ($V_{in\,j,i}$) for the inflow, the amount of wood input per unit floor area

constructed was calculated by dividing the wood input amount by the constructed floor area ($S_{Pst,i}$) as shown in the following equation.

$$v_{P_{j,st,i}} = \frac{V_{p_{j,i}}}{S_{P_{st,i}}}$$

- ***Density and carbon fraction***

For the density of coniferous sawnwood, a country-specific value was estimated to appropriately reflect the densities of domestic coniferous species, by calculating their weighted average based on the species ratio of wood production in the *Report on Supply and Demand of Lumber* (MAFF).

For parameters other than the density of coniferous sawnwood, the default values shown in Table 12.1 of Vol.4 of the *2019 Refinement* were applied. Note that the density applied in section 6.10 is the oven dry mass density over air dry volume.

Table 6-72 Default values of density and carbon fraction for the HWP categories

HWP categories		Density [Mg-d.m./m^3]	Carbon fraction [Mg-C/Mg-d. m.]
Sawnwood	Coniferous sawnwood	0.37	0.5
	Non-coniferous sawnwood	0.56	0.5
Wood panels (wooden board)	Particle board (PB)	0.596	0.451
	Hardboard (HDF)	0.788	0.425
	Medium-density fireboard (MDF)	0.691	0.427
	Insulating board (other board, low density fiber)	0.159	0.474
Wood panels (plywood, LVL)		0.542	0.493

Reference: The 2019 Refinement, Vol4, Table 12.1 (excluding density for coniferous sawnwood)
Note: Country specific value is used for the density of coniferous sawnwood.

Table 6-73 Data used for parameters (Buildings)

	Variable	Reference	Note
1	Shipment quantity of sawnwood (for buildings) (domestic wood)	*Report on Supply and Demand of Lumber* (MAFF)	
2	Shipment quantity of sawnwood (for buildings) (imported wood)	*Report on Supply and Demand of Lumber* (MAFF)	
3	Quantity of log input for sawnwood	*Report on Supply and Demand of Lumber* (MAFF)	
4	Imports of sawnwood (coniferous trees)	*Trade Statistics of Japan* (MOF)	Softwood (coniferous tree) and glued-laminated wood imports are assumed as building materials because imports for building structures cannot be obtained in the statistics.
5	Sales and consumption quantity of wooden board	*Current Production Statistics, Ceramics and Building Materials Statistics* (METI)	Including own-use
6	Imports of wooden board	*Trade Statistics of Japan* (MOF)	
7	Imported wood chips	*Trade Statistics of Japan* (MOF)	
8	Production of domestic wood chips	*Report on Supply and Demand of Lumber* (MAFF)	
9	Quantity of log input for wood chips (domestic wood)	*Report on Supply and Demand of Lumber* (MAFF)	
10	Quantity of log input for wood chips (imported wood)	*Report on Supply and Demand of Lumber* (MAFF)	
11	Shipment quantity of wooden board by use	*Shipments of wood-based board production* by Japan Fiberboard and Particleboard Manufacturers Association	
12	Production of plywood	*Report on Supply and Demand of Lumber* (MAFF)	
13	Imports of veneer for plywood	*Trade Statistics of Japan* (MOF)	
14	Imports of plywood	*Trade Statistics of Japan* (MOF)	Calculated by subtracting glued-laminated wood and bamboo of plywood from glued-laminated wood by *Trade Statistics of Japan*
15	Quantity of log input for plywood (domestic wood)	*Report on Supply and Demand of Lumber* (MAFF)	
16	Quantity of log input for plywood (imported wood)	*Report on Supply and Demand of Lumber* (MAFF)	
17	Consumption of veneer for plywood (domestic wood)	*Report on Supply and Demand of Lumber* (MAFF)	
18	Consumption of veneer for plywood (imported wood)	*Report on Supply and Demand of Lumber* (MAFF)	
19	Production of LVL for construction (domestic wood)	*Report on Supply and Demand of Lumber* (MAFF)	
20	Production of LVL for construction (imported wood)	*Report on Supply and Demand of Lumber* (MAFF)	

Note: METI: Ministry of Economy, Trade and Industry; MOF: Ministry of Finance

- ***Activity Data***

➢ ***Floor area of construction ($S_{P\ st,i}$)***

The floor area of new construction and extension by use (residential or nonresidential) and by structure in *Construction Statistics for Building* by MLIT was applied.

➢ ***Floor area of emolition ($S_{W\,st,\,i}$)***

The floor area of demolition was estimated using the floor area stock in the *Fixed Property Tax Division, Local Tax Bureau (Houses)* by MIC and the floor area of construction described above. The floor area of demolished buildings by use (residential or nonresidential) and by structure in year *i* ($S_{W\,st,\,i}$) was calculated by adding the constructed floor area in *i* year ($S_{P\,st,\,i}$) to the floor area stock in year *i-1* ($S_{S\,st,\,i-1}$), and then subtracting the floor area stock in *i* year ($S_{S\,st,\,i}$).

$$S_{W_{St,i}} = S_{S_{st,i\text{-}1}} + S_{P_{st,i}} - S_{S_{st,i}}$$

Since the floor area stock and the constructed floor area include the area of extension, the floor area of demolition also includes the floor area of buildings demolished after extension. However, the floor area of renovation has been deducted from the constructed floor area since renovation is not taken into account in the calculation of the amount of wood input per unit floor area of buildings constructed.

➢ ***Wood input amount for buildings ($V_{p\,j,i}$)***

- ***Wooden board***

Amount of wood input by wooden board type and by use was calculated by multiplying the sales and consumption quantity of each wooden board type (Particleboard, Hardboard, Medium-density Fiberboard, Softboard) obtained from the *Annual Report on Production Dynamics Statistics: Resources, Ceramics, and Building Materials Statistics* (METI), by the estimated ratio for construction use obtained from the *Wooden board Shipments by Application* (Japan Fiberboard Manufacturers Association), and by the processing yield percentage when converting into final wood products.

For particleboard among wooden board, the classification of uses for estimating the ratio used for construction differs between periods before and after 2018. Therefore, the ratio used for construction in 1983 was set to 0%[16], and it was interpolated assuming a linear increase until 2019.

For processing yield percentage, the value of 0.9, set through monitoring during the development process of the J-Credit system calculation method, was used based on expert judgment for all years within the current calculation period.

- ***Plywood and LVL (from 1998 onward)***

In the subcategory of plywood and LVL, the amount of activity was calculated by combining plywood and LVL.

The amount of plywood used for buildings was calculated by multiplying the domestic consumption, which is derived by subtracting the exported quantity of coniferous plywood obtained from the *Trade Statistics* (MOF) from the structural plywood production obtained from the *Wood Supply and Demand Report* (MAFF), by the processing yield percentage when converting plywood into final wood products.

The amount of LVL used in buildings was calculated by multiplying the production of structural LVL by the building processing yield percentage when converting LVL into final wood products. Note that

[16] Based on the content in the main text of Section 4 “Particle Board” and Table 6 “Particle Board Shipment Status by Application and Region” in the newsletter *Hardboard, Particle Board, Insulation Board* No. 97 (published by Japan Fiberboard Manufacturers Association in June 1983).

since the statistical survey of LVL production began in 2017, production from that year onward are used in the calculations. Furthermore, no LVL exports have occurred.

The processing yield percentage of plywood and LVL using for buildings was set at 0.9, the same as for wooden board.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainties of carbon stock changes of buildings were assessed based on the uncertainties of the default factors provided in the *2019 Refinement* and the uncertainties of exiting statistical data. The uncertainty was estimated as 30% for the carbon stock changes in buildings.

- ***Time-series Consistency***

For wooden board, the activity date is consistently estimated from the same statistics, the time series consistency for this subcategory is ensured.

For plywood, the method of calculating wood input by multiplying the constructed floor area by the wood input amount used per unit floor area has been consistently applied over time for submissions up to 2025. However, it is highly likely that the data on the wood input amount used per unit floor area constructed does not fully capture the increasing use of thicker plywood in recent years. Consequently, recent estimates have significantly underestimated amount of plywood consumption compared to the amount from the production of ordinary plywood, coniferous plywood, and structural plywood reported in the *Wood Supply and Demand Report* by the MAFF.

Therefore, to obtain estimates more closely to actual conditions, production-based estimates were adapted for the period since 1998, when the data on “Structural plywood production” became available from the *Wood Supply and Demand Report*. For the period prior to 1997, estimates were calculated using the conventional method of multiplying the constructed floor area by the wood input amount per unit floor area constructed.

d) Category-specific QA/QC and Verification

Same as Forestland Remaining Forestland (4.A.1.). See section 6.4.1 d).

e) Category-specific Recalculations

- ***Revision of estimation of plywood input amount used for buildings***

The calculation method for estimating the plywood input amount used for buildings from 1998 onward were revised. Accordingly, the carbon stock changes from 1998 onward were recalculated.

- ***Revision of plywood input amount for buildings***

The amount of plywood input from 1998 onward were changed from consumption-based to production-based calculation. Accordingly, the domestic wood ratio of plywood used from 1989 onward were recalculated to production-based values. Accordingly, the carbon stock changes plywood from 1998 onward were recalculated.

- ***Addition of LVL in the subcategory "Plywood and LVL"***

Estimates for LVL were added in the subcategory "Plywood and LVL", since previous estimates did not include LVL input, but statistical surveys of LVL production began in 2017. Accordingly, the carbon stock changes in plywood and LVL from 2017 onward were recalculated.

- ***Consideration of processing yield percentage of wooden board Input***

The amount of wooden board input has been revised by multiplying the sales and consumption by the processing yield percentage when converting into final wood products, although previous estimates had used the sales and consumption directly. Accordingly, the carbon stock changes in wooden board for all years were recalculated.

- ***Revision of estimation of past-year input of particle board (a type of wooden board)***

The statistical classification for building and other uses than building was revised in estimating the amount of particleboard used in construction. Accordingly, the carbon stock changes in wooden board from 1990 to 2018 were recalculated.

See Chapter 10 for the impact of recalculations on the trend.

f) Category-specific Planned Improvements

Statistical data on LVL production is only available from 2017 onwards; therefore, the way of constructing data prior to 2016 will be considered.

6.10.2. Wood Used for Other than Buildings

a) Category Description

This category deals with carbon stock changes in sawnwood, wooden board, and plywood and LVL used for other than buildings. The net removals (carbon stock changes) in this subcategory in FY2024 were 714 kt-CO_2; this represents an increase of 40.5% compared to the FY1990 and an increase of 3.0% compared to the previous year.

b) Methodological Issues

- ***Estimation Method***

The carbon stock changes in the HWP pool of this category were estimated as the difference between the carbon stocks in this HWP pool in the reference year and prior year using the first-order decay (FOD) function (Tier 2 method) described in the *2006 IPCC Guidelines.* Inflow to the HWP pool during one year was estimated by multiplying the amount of wood used for other than buildings by the ratio of domestic wood of each subcategory (sawnwood, wooden board, and plywood and LVL) and the carbon fraction. The estimation equations are as follows.

$$\Delta C_{j,i} = C_{j,i} - C_{j,i-1}$$

$$C_{j,i} = e^{-k_j} \times C_{j,i-1} + \left[\frac{\left(1 - e^{-k_j}\right)}{k_j}\right] \times Inflow_{j,i}$$

$\Delta C_{j,i}$	: Carbon stock change in HWP of subcategory *j* of the wood used for other than buildings pool during year *i* [t-C/year]
$C_{j,i}$	: Carbon stock in HWP pool of subcategory *j* of thewood used for other than buildings at the end of year *i* [t-C] Note: $C_{j,1900}$= 0 : Carbon stock in 1900 was assumed to be zero
k_j	: $kj = ln(2) / HLj$ *HLj*:half-life in HWP pool of subcategory *j* of thewood used for other than buildings
$Inflow_{j,i}$	: Inflow to HWP pool of subcategory *j* of thewood used for other than buildings during year *i* [t-C/year]
j	: Subcategory (sawnwood, wooden board, plywood and LVL)
i	: Year for calculation

$$Inflow_{j,i} = V_{p\,j,i} \times f_{DP\,j,i} \times D_j \times CF_j$$

$Inflow_{j,i}$	: Inflow to HWP pool of subcategory *j* used for other than buildings during year *i* [t-C/year]
$VP_{j,i}$	: Amount of wood in subcategory *j* used for other than buildings [m^3/year]
$fDP_{j,i}$	: Ratio of domestic wood in subcategory *j* used for other than buildings during year *i* [%]
D_j	: Density (oven dry mass over air dry volume) [t-d.m./m^3]
CF_j	: Carbon fraction [t-C/t-d.m.]
j	: Subcategory (sawnwood, wooden board, plywood and LVL)
i	: Year for calculation

- ***Parameters***

➢ ***Ratio of domestic wood ($f_{DPj,i}$)***

- ***Sawnwood***

The ratio of domestic wood for sawnwood used for other than buildings was calculated by dividing the amount of shipped sawnwood produced from domestic wood by tree species, by the amount of shipment (domestic wood, used for other than buildings).

- ***Wooden board***

The ratio of domestic wood for each raw material was estimated in the same way as for that of wooden board for buildings described in 6.10.1.

- ***Plywood and LVL (Up to 1997)***

The ratio of domestic wood for plywood used for other than buildings, was calculated by dividing the amount of input materials from domestic wood for plywood used for other than buildings by the sum of the amount of input materials for plywood and imported veneers for plywood (in roundwood-equivalent volume). The values were estimated separately for coniferous and non-coniferous wood, in the same manner as for sawnwood used for buildings.

- ***Plywood and LVL (from 1998 onward)***

The ratio of domestic wood for each raw material was estimated in the same way as for buildings described in 6.10.1.

➢ ***Default half-lives (k_j)***

The default half-lives (sawnwood: 35 years, wood panels: 25 years) described in the *2019 Refinement* were applied (Table 12.3). The default half-lives of wood panels are used for wooden board and plywood.

➢ ***Density and carbon fraction (D_i)***

The same values as for the "wood used for Buildings" category were used (section 6.10.1.) (See Table 6-72 for the details).

Table 6-74 Data used for parameters (wood used for other than buildings)

	Variable	Reference	Note
1	Shipment quantity of sawnwood (domestic wood for other uses than buildings)	*Report on Supply and Demand of Lumber* (MAFF)	
2	Sales and consumption quantity of wooden board	*Current Production Statistics, Ceramics and Building Materials Statistics* (METI)	Including own-use
3	Imported wood chips	*Trade Statistics of Japan* (MOF)	
4	Production of domestic wood chips	*Report on Supply and Demand of Lumber* (MAFF)	
5	Domestic log chips (for pulp)	*Trends in Pulp Collection* by Japan Paper Association	
6	Quantity of log input for wood chips (domestic wood)	*Report on Supply and Demand of Lumber* (MAFF)	
7	Quantity of wood input for wood chips (imported wood)	*Report on Supply and Demand of Lumber* (MAFF)	
8	Imports of plywood (veneer)	*Trade Statistics of Japan* (MOF)	
9	Quantity of log input for plywood (domestic wood)	*Report on Supply and Demand of Lumber* (MAFF)	
10	Quantity of log input for plywood (imported wood)	*Report on Supply and Demand of Lumber* (MAFF)	
11	Production of LVL for structure (domestic wood)	*Report on Supply and Demand of Lumber* (MAFF)	
12	Production of LVL for structure (imported wood)	*Report on Supply and Demand of Lumber* (MAFF)	

Note: METI: Ministry of Economy, Trade and Industry; MOF: Ministry of Finance

● ***Activity Data (amount of wood used)***

- ***Sawnwood***

The shipment of sawnwood used for other than buildings was estimated by subtracting the shipment quantity of sawnwood for buildings from the total shipment quantity of sawnwood obtained from *the Report on Supply and Demand of Lumber* (MAFF).

- ***Wooden board***

The sales and consumption quantity of wooden board for other uses than buildings was estimated by multiplying the sales and consumption quantity of wooden board of each type (PB, HB, MDF and LDF)

obtained from the *Current Production Statistics, Ceramics and building materials statistics* (METI), by the ratio of other uses than buildings, calculated from *Shipments of wood-based board production* (Japan Fiberboard and Particleboard Manufacturers Association).

- ***Plywood and LVL***

For the amount of production of plywood obtained from the *Century of Plywood* (the Japan Plywood Industry Association) were applied for periods prior to 1953. While from 1954 to 1997, it was estimated by subtracting the amount of production of plywood used for buildings from the amount of total production of normal plywood obtained from the *Report on Supply and Demand of Lumber* (MAFF). After 1998 onward, due to changes in the amount of activity used for building, the amount obtained by subtracting the production of structural plywood for building from the production of normal plywood were used.

The amount of LVL was calculated by applying the production of LVL in "Other" from the *Wood Supply and Demand Report* (MAFF). Note that the wood used for renovations, the floor area of which has been subtracted from that of building construction, is taken into account in this category.

➢ ***Method of tracing back up to 1900***

As for sawnwood, the data were extrapolated backward to 1900 using the equation 12.6 described in section 12.2.3 in *the 2006 IPCC Guidelines*. For the estimated annual rate for industrial round wood production (*U*), the default value of Asia between 1900 and 1961 (0.0217) was used (*2006 IPCC Guidelines*, Table 12.3).

$$V_t = V_{1961} \times e^{[U \times (t-1961)]}$$

V_t	: Annual production of wood used for other than buildings [kt-C/year]
t	: Year (1900-1961)
V_{1961}	: Annual production of wood used for other than buildings in 1961 [kt-C/year]
U	: Estimated continuous rate of change in industrial roundwood consumption for the region that includes the reporting country between 1900 and 1961

As for plywood and wooden board, production data from the *100 Years of Plywood* (Japan Plywood Manufacturers' Association) and from the *Annual Fiberwood, the Sales and the Stocks* (METI) were used, respectively. The plywood production before 1908 and wooden board production before 1953 were set to 0, taking into account the years in which their production had started.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainties of carbon stock changes of wood used for other than buildings were assessed based on the uncertainties of the default factors provided in the *2019 Refinement* and the uncertainties of statistical data. The uncertainty was estimated as 30% for the carbon stock changes in wood used for other than buildings.

- ***Time-series Consistency***

The activity data for wooden board and any parameter used for the estimation under this category use consistent statistics in the time-series. As for sawnwood, the activity data before 1961 were extrapolated backward to 1900 using the equation 12.6 described in section 12.2.3 in *the 2006 IPCC Guidelines*, and

the time-series consistency for this subcategory is ensured. As for plywood, the activity data were obtained by excluding the amount used for buildings from the total production from the *Report on Supply and Demand of Lumber* (MAFF) in 1954 and onwards, and from the *100 years of Plywood* (Japan Plywood Manufacturers' Association) in years before 1954 where the data were lacking in the aforementioned statistics. The *100 years of Plywood*, showing the start of plywood production in 1907, was judged to be a reliable source by experts.

d) Category-specific QA/QC and Verification

Same as Forestland Remaining Forestland (4.A.1.). See section 6.4.1 d).

e) Category-specific Recalculations

- ***Revision of estimation of plywood input for buildings and corresponding adjustment of the domestic wood ratio***

Similar to the revision of Section on "wood used for buildings" 6.10.1.e), the carbon stock changes in plywood and LVL from 1998 onward have been recalculated.

- ***Addition of LVL to the subcategory "Plywood and LVL"***

Similar to the revision of Section on "wood used for buildings" 6.10.1.e), the carbon stock changes in plywood and LVL from 2017 onward have been recalculated.

- ***Revision of estimation of past-year input of particleboard (a type of wooden board)***

Similar to the revision of Section on "wood used for buildings" 6.10.1.e), the carbon stock changes in wooden board from 1990 to 2018 have been recalculated.

See Chapter 10 for the impact of recalculations on the trend.

f) Category-specific Planned Improvements

Statistical data on LVL production is only available from 2017 onwards; therefore, the way of constructing data prior to 2016 will be considered.

6.10.3. Paper and Paperboard

a) Category Description

This category deals with carbon stock changes in paper and paperboard (including waste paper). The net removals (carbon stock changes) in this subcategory in FY1990 were 712 kt-CO_2, the net emissions in the previous year were 499 kt-CO_2, and the net emissions in FY2024 were 394 kt-CO_2.

b) Methodological Issues

- ***Estimation Method***

The carbon stocks changes in the HWP pool in paper and paperboard were estimated from the difference between the HWP pool in the reference year and prior year in the same way as used in the "wood used for other than buildings" 6.10.2) category using the FOD function (Tier 2 method) described in the *2006 IPCC Guidelines.* Inflow to the HWP pool during one year was estimated by multiplying the amount of production of paper and paperboard, by the ratio of domestic wood for paper and paperboard and the

carbon conversion factor. The estimation equations are as follows.

$$\Delta C_i = C_i - C_{i-1}$$

$$C_i = e^{-k} \times C_{i-1} + \left[\frac{(1-e^{-k})}{k}\right] \times Inflow_i$$

ΔC_i	: Carbon stock change in HWP pool of paper products during year *i* [t-C/year]
C_i	: Carbon stock in HWP pool of paper products at the end of year *i* [t-C] Note: C_{1900}=0; Carbon stock in 1900 was assumed to be 0.
$Inflow_i$	: Inflow to the HWP pool in year *i* [t-C/year]
k	: $k = ln(2) / HL$ *HL*: half-life of the HWP pool: two years
i	: year for calculation

$$Inflow_i = PP_{p\,i} \times f_{DP\,i} \times C_{cf}$$

$Inflow_i$	: Inflow to the HWP pool in year *i*[t-C/year]
$PP_{P\,i}$	: Production of paper and paperboard during year *i* [t]
$f_{DP\,i}$	: Rate of domestic logs for paper and paperboard during year *i* [%]
C_{cf}	: C conversion fraction [t-C/t]
i	: year for calculation

- ***Parameters***

➢ ***Ratio of domestic wood ($f_{DPj,i}$)***

The ratio of domestic wood for paper and paperboard was estimated by dividing the sum of consumption of paper pulp, wastepaper and wastepaper pulp originated from domestic wood by the total consumption of paper pulp, wastepaper, wastepaper pulp and other fibrous cellulosic pulp.

The total consumption of paper pulp was obtained from the *Current Production Statistics, Paper, printing, plastic products and rubber products statistics* (METI), of which the consumption originated from domestic wood was derived by subtracting the imported amount of paper pulp in the *Trade Statistics of Japan* (MOF) from the total consumption and then multiplying it by the ratio of domestic wood for paper pulp. The ratio of domestic wood for paper pulp was estimated by dividing the sum of consumption of domestic logs and wood chips for paper pulp by the total consumption of logs and wood chips. The values of consumption of logs and wood chips for paper pulp were obtained from the "statistics for raw materials (pulp)" in the *Current Production Statistics, Paper, printing, plastic products and rubber products statistics* (METI). Wood chips domestically produced from domestic wood (excluding those domestically produced from imported wood) was calculated by multiplying the total amount of domestic wood chips in the statistics by the average ratio of domestic wood for each type of raw material used for wood chip production weighted by the proportion of each type of raw material in the total chip production.

The total consumption of wastepaper and wastepaper pulp was obtained from the *Current Production Statistics, Paper, printing, plastic products and rubber products statistics* (METI), of which the consumption originated from domestic wood was derived by subtracting the imported amount of wastepaper and wastepaper pulp in the *Trade Statistics of Japan* (MOF) from the total consumption and then multiplying it by the ratio of domestic wood for wastepaper and wastepaper pulp. The ratio of domestic wood for wastepaper and wastepaper pulp was estimated by dividing the disposal of domestic paper and paper board in the previous year by the total disposal of paper and paper board of the same year.

Table 6-75 Data used for parameters (Paper and paperboard)

	Variable	Reference	Note
1	Paper pulp, wastepaper, wastepaper pulp, other fibrous cellulosic pulp	*Current Production Statistics, Paper, Printing, Plastic Products and Rubber Products Statistics (*METI)	Used for calculating the ratio of domestic wood for paper and paper board
2	Consumptions of raw material for paper pulp (logs, wood chips) Originated from domestic wood Logs Wood chips	*Current Production Statistics, Paper, Printing, Plastic Products and Rubber Products Statistics* (METI)	Used for calculating the ratio of domestic wood for paper pulp
3	Imports of paper pulp	*Trade Statistics of Japan* (MOF)	
4	Imports of wastepaper and wastepaper pulp	*Trade Statistics of Japan* (MOF)	
5	Ratios of domestic wood chips by provision type	*Report on Supply and Demand of Lumber* (MAFF)	Used for estimating the ratio of domestic wood for pulp production chips
6	Quantity of wood input for wood chips (domestic wood)	*Report on Supply and Demand of Lumber* (MAFF)	
7	Quantity of wood input for wood chips (imported wood)	*Report on Supply and Demand of Lumber* (MAFF)	

Note: METI: Ministry of Economy, Trade and Industry; MOF: Ministry of Finance

➢ ***Half-life (k)***

The default half-life for paper and paperboard (2 years) described in the *2019 Refinement* (Vol.4, Tables 12.3) was used.

➢ ***Carbon conversion factors (C_{cf})***

The default parameter (C conversion factor: 0.386 t-C/t) for paper and paperboard described in the *2019 Refinement* (Tables 12.1) is used.

● ***Activity Data***

➢ ***Method since 1961***

The amount of domestic production of paper and paperboard used was the sum of domestic pulpwood and wood chips obtained from the *Current Production Statistics, Paper, Printing, Plastic Products and Rubber Products Statistics* (METI). These are the same as the production amount of Paper and Paperboard in FAOSTAT.

➢ ***Method of tracing back up to 1900***

Data from the *Yearbook for Paper and Pulp Statistics* (METI) were used.

c) Uncertainty Assessment and Time-series Consistency

● ***Uncertainty Assessment***

The uncertainties of carbon stock changes of paper and paperboard were assessed based on the uncertainties of the default factors provided in the *2019 Refinement* and the uncertainties of exiting statistical data.

The uncertainty was estimated as 30% for carbon stock changes in paper and paperboard.

- ***Time-series Consistency***

The activity data and any parameter used consistent statistics in the time-series.

d) Category-specific QA/QC and Verification

Same as Forestland Remaining Forestland (4.A.1.). See section 6.4.1 d).

e) Category-specific Recalculations

Due to the correction of an aggregation error in the activity data, recalculations were carried out for all fiscal years. See Chapter 10 for the impact of recalculations on the trend.

f) Category-specific Planned Improvements

No improvements are planned.

6.10.4. Other

a) Category Description

This category deals with HWP derived from industrial roundwood other than semi-finished goods, and reports carbon stock changes for "underground buried logs". In Japan, pile logs have long been driven into the ground for ground improvement. Although demand had been declining for many years, new construction methods for addressing soft ground and other issues have been developed in recent years, leading to an expanding trend in the pile logs driven for underground utilization. It is known that logs buried underground do not decay semi-permanently. Furthermore, excavation verification tests in Japan have confirmed that when located below the groundwater level, their mass is retained almost permanently (Numata et al., (2024), Numata et al., (2025)). The calculation for "underground buried logs" is based on these findings. The net removals (carbon stock changes) in this subcategory in FY2024 were 15 kt-CO_2; this represents an increase of 242.3% compared to the FY1990 and a decrease of 11.1% compared to the previous year.

b) Methodological Issues

- ***Estimation Method***

In the *2019 refinement,* no Tier 1-2 methodologies are provided for calculating HWP derived from industrial roundwood other than semi-finished products, they must be calculated using the country specific methodology Tier 3 when including such products in the calculation scope. Tier 3 for underground buried logs is based on calculating carbon stock changes through the difference between inflows and outflows in the HWP pool of underground buried logs. When calculating, it distinguishes between used for construction and for civil engineering, taking into account differences in uses and extraction conditions.

- ***Underground Buried Logs for Construction***

Construction methods include three types standardized under the Building Standards Act. The carbon stock changes in underground buried logs using any of these methods is subject to calculation. Details of the construction method are as shown in Table 6-76. Regardless of the construction method, since the log piles are either specified to extend below the groundwater level or protected from decay and

deterioration through measures such as preservative treatment, top concrete, or protective soil covering the pile tops, all underground buried logs are considered permanently retained during their burial period. Inflow shall be the volume of log piles driven during the relevant year, and outflow shall be the volume of log piles extracted during the demolition of structures occurring during the relevant year. The volume of log piles was obtained for each tree species and calculated using the specific volume density and carbon fraction of each species. Outflow was calculated by summing the following: the volume of underground buried logs for each year, placed from year *t* to the end of year *i*-1 and remaining underground at the end of year *i*-1; multiplied by the annual demolition ratio for buildings constructed from year *t* to year *i*-1 and demolished in year *i-t* to year *i*-1; and the ratio at which log piles are extracted. All log piles are sourced domestically. The calculator equation is as follows.

$$\Delta C_{\_pile\ a\ i} = Inflow_{\_pile\ a\ i} - Outflow_{\_pile\ a\ i}$$

$\Delta C_{\_pile\ a\ i}$	: Carbon stock changes in HWP pool of underground buried logs used for construction during year *i* [t-C/year]
$Inflow_{\_pilei\ ai}$	: Inflow to HWP pool of underground buried logs used for construction during year *i* [t-C/year]
$Outflow_{\_pile\ a\ i}$	: Outflow from HWP pool of underground buried logs for used construction during year *i* [t-C/year]
i	: Year for calculation

$$Inflow_{\_pile\ a\ i} = \sum_{j} \left\{ V_{pile\ a\ i,j} \times D_j \times CF_j \right\}$$

$Inflow_{\_pilei\ ai}$	: Inflow to HWP pool of underground buried logs used for construction during year *i* [t-C/year]
$V_{pile\ a\ i,j}$	: Volume of underground buried logs of tree species *j* used for construction during year *i* [m³/year]
D_j	: Density of tree species *j* [t-d.m./m³]
CF_j	: Carbon fraction of tree species *j* [t-C/t-d.m.] (All tree species are conifers)
i	: Year for calculation
j	: Tree species (Japanese cedar, Hinoki cypress, Japanese red pine, Japanese larch, Sakhalin fir)

$$Outflow_{\_pile\ a\ i} = \int_{t=1}^{i-1} (Remain_{t,i-t} \times K_{i-t} \times N)$$

$$Remain_{t,i-t} = Remain_{t,i-(t-1)} \times \left(1 - K_{i-(t-1)} \times N\right)$$

$Outflow_{\_pile\ a\ i}$	: Outflow from HWP pool of underground buried logs used for construction during year *i* [t-C/year]
$Remain_{pile\ a\ t,\ i-t}$	: Remaining of carbon stock in underground buried logs at the end of year *i-t* buried in year *t* [t-C]
K_{i-t}	: Demolition ratio in year *i-t* for buildings constructed in year *t*
N	: Ratio at which underground buried logs are extracted from demolished buildings
i	: Year for calculation
t	: The year of piling

- ***Underground Buried Logs Used for Civil Engineering***

Only one method is currently eligible for estimation under the civil engineering construction methods, and the calculation targets the carbon stock changes of the underground buried logs using this method. Details of the construction method are as shown in Table 6-76. In this method, log piles are driven below the groundwater level within the soft ground under road or embankment. However, since the top of piles are located above the groundwater level, calculations are performed assuming a reduction in mass due to decomposition at the pile tops. Therefore, they are calculated separately that the permanent storage portion below the groundwater level and the top of log piles representing mass reduction due to

decomposition occurring above the groundwater level. The inflow was calculated based on the species-specific piling volume, similar to construction methods. On the other hand, since underground buried logs for civil engineering are not extracted, the outflow for the portion driven below the groundwater level was assumed to be zero, and the portion of top of that was calculated using a decreasing liner function.

$$\Delta C_{\_pile\ b\ i} = Inflow_{\_pile\ b\ bottom\ i} + \Delta C_{\_pile\ b\ top\ i}$$

$$Inflow_{\_pile\ b\ bottom\ i} = Inflow_{\_pile\ b\ i} - Inflow_{\_pile\ b\ top\ i}$$

$$Inflow_{\_pile\ b\ i} = \sum_j \left\{ V_{pile\ b\ i,j} \times D_j \times CF_j \right\}$$

$$\Delta C_{\_pile\ b\ top\ i} = C_{\_pile\ b\ top\ i} - C_{\_pile\ b\ top\ (i-1)}$$

$$C_{\_pile\ b\ top\ i} = e^{k_{pile\ b\ top}} \times C_{\_pile\ b\ top\ (i-1)} + \left[\frac{\left(1 - e^{-k_{pile\ b\ top}}\right)}{k_{pile\ b\ top}} \right] \times Inflow_{\_pile\ b\ top\ i}$$

$\Delta C_{\_pile\ b\ i}$: Carbon stock changes in HWP pool of underground buried logs for civil engineering during year i [t-C/year]
$Inflow_{\_pile\ b\ bottom\ i}$: Inflow to HWP pool of the permanent storage portion of underground buried logs for civil engineering during year i [t-C/year]
$\Delta C_{\_pile\ b\ top\ i}$: Carbon stock changes in HWP pool of the top of underground buried logs for civil engineering during year i [t-C/year]
$Inflow_{\_pile\ b\ i}$: Inflow to HWP pool of underground buried logs for civil engineering during year i [t-C/year]
$Inflow_{\_pile\ b\ top\ i}$: Inflow to HWP pool of the top of underground buried logs for civil engineering during year i [t-C/year]
$V_{pile\ b\ i,j}$: Volume of underground buried logs of tree species j for civil engineering [m³/year]
D_j : Density of tree species j [t-d.m./m³]
CF_j : Carbon fraction of tree species j [t-C/t-d.m.] (All tree species are conifers)
$C_{\_pile\ b\ top\ i}$: Remaining of mass reduction portion at the end of year i [t-C]
i : Year for calculation
j : Tree species (Japanese cedar, Japanese larch, Sakhalin fir)
$K_{pile\ b\ top}$: Constant of decreasing linear function of buried pile tops for civil engineering
K=In (2)/225 years

Table 6-76 Overview of the Construction Method

Construction method		Starting year	Tree species	Purpose	Construction standards
Methods for Buildings					
	Method A	2010	Mostly Japanese cedar, with some Japanese larch and Hinoki cypress	Detached houses, low-rise buildings of three stories or less	- Preservative treatment ensures high durability - Usable even above the groundwater level
	Method B	P-LiC : 2013 LP-SoC : 2020	Japanese ceder, Japanese larch	Detached houses, low-rise buildings of three stories or less	- Use below the groundwater level is required. - To prevent corrosion, the top of pile must be sealed by the overlying soil.
	Method C	2012	Japanese cedar,	Small-scale buildings such as detached houses	- When the top of pile is above the groundwater level, place top concrete or similar materials to ensure the top remains below the groundwater level during construction.
Methods for Civil Engineering					
	Method D	1976	Japanese cedar, Japanese larch, Sakhalin fir	River embankments, road embankments, track embankments	- Designed to remain below the groundwater level.

- ***Parameters***

➢ ***Wood density (D)***

The wood density for each tree species in Table 6-21 were used. The value of 0.31, 0.41, 0.45, 0.40, and 0.32 (t-d.m./m^3), for Japanese cedar, Hinoki cypress, Japanese red pine, Japanese larch, and Sakhalin fir were used respectively.

➢ ***Carbon fraction (CF)***

Based on the research results in Japan similar to those for calculating forest biomass, the conifer value (0.51 (t-C/t-d.m.)) was used.

- ***Underground buried logs for construction***

➢ ***Building demolition rate (K_{i-t})***

For buildings constructed in year *t*, the demolition ratio occurring in year *i* after construction (i-t years after construction) was calculated using the floor area data employed to calculate the HWP of the buildings.

➢ ***Pull-out ratio (N) of underground buried logs for construction***

Since the construction method for buildings was newly introduced in 2010, no pull-out test results have been reported at this time. Therefore, the estimated value of 54% obtained from an existing questionnaire survey (Japanese Geotechnical Society, Kanto Branch, Research Committee on Removal and Backfilling of Existing Piles Interfering with New Piles, 2022) regarding the retention or removal of existing log piles during reconstruction was provisionally used.

- ***Underground buried logs for civil engineering***

➢ ***Half-life of the top of underground buried logs for civil engineering ($K_{pile\ b\ top}$)***

The half-life of mass reduction at pile tops located above the groundwater level was estimated to be between 225 and 1392 years based on excavation test results (Numata et al., (2024), Numata et al., (2025)). Therefore, 225 years was adopted as a conservative minimum value.

- ***Activity Data***

➢ ***Volume of piling (V_{pile})***

The volume of piling per tree species was obtained using the data provided by organizations such as the Construction Methods Association. For the permanent storage portion located below the groundwater level, the volume of piling was calculated for each construction project based on the number, diameter, and length data of the piles used. This volume was determined by subtracting the pile top portion from the total pile volume. The pile top length was set at 40 cm.

Table 6-77 the Volume of Piling per Tree Species

			Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Total			㎥	6,435	6,420	2,581	1,887	3,290	12,889	22,717	26,090	26,997	29,428	28,226	25,049
	Methods for Buildings		㎥	NO	NO	NO	NO	3,245	11,957	22,006	25,252	26,953	29,406	28,226	25,049
		Japanese ceder	㎥	NO	NO	NO	NO	3,145	10,962	18,630	24,203	25,994	28,642	27,521	24,266
		Mixed of Japanese larch and Hinoki cypress	㎥	NO	NO	NO	NO	100	300	490	600	620	680	679	677
		Japanese larch	㎥	NO	NO	NO	NO	NO	NO	605	429	339	80	26	106
		Japanese red pine	㎥	NO	NO	NO	NO	NO	695	2,281	20	NO	4	NO	NO
	Methods for Civil Engineering		㎥	6,435	6,420	2,581	1,887	45	932	711	838	44	22	NO	NO
		Mixed of Japanese larch and Sakhalin fir (in Hokkaido)	㎥	5,797	4,422	2,331	783	45	519	711	15	44	22	NO	NO
		Mixed of Japanese larch andJapanese cedar (outside Hokkaido)	㎥	638	1,998	250	1,103	NO	413	NO	823	NO	NO	NO	NO
		Volume of Permanent Storage	㎥	6,152	6,115	2,443	1,753	42	884	676	755	40	19	NO	NO
		Volume of disassembled top of piles	㎥	283	305	138	134	3	48	34	83	4	3	NO	NO

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainty of carbon stock changes was assessed based on the uncertainty of the default factors provided in the *2019 Refinement* and the uncertainties of exiting statistical data, and was estimated to be 30%.

- ***Time-series Consistency***

The activity data and any parameter used consistent statistics in the time-series.

d) Category-specific QA/QC and Verification

Same as Forestland Remaining Forestland (4.A.1.). See section 6.4.1 d).

e) Category-specific Recalculations

In this submission, calculations for carbon stock changes in underground buried logs within the “Other” category have commenced, thereby adding time-series data for this category. See Chapter 10 for the impact of recalculations on the trend.

f) Category-specific Planned Improvements

Regarding the pile extraction ratio associated with building demolition, date accumulation through methods such as sampling will continue, aiming to improve accuracy.

6.11. Other (4.H.)

6.11.1. Concrete Using Biochar

a) Category Description

This category deals with the amount of CO_2 fixed in concrete that stores carbon by mixing it into concrete biochar made by carbonated wood biomass. The net CO_2 removals from this category in FY2024 is 98.4 t-CO_2. For more details, see section 4.9.5.1.c.

6.12. Direct /Indirect N_2O Emissions from N Inputs to Managed Soils (4.(I))

a) Category Description

This category deals with direct /indirect N_2O emissions from N fertilization in land other than cropland and grassland. Emissions from the application of N fertilizer to forest land was estimated assuming that all fertilizers were synthetic, since the survey by the Forestry Agency showed that the majority of N fertilizers applied to forest land were mineral N fertilizers (synthetic N fertilizers). The indirect N_2O emissions were estimated to include N_2O emissions from N volatilization as NH_3 and NO_x and deposition of these gases and their products NH_4^+ and NO_3^- onto soils and the surface of lakes and other waters, and N_2O emissions from leaching and runoff in regions where these events occur. The amount of N fertilizers applied to wetlands or settlements is not individually distinguished, however, their direct N_2O emissions from those categories were reported as "IE" since all direct N_2O emissions from all application of N fertilizers except those applied to forest land are estimated and reported in the Agriculture sector. The emissions from N fertilization in other land were reported as "NO" because there were no actual activities involving N fertilizer in other lands. Fertilization to forest land was reported all together in forest land remaining forest land because it was not possible to separate forest land remaining forest land from forest land converted to forest land. The emissions by this subcategory in FY2024 were 0.57 kt-CO_2 eq. This represents a decrease of 54.5% compared to FY1990.

Table 6-78 Direct /Indirect N_2O emissions from N fertilization

Category	Unit	1990	1995	2000	2005	2010	2011	2012	2013	2015	2020	2021	2022	2023	2024
Total	kt-N_2O	0.005	0.004	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.002	0.002
	kt-CO_2 eq.	1.24	1.07	0.99	0.96	0.83	0.79	0.81	0.83	0.76	0.72	0.85	0.77	0.57	0.57
Forest land	kt-N_2O	0.005	0.004	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.002	0.002
Wetlands	kt-N_2O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Settlements	kt-N_2O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE

b) Methodological Issues

1) Direct N_2O emissions from synthetic N fertilization

- ***Estimation Method***

The direct N_2O emissions from synthetic N fertilization in forest land were estimated by applying Tier 2 estimation method based on decision tree described in the *2006 IPCC Guidelines* because country specific emission factors can be used. The estimation equation was the same as the Agriculture sector.

- ***Parameters***

The country specific emission factor of 0.62% [kg-N_2O-N/kg-N] (Akiyama et al. (2006)), which was applied to the estimation of N_2O emissions resulting from application of synthetic N fertilizer (no nitrification inhibitors) to agricultural soils (other crops), was also applied to the estimation of N_2O emissions from synthetic N fertilization to soils in forest land. For detailed information on the emission factor, see section 5.5.1.1.b) in Chapter 5.

- ***Activity Data***

Results of surveys from 2006 to 2008 on fertilizer application to soils in forest land by the Forestry Agency of Japan were used as activity data. The amount of synthetic N fertilizer applied to soils in forest land in the years in which the surveyed data did not exist was estimated by multiplying the total

amount of synthetic N fertilizer application in *Yearbook of Fertilizer Statistics (Pocket Edition)* up to FY2016 and the amount surveyed by Agricultural Technology Promotion Division, MAFF from FY2017 onwards, by the average percentage of synthetic N fertilizer application to soils in forest land in the period from 2006 to 2008. The average percentage is 0.047% of the total amount of synthetic N fertilizer application.

2) Indirect N_2O emissions from atmospheric deposition of N volatilization

- ***Estimation Method***

Tier 1 method described in section 11.2.2.1 in Vol.4 of the *2006 IPCC Guidelines* is used.

$$N_2O\text{-}N_{ATD} = (F_{SN} \times Frac_{GASF}) \times EF_4$$

$N_2O\text{-}N_{ATD}$	: Annual amount of N_2O-N produced from atmospheric deposition N volatilized [kg N_2O-N]
F_{SN}	: Annual amount of synthetic N fertilizer applied to forest land [kg-N]
$Frac_{GASF}$	: Fraction of synthetic N fertilizer that volatilized as NH_3 and NO_X [kg-NH_3-N + NO_X-N/kg-N]
EF_4	: N_2O emission factor from atmospheric deposition on soils and water surfaces [kg-N_2O-N/kg-NH_3-N+NO_X-N]

- ***Parameters***

Default values from the *2019 Refinement* were used.

➢ ***Fraction of synthetic N fertilizer volatilized as NH_3 and NO_x***

0.11 [kg NH_3-N +NOx-N/kg N applied] (Vol.4 Table 11.3, aggregated)

➢ ***Emission factor (atmospheric deposition)***

0.014 [kg N_2O-N/kg NH_3-N +NOx-N] (Vol.4、Table 11.3, disaggregated, wet climate)

- ***Activity Data***

Amount of N fertilizer applied to forest land as mentioned above.

3) N_2O emissions from leaching /runoff

- ***Estimation Method***

The Tier 1 method described in section 11.2.2.1 in Vol.4 of the *2006 IPCC Guidelines* is used.

$$N_2O\text{-}N_{leach} = (F_{SN} + F_{SOM}) \times Frac_{LEACH-H} \times EF_5$$

$N_2O\text{-}N_{leach}$	: Annual amount of N_2O–N produced from leaching and runoff of N additions [kg N_2O-N]
F_{SN}	: Annual amount of synthetic fertilizer N applied to forest land [kg-N]
F_{SOM}	: Annual amount of N mineralized in mineral soils associated with loss of soil C from soil organic matter [kg-N]
$Frac_{LEACH-H}$	: Fraction of all N mineralized in managed soils in regions where leaching/runoff occurs that is lost through leaching and runoff [kg-N/kg-N]
EF_5	: Emission factor for N_2O emissions from N leaching and runoff [kg-N_2O-N]

- ***Parameters***

Default values from the *2019 Refinement* were used.

➢ ***Fraction of all N mineralized in managed soils***

0.24 [kg N/kg N] (Table 11.3 in Vol.4, aggregated)

➢ ***Emission factor (N leaching and runoff)***

0.011 [kg N_2O-N/kg N] (Table 11.3 in Vol.4, aggregated)

● ***Activity Data***

Amount of N fertilizer applied to forest land as mentioned above.

c) Uncertainty Assessment and Time-series Consistency

● ***Uncertainty Assessment***

The uncertainty estimates of N_2O emissions from N fertilization were 38% by applying the same value as the estimation of the N_2O emissions from N fertilization in the Agriculture sector. The uncertainty of indirect N_2O emissions from N fertilizer was assessed based on the uncertainty of the emission factor (see the *2006 IPCC Guidelines,* Vol.4, p.11.24) and that of the amount of N fertilizer activity. Consequently, the uncertainty of indirect N_2O emissions from this category was assessed at -143% to +493%.

● ***Time-series Consistency***

The emission factor is constant throughout the time series. For activity data, the same sources are multiplied by same ratio throughout the time series. Time-series consistency for this category is ensured.

d) Category-specific QA/QC and Verification

Same as Forest Land remaining Forest Land (4.A.1.). See section 6.4.1.d)

e) Category-specific Recalculations

Due to the revision of the nitrogen fertilizer demand since FY 2017, the emissions from FY2017 onwards were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

6.13. CH_4 and N_2O Emissions from Drainage and Other Management of Organic Soils (4.(II))

a) Category Description

Regarding the CRT-category 4.(II) “emissions and removals from drainage and rewetting and other management of organic and mineral soils”, the CH_4 and N_2O emissions from drainage and cultivation of organic soils were estimated but removals from rewetting of organic soils nor mineral soils were not included. The estimation status of each land-use category is as follows. The emissions from soil drainage activities in forest land are reported as “NO” because soil drainage activities are not carried out in general in Japan. Among cropland and grassland, N_2O emissions from cultivation of organic soils in pasture land and CH_4 emissions from rice cultivation in rice fields were reported in the Agriculture

sector. As for the estimation of CH_4 emissions in other cropland and grassland in this category, only the emissions from uplands fields are estimated since the emissions from orchards and dilapidated farmland are reported as "NO" because soil drainage activities are not carried out. In the case of grassland, only CH_4 emissions from pasture land are estimated in this category because no farming activities are conducted in grassland other than pasture land (grazed meadow and wild land). As explained in section 6.7.1. a), peatlands classified as wetland are reported as "NE" because they are considered to be a minor emission source, while flooded lands and other wetlands are reported as "NA" because the methodologies proposed in the *2006 IPCC Guidelines* and the *Wetland Guidelines* were not applied in Japan. The emissions and removals in the coastal wetland in this category were also reported as "NA" similar to the above. In addition, CH_4 and N_2O emissions from organic soil drainage activities in settlements converted from other land-use categories were estimated.

The emissions by this subcategory in FY2024 were 46.5 kt-CO_2 eq. This represents a decrease of 29.8% compared to FY1990, and a decrease of 0.2 % compared to the previous year.

Table 6-79 CH_4 and N_2O emissions from drainage of organic soils

Category		Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Total		kt-CO_2 eq.	66.2	57.8	53.4	51.4	49.6	47.1	46.8	46.4	46.8	46.6	46.6	46.5
CH_4 Total		kt-CH_4	2.27	1.99	1.85	1.78	1.72	1.64	1.63	1.61	1.63	1.62	1.62	1.62
		kt-CO_2 eq.	63.6	55.8	51.7	49.9	48.2	45.8	45.6	45.2	45.6	45.3	45.3	45.2
	Forest land	kt-CH_4	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA
	Cropland	kt-CH_4	0.96	0.97	0.99	0.99	0.98	0.97	0.96	0.95	0.95	0.95	0.94	0.94
	Grassland	kt-CH_4	0.08	0.09	0.09	0.09	0.08	0.10	0.12	0.09	0.09	0.09	0.09	0.09
	Wetlands	kt-CH_4	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE
	Settlements	kt-CH_4	1.23	0.94	0.77	0.71	0.66	0.57	0.55	0.57	0.59	0.59	0.59	0.59
	Other	kt-CH_4	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA
N_2O Total		kt-N_2O	0.010	0.007	0.006	0.006	0.005	0.005	0.004	0.005	0.005	0.005	0.005	0.005
		kt-CO_2 eq.	2.62	1.99	1.63	1.50	1.40	1.22	1.17	1.22	1.26	1.24	1.25	1.25
	Forest land	kt-N_2O	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA	NO,NA
	Wetlands	kt-N_2O	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE
	Settlements	kt-N_2O	0.010	0.007	0.006	0.006	0.005	0.005	0.004	0.005	0.005	0.005	0.005	0.005

b) Methodological Issues

- ***Estimation Method***

As for upland fields, grassland and settlements converted from other land-use categories, CH_4 emissions from drained inland organic soils were estimated by using Tier 1 method (Equation 2.6) described in section 2.2.2.1 in the *Wetlands Guidelines*.

$$CH_{4_{os}} = A_{os} \times \left[(1 - Frac_{ditch}) \times EF_{CH4\_land} + Frac_{ditch} \times EF_{CH4\_ditch}\right]$$

CH_{4os} : Annual CH_4 emissions from drained organic soils [kg-CH_4]
A_{os} : Land area of drained organic soils [ha]
EF_{CH4_land} : Emission factors for direct CH_4 emissions from drained organic soil from land surface [kg-CH_4/ha]
EF_{CH4_ditch} : Emission factors for CH_4 emissions from drainage ditches [kg-CH_4/ha]
$Frac_{ditch}$: Fraction of the total area of drained organic soil which is occupied by ditches

N_2O emissions from drained organic soil in settlements converted from other land-use categories were estimated by using Tier 2 method (Equation 2.7) described in section 2.2.2.2 in the *Wetlands Guidelines*.

$$N_2O\text{-}N_{os} = A_{os} \times EF_{os}$$

$N_2O\text{-}N_{os}$: N_2O-N emissions from drained organic soil [kg-N_2O-N/yr]
A_{os} : Area of organic soil in settlements converted from other land-use categories [ha]

EF_{os} : N_2O emission factor form drained organic soil [kg-N_2O-N/ha/yr]

- ***Parameters***

As for upland fields, grassland and Land converted to Settlements, the following emission factors for CH_4 from drained organic soils, emission factors for CH_4 from drainage ditches, and the proportion of ditches to the total area of drained organic soils which were provided by the *Wetlands Guidelines* Table 2.3 and Table 2.4, were applied to the estimation. Regarding to emission factors for N_2O from settlements converted from other land-use categories, since default emission factors for settlements have not been provided in the *2006 IPCC Guidelines* and the *Wetlands Guidelines*, considering that conversion to settlements mainly occurs in rice fields in Japan, country specific emission factor for rice field was applied.

Table 6-80 CH_4 and N_2O emission factors for drained organic soils from land surface

Land-use category	Emission factor	Unit	Climate/ vegetation zones
Cropland/Land converted to Settlements	0	kgCH_4/ha/yr	Cropland, drained, Boreal and Temperate (the *Wetlands Guidelines*, Table 2.3)
Grassland	16	kgCH_4/ha/yr	Grassland, deep-drained, nutrient-rich, Temperate (the *Wetlands Guidelines*, Table 2.3)
Land converted to Settlements	0.297	kgN_2O-N/ha/yr	Country specific data (Actual measurement in rice field in Hokkaido)

Table 6-81 CH_4 emission factors for drained organic ditches

Land-use category	Emission factor	Unit	Frac $_{ditch}$ (indicative values)	Climate/ vegetation zones
Deep-drained Grassland/ Cropland/Land converted to Settlements	1165	kgCH_4/ha/yr	0.05	Boreal/ Temperate, Deep drained Grassland, Cropland (the *Wetlands Guidelines*, Table2.4)

- ***Activity Data***

For detailed information on the methods of determining the areas of organic soils in upland fields, grassland and settlements converted from other land-use categories, see section 6.5.1. and section 6.6.1.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainties for parameters were assessed on the basis of default values provided in the *Wetlands Guidelines.* As a result, the uncertainty estimates for the CH_4 emissions from drained inland organic soils were -26% to +48%.

- ***Time-series Consistency***

The emission factor is constant throughout the time series. For activity data, the same sources are used throughout the time series. Time-series consistency for this category is ensured.

d) Category-specific QA/QC and Verification

Same as Forest Land remaining Forest Land (4.A.1.). See section 6.4.1.d)

e) Category-specific Recalculations

Due to a revision of the interpretations of the Land Use Change Survey by Satellite Interpretation, the areas of organic soils were recalculated. With this revision, CH_4 and N_2O emissions from this category

were recalculated for all years. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

6.14. Direct /Indirect N_2O Emissions from N Mineralization Associated with Loss of Soil Organic Matter Resulting from Change of Land Use or Management of Mineral Soils (4.(III))

a) Category Description

The category 4.(III) deals with direct /indirect N_2O emissions from N mineralization or N immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils. In accordance with the *2006 IPCC Guidelines*, N immobilization associated with the gain of soil organic matter is not considered, and only N_2O emissions from mineralization associated with loss of soil organic matter were estimated in Japan.

For forest land, the N_2O emissions from N mineralization associated with loss of soil organic matter resulting from normal forest management of forest land remaining forest land are included in the calculation because soil organic matter increases in land converted to forest land. For cropland, only the emissions from land converted to cropland are included in the calculation because the emissions from cropland remaining cropland are calculated in the Agriculture sector. For grassland, only the emissions from land converted to grassland are included in the calculation because the emissions from grassland remaining grassland are calculated in the Agriculture sector. Only pasture land was included in the calculations, since changes of soil organic matter occur only in pasture land among the three subcategories under the grassland category. For wetlands remaining wetlands and other land remaining settlements, N_2O emissions were reported as “NA” because the decrease in soil carbon stocks does not occur. The emissions from wetlands converted from other land use were reported as “NE” because methodology for the calculation of changes in the accumulation of soil organic matter is not provided. For land converted to settlements and land converted to other land, emissions associated with the loss of soil organic matter were calculated because the reduction in soil carbon stocks is calculated with land-use change.

The emissions from this subcategory in FY2024 were 413.5 kt-CO_2 eq. This represents a decrease of 51.2% compared to FY1990, and an increase of 2.6 % compared to the previous year.

Table 6-82 Direct /Indirect N_2O emissions from N mineralization

Category			Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Total			kt-N_2O	3.20	2.81	2.59	2.31	1.89	1.64	1.53	1.45	1.46	1.48	1.52	1.56
			kt-CO_2 eq.	847.5	744.8	686.2	610.9	501.6	433.4	405.5	384.0	388.0	392.2	403.0	413.5
	Forest land		kt-N_2O	0.39	0.39	0.39	0.40	0.40	0.40	0.40	0.42	0.43	0.44	0.45	0.46
		Forest land remaining Forest land	kt-N_2O	0.39	0.39	0.39	0.40	0.40	0.40	0.40	0.42	0.43	0.44	0.45	0.46
		Land converted to Forest land	kt-N_2O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Cropland		kt-N_2O	0.13	0.09	0.05	0.03	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.05
		Land converted to Cropland	kt-N_2O	0.13	0.09	0.05	0.03	0.02	0.03	0.03	0.04	0.04	0.05	0.05	0.05
	Graassland		kt-N_2O	0.0056	0.0034	0.0020	0.0012	0.0006	0.0011	0.0007	0.0004	0.0004	0.0004	0.0003	0.0003
		Land converted to Graassland	kt-N_2O	0.0056	0.0034	0.0020	0.0012	0.0006	0.0011	0.0007	0.0004	0.0004	0.0004	0.0003	0.0003
	Wetlands		kt-N_2O	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE	NA,NE
		Wetlands remaining Wetlands	kt-N_2O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Land converted to Wetlands	kt-N_2O	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	Settlements		kt-N_2O	2.29	1.98	1.84	1.61	1.28	1.05	0.95	0.86	0.87	0.88	0.91	0.94
		Settlements remaining Settlements	kt-N_2O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Land converted to Settlements	kt-N_2O	2.29	1.98	1.84	1.61	1.28	1.05	0.95	0.86	0.87	0.88	0.91	0.94
	Other land		kt-N_2O	0.39	0.35	0.31	0.26	0.19	0.16	0.15	0.12	0.12	0.11	0.11	0.11
		Land converted to Other land	kt-N_2O	0.39	0.35	0.31	0.26	0.19	0.16	0.15	0.12	0.12	0.11	0.11	0.11

b) Methodological Issues

- ***Estimation Method***

Equation 11.1 and Equation 11.8 described in session 11.2.1 in Vol.4 of the *2006 IPCC Guidelines* is used for estimation.

$$N_2O = N_2O - N_{direct\_N_{mineral,i}} \times 44/28$$

$$N_2O\text{-}N_{direct\text{-}N_{Minerarl_i}} = F_{SOM_i} \times EF1_i \quad \text{(Equation 11.1, Vol.4 of the } \textit{2006 IPCC Guidelines}\text{)}$$

$$F_{SOM_i} = \Delta C_{Mineral_i} \times 1/R_i \quad \text{(Equation 11.8, Vol.4 of the } \textit{2006 IPCC Guidelines}\text{)}$$

$N_2O\text{-}N_{direct\text{-}Nmineral}$	: Direct N_2O emissions from N mineralization as a result of loss of organic matter in mineral soils [kg-N_2O-N]
F_{SOM}	: Annual amount of N mineralized in mineral soils as a result of loss of organic matter in mineral soils [kg-N]
$EF1$	: Emission factor for N_2O-N direct emissions per amount of N mineralization [kg-N_2O-N/kg-N]
$\Delta C_{Mineral}$	: Average annual loss of soil carbon as a result of loss of organic matter in mineral soils [kg-C]
R	: C:N ratio for the soil organic matter (refer to Table 6-83)
i	: Land use/type of land (forest land remining forest land, land converted to cropland (rice fields, upland fields, orchards), land converted to grassland (pasture land), land converted to Settlement, land converted to other land)

For land converted to cropland and land converted to grassland, the equations above were summarized as follows and the value was calculated using the N_2O-N direct emission factor per unit area ($EF_{N2O\text{-}Ni,j}$) [kg-N_2O-N/ha].

$$N_2O\text{-}N_{direct\text{-}N_{Mineral_{i,j}}} = EF_{N2O\text{-}N_{i,j}} \times A_{i,j}$$

A	: Area of mineral soil with loss of soil carbon due to loss of soil organic matter [ha]
i	: Type of land-use subcategory (rice field, upland fields, orchards (fruit orchards, tea gardens), grasslands (pastures))
j	: Regions (Hokkaido, Tohoku, Kanto, Hokuriku, Tokai/Kinki, Chugoku/Shikoku, Kyushu/Okinawa)

- ***Parameters***

➢ ***Parameters used for forest land remaining forest land, Land converted to Settlements and Land converted to Other land***

- ***Soil carbon loss resulting from loss of organic matter in mineral soils in forests land remaining forest land ($\Delta C_{Mineral}$)***

The change in soil carbon stock per unit area obtained by the Century-jfos model described in 6.5.1. b)2 where the decrease in soil carbon occurred were multiplied by the area.

- ***Soil carbon loss resulting from loss of organic matter in mineral soils on other land converted to settlement and other land converted from other land use ($\Delta C_{Mineral}$)***

For the amount of soil carbon loss resulting from loss of organic matter in mineral soils in land converted to other land, the amount of loss in carbon stock in mineral soils caused by land-use change obtained in 6.8.2. b)3) and 6.9.2. b)3 was used.

- ***Emissions of N_2O per amount of N mineralization (EF_i)***

The default value [0.006 kg-N_2O-N/kg-N] provided in the *2019 Refinement* was used.

- ***C/N ratio for solids (R_i)***

C:N ratios for forest land were applied for forest land remining forest land, and C:N ratios for forest, cropland, and grassland before land-use conversion were used for land converted to settlements and land converted to other land, respectively. For C/N ratio for forest land, since there was no significant difference between the domestic survey and the default value in the *2006 IPCC Guidelines,* the latter was applied. For C/N ratio for cropland and grassland, the average values for each land use (Table 6-83) obtained from the soil survey by Matsui et al. (2021) was applied.

Table 6-83 C/N ratio for soil by land use [kg-C/kg-N]

Land use	C/N ratio	Reference and method
Forest	15.0	*2006 IPCC Guidelines*, Vol.4, chp.11, p11-16
Rice fields	11.5	Established by all carbon amount and all nitrogen amount in soil expect for organic soil in each land use from the data of soil group based on regular point observation from 2015 to 2018 in Matsui, et al. (2021).
Paddy fields	12.3	
Orchards	11.6	
Pasture land	13.1	

➢ ***Parameters used for cropland converted from other land-use and grassland converted from other land use***

The following parameters were set by Shirato et al. (2021). An overview of the settings is given as below. Note that the same parameters as those used in the agriculture sector are used (See section 5.5.1.5.b).

- ***Amount of emission factors of N_2O per unit area ($EF_{N2O\_Ni,j}$)***

The emissions of N_2O per unit area ($EF_{N2O\text{-}Ni,j}$) in land use and soil type of land (i) and region (j) were calculated using the N_2O statistical model of Mu et al. (2009) given by the following equation.

$$EF_{N2O\text{-}N_{i,j}} = 0.0801 \times e^{0.00722 \times C_{ms-loss_{i,j,k}} \times \frac{1}{R_{i,k}}}$$

However, since the aforementioned statistical model does not take into account for the data of rice fields, the default emission factor for N_2O per mineralized N in rice fields (EF_{1FR}=0.004) listed in

Table 11 of section 11.2.1.2 in the *2019 Refinement* was applied for rice fields.

The results of the calculations performed by Shirato et al. (2021) are shown in the Table 6-84.

Table 6-84 Emission factors of N_2O per unit area in each region for each type of land use in cropland and grassland ($EF_{N2O\text{-}Ni,j}$)

Region	Rice fields	Upland fields	Orchards and tea plantations		Pasture land
			Orchards	Tea plantations	
Hokkaido	0.244	0.210	0.246	—	0.206
Tohoku	0.269	0.189	0.197	—	0.187
Kanto	0.291	0.166	0.181	0.178	0.178
Hokuriku	0.265	0.167	0.192	0.177	0.199
Tokai-Kinki	0.284	0.172	0.194	0.179	0.195
Chugoku-Shikoku	0.307	0.200	0.190	0.199	0.191
Kyusyu-Okinawa	0.310	0.197	0.181	0.178	0.173

- ***Soil carbon loss per unit area resulting from loss of organic matter in mineral soil ($c_{ms\text{-}loss\ i,j,k}$)***

The decomposition amount of soil carbon per unit area not derived from the input of organic matter was calculated by using the Roth C model described in section 6.5.1. b)3) by setting the input of organic matter at zero for the most recent year after giving the long-term normal operation of the models calculating the changes in soil carbon stock for the past years. Calculations were performed for five years from FY2014 to FY2018, taking annual variations into account. The average value for five years was calculated for each land type, region, and soil type, and this constant value was used as a fixed value in the time series.

C/N ratio for solids ($R_{i,k}$)

The 0-30 cm depth data obtained from field surveys conducted in 2015-2018 for each land use and each soil type of agricultural land were used.

- ***Activity Data***

➢ ***Mineral soil area with loss of soil carbon resulting from loss of soil organic matter in cropland and grassland (A)***

In cropland and grassland, area of mineral soils in cropland and grassland (pasture land) was used as activity data because soil disturbance caused by land-use change and normal agricultural activities oxidizes the organic matter in mineral soils and causes carbon loss. In pasture land, the area of activity was defined as the mineral soil area multiplied by the renewal rate used in 6.6.1. b), because the area where renewal was carried out was considered to be the area where there was actual activity involving soil disturbance.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainties of emissions/removals for forest land, settlements and other land were assessed on the basis of carbon stock change in soil and C:N ratio for the soil organic matter. The uncertainties of parameters provided in the *2006 IPCC Guidelines* were used. The uncertainty of the carbon stock change for land converted to cropland and grassland were assessed by using the standard deviation for EFs described in Shirato et al. (2021) and by using the standard error for ADs given in the *Statistics of Cultivated and Planted Area*, which are the same as the assessments conducted in Agriculture sector.

As a result, the uncertainties of direct N_2O emissions from N mineralization associated with loss of soil organic matter were assessed at -59% to +159%. The uncertainty of indirect N_2O emissions from N mineralization associated with loss of soil organic matter was from -118% to +288%, which is the same value with the uncertainty of direct N_2O emissions from N mineralization associated with loss of soil organic matter.

- ***Time-series Consistency***

The emission factor is constant throughout the time series. For activity data, the same sources are used throughout the time series. Time-series consistency for this category is ensured.

d) Category-specific QA/QC and Verification

Same as Forest Land remaining Forest Land (4.A.1.). See section 6.4.1.d)

e) Category-specific Recalculations

Due to a revision of the interpretations of the Land Use Change Survey by Satellite Interpretation, the areas of other land-use converted from forest land were recalculated. With this revision, N_2O emissions from this category were recalculated for all years. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

6.15. Biomass Burning (4.(IV))

a) Category Description

This category deals with emissions of CH_4, CO, N_2O and NOx from biomass burning. Those emissions are reported by each land use, for those associated with wildfires, and for those associated with controlled burning activities. In Japan, the burning of vegetation on the previous land use is not implemented when a land use is converted to another land use, and activity data of fire and controlled burning is not possible to be separated by land-use conversion history. Therefore, it is reported without classifying land by conversion or no conversion. In the CRT, they are reported collectively in the land use remaining in the same land-use category. The emissions of CO and NO_X are shown in Annex 5.

The emissions from wildfires in forest land are estimated using the data on the actual area affected by forest fires and the volume of standing stock damaged. The emissions from controlled burning activities in forests are reported as “NO” because the activities are stringently restricted by the “Waste Management and Public Cleansing Act” and “Fire Service Act” and are not implemented in Japan.

The emissions from controlled burning in cropland are estimated for woody biomass burning of pruned branches from orchard (agricultural residues burning). One of the characteristics of Japan’s cropland is intensive management. Under this management style, the occurrences of wildfire are regarded as negligible, and therefore, the emissions from wildfires in cropland are reported as “NO”.

The emissions from controlled burning in grassland are estimated because open burning is conducted to maintain the grassland. However, the emissions from wildfires in grassland are reported as “NO” for the same reasons as cropland.

The emissions from wildfires and controlled burning in wetland are assessed as insignificant "NE" and are not estimated.

The emissions from wildfires in settlements and other land are reported as "NO" because the activities are stringently restricted by the "Waste Management and Public Cleansing Act" and "Fire Service Act" and are not implemented in Japan.

In addition, CO_2 emissions are not included in this category because it was included in the estimation of carbon stock changes.

The emissions from this subcategory in FY2024 were 234.4 kt-CO_2 eq. This represents an increase of 222.0% compared to FY1990 and an increase of 299.7% compared to the previous year. These substantial variations are driven by the occurrence of wildfires in forests.

Table 6-85 Non-CO_2 emissions from biomass burning

Category		Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Total		kt-CO_2 eq.	72.8	70.0	65.8	65.9	57.0	54.9	56.7	50.5	58.2	51.1	58.6	234.4
CH_4 Total		kt-CH_4	1.9	1.8	1.7	1.7	1.4	1.3	1.4	1.2	1.5	1.2	1.5	7.4
		kt-CO_2 eq.	53.1	50.8	47.3	47.7	39.5	37.7	39.5	34.0	41.3	34.6	41.7	206.8
	Forest land	kt-CH_4	0.4	0.4	0.4	0.4	0.2	0.2	0.2	0.1	0.4	0.2	0.4	6.3
	Cropland	kt-CH_4	1.0	0.9	0.8	0.8	0.7	0.7	0.7	0.6	0.6	0.6	0.6	0.6
	Grassland	kt-CH_4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
	Wetlands	kt-CH_4	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	Settlements	kt-CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Other land	kt-CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N_2O Total		kt-N_2O	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.06	0.10
		kt-CO_2 eq.	19.7	19.1	18.5	18.2	17.5	17.2	17.2	16.6	17.0	16.5	16.9	27.6
	Forest land	kt-N_2O	0.003	0.003	0.003	0.003	0.001	0.001	0.002	0.001	0.003	0.001	0.003	0.043
	Cropland	kt-N_2O	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01
	Grassland	kt-N_2O	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
	Wetlands	kt-N_2O	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	Settlements	kt-N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Other land	kt-N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

b) Methodological Issues

1) CH_4 and N_2O emissions from forest fires (wildfires)

- ***Estimation Method***

For CH_4, and N_2O emissions due to biomass burning from forest fires, the equation in *GPG-LULUCF* (Equation 3.2.19, page 3-49, Chapter 3) was used.

- ***CH_4***

$$bbGHG_F = Lc_{F\_bb} \times ER \times 16/12$$

- ***N_2O***

$$bbGHG_F = Lc_{F\_bb} \times NC_{ratio} \times ER \times 28/12$$

$bbGHG_F$: GHG emissions due to forest biomass burning [t-GHG]
Lc_{F_bb} : Loss of carbon stock due to forest fires [t-C/yr]
ER : Emission ratio (CH_4 : 0.012, N_2O : 0.007)
NC_{ratio} : Nitrogen-to-carbon ratio of the biomass

- ***Parameters***

➢ ***Emission ratio (ER)***

The following default values provided in the *GPG-LULUCF*, Table 3A.1.15 are applied.

CH_4: 0.012, N_2O: 0.007

➢ ***N/C ratio (NC_{ratio})***

The following default value provided in the *GPG-LULUCF*, page 3.50 is applied.

N/C ratio: 0.01

- ***Activity Data***

➢ ***Loss of carbon stock due to forest fire (Lc_{F_bb})***

The loss of carbon stock due to forest fire is estimated by the Tier 2 method in the *2006 IPCC Guidelines*. For each of the national forest land and private forest land, the loss of carbon stock is estimated from the fire-damaged stock volume multiplied by wood density, the biomass expansion factor and the carbon fraction of dry matter.

$$Lc_{F\_bb} = \sum_j V_{F\_bb_j} \times D_j \times BEF_j \times CF_j$$

Lc_{F_bb}	: Loss of carbon stock due to forest fires [t-C/yr]
V_{F_bbj}	: Volume of fire-damaged stock [m^3/yr]
D_j	: Wood density [t-d.m./m^3]
BEF_j	: Biomass expansion factor
CF_j	: Carbon fraction of dry matter [t-C/t-d.m.]
j	: National forests or private forests

Fire-damaged stock volume (V_{F_bbj}) is separately estimated for national forests and private forests. With regard to national forests, the fire-damaged volume in national forests is estimated by using the *Handbook of Forestry Statistics*. With regard to private forests, the fire-damaged stock volume is estimated by using the actual damaged area and damaged stock volume by age class (inquiry survey by Forestry Agency). The actual lost area and fire-damaged stock volume can be obtained for age 5 and above, but only the actual lost area can be obtained for age 4 and below. Therefore, firstly, "the damaged stock volume per unit area" is estimated by multiplying "the stand volume per unit area of age class equal to or under 4" estimated by the *Forestry Status Survey* and the NFRDB, by "loss ratio of damaged stock volumes (ratio of damaged stock volume to standing stock volume) of age classes equal to or over 5 in private forests" under the assumption that the loss ratio is constant regardless of age class. Then, the fire-damaged stock volume in private forests below the age of 4 was estimated by multiplying "the damaged stock volume per area" by the actual lost area.

The values for wood density (D_j) and biomass expansion factors (BEF_j) for national and private forest land are determined as weighted averages using the ratios of intensively managed forests and semi-natural forests. The average value for conifer and broad leaf (0.5) was used for the carbon fraction of dry matter (CF_j).

Table 6-86 Wood density and biomass expansion factors for national and private forests

Type	Wood density [t-d.m./m^3]	Biomass expansion factor
National forest	0.49	1.61
Private forest	0.46	1.61

Reference: Based on Forestry Agency data

Table 6-87 Damaged stock volume due to forest fire (wildfire)

Category		Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Damaged timber volume due to forest fire in national forest		m³	3,688	1,014	1,599	359	16,091	279	2,472	275	498	734	342	1,579
Damaged timber volume due to forest fire in private forest		m³	64,918	69,180	60,640	73,348	15,810	26,620	38,571	17,235	62,745	24,479	69,476	1,060,902
≧5	Actual damaged area	kha	0.29	0.94	0.48	0.35	0.07	0.18	0.22	0.07	0.30	0.05	0.16	2.02
	Damaged timber volume	m³	47,390	58,129	54,487	59,235	12,780	25,204	36,693	15,914	61,583	18,048	64,887	1,059,875
≦4	Actual damaged area	kha	0.27	0.51	0.16	0.27	0.06	0.04	0.05	0.03	0.03	0.08	0.06	0.01
	Damaged timber volume	m³	17,528	11,051	6,153	14,113	3,030	1,416	1,878	1,321	1,163	6,430	4,589	1,027

Reference: Based on *Handbook of Forestry Statistics* for national forest, and Forestry Agency data for actual damaged areas and damaged stock volume of private forest of 5 years old and above, and those of 4 years old and below are estimated values.

2) CH_4 and N_2O emissions from burning of pruned branches from orchard trees (agricultural residues burning)

- ***Estimation Method***

For CH_4 and N_2O emissions due to residues burning of pruned branches from orchard trees, the equation provided in the *2006 IPCC Guidelines* (Equation 2.27, p2.42, Vol.4) was applied. The estimation equation is as follows:

$$bbGHG_C = W_{C\_bb} \times C_f \times G_{ef} \times 10^{-6}$$

$bbGHG_C$: GHG emissions due to biomass burning of pruned branches from orchard trees [kt- GHG]
W_{C_bb} : Amount of biomass burned from pruned branches [t-d.m.]
C_f : Combustion factor
G_{ef} : Emission factor [t/kt-d.m.]

- ***Parameters***

For the combustion factor (C_f), a value of 0.9 which has been used in field burning of crop residues in agriculture in Japan is applied. For emission factor (G_{ef}), the default emission factors of "Agricultural residue" provided in the *2006 IPCC Guidelines* are used.

Table 6-88 Emission factors [t/kt-d.m.]

Category	CH_4	N_2O
Agricultural residue	2.7	0.07

Reference: *2006 IPCC Guidelines*, Vol.4, chp.2, Table 2.5

- ***Activity Data***

➢ ***Burnt amount of pruned branches from orchard trees (residues burned)***

The burnt amount was calculated by multiplying the same cultivation area of the orchards as 4.B, by burnt amount of pruned branches from orchard trees (dry matter residues) per unit area (400 kg-d.m./10a) from the domestic field survey conducted by the National Institute of Resources (1982), and by the combustion ratio of burning pruned branches in field (25 %) from the result of monitoring survey of soils in 2008.

$$W_{C\_bb} = \sum_i A_i \times E \times 10 \times R$$

W_{C_bb} : Burnt amount of pruned branches from orchard trees (residues burned) [kg-d.m.]
A_i : Cultivation area of orchard tree *i* [ha]
E : Dry matter residue weight per unit area [kg-d.m./10a]
R : Combustion ratio of residues
i : Type of orchard tree

3) CH_4 and N_2O emissions from grassland burning (controlled burning)

- ***Estimation method***

For CH_4 and N_2O emissions due to biomass burning in grassland, the equation described in the *2006 IPCC Guidelines* (Equation 2.27, p2.42, Vol.4) was applied. The estimation equation is as follows:

$$bbHGH_G = A_{G\_bb} \times m_{G\_bb} \times C_f \times G_{ef} \times 10^{-6}$$

$bbHGH_G$: GHG emissions from biomass burning in grassland [kt-GHG]
A_{G_bb} : Area burned in grassland[ha]
m_{G_bb} : Mass of available fuel for combustion [t-d.m./ha]
C_f : Combustion factor
G_{ef} : Emission factor [t/kt-d.m.]

- ***Parameters***

For the combustion factor, value of 0.9 is applied according to expert judgment that considering survey data on burning of grassland in Japan. For emission factor, the default emission factors of "Savanna and grassland" provided in the *2006 IPCC Guidelines* are used.

Table 6-89 Emission factors [t/kt-d.m.]

Category	CH_4	N_2O
Savanna and grassland	2.3	0.21

Reference: *2006 IPCC Guidelines*, Vol.4, chp.2, Table 2.5

- ***Activity data***

➢ ***Burnt Amount***

The total mass of available fuel for combustion in grassland is calculated by multiplying the area of grassland burned (A_{G_bb}), by the average amount of dry mass per unit area. There is no comprehensive statistical information or official data relating to the area of grassland burned. However, the area of controlled large-scale burning events on grassland which may affect national GHG emissions is limited in Japan. The area burned for this estimation is estimated based on the five controlled large-scale burning events exceeding 1,000 ha: Aso, Higashi-Fuji exercise area, Kita-Fuji exercise area, Watarase flood control basin, and Akiyoshidai. The total planned burnt areas of these five events of 24,400ha are used as activity data uniformly over the whole year. For the amount burned per unit area, a value of 10 t-d.m./ha is applied according to expert judgment considering survey data on grassland burned in Japan.

4) CH_4 and N_2O emissions from biomass burning in Wetlands

Controlled burning and wildfire occur only at riverside in Wetlands in Japan.

The emissions from biomass burning in Wetland were estimated with Tier 1 methodology (the *2006 IPCC Guidelines*, Equation 2.27) with default EF of All savanna and grassland on Table 2.5 in the *2006 IPCC Guidelines*. 'MB × Cf' was applied 10.0 t-d.m./ha of All savanna grasslands (mid/late dry season burns) on table 2.4 in *the 2006 IPCC Guidelines*. (i.e. 1.2 t-CO_2 eq./ha)

From the fire and disaster statistics, 5,500 - 8,000 wildfire occurred on non-forest, agriculture and settlement area per year which included wildfire at riverside. Under the assumption that all these wildfires occurred at riverside, if area burned per a wildfire accounts for more than 11 ha, total emission from this category is classified as "significant" in LULUCF sector in Committee for GHG Emissions Estimation Methods in Japan.

Area of wildfire in forest land in Japan reaches some hundreds ha at the most. Over 10 ha wildfire is regarded as massive fire in Japan. In the view of these facts and uncertainty of parameters, emission in this category was judged as insignificant. Furthermore, the emissions from biomass burning along downstream of Arakawa River at which data on wildfire is available was about 300 t-CO_2 eq. This value applied to estimate the upper limit of applicability of "NE" for being considered insignificant.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainly Assessment***

The uncertainties for parameters and activity data related to forest fires were individually assessed on the basis of field studies, expert judgment, or default values provided in the *2006 IPCC Guidelines*. Regarding the uncertainties for parameters and activity data related to biomass burning for pruned branches from orchard trees, the uncertainties (CH_4: 296%, N_2O: 300%) for crop residues burning in the Agriculture sector were substituted. For the uncertainty for biomass burning from grassland, the uncertainties for parameters and activity data were assessed on the basis of field studies, and default values provided in the *2006 IPCC Guidelines* (CH_4: 56%, N_2O: 63%). As a result, the uncertainty estimates for the emissions resulting from biomass burning were 32% for CH_4 and 52% for N_2O, respectively.

- ***Time-series Consistency***

Time-series consistency for biomass burning in forest land remaining forest land is ensured by using the same data sources (*Handbook of Forestry Statistics* compiled by the Forestry Agency, and the data provided by the Agency) and the same methodology from 1990 to 2024. Time-series consistency for biomass burning for pruned branches from orchard trees and for grassland is ensured by using the same data sources (*Statistics of Cultivated and Planted Area* by the MAFF.)

d) Category-specific QA/QC and Verification

Same as Forest Land remaining Forest Land (4.A.1.). See section 6.4.1.d)

e) Category-specific Recalculations

Due to the revisions to some orchard area from FY 2021 onwards, CH_4 and N_2O emissions from burning of pruned residues in orchards have been recalculated for FY 2021 and subsequent years. See Chapter 10 for the impact of recalculations on the trend.

f) Category-specific Planned Improvements

No improvements are planned.

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Chapter 7. Waste (CRT sector 5)

7.1. Overview of Sector

7.1.1. Overview of Waste Management and Estimation Category

In the waste sector, greenhouse gas (GHG) emissions from treatment and disposal of waste are estimated for solid waste disposal (5.A.), biological treatment of solid waste (5.B.), incineration and open burning of waste (5.C.), wastewater treatment and discharge (5.D.), and other (5.E.)[1] in accordance with treatment processes. Figure 7-1 and Figure 7-2 show the estimation categories of waste/wastewater treatment system and/or waste classification in Japan.

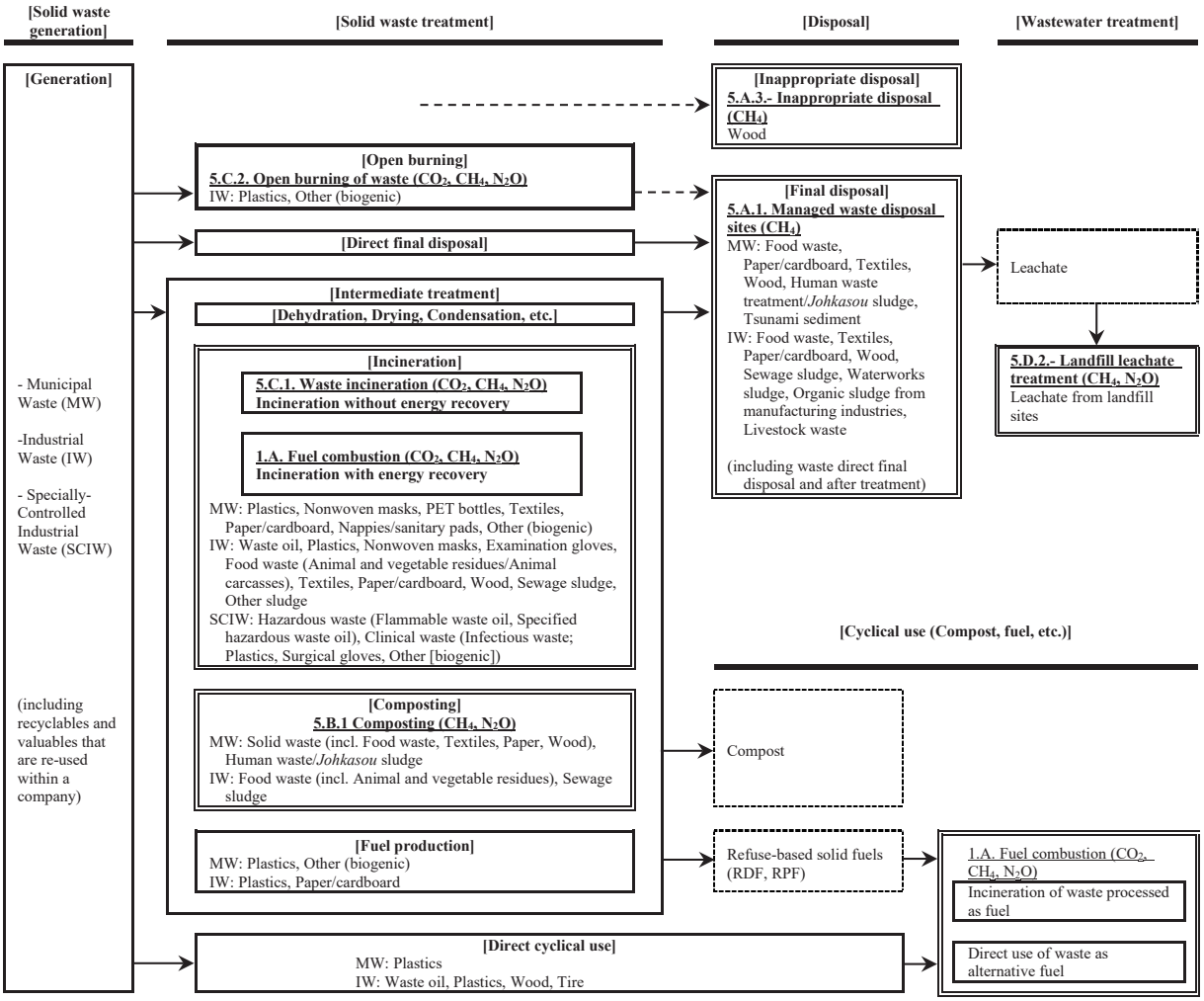

Figure 7-1 Flow chart of solid waste management and the estimation categories

[1] Data for some emission source categories in the waste sector are complemented by estimation, when statistical data or related data are not available. The methodologies for this estimation are not described in this chapter. For details, refer to the website of MOE, *Committee for the Greenhouse Gas Emissions Estimation Methods* (https://www.env.go.jp/earth/ondanka/ghg-mrv/committee/).

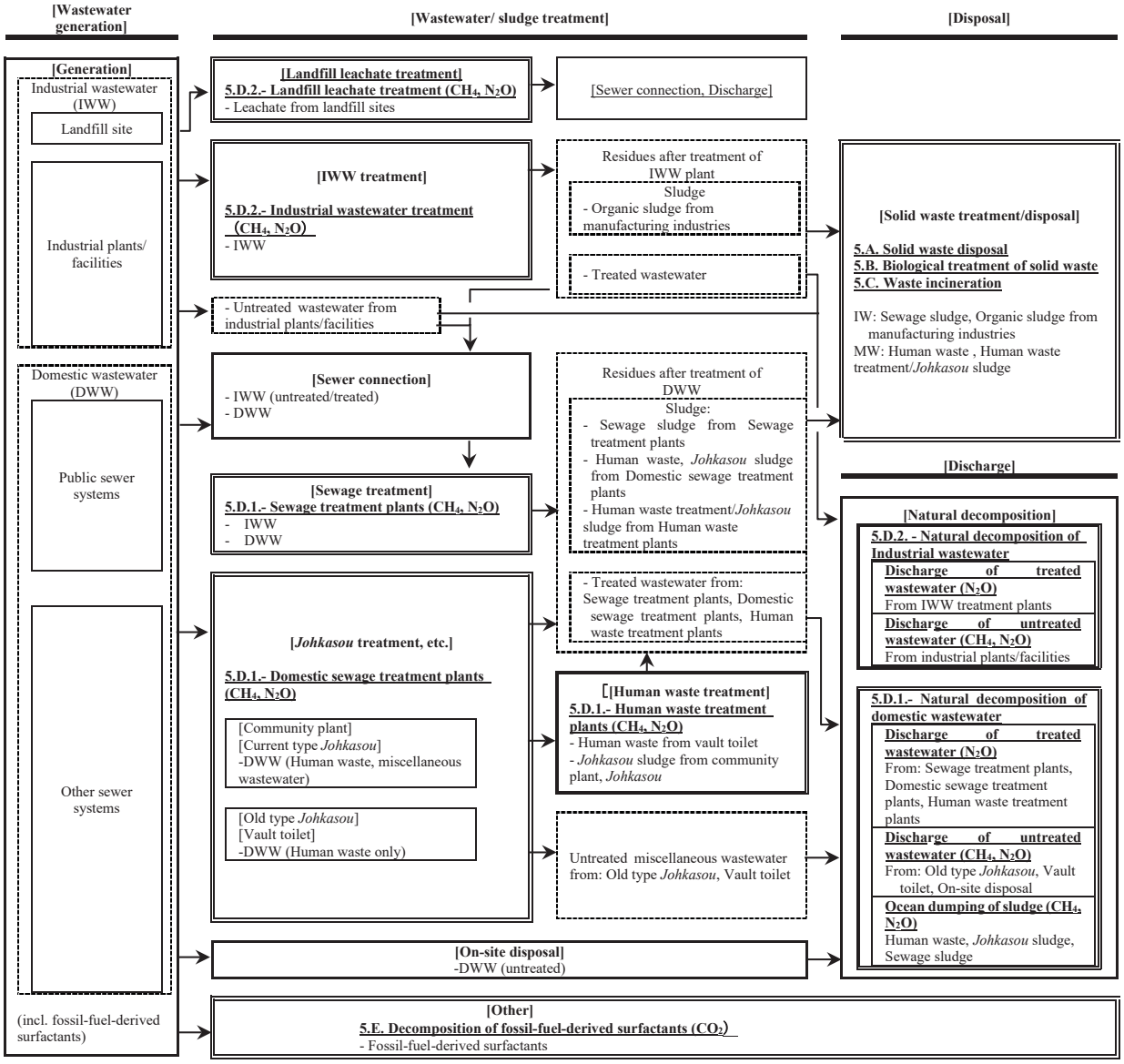

Figure 7-2 Flow chart of wastewater/sludge treatments and the GHG estimation categories

"Waste" to be covered in this sector is the waste as defined in the *2006 IPCC Guidelines*. In the case of Japan, the waste includes not only Municipal Waste (MW), including Municipal Solid Waste (MSW) and human waste, and Industrial Waste (IW), including Specially-Controlled Industrial Waste (SCIW) as defined by the Waste Management and Public Cleansing Act, but also recyclables and valuables that are reused within a company. These items are reported under sections "7.3.1. Composting (5.B.1)", "7.4.3.2. Direct Use of Waste as Alternative Fuel (1.A.)", and "7.4.3.3. Incineration of Waste Processed as Fuel (1.A.)". Since the waste statistics are compiled separately for MW and IW in Japan, estimation methodologies for many of emission sources in the waste sector are discussed respectively for MW and IW. Emissions from the treatment of disaster waste caused by the Great East Japan Earthquake, which occurred on 11th March, 2011, are reported in this sector.

7.1.2. Overview of Greenhouse Gas Emissions in Waste Sector

In FY2024, emissions from the Waste sector resulted in 15,310 kt-CO_2 eq. and accounted for 1.5% of Japan's total GHG emissions (excluding LULUCF). Total emissions had decreased by 46.8% compared

to those of FY1990 and decreased by 3.2% compared to those of the previous year. Breakdown of FY2023 emissions of the Waste sector by category shows that the largest contributor to the emissions is Incineration and Open Burning of Waste (5.C.) (excluding emissions from waste incineration and energy use reported in the energy sector) accounting for 63.2% (a decrease by 14.1% from FY1990) followed by the Wastewater Treatment and Discharge (5.D.) accounting for 22.0% (a decrease by 37.8% compared to FY1990), Solid Waste Disposal (5.A.) accounting for 9.5% (a decrease by 87.1% from FY1990), Other (5.E.) accounting for 3.7% (a decrease by 20.3% from FY1990), and Biological Treatment of Solid Waste (5.B.) accounting for 1.7% (an increase by 18.3% from FY1990). Breakdown of the emissions of the Waste sector by gas/category shows that the largest contributor to the emissions is CO_2 emissions associated with the incineration/open burning of fossil-fuel-derived waste such as waste plastics and waste oil accounting for 55.3%, followed by N_2O emissions from wastewater treatment and discharge accounting for 11.3%, CH_4 emissions from wastewater treatment and discharge accounting for 10.7%.

The changes in GHG emissions from the Waste sector since FY1990 show a trend in a decrease in CH_4 emissions from the solid waste disposal on land associated with a decrease in the amount of disposal of biodegradable waste due to the improvement in recycling rate since the enactment of the Basic Law for Establishing the Recycling-based Society and other recycling laws. Note that while the recycling rate of waste in Japan has increased in FY2022 (16.3%) in comparison with FY1990 (7.4%), the total disposal amount has decreased in FY2022 (13 Mt) in comparison with FY1990 (109 Mt) (the *Annual Report on the Environment in Japan*, Ministry of the Environment: MOE). On the other hand, emissions from the incineration of fossil-fuel-derived waste with energy recovery, emissions from the direct use of fossil-fuel-derived waste as alternative fuel, and emissions from the incineration of fossil-fuel-derived waste processed as fuel, which are accounted for in the energy sector, have increased along with an increase of waste recycling rate (an increase by 62.5% from FY1990).

7.1.3. General Description for Methodological Issues on the Waste Sector

- ***Estimation Method and Emission Factors***

Japan generally employs country-specific methodologies and emission factors in GHG emission estimations on the waste sector. For the category on which sufficient views are not obtained from domestic survey, default methodologies and emission factors in the *2006 IPCC Guidelines* are partially applied. For details, see articles "*b) Methodological Issues*" in each category's section.

Table 7-1 Summary for methods and emission factors used on waste sector

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2		CH_4		N_2O	
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
5. Waste	CS	CS	CS, D, T2, T3	CS, D	CS, D, T2	CS, D
A. Solid waste disposal	NA	NA	T3	CS		
B. Biological treatment of solid waste			T2	CS	T2	CS
C. Incineration and open burning of waste	CS	CS	CS, T2	CS, D	CS, T2	CS, D
D. Wastewater treatment and discharge			CS, D	CS, D	CS, D	CS, D
E. Other	CS	CS	NA	NA	NA	NA

Note:
D: IPCC default, T2: IPCC Tier 2, T3: IPCC Tier 3, CS: country-specific method or EF, NA: not applicable

- ***Activity Data***

As activity data in the methodologies on the waste sector, the *Report of the Survey on the State of Wide-Range Movement and Cyclical Use of Waste – Volume on Cyclical Use* (Environmental Regeneration and Material Cycles Bureau of MOE) (hereinafter referred to as the *Cyclical Use of Waste Report*), the *Waste Treatment in Japan* (the same agency of MOE), and the *annual editions of Sewage Statistics – Admin. Ed.* (Japan Sewage Works Association: JSWA) (hereinafter referred to as the *Sewage Statistics*) are mainly referred. Also, various other statistics related to the waste management and provided data from relevant agencies and bodies are used. For details, see articles "*b) Methodological Issues*" in each category's section.

Note that treatment and disposal amount of disaster wastes since FY2011, when the Great East Japan Earthquake occurred, are surveyed by Environmental Regeneration and Material Cycles Bureau of MOE, and are considered in the activity data to estimate GHG emissions from these sources.

7.1.4. General Assessment Procedure for the Uncertainties in the Waste Sector

The uncertainty of GHG emissions in the waste sector is assessed based on the *2006 IPCC Guidelines* and MOE (2013a). The general assessment procedures are indicated below. For details, see articles "*c) Uncertainty Assessment and Time-series Consistency*" in each category's section.

- ***Emission Factors***

The uncertainties in emission factors are assessed by using the 95% confidence interval of measured data, or by expert judgment. When emission factor is derived from formulas depending on several parameters, the uncertainty is assessed by combining the uncertainties of these parameters using error propagation equation.

- ***Activity Data***

Regarding the uncertainty for activity data, due to the lack of information on statistical errors in quoted references, it is difficult to assess uncertainties based on concrete evidence. Therefore, it is assessed by expert judgment as indicated in the Table 7-2.

Table 7-2 Uncertainty for statistics used for activity data on waste sector

Statistics used for activity data	Range of uncertainty		Justification for assessing the uncertainty
	(-)	(+)	
Municipal waste (Domestic wastewater excl. sewage)	-10%	+10%	In the uncertainty which is provided as default value in the *2006 IPCC Guidelines*, the value (±10%) in the case where waste weight is measured by truck scale is adopted based on expert judgment.
Industrial waste (Industrial wastewater)	-30%	+30%	In the uncertainty which is provided as default value in the *2006 IPCC Guidelines*, the value (±30%) "in the case where amount of generated waste is regularly collected" is adopted based on expert judgment.
Specially-Controlled industrial waste	-60%	+60%	The twofold higher uncertainty than the value of IW statistics is adopted based on expert judgment.
Valuables (valuable waste)	-30%	+30%	In the uncertainty which is provided as default value in the *2006 IPCC Guidelines*, the value (±30%) "in the case where amount of generated waste is regularly collected" is adopted based on expert judgment.
Sewage	-5%	+5%	Since the data has collected through complete survey for whole sewage treatment plants in Japan, it is considered that data is accurate enough to reflect the current status. Therefore, the uncertainty is assessed at 5% based on expert judgment.
Water works	-5%	+10%	Sampling error in the statistics is assessed at 5% based on expert judgment as well as sewage statistics. However, water works statistics target only water companies and suppliers of city water which have more than 5001 official water supplied population; sludge generated from small-sized filter plants by private water-supply system is not identified. Therefore, a 5% is added to the upper limit of uncertainty since the population of private water-supply system account for 5% of the total.

- ***Emissions***

Since emissions are calculated by formulas, the uncertainty is assessed by combining the uncertainties of emission factors and activity data using the error-propagation formula.

7.1.5. Sector-specific QA/QC and Verification

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Annex 4.

7.1.6. General Recalculations for Emissions from Waste Sector

- ***Update of the Statistical Data***

Most of statistics in Japan are compiled on the basis of Japan's fiscal year (starting on April 1 of the year and ending on March 31 of the following year). Therefore, some process of compiling statistics for the latest fiscal year, which is referred to in waste sector inventory, does not complete in time for an inventory compilation.

In such a case, the activity data of previous fiscal year are generally adopted for the latest fiscal year in accordance with the *2006 IPCC Guidelines*, but adoptions of more appropriate estimations are desirable for data of latest fiscal year for the main categories. To obtain such better activity data related to solid waste to be quoted from the *Cyclical Use of Waste Report* (MOE) as main statistics, "the Committee for Improvement of the Survey on the State of Cyclical Use of Waste" organized by Environmental Regeneration and Material Cycles Bureau of MOE, annually prepares preliminary data for the latest year estimated by using economic indexes such as volume/value of shipment of products to be finally disposed of (*Review Report on Improvement of Accuracy and Faster Compilation of Waste Statistics*, MOE). Thus, GHG emissions for the latest fiscal year in the waste sector are estimated by using this preliminary activity data. Consequently, every year, these preliminary data are updated with definite data, and emissions are recalculated in the inventory of its next annual submission.

- ***Improvement of Estimation Methodologies***

To better reflect the actual status of national GHG emissions in waste sector in the methodology, the choice of the estimation methodologies, activity data, emission factors and parameters used in this sector

are reviewed by the breakout group on waste sector in the Committee for the Greenhouse Gas Emissions Estimation Methods. Methodological changes based on the considerations at the committee are reflected to the inventory submitted every year, and consequently the GHG emissions from categories whose methodologies have been changed are recalculated. For details of the methodological changes in this submission, see the sections for recalculation for each category in this chapter and related Table 10-8 in Chapter 10.

7.2. Solid Waste Disposal (5.A.)

This category covers CH_4 emissions from solid waste disposal on land. For this emission source category, estimation methodologies are discussed separately for MW and IW in accordance with Japan's waste classification system, and emissions are estimated for the sources presented in Table 7-3. As for reporting category in the CRT for each waste type, see also Table 7-6.

Table 7-3 Categories whose emissions are estimated for solid waste disposal (5.A.)

Category	Waste type			Disposal type		CH_4
5.A.1. (Sec. 7.2.1)	MW	Food waste		Managed waste disposal sites	a. Anaerobic b. Semi-aerobic - Managed well - Managed poorly	○
		Paper/cardboard				○
		Wood				○
		Textiles	Natural fiber [1]			○
		Sludge	Human waste treatment/*Johkasou* sludge			○
			Tsunami sediment [2]			○[2]
	IW	Food waste [3]	Animal and vegetable residues, Animal carcasses			○
		Paper/cardboard				○
		Wood				○
		Textiles	Natural fiber [1]			○
		Sludge	Sewage sludge: Digested sewage sludge [4]			○
			Sewage sludge: Other sewage sludge			○
			Waterworks sludge			○
			Organic sludge from manufacturing industries			○
			Livestock waste [5]			○
	NA				c. Active-aeration	NO
5.A.2. (Sec. 7.2.2)	NA			Unmanaged waste disposal sites		NO
5.A.3. (Sec. 7.2.3)	IW		Wood	Inappropriate disposal [6] (Anaerobic landfill)		○

Note:

1) Only natural fiber textiles are included in the estimation under the assumption that synthetic fiber waste is not biologically decomposed in landfills.
2) Part of tsunami sediment generated by the Great East Japan Earthquake, which occurred on 11th March, 2011, is disposed of finally. Since disposed tsunami sediment includes organic matters, CH_4 emissions from this source are estimated using the emission factor for wood by expert judgment. Since the disposal type for tsunami sediment have not been identified, it is conservatively assumed as anaerobic landfill (MCF=1.0) with larger emissions.
3) Japan's IW classifications of "Animal and vegetable residues" and "Animal carcasses" are aggregated as food waste.
4) "Digested sewage sludge" includes sewage sludge landfilled after digested and dehydrated. Because digestion treatment reduces the amount of carbon content biodegraded in sludge decreases, CH_4 emissions are estimated separately by landfilled sewage sludge with and without digestion treatment.
5) Although livestock waste is not classified as "sludge" under Japanese law, the emissions from the waste are estimated within the category of sludge since both properties are similar.
6) The emissions from wood are currently considered as inappropriate disposal of waste containing biodegradable carbon.

Table 7-4 GHG emissions from solid waste disposal (5.A.)

Gas	Category			Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
CH_4	5.A.1. Managed waste disposal sites	a. Anaerobic	MW	kt-CH_4	220.9	184.5	136.8	98.6	66.1	51.9	44.1	29.2	26.9	24.5	22.6	20.8
			IW	kt-CH_4	156.2	141.9	109.1	71.1	40.9	30.7	25.1	16.6	15.6	14.7	14.0	13.3
		b. Semi-aerobic	MW	kt-CH_4	17.7	25.9	28.7	30.6	24.9	21.7	19.4	13.9	12.8	11.8	11.1	10.4
			IW	kt-CH_4	4.7	8.4	12.3	13.8	10.6	9.9	8.8	7.3	7.2	7.0	6.9	6.9
		c. Active-aeration		kt-CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	5.A.2. Unmanaged waste disposal sites			kt-CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	5.A.3. Uncategorized waste disposal sites	Inappropriate disposal		kt-CH_4	0.1	0.2	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3
	Total			kt-CH_4	399.6	360.9	287.5	214.6	143.0	114.6	97.7	67.4	62.9	58.4	54.8	51.7
				kt-CO_2 eq.	11,189	10,105	8,051	6,009	4,003	3,209	2,737	1,888	1,760	1,634	1,535	1,447

Estimated GHG emissions from solid waste disposal on land are shown in Table 7-4. In FY2024, GHG emissions from this source category were 1,447 kt-CO_2 eq. and accounted for 0.1% of the national total emissions (excluding LULUCF). Emissions from this category decreased by 87.1% compared to the emissions in FY1990. This CH_4 emissions decrease is the result of decrease in the amount of biodegradable waste landfilled due to the increase in the practice of waste incineration to reduce waste volume in Japan.

For the category "Managed Waste Disposal Sites", while trend in the disposal amount of biodegradable waste has steadily decreased since FY1990, trend in the estimations of CH_4 generated from degradation of waste has relatively slowly decrease due to the time lags derived from long half-lives of waste in the FOD method (e.g. 7 years for half-life of paper/cardboard). Hence trend in the implied emission factors (IEFs) has increased since FY1990. For the category "uncategorized waste disposal sites (inappropriate disposal)", while trend in the disposal amount irregularly fluctuate year by year since the estimations should consider only disposal amount for revealed matters, trend in CH_4 emissions estimated by FOD method is relatively stable. Hence trend in the IEFs also tend to irregularly fluctuate year by year.

7.2.1. Managed Waste Disposal Sites (5.A.1.)

a) Category Description

In Japan, part of food waste, paper/cardboard, textiles, wood, and sludge in MW and IW is landfilled without incineration; therefore, CH_4 is generated as a result of biodegradation of organic materials from the landfill sites. Because Japanese landfill sites are appropriately managed pursuant to the Waste Management and Public Cleansing Act, the amount of CH_4 emitted from there is reported under the category "Managed Waste Disposal Sites (5.A.1.)" (either "Anaerobic (5.A.1.a.)" or "Semi-aerobic (5.A.1.b.)"). Note that CH_4 emissions under the category "Active-aeration (5.A.1.c.)" are reported as NO, because final disposal at active aerobic sites does not occur in Japan.

b) Methodological Issues

- ***Estimation Method***

The first order decay (FOD) method with country-specific parameters (Tier 3) given in the *2006 IPCC Guidelines* is used to estimate emissions from this source. In this method, for consistency with Japan's domestic estimation method under the *Mandatory GHG Accounting and Reporting System*, emission factors are specifically defined as "CH_4 emissions from biodegradable waste", and activity data are defined as "the amount of waste biodegraded within the reporting fiscal year". Note that there are no substantial differences between Japan's country-specific method (see following equation) and that in the *2006 IPCC Guidelines* (vol. 5, chap. 3, equation 3.1) since the emission factors and activity data in

Japan's method are defined by combining parameters in a way that maintains their relevance shown in the guidelines.

$$E = \left\{ \sum_{i,j} \left(EF_{i,j} \times A_{i,j} \right) - R \right\} \times (1 - OX)$$

E : CH_4 emissions from landfill sites [kg-CH_4]
$EF_{i,j}$: Emission factor for a biodegradable waste i that is damped into a landfill site j without incineration [kg-CH_4/t (dry)]
$A_{i,j}$: Amount of a biodegradable waste i that is dumped into a landfill site j without incineration and is biodegraded within an inventory year) [t (dry)]
R : Recovered CH_4 in an inventory year [kg-CH_4]
OX : Oxidation factor of CH_4 related to soil cover

- ***Emission Factors***

Emission factors are defined as the amount of CH_4 [kg] generated through decomposition of one ton of biodegradable landfill wastes (dry basis) without incineration. They are established by the type of biodegradable waste (i.e., food waste, paper/cardboard, natural fibers, wood, sewage sludge, human waste, waterworks sludge, organic sludge from manufacturing industries and livestock waste) and by the type of landfill site (i.e., anaerobic or semi-aerobic landfill). Emission factors are estimated as indicated below.

$$EF = DOC_i \times DOCf_i \times MCF_j \times F \times 1000 \times \frac{16}{12}$$

DOC_i : Fraction of carbon content in a biodegradable waste i
$DOCf_i$: Fraction of degradable organic carbon that decomposes for waste i
MCF_j : Methane correction factor in a landfill site j (Anaerobic, Managed well – semi-aerobic, Managed poorly – semi-aerobic)
F : Percentages of CH_4 in landfill gas

➢ ***Carbon Content (DOC: Per Dry Weight)***

Carbon content per dry weight, which is used as uniform value every year because the property of each waste type does not vary significantly over time, is determined based on MOE (2006b) and MOE (2010) as indicated in Table 7-5.

Table 7-5 Carbon content of waste disposed of in managed landfill sites (dry basis)

Item		Carbon Content	Reference
MW	Food waste	43.4 %	Calculated by taking the averages of carbon contents of MSW provided by Tokyo, Yokohama, Kawasaki, Kobe, and Fukuoka (FY1990-2004) (MOE, 2006b)
	Wood	45.2 %	
	Paper/cardboard	40.8 %	Calculated by taking the averages of measured carbon contents of MSW at domestic 14 cities (MOE, 2020b)
	Textiles (natural fiber)	45.0 %	Calculated by taking a weighted average of carbon content estimated based on the constituent of each natural fiber type (cotton, wool, silk, linen, and recycled textiles) by the domestic demand of natural fibers (FY1990-2004) (MOE, 2006b)
	Human waste treatment/ *Johkasou* sludge	40.0 %	The value for "Other sewage sludge" is used
	Tsunami sediment	4.5 %	Calculated by multiplying the fraction of organic matter in tsunami sediment by the fraction of carbon contents in the organic matter; assuming the fraction of organic matter in tsunami sediment finally disposed of is 10%, and 45.2% of fraction of carbon content for wood is used for tsunami sediment by expert judgment
IW	Food waste	43.4 %	The carbon contents of MSW for that of IW are used because its properties are similar to those of MSW
	Wood	45.2 %	
	Paper/cardboard	40.8 %	
	Digested sewage sludge	30.0 %	Expert judgment based on Fujimoto (2000), Fujishima et al. (2004), Oshima et al. (1986) and Tanaka et al. (1980)
	Other sewage sludge	40.0 %	Expert judgment based on domestic research (MOE, 2006b)
	Waterworks sludge	6.0 %	Average values of survey results conducted at 23 water purification plants (MOE, 2010)
	Organic sludge from manufacturing industries	45.0 %	Value for paper industry is used because it generates the largest amount of organic sludge finally disposed of. Estimated based on the carbon content of cellulose because the main constituent of organic sludge generated is paper sludge (MOE, 2006b)
	Livestock waste	40.0 %	The value for "Other sewage sludge" is used

- ***Fraction of the Degradable Organic Carbon That Decomposes (DOCf)***

For the fraction of the degradable organic carbon that decomposes (*DOCf*) for waste disposed of, default values in Table 7-6 given in the *2019 Refinement* are used.

Table 7-6 Fraction of the degradable organic carbon that decomposes for waste disposed of in managed landfill sites

Item		*DOCf*	Waste degradability (Reporting category in the CRT)	Reference
MW	Food waste	0.7	Highly decomposable	*2019 Refinement*
	Wood	0.1	Less decomposable	
	Paper/cardboard	0.5	Moderately decomposable	
	Textiles (natural fiber)	0.5	Moderately decomposable	
	Human waste treatment/ *Johkasou* sludge	0.7	Highly decomposable	
	Tsunami sediment	0.1	Less decomposable	
IW	Food waste	0.7	Highly decomposable	
	Wood	0.1	Less decomposable	
	Paper/cardboard	0.5	Moderately decomposable	
	Digested sewage sludge	0.7	Highly decomposable	
	Other sewage sludge	0.7	Highly decomposable	
	Waterworks sludge	0.7	Highly decomposable	
	Organic sludge from manufacturing	0.7	Highly decomposable	
	Livestock waste	0.7	Highly decomposable	

- ***Methane Correction Factor (MCF)***

For Methane correction factor (*MCF*) by the type of landfill sites, the below default values given in the *2019 Refinement* are used.

Table 7-7 Methane correction factors (*MCF*) by the type of landfill site

Types of landfill sites	*MCF*	Reference
Anaerobic landfill sites	1.0	*2019 Refinement*
Managed well – semi-aerobic landfill sites	0.5	
Managed poorly – semi-aerobic landfill sites	0.7	

➢ ***Proportions of CH_4 in Generated Gas (F)***

Default value (50%) given in the *2006 IPCC Guidelines* is used.

➢ ***Emission Factor (EF)***

Emission factors calculated by methodologies above are shown in Table 7-8.

Table 7-8 Emission factors by type of biodegradable waste and by treatment

Item		Anaerobic landfill [kg-CH_4/t (dry)]	Managed well – Semi-aerobic landfill [kg-CH_4/t (dry)]	Managed poorly – Semi-aerobic landfill [kg-CH_4/t (dry)]
MW	Food waste	203	101	142
	Paper/cardboard	136	68	95
	Textiles (natural fiber)	150	75	105
	Wood	30	15	21
	Human waste treatment/*Johkasou* sludge	187	93	131
	Tsunami sediment	3	NA	NA
IW	Food waste	203	101	142
	Paper/cardboard	136	68	95
	Textiles (natural fiber)	150	75	105
	Wood	30	15	21
	Digested sewage sludge	140	70	98
	Other sewage sludge	187	93	131
	Waterworks sludge	28	14	20
	Organic sludge from manufacturing	210	105	147
	Livestock waste	187	93	131

● ***Activity Data***

Out of the amount of waste landfilled without incineration (dry basis), the amount of waste degraded within the reporting year is calculated by multiplying the amount of waste remaining in landfills at the end of the previous reporting year by the methane generation rate constant for waste landfilled. The amount of biodegradable MW and IW are determined by type of waste and landfill site.

The amount of waste landfilled in each fiscal year (dry basis) is calculated by multiplying the amount of biodegradable waste landfilled (wet basis) by the percentage of landfill site by the type of site (wet basis), and subtracting the water content by each type of waste.

$$A_{i,j}(T) = W_{i,j}(T-1) \times (1 - e^{-k_i})$$
$$W_{i,j}(T) = W_{i,j}(T-1) \times e^{-k_i} + w_{i,j}(T)$$

$A_{i,j}(T)$: Amount of waste i degraded in site j (Anaerobic, Semi-aerobic) in the calculated year (year T) (activity data) [t (dry)]
$W_{i,j}(T)$: Amount of waste i remaining in site j in year T [t (dry)]
$w_{i,j}(T)$: Amount of waste i landfilled into site j in year T [t (dry)]
k_i : Methane generation rate constant of waste i [year^{-1}]

where,

$$w_{i,j}(T) = w_{i,wet}(T) \times S_j \times (1 - u_i)$$
$$k_i = ln(2)/H_i$$

$w_{i,wet}(T)$: Amount of waste i landfilled in year T [t (wet)]
S_j : Percentage of landfill site structure type j (Anaerobic, Semi-aerobic) [%]
u_i : Percentage of water content in waste i [%]
H_i : Decomposition half-life of waste i (the time taken by landfilled waste i to reduce in amount by half) [year]

The amount of biodegradable waste degraded in semi-aerobic landfill sites is divided into two types of waste by management conditions of landfill sites. In some semi-aerobic landfill sites in Japan, there are cases such as: the outflow port of leachate collection system is swamped, the system is full of water, it holds retaining of leachate, or leachate collection/gas extraction system is not properly extended.

Considering the variation in leachate collection system management conditions at landfill sites, a country-specific parameter – defined as "percentage of open outflow port of leachate collection system" – is applied to estimate the activity data both for "Managed well – semi-aerobic landfill sites" and "Managed poorly – semi-aerobic landfill sites" for MW and IW disposal sites, respectively, as follows:

$$A_{i,\ semiaerobic\text{-}well}(T) = A_{i,\ semiaerobic}(T) \times P$$
$$A_{i,\ semiaerobic\text{-}poorly}(T) = A_{i,\ semiaerobic}(T) \times (1 - P)$$

$A_{i,semiaerobic}(T)$: Amount of waste i degraded in semi-aerobic landfill site in the calculated year (year T) (activity data) [t (dry)]
$A_{i,semiaerobic\text{-}well}(T)$: Amount of waste i degraded in Managed – well semi-aerobic landfill site in the calculated year (year T) (activity data) [t (dry)]
$A_{i,semiaerobic\text{-}poorly}(T)$: Amount of waste i degraded in Managed poorly – semi-aerobic landfill site in the calculated year (year T) (activity data) [t (dry)]

where,

$$P = W'/W$$

P : Percentage of open outflow port of leachate collection system [%]
W' : Disposal amount in a reporting year at semi-aerobic landfill sites with open outflow port of leachate collection system [for MW: t, for IW: m^3]
W : Disposal amount in a reporting year at whole semi-aerobic landfill sites [for MW: t, for IW: m^3]

- ***Amount of Biodegradable Waste Disposed of in Landfills***

Table 7-9 shows the annual amount of biodegradable waste landfilled (dry basis) in Japan.

Table 7-9 Annual amount of biodegradable waste disposed of in landfills
(Total amount of anaerobic and semi-aerobic landfilling)

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
MW													
Food waste	kt (dry)	424	272	196	78	30	21	16	9	7	7	6	5
Paper/ cardboard	kt (dry)	1,140	859	698	492	311	226	142	58	54	57	53	50
Textiles (natural fiber)	kt (dry)	59	46	34	67	3	3	3	1	1	1	1	1
Wood	kt (dry)	363	200	155	81	40	65	22	10	9	10	9	12
Human waste treatment/ *Johkasou* sludge	kt (dry)	78	51	46	47	20	10	7	11	13	13	13	13
Tsunami sediment	kt (dry)	NO	NO	NO	NO	NO	29	NO	NO	NO	NO	NO	NO
IW													
Food waste	kt (dry)	65	177	109	45	22	11	12	18	14	14	18	17
Paper/ cardboard	kt (dry)	102	125	137	89	31	16	12	28	28	30	34	32
Textiles (natural fiber)	kt (dry)	4	16	15	17	7	6	11	10	11	10	9	6
Wood	kt (dry)	465	490	235	230	145	111	124	125	100	101	107	101
Digested sewage sludge	kt (dry)	59	50	31	11	3	4	3	4	3	3	3	3
Other sewage sludge	kt (dry)	219	185	114	42	17	11	12	5	7	6	5	6
Waterworks sludge	kt (dry)	199	166	146	66	67	67	67	67	67	67	67	67
Organic sludge from manufacturing industry	kt (dry)	358	165	69	48	31	17	13	12	11	12	12	10
Livestock waste	kt (dry)	12	12	11	11	11	12	13	13	13	13	14	13

Note: Disposal amount of tsunami sediment has increased in FY2013, since disaster waste by the 2011 earthquake has massively treated in FY2013 due to the activation of disaster restoration service. The final disposal of this tsunami sediment has finished in FY2013; therefore, the amount is accounted as 0 kt/year from FY2014 onward.

The references for the amount of biodegradable waste landfilled by waste type are indicated in Table 7-10. The amount of biodegradable waste landfilled is estimated going back as far as FY1954, when the Public Cleansing Law (now the Waste Management and Public Cleansing Act) was enforced. The statistical survey of landfilling began in 1980s, and in the case that historical data on the amount of biodegradable waste landfilled are unavailable (primarily prior to FY1980), the data of the closest and

more recent year available (primarily the data of FY1980) are applied. For the years where the data are unavailable even after FY1980, interpolated values are applied.

Table 7-10 Overview of data for the amount of biodegradable waste disposed of in landfill

Waste type			Reference	Detail	Historical data
MW	Food waste		*Cyclical Use of Waste Report* (MOE)	- Amount directly landfilled - Amount landfilled after intermediate treatment. * Fraction of natural fiber content in total waste textiles is calculated by using the fraction of natural fiber products in total textile products, which is determined by taking the ratio of the annual domestic demand for synthetic textiles to that of all textiles indicated in the *Textile Handbook* (Japan Chemical Fibers Association) and the *Yearbook of Textiles and Consumer Goods Statistics* (METI).	- Estimated by interpolation for some fiscal years, - The FY1980 values are used for the years prior to FY1980
	Paper/cardboard				
	Wood				
	Textiles (natural fiber) *				
	Human waste treatment/ *Johkasou* sludge	(Direct final disposal)	*Waste Management in Japan* (MOE)	Calculated by multiplying the amount of human waste sludge in "other treatment" (volume basis) by the weight-conversion factor (1.0 kg/L)	The FY1978 value is used for the years prior to FY1978
		(Final disposal after treatment)	*Cyclical Use of Waste Report* (MOE)	Amount landfilled after intermediate treatment, excluding ash after incineration	For the years prior to FY1998, estimated by using the amount of direct final disposal human waste sludge
	Tsunami sediment		*Waste Treatment in Japan* (MOE)	Direct final disposal of "Tsunami sediment"	Disposed from FY2011
IW	Food waste (Animal and vegetable residues, Animal carcasses)		*Cyclical Use of Waste Report* (MOE)	- Amount directly landfilled - Amount landfilled after intermediate treatment, excluding ash after incineration by using reference data * All textiles in IW are considered to be natural fiber due to the Waste Management and Public Cleansing Act	- Estimated by interpolation for some fiscal years, - The FY1980 values are used for the years prior to FY1980
	Paper/cardboard				
	Wood				
	Textiles (natural fiber) *				
	Digested sewage sludge		Data provided by MLIT	Compiled and provided by MLIT	- For some fiscal years, estimated by interpolation - The FY1985 values are used for the years prior to FY1985
	Other sewage sludge		*Sewage Statistics* (JSWA)	Total amount of sewage sludge excluding the amount of digested sewage sludge	
	Waterworks sludge		*Waterworks Statistics* (Japan Water Works Association)	Estimated by "Total amount of soil disposed" and "landfilled percentage" of each purification plant	The FY1980 value is used for the years prior to FY1980
	Organic sludge from manufacturing industries	Paper industry	Data provided by Japan Paper Association, Japan Technical Association of the Pulp and Paper Industry	Total amount of organic sludge landfilled for paper industry	The FY1989 value is used for the years prior to FY1989
		Chemical industry	*Survey of generation status of industry-specific by-products (industrial waste and recyclable waste)* (METI), etc.	Total amount of organic sludge landfilled for chemicals industry and food manufacturing industry	- For some fiscal years, estimated by interpolation - For the years from FY2015 onward, estimated with the data from *Follow-up Action Result of the Voluntary Action Plan for Establishing a Sound Material-Cycle Society* (Japan Business Federation) and the *Report on the State of Industrial Waste Generation and Treatment Survey* (MOE) - For the years prior to FY1998, estimated with the data from *Follow-up Action Result of the Voluntary Action Plan on the Environment* (Japan Business Federation) - The FY1990 values are used for the years prior to FY1990
		Food manufacturing industry			
	Livestock waste		Survey conducted by MOE	–	The FY1980 value is used for the years prior to FY1980

Note:
METI: Ministry of Economy, Trade and Industry, MLIT: Ministry of Land, Infrastructure, Transport and Tourism.

➢ *Percentage of Water Content in Waste*

In Japan, activity data are estimated on a dry basis because the carbon content of waste can be identified more precisely. The percentages of water content by each type of waste to estimate activity data on a dry basis and their sources are given in Table 7-11. In order to estimate the CO_2 emissions for the category "Incineration and Open Burning of Waste (5.C.)" as well as this source category, dry basis activity data are used for the same reason.

Table 7-11 Percentage of water content in waste disposed of in managed landfill sites

Items			Intermediate treatment	Water content	Reference
MW	Food waste		(Unseparated)	75%	Water percentage of food waste in the *Cyclical Use of Waste Report* (MOE)
	Paper/cardboard		(Unseparated)	20%	Expert judgment
	Wood		(Unseparated)	45%	Expert judgment
	Textiles (natural fiber)		(Unseparated)	20%	Expert judgment
	Human waste treatment/*Johkasou* sludge		Untreated	85%	Moisture content standard of landfill standard (sludge) specified by enforcement ordinance of the Waste Management and Public Cleansing Act
			Treated	70%	Expert judgment
	Tsunami sediment		(Unseparated)	45%	The value for wood is used by expert judgment
IW	Food waste		Untreated	75%	Water percentage of food waste in *Cyclical Use of Waste Report* (MOE)
			Treated	Specific to each FY	Specified by considering material flow
	Paper/cardboard		(Unseparated)	15%	Expert judgment
	Wood		(Unseparated)	45%	Expert judgment
	Textiles (natural fiber)		(Unseparated)	15%	Expert judgment
	Sewage sludge	Digested sewage sludge	(Unseparated)	Specific to each disposal site	Average water content of "delivered or final disposal sludge" in the *Sewage Statistics* (JSWA)
		Other sewage sludge	(Unseparated)		
	Waterworks Sludge		(Unseparated)	Not specified	Activity data on a dry basis are provided by the data sources
	Organic sludge from manufacturing industries	Paper industries	(Unseparated)	Not specified	
		Chemical industries	(Unseparated)	57%	Reference of Clean Japan Center Survey
		Food manufacturing	(Unseparated)	77%	
	Livestock waste		Untreated	83.1%	Japan Livestock Technology Association (2002)
			Treated	70%	Expert judgment

➢ *Percentages of Landfill Sites by Site Structure Type*

- *Percentages of MW Landfill Sites by Site Structure Type*

Among the Japan's MW disposal sites listed in the section "Facility by Type (Final Disposal Sites)" of the *Annual editions of Results of Study on Municipal Solid Waste Disposal* (Environmental Regeneration and Material Cycles Bureau of MOE) (hereinafter referred to as the *Results of Study on MSW Disposal*), landfill sites which have leachate treatment facilities and subsurface containment structures are regarded as semi-aerobic landfill sites, and the percentage of their total landfill capacity [m^3] is defined as the percentage of semi-aerobic landfill disposal volume.

Since the percentages of semi-aerobic landfill sites for the period FY1996 and before are not available, they are determined as indicated below:

- For the period FY1997 and after, they are determined based on measured data.
- For the period FY1977 and before, all the landfill sites including all the sea area landfills are considered to be anaerobic landfill sites since semi-aerobic landfill technology started in 1977.
- For the period FY1977-1996, they are estimated by linear interpolation using measured data of FY1997 based on expert judgment.

- ***Percentages of IW Landfill Sites by Site Structure Type***

The percentages of landfill sites by site structure type for IW are determined as follows:

- For the period FY2008 and after, they are determined based on the *Survey of Industrial Waste Treatment Facilities* (MOE).
- For the period FY1977 and before, all the landfill sites including all the sea area landfills are considered to be anaerobic landfill sites since semi-aerobic landfill technology started in 1977.
- For the period FY1990-2007, they are estimated by using the total amount of waste landfilled and the measured data of waste deposited of in semi-aerobic landfill sites in FY2008.
- For the period FY1977-1989, they are estimated by linear interpolation using the data of FY1990 based on expert judgment.

Table 7-12 Percentages of landfill sites by site structure

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
MW													
Anaerobic landfill	%	74.2	64.2	54.4	43.5	36.1	39.9	28.8	30.0	28.1	28.0	30.1	27.7
Semi-aerobic landfill	%	25.8	35.8	45.6	56.5	63.9	60.1	71.2	70.0	71.9	72.0	69.9	72.3
IW													
Anaerobic landfill	%	90.2	81.1	66.4	48.3	47.0	30.0	37.7	27.2	29.1	31.8	26.5	28.5
Semi-aerobic landfill	%	9.8	18.9	33.6	51.7	53.0	70.0	62.3	72.8	70.9	68.2	73.5	71.5

- ***Decomposition Half-life***

Decomposition half-life is the time taken for 50% of waste landfilled in a certain year to be degraded from its initial mass. Conducting several measurement surveys at the Central Breakwater Landfill Site in metropolitan Tokyo, the largest managed landfill for MW in Japan at the time, Ito (1992) obtained a set of half-lives. Assuming this research was on a representative managed waste disposal site in Japan for temperate/boreal wet climate, the half-lives in his research for food waste, paper/cardboard, textiles (natural fiber), and wood are applied as country-specific parameters (3, 7, 7, and 36 years respectively). Because no relevant research has been obtained to identify a country-specific half-life for the sludge, the default value of 3.7 years provided in the spreadsheets attached to the *2006 IPCC Guidelines* is applied. The half-life for wood is used for the half-life of tsunami sediment as a substitute by expert judgment.

Table 7-13 Decomposition half-life for biodegradable waste

Item		Half-life [year]	Reference
Food waste [1)]		3	Ito (1992)
Paper/cardboard		7	
Textiles (natural fiber)		7	
Wood [2)]		36	
Sludge	Tsunami sediment	36	The half-life of wood is applied by expert judgment.
	Human waste treatment/*Johkasou* sludge	3.7	*2006 IPCC Guidelines*
	Digested sewage sludge		
	Other sewage sludge		
	Waterworks sludge		
	Organic sludge from manufacturing		
	Livestock waste [3)]		

Note:

1) Ito (1992) identified the half-life for food waste that is shorter than the default value (4 years) for temperate/wet climate zone of the *2006 IPCC Guidelines*. This is considered to be the reason for that food waste in Japan is more rapidly degraded than theoretical waste the IPCC guidelines assume, since Japan's climate is warmer and more humid than typical temperate/wet climate assumed by the IPCC guidelines (MOE, 2006b).

2) Ito (1992) identified the half-life for wood that is longer than the default value (23 years) for temperate/wet climate zone of the *2006 IPCC Guidelines*. This is considered to be the reason for that meanwhile the IPCC default value covers wood and straw waste, the Japan's country-specific parameter does only wood (MOE, 2006b).
3) Although livestock waste is not sludge on the "Wastes Disposal and Public Cleansing Act", the IPCC default half-life for sewage sludge is adopted as that of livestock waste since livestock waste has similar property of sewage sludge.

- ***Percentage of Open Outflow Port of Leachate Collection System at Semi-aerobic Landfill Sites***

Of semi-aerobic landfill sites, those that have open outflow ports for leachate collection are regarded as "Managed well – semi-aerobic landfill sites", and the percentage of total amount of wastes disposed of in the calculated year in these sites to those amount in all semi-aerobic disposal sites is defined as the percentage of open outflow port of leachate collection system at semi-aerobic landfill sites. To evaluate the parameter for MW, the data of the condition of open outflow port and disposal amount in each semi-aerobic landfill sites provided in the *State of Municipal Waste Treatment Survey* are used. For IW, those data in each semi-aerobic landfill sites indicated in a result of questionnaire survey by Environmental Regeneration and Material Cycles Bureau of MOE, are used.

Table 7-14 Percentage of open outflow port of leachate collection system at semi-aerobic landfill sites for MW and IW

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
MW	%	64.7	64.7	64.7	64.7	69.1	69.7	70.3	71.2	72.7	75.8	74.6	73.9
IW	%	84.3	84.3	84.3	84.3	88.2	85.6	85.6	85.6	85.6	85.6	85.6	85.6

- ***Delay Time***

Delay time is the time lag from when the waste is landfilled until when the decomposition actually occurs. As no knowledge is obtained for a delay time specific to Japan, the default value (6 months) given in the *2006 IPCC Guidelines* is applied.

Table 7-15 Amount of biodegraded waste decomposed of to be degraded in each estimation year[1)]

(Activity data)

Item			Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
a. Anaerobic	MW	Food waste	kt (dry)	358	278	172	99	44	27	19	9	7	6	5	5
		Paper/cardboard	kt (dry)	1,042	913	724	545	393	319	274	179	164	150	137	126
		Textiles (natural fiber)	kt (dry)	54	48	38	31	23	18	15	9	8	7	7	6
		Wood	kt (dry)	186	186	179	167	155	147	142	129	127	124	122	120
		Human waste treatment/ *Johkasou* sludge	kt (dry)	96	66	44	29	17	12	10	6	5	5	5	5
		Tsunami sediment	kt (dry)	NO	NO	NO	NO	NO	0.4	1	1	1	1	1	1
	IW	Food waste	kt (dry)	69	102	117	74	32	21	15	7	7	6	6	6
		Paper/cardboard	kt (dry)	137	138	121	99	74	58	49	32	29	27	26	24
		Textiles (natural fiber)	kt (dry)	22	16	15	12	10	8	7	5	5	5	5	5
		Wood	kt (dry)	224	261	258	247	232	221	214	198	195	192	189	186
		Digested sewage sludge	kt (dry)	59	52	38	22	10	7	5	3	2	2	2	2
		Other sewage sludge	kt (dry)	221	196	144	83	39	26	19	9	8	7	6	5
		Waterworks sludge	kt (dry)	180	165	127	85	51	40	34	25	24	23	23	22
		Organic sludge from manufacturing industry	kt (dry)	354	274	160	90	44	30	22	11	10	9	8	7
		Livestock waste	kt (dry)	11	11	9	7	6	5	5	4	4	4	4	4
b. Semi-aerobic (Managed well)	MW	Food waste	kt (dry)	45	61	58	53	31	21	17	10	9	8	7	6
		Paper/cardboard	kt (dry)	77	124	150	170	171	161	150	112	107	103	95	88
		Textiles (natural fiber)	kt (dry)	4	7	8	11	11	9	8	5	5	4	4	4
		Woods	kt (dry)	6	10	14	16	18	18	19	18	18	18	18	18
		Human waste treatment/ *Johkasou* sludge	kt (dry)	9	12	13	14	12	10	8	6	6	7	7	7
		Tsunami sediment [2)]	kt (dry)	NO	NO	NO	NO	NO	IE	IE	IE	IE	IE	IE	IE
	IW	Food waste	kt (dry)	4	13	30	33	20	17	13	11	11	10	10	10
		Paper/cardboard	kt (dry)	5	10	17	26	31	27	24	19	19	19	19	19
		Textiles (natural fiber)	kt (dry)	1	1	2	3	4	4	4	5	5	5	5	5
		Wood	kt (dry)	5	12	17	23	30	31	33	36	37	38	38	39
		Digested sewage sludge	kt (dry)	3	5	7	7	5	4	3	3	3	2	2	2
		Other sewage sludge	kt (dry)	11	19	27	27	18	16	13	9	8	7	6	6
		Waterworks sludge	kt (dry)	10	17	25	30	32	34	35	39	39	40	39	40
		Organic sludge from manufacturing industry	kt (dry)	18	25	25	26	20	19	16	11	10	10	9	9
		Livestock waste	kt (dry)	1	1	2	3	5	5	6	7	7	7	7	8
b. Semi-aerobic (Managed poorly)	MW	Food waste	kt (dry)	25	33	32	29	14	9	7	4	3	3	2	2
		Paper/cardboard	kt (dry)	42	68	82	93	77	70	63	45	40	33	32	31
		Textiles (natural fiber)	kt (dry)	2	4	4	6	5	4	3	2	2	1	1	1
		Woods	kt (dry)	3	6	7	9	8	8	8	7	7	6	6	6
		Human waste treatment/ *Johkasou* sludge	kt (dry)	5	6	7	8	5	4	3	3	2	2	2	2
		Tsunami sediment [2)]	kt (dry)	NO	NO	NO	NO	NO	IE	IE	IE	IE	IE	IE	IE
	IW	Food waste	kt (dry)	1	2	6	6	3	3	2	2	2	2	2	2
		Paper/cardboard	kt (dry)	1	2	3	5	4	4	4	3	3	3	3	3
		Textiles (natural fiber)	kt (dry)	0.1	0.2	0.4	1	1	1	1	1	1	1	1	1
		Wood	kt (dry)	1	2	3	4	4	5	5	6	6	6	6	6
		Digested sewage sludge	kt (dry)	1	1	1	1	1	1	1	0.4	0.4	0.4	0.4	0.4
		Other sewage sludge	kt (dry)	2	4	5	5	2	3	2	1	1	1	1	1
		Waterworks sludge	kt (dry)	2	3	5	6	4	6	6	7	7	7	7	7
		Organic sludge from manufacturing industry	kt (dry)	3	5	5	5	3	3	3	2	2	2	2	1
		Livestock waste	kt (dry)	0.1	0.2	0.4	1	1	1	1	1	1	1	1	1

Note:

1) The declining trend in the amount of biodegraded waste is affected by the improvement of waste reduction that causes the decrease of landfilled waste.
2) Included in tsunami sediment at anaerobic landfill.

➢ *Amount of CH_4 Recovered from Landfills*

In order to reduce the amount of organic matter content and CH_4 emissions at landfill sites, certain intermediate treatments and landfill methods have been conducted; CH_4 recovery from landfills is not

very common practice in Japan. CH_4 recovery from landfilled MW for the purpose of electric power generation, as implemented at the Tokyo Metropolitan Government's Central Breakwater Landfill Site, is the only example of such a practice in Japan. For IW, there is no practice of CH_4 recovery from landfills implemented in Japan. Because CO_2 emitted from the combustion of recovered CH_4 is of biogenic-origin, it is not included in the total emissions. Amount of CH_4 recovered for energy in landfill sites is estimated as following equation.

$$R = r \times f \times 16/22.4/1000$$

R : Amount of CH_4 recovered in landfill [g]
r : Amount of recovered landfill gas used for electric power generation [m^3 N]
f : Ratio of CH_4 to recovered gas

- ***The Amount of Recovered Landfill Gas Used for Electric Power Generation in the Central Breakwater Landfill Site***

The amount of recovered gas used for electric power generation is provided by the Waste Disposal Management Office of Tokyo.

- ***Fraction of CH_4 to the Recovered Gas***

The fraction of CH_4 to recovered landfill gas in the Central Breakwater Landfill Site has been annually provided since FY2005 by the Waste Disposal Management Office of Tokyo. The fractions for the years prior to FY2005 are determined based on the hearing conducted with the Waste Disposal Management Office of Tokyo: 60% for FY1987, when the recovery of landfill gas was started; 40% for FY1996; interpolated for FY1988 through FY1995; The FY1996 value is used for FY1997 through FY2004.

Table 7-16 Amount of CH_4 used at the Central Breakwater Landfill Site

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Amount of landfill gas use	km^3 N	1,985	2,375	2,372	140	1,266	1,734	1,565	NO	32	508	583	619
CH_4 ratio	%	53.3	42.2	40.0	48.5	43.8	44.9	39.2	NA	68.8	69.7	73.7	73.3
Amount of CH_4 use	km^3 N	1,059	1,003	949	68	555	779	613	NO	22	354	430	454
CH_4 unit conversion	Gg-CH_4	0.76	0.72	0.68	0.05	0.40	0.56	0.44	NO	0.02	0.25	0.31	0.32

- ***CH_4 Oxidation Factor Related by Landfill Cover Soil***

Based on law enforcement ordinances and local government ordinances, daily, intermediate and final soil coverings are practiced in the managed final disposal sites for MW and IW in Japan. Therefore, the default oxidation factor for managed landfill sites (0.1) is used in accordance with the *2006 IPCC Guidelines*.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainties of the emission factors for MW and IW are assessed by combining the uncertainties in carbon content, fraction of degradable organic carbon dissimilated, percentages of CH_4 in landfill gas, methane correction factor (*MCF*), and oxidation factor evaluated by using the 95% confidence interval of measured data, or by expert judgment.

For the activity data, due to the lack of information on statistical errors in quoted references, it is difficult to assess uncertainties based on concrete evidence. Therefore, it is assessed by expert judgment as indicated in the Table 7-2. Details of the uncertainty assessment on this category are shown in the Table 7-17.

Table 7-17 Uncertainty assessment by waste type for the category "managed waste disposal sites (5.A.1.)"

Item		GHGs	Emission factor uncertainty		Activity data uncertainty		Emission uncertainty		Method for assessing emission factor uncertainty	Method for assessing activity data uncertainty	Method for assessing emission uncertainty
			(-)	(+)	(-)	(+)	(-)	(+)			
MW	Food waste	CH_4	-47%	+47%	-10%	+10%	-48%	+48%	Evaluated by combining the 95% confidence interval of measured data of carbon content, the uncertainty of fraction of degradable organic carbon dissimilated and proportion of methane in generated gas based on expert judgment, and the uncertainty of default value of MCF and oxidation factor provided by the *2006 IPCC Guidelines*, by using the error-propagation formula. (Method 1)	The uncertainty in MW statistics is applied.	Combined by using the error-propagation formula.
	Paper/cardboard	CH_4	-47%	+47%	-10%	+10%	-48%	+48%			
	Textiles (natural fiber)	CH_4	-47%	+47%	-10%	+10%	-48%	+48%			
	Wood	CH_4	-47%	+47%	-10%	+10%	-48%	+48%			
	Human waste treatment/ *Johkasou* sludge	CH_4	-49%	+49%	-10%	+10%	-50%	+50%			
	Tsunami sediment	CH_4	-47%	+47%	-10%	+10%	-48%	+48%	The uncertainty of the emission factor for wood is applied, because the substance of tsunami sediment for the emission estimation is assumed to consist of wood.		
IW	Food waste	CH_4	-47%	+47%	-30%	+30%	-56%	+56%	The uncertainties are assessed by using method 1.	The uncertainty in IW statistics is applied.	Combined by using the error-propagation formula.
	Paper/cardboard	CH_4	-47%	+47%	-30%	+30%	-56%	+56%			
	Textiles (natural fiber)	CH_4	-47%	+47%	-30%	+30%	-56%	+56%			
	Wood	CH_4	-47%	+47%	-30%	+30%	-56%	+56%			
	Sewage sludge	CH_4	-49%	+49%	-5%	+5%	-49%	+49%	The uncertainty is assessed by using method 1. The uncertainty of carbon content in the method is assessed based on expert judgment.	The uncertainty in sewage statistics is applied.	
	Waterworks sludge	CH_4	-51%	+51%	-5%	+10%	-51%	+52%	The uncertainty is assessed by using method 1.	The uncertainty in the waterworks statistics is applied.	
	Organic sludge from manufacturing industries	CH_4	-58%	+58%	-30%	+30%	-65%	+65%	The uncertainty is assessed by using method 1. The uncertainty of carbon content in the method is assessed by expert judgment.	The uncertainty in IW statistics is applied.	
	Livestock waste	CH_4	-51%	+51%	-30%	+30%	-59%	+59%	The uncertainty is assessed by using method 1. For the carbon content in the method, the uncertainty provided by the *2006 IPCC Guidelines* as default value is applied.		
Methane recovery		CH_4	-10%	+10%	-10%	+10%	-14%	+14%	The uncertainty of methane concentration in recovered gas is assessed based on expert judgment.	The uncertainty in MW statistics is applied.	Combined by using the error-propagation formula.

- ***Time-series Consistency***

Although some activity data in FY1990 and thereafter are not available, they are estimated by using the methods described in "Activity data" to develop consistent time-series data. The emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

See section 7.1.5. "Sector-specific QA/QC and Verification".

e) Category-specific Recalculations

By updating the statistical data, CH_4 emissions for the whole time series were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

For future inventories, long-term efforts on further scientific investigations will be made to identify country-specific parameters (e.g. fraction of degradable organic carbon dissimilated for each type of biodegradable waste and country-specific half-life for sludge at final disposal sites).

7.2.2. Unmanaged Waste Disposal Sites (5.A.2.)

a) Category Description

Because landfill sites in Japan are appropriately managed pursuant to the Waste Management and Public Cleansing Act, there are no unmanaged waste disposal sites in Japan. Therefore, the emissions from this source category are reported as "NO".

7.2.3. Uncategorized Waste Disposal Sites (5.A.3.)

7.2.3.1. Inappropriate Disposal (5.A.3.-)

a) Category Description

In Japan, the definition of "inappropriate disposal" is waste disposal violating the Waste Management and Public Cleansing Act (illegal dumping and other forms of improper disposal on lands or areas other than landfill sites). Activities in the category of inappropriate disposal are identified as 1) illegal dumping, and 2) revealed matter; both are irregular events. The ratio of the amount of inappropriate waste disposal is quite small compared to the one of appropriate waste disposal. Although these inappropriate disposal lands or areas generally satisfy the conditions of managed waste disposal sites defined in the *2006 IPCC Guidelines*, CH_4 emissions from inappropriate disposal are reported under "Uncategorized Waste Disposal Sites (5.A.3.)".

b) Methodological Issues

- ***Estimation Method***

Wood and paper/cardboard are the wastes containing biodegradable carbon and being inappropriately disposed without incineration; however, only wood is the subject for the estimation, because the residual amount of paper/cardboard should be very small.

In a similar manner for the "Managed Waste Disposal Sites (5.A.1.)", a FOD method with Japan's country-specific parameters is used for the estimation. Emissions are estimated by multiplying the amount of wood (dry basis) degraded in a reporting year by an emission factor.

- ***Emission Factor***

The emission factor for wood in anaerobic disposal sites (30 kg-CH_4/t) shown in Table 7-8 is adopted for this category.

- ***Activity Data***

As activity data for this category, amount of wood (dry basis) degraded in a reporting year is estimated in a similar manner described in the section "7.2.1. Managed Waste Disposal Sites (5.A.1.)". The parameters employed in the method to estimate activity data for this category are shown below.

➢ ***Amount of Waste Disposed of in Inappropriate Disposal Sites***

The amount of waste disposed of from FY1980 onward in inappropriate disposal sites and remaining without removal from these sites have been reported since FY2003 in the *Study on Residual Amounts of Industrial Waste from Illegal Dumping and other Sources* (Environmental Regeneration and Material Cycles Bureau, MOE) as data of residual amount by each disposal fiscal year (wet basis). Note that these reported residual amounts in inappropriate disposal sites can be changed in future reports due to new revealment of hidden inappropriate disposal and/or removal of waste from inappropriate disposal sites after the revealment. Based on the residual amount of wood (construction waste) in the data of "remaining case and residual amount of waste by type" in the investigation, considering changes in the data series in the past reports, initial amount of waste disposed of in the past are estimated as shown in Table 7-18.

Table 7-18 Annual amount of waste disposed of in inappropriate disposal sites

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Wood	kt (dry)	48.8	51.9	144.9	21.1	19.0	5.1	25.7	5.7	6.6	3.4	3.5	4.2

Note: Annual amount of waste disposed of in inappropriate disposal sites includes those which had already been removed from these sites, but excludes those that are not revealed at present. Note that the values in the table are indicated in dry basis considering percentage of water content in waste shown below.

➢ ***Percentage of Water Content in Waste***

Percentage of water content in IW wood disposed of in managed waste disposal sites (45%) in Table 7-11 is adopted for this category.

➢ ***Landfill Site Structure***

Since the actual condition of CH_4 generation from inappropriate disposal is unidentified, all inappropriate disposal sites are conservatively assumed to be under anaerobic conditions in the CH_4 estimation.

➢ ***Decomposition Half-life***

A half-life for wood (36 years) in Table 7-13 is adopted for this category.

➢ ***Delay Time***

Similar to the category Managed Waste Disposal Sites (5.A.1.), the default value (6 months) given in the *2006 IPCC Guidelines* is adopted for this category.

➢ ***Amount of Wood Decomposed in Each Year (Activity Data)***

Amounts of waste inappropriately disposed of to be degraded in each estimation year are shown in Table 7-19. Note that it is considered in the estimation of these amount that the amount removed from inappropriate disposal sites cannot be degraded in these sites after the removal fiscal year.

Table 7-19 Amount of waste inappropriately disposed of to be degraded in each estimation year (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Wood	kt (dry)	2.6	5.8	16.6	17.3	16.1	15.3	14.0	13.2	12.2	9.9	9.7	9.4

➢ ***Amount of CH_4 Recovered from Landfills***

Since activities of CH_4 recoveries both for flaring and energy use are not observed in inappropriate disposal sites in Japan, these reporting items in this category are reported as "NO".

➢ ***CH_4 Oxidation Factor Related to Landfill Cover Soil***

Since no literature is available related to the condition of cover soil in inappropriate disposal sites, the default oxidation factor for uncategorized solid waste disposal site (0) given in the *2006 IPCC Guidelines* is adopted for this category.

c) Uncertainty Assessment and Time-series Consistency

● ***Uncertainty Assessment***

The uncertainties of emission factor and activity data are assessed by using the same methods that are used for "Managed Waste Disposal Sites (5.A.1.)". Details of the uncertainty assessment for this category are shown in the Table 7-20.

Table 7-20 Uncertainty assessment for the category "inappropriate disposal sites (5.A.3.-)"

Item	GHGs	Emission factor uncertainty		Activity data uncertainty		Emission uncertainty		Method for assessing emission factor uncertainty	Method for assessing activity data uncertainty	Method for assessing emission uncertainty
		(-)	(+)	(-)	(+)	(-)	(+)			
Inappropriately disposed waste	CH_4	-42%	+41%	-60%	+60%	-74%	+73%	The uncertainty of emission factor for wood is applied, since the source for estimation is assumed to be wood.	The twofold higher uncertainty than the value in IW statistics is applied (see also Table 7-2).	Combined by using the error-propagation formula.

● ***Time Series Consistency***

Because data on inappropriate disposal are available only since FY2002, activity data prior to FY2002 are estimated. The emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

See section 7.1.5. "Sector-specific QA/QC and Verification".

e) Category-specific Recalculations

Due to the removals of inappropriately disposed waste, revelations of inappropriate disposal in the past, and etc., the amount of identified inappropriate disposal in the past has been updated annually. By updating the amount of past inappropriate disposal in such manner, CH_4 emissions for the whole time series were recalculated. See chapter 10 for impact on trend.

f) Category-specific Planned Improvements

For future inventories, long-term efforts on further scientific investigations will be made to identify country-specific parameters.

7.3. Biological Treatment of Solid Waste (5.B.)

In this category, CH_4 and N_2O emissions from biological treatment of solid waste are calculated. The target categories are shown in Table 7-21.

Table 7-21 Categories whose emissions are estimated for biological treatment of solid waste (5.B.)

Category	Waste type		Treatment type	CH_4	N_2O
5.B.1. (Sec. 7.3.1)	Municipal solid waste	Food waste	Composting	○	○
		Paper/cardboard			
		Textiles			
		Wood (garden and park waste)		○	○
	Human waste/*Johkasou* sludge			○	○
	Industrial waste	Food waste (animal and vegetable residues, other food waste)		○	○
		Sewage sludge		○	○
5.B.2. (Sec. 7.3.2)	Municipal solid waste, industrial waste including sewage sludge		Anaerobic digestion	NE	NO

Estimated GHG emissions from this category are shown in Table 7-22. In FY2024, emissions from this source category were 262 kt-CO_2 eq. and accounted for 0.03% of the national total emissions (excluding LULUCF). The emissions from this source category had increased by 18.3% compared to those in FY1990. This emission increase is primarily due to the enhancement of effective utilization of waste as recycled resources. While Japan adopts country-specific emission factors (wet basis) in this category, due to low variation in time series of waste composition for composting, the IEFs for whole category were stable (approximately 2.8 kg-CH_4/t [dry] and 0.77-0.79 kg-N_2O/t [dry]).

Table 7-22 GHG emissions from biological treatment of solid waste (5.B.)

Gas	Category		Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
CH_4	5.B.1. Composting	Municipal solid waste	kt-CH_4	0.1	0.04	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		Human waste/ *Jokasou* sludge	kt-CH_4	NO	NO	NO	0.004	0.02	0.02	0.03	0.02	0.02	0.02	0.02	0.02
		Industrial waste	kt-CH_4	2.1	2.1	2.1	3.7	3.6	3.9	3.9	2.8	2.9	2.6	2.5	2.4
	5.B.2. Anaerobic digestion at biogas facilities		kt-CH_4	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	Total		kt-CH_4	2.2	2.1	2.2	3.8	3.7	4.0	4.1	3.0	3.1	2.8	2.6	2.6
			kt-CO_2 eq.	60	60	61	107	104	112	114	83	86	77	73	72
N_2O	5.B.1. Composting	Municipal solid waste	kt-N_2O	0.02	0.01	0.01	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02
		Human waste/ *Jokasou* sludge	kt-N_2O	NO	NO	NO	0.001	0.005	0.01	0.01	0.01	0.01	0.01	0.01	0.00
		Industrial waste	kt-N_2O	0.59	0.59	0.59	1.05	1.00	1.09	1.10	0.79	0.82	0.74	0.70	0.69
	5.B.2. Anaerobic digestion at biogas facilities		kt-N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Total		kt-N_2O	0.61	0.60	0.61	1.07	1.04	1.12	1.14	0.83	0.85	0.77	0.73	0.72
			kt-CO_2 eq.	161	159	161	284	275	298	302	220	226	204	193	190
Total			kt-CO_2 eq.	221	219	222	391	379	410	416	303	312	282	266	262

7.3.1. Composting (5.B.1.)

a) Category Description

Part of the MSW, human waste/*Johkasou* sludge and IW generated in Japan is composted, and CH_4 and N_2O generated in that process are emitted from composting facilities. Emissions from composting of livestock waste are reported under the section "5.3. Manure management (3.B)" in the agriculture sector.

b) Methodological Issues

- ***Estimation Method***

Emissions are calculated by taking the amount of organic waste composted, which is obtained from the statistical information available in Japan, and multiplying it by country-specific emission factors. The calculation method is the same for both CH_4 and N_2O emissions.

$$E = \sum_i EF_i \times A_i$$

E : Amount of CH_4 or N_2O emissions generated by composting organic waste [kg-CH_4], [kg-N_2O]
EF_i : Emission factor for organic waste i [kg-CH_4/t (wet)], [kg-N_2O/t (wet)]
A_i : Amount of composted organic waste i (activity data) [t (wet)]

- ***Emission Factor***

Country-specific emission factors derived from measurements at 9 facilities during both summer and winter reported by MOE (2018a) are adopted (MOE, 2018b).

Table 7-23 GHG emission factors for composting (5.B.1) (wet basis)

Waste type		CH_4 emission factor [kg-CH_4/t (wet)]	N_2O emission factor [kg-N_2O/t (wet)]	Note
MSW	Wood (garden and park waste)	0.35	0.0015	Low degradable
	Food waste	0.96	0.27	High degradable
	Paper/cardboard			
	Textiles			
Human waste/*Johkasou* sludge				
IW	Food waste (animal and vegetable residues, other food waste)			
	Sewage sludge			

Note: Each composting facility in which measurement surveys were conducted treats different type of waste respectively. According to the study, the emission factors for the facilities composting wood (garden and park waste) are lower than those for the facilities composting food waste, human waste, *Johkasou* sludge and sewage sludge. Although only one facility solely composts park and garden waste among facilities treated in this study, the expert acknowledged the significantly lower CH_4 and N_2O emissions from composting process for only garden and park waste by considering obviously lower degradability of garden and park waste than that of sludge and food waste. Hence based on these measurement surveys, CH_4 and N_2O emission factors for composting distinguished by waste type, such as low degradable and high degradable waste, are defined and applied in the category 5.B.1 composting (MOE 2018b) as shown in Table 7-23.

Since management practice in Japanese composting facilities includes turning over compost regularly or blowing air into the lower part of fermentation tanks to keep aerobic conditions, the country-specific CH_4 emission factors are lower than the default value in the 2006 *IPCC Guidelines*.

- ***Activity Data***

Activity data for the category composting (5.B.1) are obtained from the references shown on the Table 7-24.

Table 7-24 References of activity data for composting (5.B.1.)

Waste type		Reference	Note
MSW	Food waste	- *Waste Treatment in Japan* (MOE) - *Cyclical Use of Waste Report* (MOE)	Amount of MSW treated at waste composting facilities indicated in the *Waste Treatment in Japan* (MOE), is disaggregated by using MSW composition treated at high-rate composting facilities provided in the *Cyclical Use of Waste Report* (MOE).
	Paper/cardboard		
	Textiles		
	Wood (garden and park waste)		
Human waste/*Johkasou* sludge		*Waste Treatment in Japan* (MOE)	–
IW	Food waste (animal and vegetable residues, other food waste)	*Review Report on Improvement of Accuracy and Faster Compilation of Waste Statistics* (MOE)	This category includes: - Animal and vegetable residues generated by food and beverage manufacturing. - Food waste including valuables other than the above: although it falls under the category other than IW in the Waste Management and Public Cleansing Act, it is included in IW because of its source and properties.
	Additives (e.g. wood, etc.)	Expert judgment	Estimated by using additive ratio of 30% in food waste, derived from expert judgment referring to the *Cyclical Use of Waste Report* (MOE).
	Sewage sludge	*Sewage Statistics* (JSWA)	–
	Additives (e.g. wood, etc.)	Data provided by MLIT	

Activity data (wet basis) obtained is shown on the Table 7-25.

Table 7-25 Amounts of composted waste (Activity data: wet basis)

Item		Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
MSW	Food waste	kt (wet)	35	20	29	66	117	121	122	122	110	102	96	86
	Paper/cardboard	kt (wet)	28	16	23	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Textiles	kt (wet)	3	2	2	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Wood	kt (wet)	8	5	4	33	48	45	60	73	74	71	79	70
	Total	kt (wet)	74	42	58	99	165	166	182	195	184	173	175	156
Human waste/*Johkasou* sludge		kt (wet)	NO	NO	NO	4	17	19	35	22	23	21	21	16
IW	Food waste	kt (wet)	2,063	2,063	2,063	3,747	3,564	3,883	3,923	2,849	2,950	2,630	2,491	2,460
	Sewage sludge	kt (wet)	118	126	135	147	144	136	140	77	77	104	84	90
	Total	kt (wet)	2,180	2,189	2,198	3,894	3,708	4,019	4,063	2,925	3,027	2,734	2,575	2,550

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainties of the emission factors are assessed according to the survey for EFs (MOE, 2018a). As for the uncertainty of the activity data, since valuables account for much of activity data in biological treatment, the uncertainty of valuables indicated in Table 7-2 is adopted for that of activity data based on expert judgment. Details of the uncertainty assessment for this category are indicated in the Table 7-26.

Table 7-26 Uncertainty assessment for the category "composting (5.B.1.)"

Item	GHGs	Emission factor uncertainty		Activity data uncertainty		Emission uncertainty		Method for assessing emission factor uncertainty	Method for assessing activity data uncertainty	Method for assessing emission uncertainty
		(-)	(+)	(-)	(+)	(-)	(+)			
Composting	CH_4	-79%	+79%	-30%	+30%	-84%	+84%	MOE (2018a)	The uncertainty for valuables is applied since AD mostly consists of valuables.	Combined by using the error-propagation formula.
	N_2O	-167%	+167%	-30%	+30%	-170%	+170%			

- ***Time-series Consistency***

Since the amount of composted animal and plant residues generated by food manufacturing and food waste other than those for FY1990-2000 are unavailable, the data for FY2001 are used for those years. Since the data of the amount of additives (e.g. wood, etc.) to be added to sewage sludge treated at composting facilities for FY1990-1995 are unavailable, those data are estimated by multiplying the sewage sludge for FY1990-1995 by the ratio of additives for FY1996; thus, time-series consistency in emission estimates has been ensured.

d) Category-specific QA/QC and Verification

See section 7.1.5. "Sector-specific QA/QC and Verification".

e) Category-specific Recalculations

By updating the statistical data, CH_4 and N_2O emissions in FY2023 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

The implementation of emission estimates from domestic and commercial composting machine will be further considered. Because this kind of research could not be completed in a short period of time, a long-term effort on scientific investigations will be necessary.

7.3.2. Anaerobic Digestion at Biogas Facilities (5.B.2.)

a) Category Description

- ***Biogas Facilities in Japan***

As biogas facilities to be considered in this category, anaerobic digestion equipment at sewage treatment plants, biogas facilities for MW, and biogas facilities for IW are operated in Japan.

➢ ***Anaerobic Digestion Equipment for Sewage Sludge at Sewage Treatment Plants***

JSWA (2009) states that digestion tanks for sludge at sewage treatment plants should be kept airtight to prohibit explosions and odors caused by biogas leakage. It also states that unutilized digestion gas from such equipment should be combusted in view of safety and climate change mitigation. In addition, Japan estimates CH_4 and N_2O emissions from sludge thickening tank and dehydration room by using emission factors considering whole treatment system including these processes; CH_4 and N_2O emissions from this source stated in the *2006 IPCC Guidelines* are included in the category "Sewage Treatment Plants (5.D.1.-)" (see section 7.5.1.1.).

➢ ***Biogas Facilities for Municipal Waste***

MOE (2008) states that fermentation equipment at biogas facilities for MW should be kept airtight. It also states that biogas from such equipment should be combusted by the excess gas combustion system and discharged safely when the facilities cannot supply biogas to consumers in emergencies or maintenances.

➢ ***Biogas Facilities for Industrial Waste***

Although biogas facilities for IW are not controlled by the guidelines such as for those for MW, operators ought to keep airtight at the facilities in their installations as a safety measure.

- ***Emission Estimates***

Biogas facilities in Japan for MW and IW are leaking small amounts of CH_4. By assuming 2% of the leakage fraction of biogas produced in a facility (a consideration of actual situation of the CH_4 emission) and 60% of the CH_4 concentration in biogas (the *JARUS Reference System for Information of Biomass Recycling Technology*, The Japan Association of Rural Resource Recycling Solutions), the CH_4 emissions from this source category were tentatively estimated as 1.6 kt-CO_2 eq. per year at a maximum. Hence the emissions from this source category are reported as "NE" which stands for "considered insignificant" guided by the decision tree on the Figure A6-2 of Annex 6.

Assumed to be negligible in accordance with the *2006 IPCC Guidelines*, N_2O emission from this source category are reported as "NO".

7.4. Incineration and Open Burning of Waste (5.C.)

In Japan, waste disposed of has been reduced in volume primarily by incineration. Emissions from waste incineration are categorized into different types as shown in Table 7-27. CO_2, CH_4, N_2O emissions from categories "Waste Incineration (without Energy Recovery) (5.C.1.)" (see section 7.4.1.) and "Open Burning of Waste (5.C.2.)" (see section 7.4.2.) are reported under this category.

Also, waste incineration includes the following practices of waste used as raw material or fuel: "Waste Incineration with Energy Recovery (1.A.)" (see section 7.4.3.1.), "Direct Use of Waste as Alternative Fuel (1.A.)" (See section 7.4.3.2.), and "Incineration of Waste Processed as Fuel (1.A.)" (see section 7.4.3.3.). In accordance with the *2006 IPCC Guidelines*, estimated emissions from the sources listed above are allocated to energy sector (Sector 1) as category "Waste Incineration and Energy Use (Reported in Energy Sector) (1.A.)" (see section 7.4.3.). For details of reporting category in the energy sector, see Table 7-29.

In order to avoid double-counting or any other confusion, emissions from the categories indicated in Table 7-27, Table 7-28 and Table 7-29 with or without energy use are estimated collectively under the waste sector, thus the estimation methodology for these categories are provided in this section.

Estimated GHG emissions from waste incineration (category 5.C.) are shown in Table 7-30. In FY2024, emissions from waste incineration were 9,673 kt-CO_2 eq. and accounted for 0.9% of the national total emissions (excluding LULUCF). The emissions from this source category decreased by 14.1% compared to those in FY1990. For the period FY1990-1997, CO_2 emissions increased as the practice of intermediate treatment by waste incineration increased in order to decrease the total volume of waste landfilled. From FY2001 onwards, as the use of waste as raw material or fuel has been replacing the incineration of fossil-origin waste for intermediate treatments, and these CO_2 emissions which used to be allocated to the waste sector are now allocated to the energy sector, CO_2 emission estimates from the waste sector decreased. For this category, the IEFs of fossil-fuel-derived CO_2 range from 0.36 to 0.46 [t-CO_2/t-total waste incinerated (wet)]. On the other hand, N_2O emissions increased compared to FY1990 level due to the increase in sewage sludge incineration practice for the period FY1990-1997. From FY2005 onward, N_2O emissions from this source decreased because the practice of high temperature incineration of sewage sludge increased.

For reference, the GHG emissions from waste incineration for energy purpose and with energy recovery are shown in Table 7-31. In FY2024, the emissions from waste incineration including these sources were 26,544 kt-CO_2, and it accounts for 2.5% of Japan's total GHG emissions (excluding LULUCF). The emissions from this source's category had increased by 22.7% compared to those in FY1990.

Table 7-27 Categories whose emissions are estimated for waste incineration and open burning (5.C.)

Category	Waste type			Reporting category in the CRT	Treatment type		CO_2	CH_4	N_2O
5.C.1 (Sec. 7.4.1)	Municipal Solid Waste (Sec. 7.4.1.1)	Plastics	Fossil-fuel-derived plastics	5.C.1.b.i. Municipal solid waste	Incineration without energy recovery	Incinerator -continuous -semi-continuous -batch type	○	○[2]	○[2]
			Biomass-based plastics	5.C.1.a.i. Municipal solid waste			NA[1]		
		Plastic products for infection control (home use nonwoven masks)		5.C.1.a.i. Municipal solid waste			○		
		PET bottles	Fossil-fuel-derived PET bottles	5.C.1.b.i. Municipal solid waste			○		
			Biomass-based PET bottles	5.C.1.a.i. Municipal solid waste			NA[1]		
		Paper/ cardboard	Fossil-fuel-derived fraction	5.C.1.b.i. Municipal solid waste			○		
			Biogenic fraction	5.C.1.a.i. Municipal solid waste			NA[1]		
		Nappies/Sanitary pads	Fossil-fuel-derived fraction	5.C.1.b.i. Municipal solid waste		Gasification melting furnace	○		
			Biogenic fraction	5.C.1.a.i. Municipal solid waste			NA[1]		
		Textiles	Synthetic textiles	5.C.1.b.i. Municipal solid waste			○		
			Natural fiber	5.C.1.a.i. Municipal solid waste			NA[1]		
		Other (Biogenic)		5.C.1.a.i. Municipal solid waste			NA[1]		
	Industrial waste (Sec. 7.4.1.2)	Waste oil	Fossil-fuel-derived waste oil	5.C.1.b.ii.5. Fossil liquid waste		Incinerator	○	○	○
			Animal and vegetable waste oil	5.C.1.a.ii.5. Other (Non-fossil liquid waste)			NA[1]	○	○
		Plastics	Fossil-fuel-derived plastics	5.C.1.b.ii.1. Industrial solid wastes			○	○	○
			Biomass-based plastics	5.C.1.a.ii.1. Industrial solid wastes			NA[1]	IE[3]	IE[3]
		Plastic products for infection control (medical nonwoven masks, examination gloves)		5.C.1.b.ii.1. Industrial solid wastes			○	IE[3]	IE[3]
		Food waste [Animal and vegetable residues/animal carcasses]		5.C.1.a.ii.1. Industrial solid wastes			NA[1]	○	○
		Paper/ cardboard	Fossil-fuel-derived fraction	5.C.1.b.ii.1. Industrial solid wastes			○	IE[4]	IE[4]
			Biogenic fraction	5.C.1.a.ii.1. Industrial solid wastes			NA[1]	○	○
		Wood		5.C.1.a.ii.1. Industrial solid wastes			NA[1]	○	○
		Textiles	Synthetic textiles	5.C.1.a.ii.1. Industrial solid wastes			IE[3]	IE[3]	IE[3]
			Natural fiber	5.C.1.a.ii.1. Industrial solid wastes			NA[1]	○	○
		Sludge	Sewage sludge	5.C.1.a.ii.5. Other (Sludge)		Various types of incinerations[5]	NA[1]	○	○
			Sludge (excl. sewage sludge)	5.C.1.a.ii.5. Other (Sludge)		Incinerator	NA[1]	○	○
	Specially-Controlled industrial waste (Sec. 7.4.1.3)	Hazardous waste (Waste oil)	Flammable waste oil	5.C.1.b.ii.2. Hazardous waste			○	○	○
			Specified hazardous IW oil	5.C.1.b.ii.2. Hazardous waste			○	○	○
		Infectious waste	Plastics	5.C.1.b.ii.3. Clinical waste			○	○	○
			Plastic products (Surgical gloves)	5.C.1.b.ii.3. Clinical waste			○	IE[6]	IE[6]
			Other (except plastics)	5.C.1.a.ii.3. Clinical waste			NA[1]	○	○
5.C.2 (Sec. 7.4.2)	Municipal solid waste (Sec. 7.4.2.1)			5.C.2.a/b.i. Municipal solid waste	Open burning		NO	NO	NO
	Industrial waste (Sec. 7.4.2.2)	Plastics (Fossil-fuel-derived)		5.C.2.b.ii. Other (Industrial solid wastes)			○	○	○
		Other (Biogenic)		5.C.2.a.ii. Other (Industrial solid wastes)			NA[1]	IE[7]	IE[7]

Note:

1) CO_2 emissions from the incineration of biomass-derived waste are not included in the total emissions in accordance with the *2006 IPCC Guidelines*; instead, it is estimated as a reference value and reported under "Biogenic (5.C.1.a.)".
2) CH_4 and N_2O emissions from incineration of MSW in bulk are estimated by each incineration type and reported under "Municipal solid waste (Non-biogenic) (5.C.1.b.i.)".
3) Included in fossil-fuel-derived plastics in industrial solid waste (ISW)
4) Included in biogenic fraction of paper/cardboard
5) For details of incineration types for sewage sludge, see section 7.4.1.2.
6) Included in infectious waste plastics
7) CH_4 and N_2O emissions from open burning of industrial solid waste in bulk are reported under "Industrial solid wastes (Non-biogenic) (5.C.1.b.ii.1.)".

Table 7-28 Waste types whose emissions are estimated for waste incineration and energy use (reported in the energy sector) (1.A.)

Category	Waste type			Fuel type in the energy sector	Treatment type		CO_2	CH_4	N_2O
1.A.4. (Sec. 7.4.3.1)[7]	MSW	Plastics	Fossil-fuel-derived plastics	Other fossil fuels	Incineration with energy recovery	・Incinerator -continuous, -semi-continuous -batch type ・Gasification melting furnace	○	○[2]	○[2]
			Biomass-based plastics	Biomass[8]			NA[1]		
		Plastic products for infection control (home use nonwoven masks)		Other fossil fuels			○		
		PET bottles	Fossil-fuel-derived PET bottles	Other fossil fuels			○		
			Biomass-based PET bottles	Biomass[8]			NA[1]		
		Paper/ cardboard	Fossil-fuel-derived fraction	Other fossil fuels[9]			○		
			Biogenic fraction	Biomass			NA[1]		
		Nappies/Sanitary pads	Fossil-fuel-derived fraction	Other fossil fuels			○		
			Biogenic fraction	Biomass			NA[1]		
		Textiles	Synthetic textiles	Other fossil fuels			○		
			Natural fiber	Biomass			NA[1]		
		Other (biogenic)		Biomass			NA[1]		
	IW	Waste oil	Fossil-fuel-derived waste oil	Other fossil fuels		Incinerator	○	○	○
			Animal and vegetable waste oil	Biomass			NA[1]	○	○
		Plastics	Fossil-fuel-derived plastics	Other fossil fuels			○	○	○
			Biomass-based plastics	Biomass[8]			NA[1]	IE[3]	IE[3]
		Plastic products for infection control (medical nonwoven masks, examination and screening gloves)		Other fossil fuels			○	IE[3]	IE[3]
		Food waste [Animal and vegetable residues/animal carcasses]		Biomass			NA[1]	○	○
		Paper/ cardboard	Fossil-fuel-derived fraction	Other fossil fuels[9]			○	IE[4]	IE[4]
			Biogenic fraction	Biomass			NA[1]	○	○
		Wood		Biomass			NA[1]	○	○
		Textiles	Synthetic textiles	Other fossil fuels			IE[3]	IE[3]	IE[3]
			Natural fiber	Biomass			NA[1]	○	○
		Sludge	Sewage sludge	NA			NO	NO	NO
			Sludge (excl. sewage sludge)	Biomass			NA[1]	○	○
	SCIW			Other fossil fuels/ Biomass			IE[5]	IE[5]	IE[5]
1.A.1./ 1.A.2./ 1.A.4. (Sec. 7.4.3.2)[7]	MSW	Plastics	Fossil-fuel-derived plastics	Other fossil fuels		Direct use as alternative fuel	○	○	○
			Biomass-based plastics	Biomass[8]			NA[1]	IE[3]	IE[3]
		PET bottles		NA			NO	NO	NO
	IW	Waste oil	Fossil-fuel-derived waste oil	Other fossil fuels			○	○	○
			Animal and vegetable waste oil	Biomass			NA[1]	○	○
		Waste oil (Valuables)	Recycled oil from used solvent	Other fossil fuels			○	○	○
			Recycled heavy oil	Other fossil fuels			○	○	○
		Plastics	Fossil-fuel-derived plastics	Other fossil fuels			○	○	○
			Biomass-based plastics	Biomass[8]			NA[1]	IE[3]	IE[3]
		Wood		Biomass			NA[1]	○	○
	Waste tire		Fossil-fuel-derived fraction	Other fossil fuels			○	○	○
			Biogenic fraction	Biomass[8]			NA[1]	IE[6]	IE[6]
1.A.1./ 1.A.2. (Sec. 7.4.3.3)[7]	Refuse Derived Fuel (RDF)		Fossil-fuel-derived fraction	Other fossil fuels		Incineration of waste processed as fuel	○	○	○
			Biogenic fraction	Biomass[8]			NA[1]	IE[6]	IE[6]
	Refuse Paper and Plastic Fuel (RPF)		Fossil-fuel-derived fraction	Other fossil fuels			○	○	○
			Biogenic fraction	Biomass[8]			NA[1]	IE[6]	IE[6]

Note:

1) CO_2 emissions from the incineration of biomass-derived waste are not included in the total emissions; instead, it is estimated as a reference value and reported as “Biomass” fuel in the CRTs.
2) CH_4 and N_2O emissions from incineration of MSW in bulk are estimated by each incineration type and reported as “Other fossil fuels” in the CRT.
3) Included in fossil-fuel-derived plastics in ISW
4) Included in biogenic fraction of paper/cardboard
5) Included in SCIW incineration without energy recovery
6) Included in the fossil-fuel-derived fraction
7) For details of categories to be reported in the CRT, see Table 7-29.
8) For the biomass fraction in solid waste, etc. such as plastics, waste tire, RPF and RDF, it is difficult to distinguish the activity data on calorie basis for energy sector from the fossil-fuel-derived fraction since there is no appropriate way to decompose calorimetric data of mixed solid waste. Hence, the activity data is reported as “IE”, and is included in “other fossil fuels”.
9) For the fossil-fuel-derived fraction in “paper/cardboard”, it is difficult to distinguish the activity data on calorie basis for energy sector from the biogenic fraction. Hence, the activity data is reported as “IE”, and is included in “biomass”.

Table 7-29 Reporting categories for emissions from waste incineration and energy use (reported in the energy sector) (1.A.)

Treatment type	Waste type		Application breakdown	Major application	Reporting category in the energy sector	CO_2[2)]	CH_4	N_2O
Waste incineration with energy recovery	MSW		(Unclassified)	Waste incineration with energy recovery	1.A.4.a. Commercial/institutional	○	○	○
	IW					○	○	○
Direct use of waste as alternative fuel	MSW	Plastics	Liquefaction	Fuel	1.A.2.g. Other	○	○	○
			Blast furnace reducing agent	Reducing agent in blast furnace	1.A.2.a. Iron and steel	○	NO[3)]	NO[3)]
			Coke oven chemical feedstock	Raw material in coke oven	1.A.1.c. Manufacture of solid fuels and other energy industries	○	IE[4)]	NO[5)]
			Gasification	Fuel	1.A.2.g. Other	○	NE[6)]	NE[6)]
	IW	Waste oil	(Unclassified)	Fuel	1.A.2.g. Other	○	○	○
		Plastics	Blast furnace reducing agent	Blast furnace reducing agent	1.A.2.a. Iron and steel	○	NO[3)]	NO[3)]
			Chemical industry	Boiler fuel	1.A.2.c. Chemicals	○	○	○
			Paper industry	Boiler fuel	1.A.2.d. Pulp, paper and print	○	○	○
			Cement burning	Cement burning	1.A.2.f. Non-metallic minerals	○	○	○
			Automobile manufacturer	Boiler fuel	1.A.2.g. Other	○	○	○
			Liquefaction	Fuel	1.A.2.g. Other	○	○	○
			Gasification	Fuel	1.A.2.g. Other	○	NE[6)]	NE[6)]
		Wood	(Unclassified)	Fuel	1.A.2.g. Other	NA	○	○
	Waste tire		Cement burning	Cement burning	1.A.2.f. Non-metallic minerals	○	○	○
			Boiler	Fuel	1.A.2.g. Other	○	○	○
			Iron manufacture	Raw materials in iron manufacturing	1.A.2.a. Iron and steel	○	NO[3)]	NO[3)]
			Gasification	Fuel in iron manufacturing	1.A.2.a. Iron and steel	○	○	○
			Metal refining	Fuel in metal refining	1.A.2.b. Non-ferrous metals	○	○	○
			Tire manufacture	Fuel in tire manufacturing	1.A.2.c. Chemicals	○	○	○
			Paper manufacture	Fuel in paper manufacturing	1.A.2.d. Pulp, paper and print	○	○	○
			Power generation	Power generation	1.A.4.a. Commercial/institutional	○	○	○
Incineration of waste processed as fuel	RDF		(Unclassified)	Fuel use (including power generation)	1.A.2.g. Other [1)]	○	○	○
	RPF		Petroleum product manufacturer	Boiler fuel	1.A.1.b. Petroleum refining	○	○	○
			Chemical industry	Boiler fuel	1.A.2.c. Chemicals	○	○	○
			Paper industry	Fuel use in paper manufacturing	1.A.2.d. Pulp, paper and print	○	○	○
			Cement manufacturer	Cement burning	1.A.2.f. Non-metallic minerals	○	○	○

Note:

1) Emissions from power generation and heat supply excluding in-house use should be included in the category 1.A.4.a. However, they are reported in the category 1.A.2.g., because the actual circumstances are not understood at the moment.
2) CO_2 emissions from the incineration of biomass-derived fraction are not included in the total emissions; instead, it is estimated as a reference value and reported as “Biomass” fuel in the CRT. For details, see Table 7-28 .
3) Blast furnace gas generated by steel industry is entirely recovered.
4) These emissions are included in “solid fuels” in same category 1.A.1.c.
5) N_2O is likely not produced since the atmosphere in a coke oven is normally at least 1,000 degrees Celsius, and reducing.
6) Considering that small fraction of these sources is combusted as alternative fuel, but these are mostly used to obtain feedstock for ammonia productions, the emissions are not estimated.

Table 7-30 GHG emissions from waste incineration and open burning (5.C.)

Gas	Category			Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
CO_2	5.C.1. Waste incineration	MSW	Plastics[1), 4)]	kt-CO_2	3,981	3,973	4,067	2,387	1,636	2,133	1,938	1,717	1,860	1,881	1,815	1,788
			PET bottles[1)]	kt-CO_2	289	289	366	202	131	161	184	194	172	218	239	224
			Paper/cardboard[1)]	kt-CO_2	586	606	585	486	423	449	433	334	339	335	336	322
			Nappies/sanitary pads[1)]	kt-CO_2	190	214	189	191	215	232	246	209	214	217	223	219
			Synthetic textiles[1)]	kt-CO_2	540	568	440	446	591	451	521	351	379	370	386	374
		IW	Waste oil[1)]	kt-CO_2	1,913	2,275	2,502	2,226	2,151	1,904	1,733	1,681	1,747	1,768	1,902	1,801
			Plastics[1), 4)]	kt-CO_2	1,486	3,164	3,054	3,021	2,641	2,754	2,636	2,107	2,303	2,342	2,451	2,330
			Paper/cardboard[1)]	kt-CO_2	41	86	87	39	34	17	12	2	2	2	2	2
		SCIW	Flammable waste oil[1)]	kt-CO_2	698	1,036	1,525	1,402	1,143	796	691	912	883	827	824	755
			Specified hazardous IW oil [1)]	kt-CO_2	19	28	41	38	42	55	149	77	39	40	34	61
			Infectious waste (plastics)[1), 4)]	kt-CO_2	199	328	428	435	395	341	426	467	449	503	570	593
	5.C.2. Open burning (IW plastics)[1)]			kt-CO_2	6.3	6.3	1.7	0.4	0.2	0.1	0.0	0.1	0.0	0.0	0.0	0.0
	Total			kt-CO_2	9,949	12,576	13,285	10,873	9,403	9,293	8,970	8,049	8,387	8,502	8,782	8,468
CH_4	5.C.1. Waste incineration	MSW[2)]		kt-CH_4	0.5	0.4	0.4	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0
		IW	Waste oil[2)]	kt-CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			Plastics[2), 4)]	kt-CH_4	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			Food waste[3)]	kt-CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			Paper/cardboard[2)]	kt-CH_4	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			Wood[3)]	kt-CH_4	0.1	0.1	0.1	0.4	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.2
			Natural fiber[3)]	kt-CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			Sludge (incl. sewage sludge)[3)]	kt-CH_4	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		SCIW	Flammable waste oil[1)]	kt-CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			Specified hazardous IW oil [1)]	kt-CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			Infectious waste (plastics)[1), 4)]	kt-CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			Infectious waste (except plastics)[3)]	kt-CH_4	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	5.C.2. Open burning (IW)[2)]			kt-CH_4	0.5	0.5	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total			kt-CH_4	1.1	1.2	0.8	0.7	0.5	0.5	0.4	0.4	0.3	0.3	0.3	0.3
				kt-CO_2 eq.	31	33	23	20	13	13	11	10	9	10	10	9
N_2O	5.C.1. Waste incineration	MSW[2)]		kt-N_2O	1.03	1.05	0.98	0.52	0.46	0.47	0.47	0.34	0.34	0.33	0.33	0.32
		IW	Waste oil[2)]	kt-N_2O	0.01	0.02	0.02	0.09	0.09	0.08	0.07	0.07	0.07	0.08	0.08	0.08
			Plastics[2), 4)]	kt-N_2O	0.15	0.32	0.31	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
			Food waste[3)]	kt-N_2O	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
			Paper/cardboard[2)]	kt-N_2O	0.01	0.01	0.01	0.02	0.02	0.01	0.01	0.00	0.00	0.00	0.00	0.00
			Wood[3)]	kt-N_2O	0.06	0.10	0.06	0.14	0.08	0.10	0.08	0.07	0.07	0.07	0.07	0.07
			Natural fiber[3)]	kt-N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Sewage sludge[3)]	kt-N_2O	2.63	3.44	4.09	6.06	4.55	4.86	4.18	4.05	3.89	3.81	3.92	3.84
			Sludge (excl. sewage sludge) [3)]	kt-N_2O	0.89	0.92	0.94	0.22	0.19	0.18	0.16	0.15	0.15	0.15	0.14	0.14
		SCIW	Flammable waste oil[1)]	kt-N_2O	0.00	0.00	0.01	0.03	0.02	0.02	0.01	0.02	0.02	0.02	0.02	0.02
			Specified hazardous IW oil [1)]	kt-N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
			Infectious waste (plastics)[1), 4)]	kt-N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
			Infectious waste (except plastics)[3)]	kt-N_2O	0.00	0.00	0.00	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	5.C.2. Open burning (IW)[2)]			kt-N_2O	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Total			kt-N_2O	4.81	5.89	6.47	7.16	5.48	5.77	5.04	4.76	4.58	4.51	4.62	4.51
				kt-CO_2 eq.	1,274	1,562	1,713	1,898	1,451	1,528	1,335	1,261	1,214	1,194	1,224	1,196
Total				kt-CO_2 eq.	11,255	14,171	15,022	12,791	10,867	10,834	10,316	9,320	9,611	9,706	10,015	9,673

Note:
1) Include fossil-fuel-derived component only.
2) Include both fossil-fuel-derived component and biogenic component.
3) Include biogenic component only.
4) Include plastic products for infection control (nonwoven masks examination/surgical gloves).

Table 7-31 Total GHG emissions from incineration of waste (reference value) including emissions from waste incineration for energy use and energy recovery

Gas	Category				Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
CO_2	5.C. Waste incineration and open burning (without energy recovery)[1]				kt-CO_2	9,949	12,576	13,285	10,873	9,403	9,293	8,970	8,049	8,387	8,502	8,782	8,468
	1.A. Fuel combustion	Waste incineration with energy recovery	MSW	Plastics[1), 4)]	kt-CO_2	4,626	4,983	6,376	5,156	3,310	4,223	3,596	4,498	4,741	4,776	4,478	4,573
				PET bottles[1)]	kt-CO_2	336	363	573	436	264	318	342	509	437	553	590	572
				Paper/cardboard[1)]	kt-CO_2	680	760	917	1,050	856	888	803	874	864	850	828	824
				Nappies/sanitary pads[1)]	kt-CO_2	221	268	297	412	435	459	456	549	546	551	551	560
				Synthetic textiles[1)]	kt-CO_2	627	713	689	964	1,196	894	966	920	966	939	952	957
			IW	Waste oil[1)]	kt-CO_2	11	16	14	57	92	79	88	69	40	89	167	158
				Plastics[1), 4)]	kt-CO_2	22	46	131	214	405	424	628	733	627	584	786	747
				Paper/cardboard[1)]	kt-CO_2	0.1	0.7	1.0	0.6	2.1	1.6	1.4	0.2	0.2	0.2	0.4	0.4
		Direct use of waste as alternative fuel	MSW	Plastics[1)]	kt-CO_2	NO	NO	94	522	464	239	270	221	209	214	252	247
			IW	Waste oil[1)]	kt-CO_2	2,860	2,976	2,755	3,323	3,042	3,040	3,138	3,086	3,166	3,162	3,441	3,396
				Plastics[1)]	kt-CO_2	38	41	314	863	1,280	1,319	1,461	1,756	1,855	1,820	1,802	1,731
			Waste tire[1)]		kt-CO_2	527	845	1,044	869	1,008	958	1,037	946	940	980	986	905
		Incineration of waste processed as fuel	RDF[1)]		kt-CO_2	34	40	151	423	386	393	366	314	300	287	267	190
			RPF[1)]		kt-CO_2	NO	11	46	684	1,171	1,343	1,355	1,410	1,502	1,450	1,454	1,562
	Total				kt-CO_2	19,932	23,638	26,689	25,846	23,314	23,871	23,477	23,934	24,580	24,758	25,336	24,890
CH_4	5.C. Waste Incineration and open burning (without energy recovery)[2]				kt-CH_4	1.1	1.2	0.8	0.7	0.5	0.5	0.4	0.4	0.3	0.3	0.3	0.3
	1.A. Fuel combustion	Waste incineration with energy recovery	MSW[2)]		kt-CH_4	0.5	0.5	0.6	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
			IW	Waste oil[2)]	kt-CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				Plastics[2), 4)]	kt-CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				Food waste[3)]	kt-CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				Paper/cardboard[2)]	kt-CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				Wood[3)]	kt-CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				Natural fiber[3)]	kt-CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				Sludge (excl. sewage sludge)[3)]	kt-CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Direct use of waste as alternative fuel	MSW	Plastics[2)]	kt-CH_4	NO	NO	0.0	0.0	0.0	NO	NO	NO	NO	NO	NO	NO
			IW	Waste oil[2)]	kt-CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
				Plastics[2)]	kt-CH_4	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3
				Wood[3)]	kt-CH_4	1.8	1.8	2.2	2.9	4.2	4.8	5.0	5.4	5.4	5.3	5.8	5.7
			Waste tire[2)]		kt-CH_4	0.0	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Incineration of waste processed as fuel	RDF[2)]		kt-CH_4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
			RPF[2)]		kt-CH_4	NO	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Total				kt-CH_4	3.5	3.6	3.8	4.0	5.0	5.6	5.8	6.2	6.2	6.2	6.6	6.5
					kt-CO_2 eq.	97	100	106	111	141	158	163	174	173	173	186	183
N_2O	5.C. Waste Incineration and open burning (without energy recovery)[2]				kt-N_2O	4.81	5.89	6.47	7.16	5.48	5.77	5.04	4.76	4.58	4.51	4.62	4.51
	1.A. Fuel combustion	Waste incineration with energy recovery	MSW[2)]		kt-N_2O	1.19	1.32	1.53	1.13	0.93	0.93	0.86	0.89	0.86	0.85	0.81	0.81
			IW	Waste oil[2)]	kt-N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01
				Plastics[2), 4)]	kt-N_2O	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.01
				Food waste[3)]	kt-N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
				Paper/cardboard[2)]	kt-N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
				Wood[3)]	kt-N_2O	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02
				Natural fiber[3)]	kt-N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
				Sludge (excl. sewage sludge)[3)]	kt-N_2O	0.01	0.01	0.01	0.00	0.00	0.02	0.02	0.03	0.02	0.01	0.02	0.02
		Direct use of waste as alternative fuel	MSW	Plastics[2)]	kt-N_2O	NO	NO	0.00	0.00	0.00	NO	NO	NO	NO	NO	NO	NO
			IW	Waste oil[2)]	kt-N_2O	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02
				Plastics[2)]	kt-N_2O	0.03	0.02	0.03	0.02	0.05	0.04	0.05	0.06	0.06	0.06	0.05	0.05
				Wood[3)]	kt-N_2O	0.02	0.02	0.03	0.03	0.05	0.05	0.06	0.06	0.06	0.06	0.07	0.06
			Waste tire[2)]		kt-N_2O	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		Incineration of waste processed as fuel	RDF[2)]		kt-N_2O	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00
			RPF[2)]		kt-N_2O	NO	0.00	0.00	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03
	Total				kt-N_2O	6.08	7.29	8.10	8.41	6.57	6.89	6.11	5.88	5.67	5.57	5.67	5.55
					kt-CO_2 eq.	1,611	1,931	2,147	2,229	1,742	1,825	1,618	1,558	1,503	1,475	1,501	1,471
Total					kt-CO_2 eq.	21,640	25,670	28,943	28,186	25,197	25,854	25,258	25,666	26,256	26,405	27,023	26,544

Note:
1) Include fossil-fuel-derived component only.
2) Include both fossil-fuel-derived component and biogenic component.
3) Include biogenic component only.
4) Include plastic products for infection control (nonwoven masks and examination gloves).

7.4.1. Waste Incineration (without Energy Recovery) (5.C.1.)

7.4.1.1. Municipal Solid Waste (5.C.1.-)

a) Category Description

This category covers the emissions from incineration of MSW without energy recovery. Emissions of CO_2 are reported under either "Municipal solid waste (Biogenic) (5.C.1.a.i.)" or "Municipal solid waste (Non-biogenic) (5.C.1.b.i.)" in accordance with the waste type as indicated in the Table 7-27. Emissions of CH_4 and N_2O are estimated for each type of furnace. The data used for the estimation on MSW incineration cannot distinguish biogenic-origin wastes and non-biogenic origin wastes. Therefore, total emissions including biogenic-origin ones are reported altogether under "Municipal solid waste (Non-biogenic) (5.C.1.b.i.)".

b) Methodological Issues

1) CO_2

- ***Estimation Method***

Emissions of CO_2 from this emission source are calculated based on Japan's country-specific emission factors, the amount of waste incinerated (dry basis) and the percentage of MSW treated at the municipal incineration facilities that are accompanied by energy recovery, in accordance with the decision tree in the *2006 IPCC Guidelines* (Volume 5, Page 5.9, Fig. 5.1). In order to estimate CO_2 emissions from the incineration of fossil-fuel-derived waste[2], emissions from fossil-fuel-derived fraction in bottles made from polyethylene terephthalate (PET bottles), plastics other than PET bottles (herein after referred to "plastics"), plastic products for infection control (home use nonwoven masks), synthetic textiles, paper/cardboard and nappies/sanitary pads in MSW are estimated.

$$E = \sum_i \{EF_i \times A_i \times (1 - R)\}$$

E : CO_2 Emissions from the incineration of MSW type i [kg-CO_2]
EF_i : Emission factor for the incineration of waste type i [kg-CO_2/t (dry)]
A_i : Amount of waste type i incinerated [t (dry)]
R : Percentage of MSW incinerated at incineration facilities with energy recovery

- ***Emission Factor***

➢ ***Equation***

In accordance with the *2006 IPCC Guidelines*, the emission factors are calculated as follows.

$$EF_i = CF_i \times FCF_i \times OF \times 44/12$$

EF_i : Emission factor for the incineration of waste type i [kg-CO_2/t (dry)]
CF_i : Carbon content in waste type i [% (dry)]
FCF_i : Fossil-fuel-derived fraction in carbon in waste type i [%]
OF : Oxidation factor [%]

➢ ***Carbon Content (CF)***

The carbon contents in MSW by waste type are shown in the following table.

[2] CO_2 emissions from the incineration of food waste, biogenic fraction of paper/cardboard, natural fiber textiles, wood and biomass-based plastics are reported as the reference figures of "Municipal solid waste (Biogenic)(5.C.1.a.i.)". Estimation methods for their emissions are the same as those for emissions from the incineration of fossil-fuel-derived waste.

Table 7-32 Carbon content of each waste type in MSW (*CF*: dry basis)

Item	Carbon content	Reference
Plastics	76.8 %	Survey for the fraction and carbon content in each plastic material composition in MSW generated by 14 domestic cities (MOE, 2020b)
Home use nonwoven masks	81.1%	Based on the measured material composition ratios and carbon contents of products from 14 domestic manufacturers (MOE, 2026)
PET bottles	62.1 %	Averaged value of the measured data obtained at domestic 10 cities (MOE, 2020b)
Synthetic textiles	63.0 %	Weighted average of carbon content by each type of synthetic textile (MOE, 2006b)
Paper/cardboard	40.8 %	Averaged value of the measured data at domestic 14 cities (MOE, 2020b)
Nappies	56.0 %	Estimated based on an interview survey of *Japan Hygiene Products Industry Association* (MOE, 2021)
Sanitary pads		Regarded as equivalent to nappies based on measurement surveys and expert judgment. (MOE, 2026)

➢ ***Fossil-fuel-derived Fraction in Carbon in Waste (FCF)***

- ***Home Use Nonwoven Masks, Synthetic Textiles, Paper/Cardboard, Nappies, Sanitary Pads***

The fossil-fuel-derived fractions in carbon in home use nonwoven masks, synthetic textiles, paper/cardboard, nappies and sanitary pads in MSW are shown in the following table.

Table 7-33 Fossil-fuel-derived fraction of carbon in each waste type in MSW (*FCF*)

Item	Fossil-fuel-derived fraction in carbon	Reference
Home use nonwoven mask	100%	Assumed that all is fossil-fuel-derived by expert judgement (MOE, 2026)
Synthetic textiles	100%	Assumed that all is fossil-fuel-derived by expert judgement (MOE, 2006b)
Paper/cardboard	9.6%	Based on research of present Modern Carbon (pMC) from ^{14}C in the waste measured by Accelerator Mass Spectrometer (ASTM D6866) (MOE, 2020b)
Nappies	59%	Estimated based on an interview survey of *Japan Hygiene Products Industry Association* (MOE, 2021)
Sanitary Pads		Regarded as equivalent to nappies based on measurement surveys and expert judgment. (MOE, 2026)

Note: Fossil-fuel-derived carbon in paper/cardboard incinerated comes from loading materials, colorant, strength agents, adhesive, ink, laminate film, and other additives added at paper manufacturing or processing.

- ***Plastics, PET Bottles***

Fossil-fuel-derived fraction in carbon in plastics and PET bottles are estimated based on biomass-based plastic content in those items. Note that "biomass-based plastics" is a general term for plastics using the biomass as raw material, including bio composite plastics and plastic-like material. Fossil-fuel-derived fraction in plastics is estimated as follows.

$$FCF_i(T) = 1 - \frac{BPW_i(T)}{PW_i(T)}$$

$FCF_i(T)$: Fossil-fuel-derived fraction in plastic i (MSW plastics, MSW PET bottles or IW plastics) in FY T [%]
$BPW_i(T)$: Amount of biogenic fraction in plastic i in FY T [t (dry)]
$PW_i(T)$: Amount of plastic i generation in FY T, excluding impurities [t (dry)]

Amount of MSW plastics, MSW PET bottles and IW plastics generation in *FY T* ($PW_i(T)$) are obtained from the *Cyclical Use of Waste Report*. Amount of biogenic fraction in MSW plastics, MSW PET bottles and IW plastics in *FY T* ($BPW_i(T)$) are calculated by following equation.

$$BPW_i(T) = \sum_t^T \sum_j (BP_{j,t} \times DP_{j,t} \times B_j \times W_{i,j,t}(T) \times DW_i(T))$$

$BPW_{j,t}$: Amount of biomass-based plastics product j production in FY t [t (dry)]
$DP_{j,t}$: Share of domestic shipments of biomass-based plastics product j in FY t [%]
B_j : Biogenic fraction of biomass-based plastics product j [%]
$W_{i,j,t}(T)$: Probability that biomass-based plastic product j, which was produced in FY t, is disposed of as plastic i (MSW plastics, MSW PET bottles or IW plastics) in FY T after use [%]
$DW_i(T)$: Fraction of plastic i treated domestically in FY T [%]

For the amount of biomass-based plastic products production ($BP_{j,t}$), the share of domestic shipments ($DP_{j,t}$), and the biogenic fraction (B_i) are obtained from a survey by the Japan Society of Biomass Industries and Japan BioPlastics Association. Note that the survey distinguishes final products made of bio-based resin by type (e.g. bio-PE, bio-PET, PLA, etc.) and by use (e.g. wrapping material, containers, daily use products, LCD, etc.).

The survey also provides the supplied amount of bio-based resin as intermediate products of bio-PE, bio-PET and PLA. By subtracting the amount of bio-based resin in final products identified above from the supplied amount of intermediate products by each bio-based resin type, unidentified amount of final products (BP) in the survey are also estimated as resin amounts. The shares of domestic shipments (DP) and the biogenic fractions (B) for those unidentified final products are given by an expert judgement.

A part of bio-PET resin in PET bottles, one of a bio-based resin widely used in Japan, are recovered after use, materially recycled as final products such as bottle or other commodities, and disposed/incinerated finally. In such circumstances, amount of biogenic fraction in MSW PET bottles ($BPW_{MSW\ PET\ bottles}(T)$) are identified by considering disposal amount of bio-based resin not only after first use in products but also after use in recycled products. The amount of recycled bio-PET resin in each product is estimated by considering data of material recycled plastics after bottle use provided by the *Annual Report on PET Bottle Recycling* (the Council for PET Bottle Recycling).

The probability that is disposed of as MSW ($W_{i,j,t}(T)$) is estimated by the expert judgement.

Fractions of MSW plastics and IW plastics treated domestically in $FY\ T$ ($DW_i(T)$) are assumed as 100% for plastics other than PET bottles since the export status is not clear. The parameters for PET bottles are obtained from *Annual Report on PET Bottle Recycling* (Table 7-34).

Table 7-34 Fraction of waste plastic treated domestically (*DW*)

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Plastics in MSW	%	100	100	100	100	100	100	100	100	100	100	100	100
PET bottle in MSW	%	48.6	48.6	48.6	48.6	47.5	51.6	52.0	69.0	74.6	81.1	75.2	78.8
Plastics in IW	%	100	100	100	100	100	100	100	100	100	100	100	100

Fossil-fuel-derived fractions in plastics calculated by methodologies above are shown in Table 7-35. Note that fossil-fuel-derived fractions for plastics in IW are applied only to the plastic element of IW plastics (see also section “7.4.1.2. Industrial Waste (5.C.1.-)”).

Table 7-35 Fossil-fuel-derived fraction in waste plastics (*FCF*)

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Plastics in MSW	%	100.0	100.0	100.0	99.6	99.2	99.4	99.2	98.7	98.7	98.0	97.8	97.8
PET bottle in MSW	%	100.0	100.0	100.0	100.0	100.0	99.8	99.8	99.6	99.6	99.5	99.2	99.0
Plastics in IW	%	100.0	100.0	100.0	100.0	99.9	99.7	99.7	99.9	99.9	99.9	99.9	99.9

- ***Oxidation Factor***

Taking into account Japan’s circumstances, the default value of 100% indicated in the *2006 IPCC Guidelines* is used.

- ***Emission Factor***

Emission factors calculated by methodologies above are shown in Table 7-36.

Table 7-36 Fossil-fuel-derived CO_2 emission factors for MSW incineration

Item	Unit	Emission factor	Note
Plastics	kg-CO_2/t (dry)	2,816	In case of *FCF*=1
PET bottles	kg-CO_2/t (dry)	2,277	
Home use nonwoven masks	kg-CO_2/t (dry)	2,972	–
Synthetic textiles	kg-CO_2/t (dry)	2,310	–
Paper/cardboard	kg-CO_2/t (dry)	144	–
Nappies	kg-CO_2/t (dry)	1,220	–
Sanitary pads	kg-CO_2/t (dry)		–

- ***Activity Data***

As basic information to estimate activity data, the amount of plastic, PET bottles distinguished from plastics, textiles and paper/cardboard incinerated are obtained from the *Cyclical Use of Waste Report*. Note the reported amounts of plastic including PET bottles potentially include biomass-based plastics. The activity data for home use nonwoven masks, nappies, and sanitary pads are estimated based on their production quantities and other related information. The details of activity data estimations are shown as follows.

➢ ***Plastics, PET Bottle***

The activity data for CO_2 emissions from the incineration of plastics and PET bottles in MSW on a dry basis are calculated by following equation.

$$A_i = MSW_i \times (1 - u_i) \times (1 - F_{impurity,i})$$

A_i : Activity data for plastics or PET bottles in MSW incinerated [t (dry)]
MSW_i : Amount of plastics or PET bottles in MSW incinerated [t (wet)]
u_i : Percentage of water content in plastics or PET bottles in MSW [%]
$F_{impurity,\ i}$: Fraction of impurities adhered to plastics or PET bottles in MSW [%]

- ***Percentage of Water Content in Plastics (u)***

The percentage of water contents in plastics and PET bottles in MSW are shown in following table.

Table 7-37 Percentage of water contents in plastics and PET bottles in MSW

Item	Water content	Reference
Plastics	26.1 %	Based on the surveys at domestic 13 cities (MOE, 2020b)
PET bottles	8.4 %	Based on the surveys at domestic 9 cities (MOE, 2020b)

- ***Fraction of Impurities Adhered to Plastics ($F_{impurity}$)***

In many cases, some residual impurities such as biogenic food waste are adhered to the wastes categorized as plastics in investigation for MSW composition. Activity data of plastics incinerated are defined as the amount of plastics from which those impurities are subtracted. Fraction of impurities adhered to plastics are shown in the table below.

Table 7-38 Fraction of impurities adhered to plastics and PET bottles in MSW

Item	Fraction of impurities adhered	Reference
Plastics	11.9%	Based on the surveys at domestic 14 cities (MOE, 2020b)
PET bottles	0%	Expert judgement (MOE, 2020b)

➢ ***Home Use Nonwoven Masks***

Since there are no statistics that directly capture the amount of incinerated nonwoven masks used, the activity data is estimated by assuming that the entire shipment quantity of home use nonwoven masks

is incinerated as MSW, and the entire shipment quantity of medical nonwoven masks is incinerated as IW.

The shipment quantity of home use and medical nonwoven masks is obtained from the Japan Hygiene Products Industry Association (JHPIA) "*Trends in Mask Production and Stocks*".

$$A_{NM\,i} = N_i \times F_{NM} \times WT_{NM} \times 10^6$$

$A_{NM\,i}$: Incinerated amount of nonwoven mask *i* (home use or medical) [t (dry)]
N_i : Domestic shipment quantity of mask *i* [pieces]
F_{NM} : Fraction of nonwoven masks in the total mask shipments (nonwoven masks and gauze masks) [%]
WT_{NM} : Average weight of a nonwoven mask [g/piece]

Based on measured surveys and exert judgements, the fraction of nonwoven masks in the total mask shipments (F_{NM}) is assumed to be 100%, and the average weight of a nonwoven mask (WT_{NM}) is assumed to be 3.2 g/piece (MOE, 2006).

Since nonwoven masks are classified as "other combustible waste (mostly assumed to be wood)" in MSW statistics in Japan, there is no double counting with activity data for textiles or plastics.

➢ *Synthetic Textiles*

The activity data of synthetic textiles in MSW is estimated by disaggregating the amount of textiles in MSW incinerated (wet basis) by using the fraction of waste synthetic textiles in the total waste textiles, and subtracting the water content in textiles (percentage of water content: 20%; see also Table 7-11).

$$A_{textiles} = MSW_{textiles} \times (1 - u_{textiles}) \times F_{synthetic}$$

$A_{textiles}$: Activity data for incineration of synthetic textiles (MSW) incinerated [t (dry)]
$MSW_{textiles}$: Amount of textiles incinerated [t (wet)]
$u_{textiles}$: Percentage of water content in textiles [%]
$F_{synthetic}$: Fraction of synthetic fiber content in total waste textiles [%]

- *Fraction of Synthetic Textiles in Total Waste Textiles ($F_{synthetic}$)*

Fraction of synthetic textiles content in total textiles contained in MSW is calculated by using the amount of fiber based final consumption by each fiber type provided by the Japan Chemical Fibers Association.

$$F_{synthetic} = (C_{synthetic} + 0.4 \times C_{semisynthetic})/C_{total\,fiber}$$

$C_{synthetic}$: Amount of domestic final consumption of synthetic textiles [t (dry)]
$C_{semisynthetic}$: Amount of domestic final consumption of semisynthetic textiles [t (dry)]
$C_{total\,fiber}$: Amount of domestic final consumption of total textiles [t (dry)]

Note: Most semisynthetic textile for domestic use consists of acetate fiber derived from acetylcellulose, and its synthetic fraction by weight is assumed as 40% by expert judgement.

Table 7-39 Fraction of synthetic textiles in textiles

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Fraction of synthetic textile	%	52.2	52.9	55.3	54.4	59.4	62.2	65.2	61.3	61.4	60.6	61.9	62.7

➢ *Paper/Cardboard*

The activity data of paper/cardboard in MSW is estimated by subtracting the water content (percentage of water content: 20%; see also Table 7-11) in paper/cardboard from the amount of paper/cardboard in MSW incinerated (wet basis). Since the item of paper/cardboard in the *Cyclical Use of Waste Report*

includes nappies and sanitary pads, for activity data, the amounts of nappies and sanitary pads incinerated are subtracted from the amount of paper/cardboard incinerated.

$$A_{paper} = MSW_{paper} \times \left(1 - u_{paper}\right) - \left(A_{nappy} + A_{sanitary\,pad}\right)$$

A_{paper} : Activity data for incineration of paper/cardboard (MSW) [t (dry)]
MSW_{paper} : Amount of paper/cardboard incinerated [t (wet)]
u_{paper} : Percentage of water content in paper/cardboard [%]
A_{nappy} : Activity data of nappy incinerated [t (dry)]
$A_{sanitary\,pad}$: Activity data of sanitary pad incinerated [t (dry)]

➢ ***Nappies/Sanitary Pads***

- ***Nappies***

Although nappies in Japan's MSW are generally classified into paper or textiles, the incinerated amount is not clearly distinguished from these categories. Therefore, the activity data is estimated as follows.

Based on expert judgement, the amount of domestic production of nappies is applied as the activity data for nappies incinerated prior to FY2004. The amount of domestic production of nappies is derived from the reported amount of nappy for adult and infant (dry basis) on the *JHPIA News* published by JHPIA.

The amount of nappy incinerated for FY2005 onward is estimated by following equation based on MOE (2020a), as the amount of nappy consumption (See also Table 7-40 for details of used parameters).

$$A_{nappy} = \sum_i WT_i \times N_i \times PN_i \times 365/10^6$$

A_{nappy} : Activity data of nappies incinerated (amount of nappy consumption) [t (dry)]
WT_i : Weight of nappy *i* (for adult or child) per piece [t (dry)]
N_i : Number of nappy *i* consumed per person and day [piece/person/day]
PN_i : Number of nappy *i* users [person]

Table 7-40 Parameters in estimation of amount of nappy consumption

Item	User	Value	Reference
Weight of nappy per piece (*WT*)	Adult	292g (outer cover [84g×1] and inner pads [52g× 4])	MOE (2020a)
	Child	30g	
Number of nappies consumed per person per day (*N*)	Adult	1 piece (a set of 1 outer cover and 4 inner pads) /person/day	
	Child	5 pieces/person/day	
Number of nappy user (*PN*)	Adult	$PN_{adult} = \sum_a P_a \times (PS_{1/2,a} \times 0.2 + PC_{1/2,a} \times 0.64)$ P_a : Population in age-group *a* $PS_{1/2,\ a}$: Fraction of Requiring support 1 or 2 in age-group *a* $PC_{1/2,\ a}$: Fraction of Requiring long-term care 1 or 2 in age-group *a*	Equations: MOE (2020a) P_a : *Current Population Estimates* (MIC) $PS_{1/2,\ a}$, $PC_{1/2,\ a}$: *Status report of Long-Term Care Insurance System* (MHLW)
	Child	$PN_{child} = P_{0-3} \times 0.9$ $P_{0\text{-}3}$: Population in age from 0 to 3	

Note: MIC: Ministry of Internal Affairs and Communications, MHLW: Ministry of Health, Labour and Welfare

- ***Sanitary Pads***

Since there are no statistics that directly capture the amount of incinerated sanitary pads and their reuse is prohibited under the Pharmaceutical and Medical Device Act, the activity data is estimated by assuming that the entire domestic shipment quantity of sanitary pads is incinerated as MSW. The activity data is estimated by using the domestic shipment quantity of sanitary pads (MHLW, the *Statistics of*

Production by Pharmaceutical Industry) and the average weight per sanitary pad (7.0 g/piece, based on an expert judgement).

➢ ***Activity Data***

Activity data calculated by methodologies above is shown in Table 7-41.

Table 7-41 Activity data to estimate CO_2 emissions from MSW incinerated

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Plastics Home use nonwoven masks	kt (dry)	3,056	3,180	3,708	2,689	1,770	2,270	1,981	2,233	2,373	2,410	2,283	2,309
PET bottles	kt (dry)	275	286	412	280	173	211	232	310	268	340	367	353
Synthetic textiles	kt (dry)	505	555	489	610	774	582	644	550	582	567	579	576
Paper/ cardboard	kt (dry)	8,819	9,521	10,464	10,698	8,915	9,314	8,611	8,412	8,382	8,255	8,107	7,983
Nappy/ sanitary pad	kt (dry)	337	395	399	494	533	567	575	621	623	630	634	638

● ***Percentage of Municipal Waste Incinerated at Municipal Incineration Facilities for Energy Recovery***

Percentage of MSW that is incinerated at municipal incineration facilities with energy recovery stands for the one being incinerated at the facilities actually supply electricity or heat outside of them. These values are obtained from the *State of Municipal Waste Treatment Survey* (MOE).

Table 7-42 Percentage of MSW incinerated at incineration facilities with energy recovery

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
With off-field power generation or heat utilization	%	53.7	55.6	61.1	68.4	66.9	66.4	65.0	72.4	71.8	71.7	71.2	71.9
Without off-field power generation or heat utilization	%	46.3	44.4	38.9	31.6	33.1	33.6	35.0	27.6	28.2	28.3	28.8	28.1

2) CH_4, N_2O

● ***Estimation Method***

In this category, CH_4 and N_2O emissions from incinerators and gasification melting furnaces are estimated. CH_4 and N_2O emissions from incinerators are estimated by multiplying the amount of MSW (wet basis) for each incineration method by each corresponding emission factor. CH_4 and N_2O emissions from gasification melting furnaces are estimated by multiplying the amount of MSW (wet basis) incinerated in gasification melting furnace by emission factors. Emissions from MSW with energy recovery are subtracted from the total emissions from this source and the rest of the emissions are allocated to the waste sector.

$$E = \sum_i \{EF_i \times A_i \times (1 - R)\}$$

E : CH_4 or N_2O emission from the incineration of MSW [kg-CH_4] [kg-N_2O]
EF_i : Emission factor for MSW incineration method (or furnace type) i [kg-CH_4/t (wet)] [kg- N_2O/t (wet)]
A_i : Amount of MSW incinerated by incineration method (or furnace type) i [t (wet)]
R : Percentage of MSW incinerated at facilities with energy recovery

● ***Emission Factor***

➢ ***Incinerator***

In order to implement countermeasures against dioxin pollutions, the renovations, repairs, or rebuilding of incineration facilities took place in the latter half of 1990 through the first half of 2000 in Japan. There have been some improvements made in CH_4 emission factors from the facilities renovated or rebuilt in FY2000 and later, compared to the values obtained before then (MOE, 2010). Therefore, based

on the survey (MOE, 2010) and expert judgment, for the CH_4 emission factors by incinerator type (stoker furnace and fluidized bed incinerator) and incineration method (continuous incinerator, semi-continuous incinerator, and batch type incinerator) for the period FY2001 and before (MOE, 2006b), and from FY2002 onward (MOE, 2010), respectively, different values are used. All the emission factors are established based on the measurement surveys. The air-intake adjustment taking into account CH_4 concentrations in the atmosphere is not made to these emission factors.

For the N_2O emission factors for incinerators by type and by incineration method, same as for the CH_4 emission factors, different values are used for the period FY2001 and before (MOE, 2006b), and from FY2002 onward (MOE, 2010), respectively.

Since activity data are obtained as the amount of incinerated waste by incineration method, emission factors both for CH_4 and N_2O are established by incineration method (continuous incinerator, semi-continuous incinerator, and batch type incinerator) by using the weighted average of fraction of the amount of incineration by incinerator type for each fiscal year.

➢ ***Gasification Melting Furnace***

Emission factors for gasification melting furnace were surveyed by each furnace type (shaft furnace, fluidized bed, and rotary kiln) (MOE, 2010), however, since activity data are based on the total amount of incineration for gasification melting furnace, emission factors in the emission estimation method are established by using the weighted average of the fraction of the amount of incineration by each furnace type for each year.

Table 7-43 CH_4 and N_2O emission factors by type of incineration method (MSW)

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
CH_4 emission factor													
Continuous incinerator	g-CH_4/t (wet)	8.2	8.2	8.3	2.6	2.7	2.7	2.7	2.6	2.5	2.5	2.5	2.5
Semi-continuous incinerator	g-CH_4/t (wet)	69.6	69.6	75.1	19.9	20.9	20.9	20.7	20.9	21.1	20.5	19.8	20.6
Batch type incinerator	g-CH_4/t (wet)	80.5	80.5	84.1	13.2	11.6	11.7	11.8	11.0	11.0	11.1	11.1	11.1
Gasification melting furnace	g-CH_4/t (wet)	NA	NA	5.6	6.9	7.0	6.9	6.9	6.8	6.9	6.9	6.9	6.9
N_2O emission factor													
Continuous incinerator	g-N_2O/t (wet)	58.8	58.8	59.1	37.9	38.0	38.0	38.1	37.9	37.7	37.6	37.7	37.6
Semi-continuous incinerator	g-N_2O/t (wet)	56.8	56.8	57.3	71.5	73.2	73.1	72.8	73.2	73.6	72.5	71.3	72.6
Batch type incinerator	g-N_2O/t (wet)	71.4	71.4	74.8	76.0	76.2	76.2	76.2	76.3	76.3	76.3	76.3	76.3
Gasification melting furnace	g-N_2O/t (wet)	NA	NA	16.9	12.0	11.5	11.7	12.2	12.7	12.7	12.8	13.1	13.2

Reference: MOE (2000), MOE (2010), the *Waste Treatment in Japan* (MOE), Ishikawa Prefecture et al. (1991-1997), Japan Society for Atmospheric Environment: JSAE (1996), Ueno et al. (1992)

● ***Activity Data***

The activity data both for CH_4 and N_2O emissions for incinerator and gasification melting furnace are estimated by multiplying the amount of MSW incinerated (wet basis) provided in the *Cyclical Use of Waste Report* (MOE) (publicized reports and the most current data from the reports prior to publication) by the fraction of each incineration method or gasification meting furnace estimated by the data from the *State of Municipal Waste Treatment Survey* (MOE).

Table 7-44 Amount of incineration of MSW by incineration method (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Continuous incinerator	kt (wet)	26,215	29,716	32,749	32,246	27,603	28,246	27,364	26,344	25,998	25,812	25,201	25,057
Semi-continuous incinerator	kt (wet)	4,810	5,455	5,882	4,047	2,968	2,827	2,349	1,760	1,580	1,488	1,326	1,239
Batch type incinerator	kt (wet)	5,643	4,328	3,131	1,562	1,078	970	842	589	562	509	485	468
Gasification melting furnace	kt (wet)	NO	NO	370	2,397	3,605	4,098	4,328	4,875	4,902	4,785	4,613	4,504

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainties in CO_2 emission factors are evaluated by using the 95% confidence interval of carbon content data in plastics. The uncertainties in CH_4 and N_2O emission factors are evaluated by using the 95% confidence interval of the measured data form the surveys for emissions factors. As for the uncertainties in activity data, the uncertainties in MW data indicated in Table 7-2 are applied. Details of the uncertainty assessment for this category are indicated in the Table 7-45 and Table 7-46.

Table 7-45 Uncertainty assessment for MSW for the category "waste incineration (5.C.1.-)" (CO_2)

Item	GHGs	Emission factor uncertainty		Activity data uncertainty		Emission uncertainty		Method for assessing emission factor uncertainty	Method for assessing activity data uncertainty	Method for assessing emission uncertainty
		(-)	(+)	(-)	(+)	(-)	(+)			
Plastics	CO_2	-1%	+1%	-10%	+10%	-10%	+10%	MOE (2020b).	The uncertainty in MW statistics is applied.	Combined by using the error-propagation formula.
Home use nonwoven masks	CO_2	-1%	+1%	-10%	+10%	-10%	+10%	MOE (2026).		
PET bottles	CO_2	-0.4%	+0.4%	-10%	+10%	-10%	+10%	MOE (2020b).		
Synthetic textiles	CO_2	-2%	+2%	-10%	+10%	-10%	+10%	Evaluated using the 95% confidence interval in measured data of carbon content in synthetic textiles.		
Paper/ cardboard	CO_2	-13%	+13%	-10%	+10%	-16%	+16%	Evaluated by combining the 95% confidence interval in measured data of carbon content with that of fossil-derived carbon.		
Nappies/ sanitary pads	CO_2	-13%	+13%	-10%	+10%	-16%	+16%	Due to the lack of information on the uncertainty of the emission factor, the value of paper/ cardboard is applied based on expert judgment.		

Table 7-46 Uncertainty assessment for MSW on the category "waste incineration (5.C.1.-)" (CH_4 and N_2O)

Item	GHGs	Emission factor uncertainty		Activity data uncertainty		Emission uncertainty		Method for assessing emission factor uncertainty	Method for assessing activity data uncertainty	Method for assessing emission uncertainty
		(-)	(+)	(-)	(+)	(-)	(+)			
Continuous incineration/ Stoker furnace	CH_4	-39%	+39%	-10%	+10%	-40%	+40%	MOE (2010).	The uncertainty in MW statistics is applied.	Combined by using the error-propagation formula.
	N_2O	-34%	+34%	-10%	+10%	-35%	+35%			
Continuous incineration/ Fluidized bed furnace	CH_4	-100%	+719%	-10%	+10%	-100%	+719%			
	N_2O	-98%	+98%	-10%	+10%	-99%	+99%			
Semi-continuous incineration/ Stoker furnace	CH_4	-82%	+82%	-10%	+10%	-83%	+83%			
	N_2O	-82%	+82%	-10%	+10%	-82%	+82%			
Semi-continuous incineration/ Fluidized bed furnace	CH_4	-100%	+162%	-10%	+10%	-100%	+162%			
	N_2O	-64%	+64%	-10%	+10%	-64%	+64%			
Batch-type incineration/ Stoker furnace	CH_4	-75%	+75%	-10%	+10%	-76%	+76%			
	N_2O	-100%	+111%	-10%	+10%	-100%	+111%			
Batch-type incineration/ Fluidized bed furnace	CH_4	-100%	+394%	-10%	+10%	-100%	+394%			
	N_2O	-100%	+133%	-10%	+10%	-100%	+134%			
Gasification melting furnace/ Shaft furnace	CH_4	-100%	+203%	-10%	+10%	-100%	+203%			
	N_2O	-45%	+45%	-10%	+10%	-46%	+46%			
Gasification melting furnace/ Fluidized bed furnace	CH_4	-100%	+133%	-10%	+10%	-100%	+134%			
	N_2O	-100%	+252%	-10%	+10%	-100%	+252%			
Gasification melting furnace/ Rotatory kiln	CH_4	-54%	+54%	-10%	+10%	-55%	+55%			
	N_2O	-87%	+87%	-10%	+10%	-88%	+88%			

- ***Time-series Consistency***

Because data on the amount of waste incinerated by type of waste are not available for years prior to FY1997, the data are estimated by using the total incinerated amount of MSW for each year and the ratio of amount of waste incinerated by waste type for FY1998. The emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

See section 7.1.5. "Sector-specific QA/QC and Verification".

e) Category-specific Recalculations

By adding the incinerated amounts of home use nonwoven masks and sanitary pads to the activity data, CO_2 emissions for the entire time series were recalculated. By updating the statistical data, CO_2 emissions from FY2015 onwards and CH_4 and N_2O emissions in FY2023 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

7.4.1.2. Industrial Waste (5.C.1.-)

a) Category Description

This category covers CO_2, CH_4 and N_2O emissions from incineration of IW without energy recovery by each waste type and the emissions are reported in the corresponding category either "Industrial solid wastes (Biogenic) (5.C.1.a.ii.1.)", "Other (Non-fossil liquid waste) (Biogenic) (5.C.1.a.ii.5.)", "Other (Sludge) (Biogenic) (5.C.1.a.ii.5.)" "Industrial solid wastes (Non-biogenic) (5.C.1.b.ii.1.)" or " Fossil liquid waste (Non-biogenic) (5.C.1.b.ii.5.)" (see Table 7-27).

b) Methodological Issues

1) CO_2

- ***Estimation Method***

Emissions of fossil-fuel-derived CO_2 from this source are calculated by using the amount of fossil-fuel-derived waste oil, plastics, plastic products for infection control (medical nonwoven masks and examination gloves) and paper/cardboard incinerated, Japan's country-specific emission factors, and the percentage of incinerated IW with energy recovery at IW incineration facilities in accordance. For waste oil, emission factors on a wet basis are applied; for plastics, plastic products for infection control, and paper/cardboard, emission factors on a dry-weight basis are applied. Also, since industrial textiles do not include synthetic textiles under the regulation of the Waste Management and Public Cleansing Act, the industrial textiles are regarded as waste natural fiber: thus the CO_2 emissions from incineration of industrial textiles are not included in national total because these emissions are biogenic-origin.

$$E = \sum_i \{EF_i \times A_i \times (1 - \mathrm{R}_i)\}$$

E_i : CO_2 Emissions from incineration of IW type i [kg-CO_2]
EF_i : Emission factor for incineration of IW type i [kg-CO_2/t (wet) -waste oil], [kg-CO_2/t (dry) -waste other than oil]
A_i : Amount of incinerated IW type i [t (wet) -waste oil], [t (dry) -waste other than oil]
R_i : Percentage of IW incinerated at facilities with energy recovery (for waste type i)

- ***Emission Factor***

➢ ***Equation***

In accordance with the approach taken by the *2006 IPCC Guidelines*, emission factor is calculated as follows.

- ***Plastics***

$$EF_{iw\ plast.} = \sum_j (CF_j \times FCF_j \times PF_j \times OF \times \frac{44}{12})$$

$EF_{iw\ plast.}$: Emission factor for CO_2 from the incineration of IW plastics [kg-CO_2/t (dry)]
CF_j : Carbon content of element *j* (plastic or non-plastic) contained in waste plastics [%]
FCF_j : Fossil fuel-derived carbon fraction of element *j* contained in waste plastics [%]
PF_j : Fraction of element *j* contained in waste plastics [%]
$PF_{plastic}$: 71.8% (dry) and $PF_{non\text{-}plastic}$: 28.2% (dry) from MOE (2026)
OF : Oxidation factor [%]

- ***Waste Oil, Medical Nonwoven Masks, Examination Gloves***

$$EF_i = CF_i \times FCF_i \times OF \times 44/12$$

EF_i : Emission factor for IW *i* [kg-CO_2/t]
CF_i : Carbon content in IW *i* [%]
FCF_i : Fossil-fuel-derived fraction in IW *i* [%]
OF : Oxidation factor [%]

➢ ***Carbon Content (CF)***

Carbon contents in IW are shown the table below.

Table 7-47 Carbon contents of IWs (*CF*)

Item		Carbon content	References
Fossil-fuel-derived waste oil		43.0% (wet)	MOE (2025)
Recycled oil from used solvent		51.6% (wet)	MOE (2025)
Recycled heavy oil		84.0% (wet)	MOE (2025)
Plastics	Total	52.1%(dry)	Weighted average with fraction of elements (*PF*) in plastics
	Plastic element	68.6%(dry)	MOE (2026)
	Non-plastic element	10.4%(dry)	Assessed only for fossil-fuel-derived fraction (MOE, 2026)
Medical nonwoven masks		81.1%(dry)	MOE (2026)
Examination gloves	PVC	53.1%(dry)	MOE (2026)
	Synthetic rubber	88.9%(dry)	MOE (2026)
Paper/cardboard		40.8% (dry)	The carbon content of MSW (MOE, 2020b) is used for that of IW because its properties are similar to those of MSW

Note: For recycled oil from used solvent and recycled heavy oil, see "7.4.3.2.b Industrial Waste (Plastics, Waste Oil, and Wood) Used as Alternative Fuels (1.A.2.) "

➢ ***Fossil-fuel-derived Fraction in Carbon in Paper/Cardboard in Industrial Waste (FCF)***

The fossil-fuel-derived fractions in carbon in IW are shown in the following table.

Table 7-48 Fossil-fuel-derived fractions of carbon in IWs (*FCF*)

Item		Fossil-fuel-derived fraction	Reference
Fossil-fuel derived waste oil		100%	Expert judgement
Recycled oil from used solvent		100%	Expert judgement
Recycled heavy oil		100%	Expert judgement
Plastics	Plastic element	Variable	See Table 7-35
	Non-plastic element	100%	The carbon content is assessed only for fossil-fuel-derived fraction.
Medical nonwoven masks		100%	Expert judgement
Examination gloves	PVC	100%	Expert judgement
	Synthetic rubber	100%	
Paper/cardboard		9.6%	The data of MSW (MOE, 2020b) is used for that of IW because its properties are similar to those of MSW

Note: For recycled oil from used solvent and recycled heavy oil, see "7.4.3.2.b Industrial Waste (Plastics, Waste Oil, and Wood) Used as Alternative Fuels (1.A.2.) "

➢ ***Oxidation Factor (OF)***

The default value of 100% given in the *2006 IPCC Guidelines* is used.

➢ ***Emission Factor (EF)***

Emission factors calculated by methodologies above are shown in Table 7-49.

Table 7-49 CO_2 emission factors for IW incineration (*EF*)

Item		Unit	Emission factor	Note
Fossil-fuel derived waste oil		kg-CO_2/t (wet)	1,576	–
Recycled oil from used solvent		kg-CO_2/t (wet)	1,892	–
Recycled heavy oil		kg-CO_2/t (wet)	3,081	–
Plastics		kg-CO_2/t (dry)	1,911	In case of $FCF_{plastic\ element}$=1
Medical nonwoven masks		kg-CO_2/t (dry)	2,972	–
Examination gloves	PVC	kg-CO_2/t (dry)	1,948	–
	Synthetic rubber	kg-CO_2/t (dry)	3,259	–
Paper/cardboard		kg-CO_2/t (dry)	144	–

Note: For recycled oil from used solvent and recycled heavy oil, see "7.4.3.2.b Industrial Waste (Plastics, Waste Oil, and Wood) Used as Alternative Fuels (1.A.2.) "

● ***Activity Data***

For the activity data for CO_2 emissions from the incineration of waste oil, plastics and paper/cardboard in IW, the amount of incineration provided by the *Cyclical Use of Waste Report* (MOE) is used. Note that the statistical data for IW from this report includes but does not distinguish SCIW. To avoid double counting in the activity data estimation, the amount of SCIW incinerated is subtracted from the statistical data (see also the section "7.4.1.3. Specially-Controlled Industrial Waste (5.C.1.-)". The activity data of medical nonwoven masks and examination gloves are estimated based on their domestic shipment quantities. Details of methodologies to estimate activity data are shown below.

➢ ***Fossil-fuel-derived Waste Oil***

$$A_{oil-fossil} = \{IW_{oil} \times (1 - F_{bio}) - SCIW_{oil}\} \times (1 - F_{non-oil})$$

$A_{oil\text{-}fossil}$: Activity data for the incineration of waste fossil-fuel-derived waste oil [t (wet)]
IW_{oil} : Amount of waste oil incinerated in IW [t (wet)]
$SCIW_{oil}$: Amount of waste oil incinerated in SCIW[1)] [t (wet)]
F_{bio} : Fraction of waste oil from animal and vegetable origin[2)] [%]
$F_{non\text{-}oil}$: Fraction of non-waste oil elements[3)] [%]

Note:
1) All the waste oils in SCIW are regarded as fossil-fuel-derived.
2) From the survey conducted by the MOE
3) Fraction of non-waste oil elements within amount of waste oil data, which includes oil containers such as metal barrels (3%: MOE, 2025)

Table 7-50 Fraction of waste oil from animal and vegetable origin (F_{bio})

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Fraction of waste animal and vegetable oil	%	2.6	3.5	4.5	5.4	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0

➢ ***Plastics***

Since the incineration amount of IW plastics reported in the *Cyclical Use of Waste Report* (MOE) includes plastic products for infection control (medical nonwoven masks and examination gloves), double counting is removed using the formula below.

$$A_{\text{plast. excl. prods.}} = \left(IW_{\text{plast.}} - A_{IMW.\text{ plasts.}}\right) \times \left(1 - u_{iw\ plast.}\right) - \left(A_{MNM} + \sum_i A_{glove\ i}\right)$$

$A_{plast.excl.\ prods.}$: Activity data for the incineration of plastics excluding plastic products for infection control [t (dry)]
$IW_{plast.}$: Incineration amount of IW plastics [t (wet)]
$A_{IMW.\ plast.}$: Amount of infectious plastics incinerated in SCIW [t (wet)]

$u_{iw\ plast.}$: Water content in IW plastics (6.4% based on MOE (2026))
A_{MNM} : Incineration amount of medical nonwoven masks [t (dry)]
$A_{glove\ i}$: Incineration amount of examination gloves made of material *i* (PVC or synthetic rubber) [t (dry)]

Note: Fossil-fuel-derived fraction of plastics in IW plastics incinerated is estimated in the same way as indicated in "7.4.1.1. Municipal Solid Waste (5.C.1.-) b) 1) CO_2". See also Table 7-35. Note it is assumed that activity data for plastics (IW) incinerated does not include PET bottles unlike MSW plastics.

- ***Medical Nonwoven Masks***

The estimation method for the activity data of medical nonwoven masks is the same as that for home use nonwoven masks (see Section 7.4.1.1. "Municipal Solid Waste (5.C.1.-)").

- ***Examination Gloves***

Since there are no statistics that directly capture the amount of incinerated medical gloves (examination gloves and surgical gloves), and their reuse is prohibited under the Pharmaceutical And Medical Device Act, the entire domestic shipment quantity of examination gloves is assumed to be incinerated as IW, and the entire domestic shipment quantity of surgical gloves is assumed to be incinerated as SCIW (infectious waste). Based on this assumption, the incineration amounts of medical gloves (on a dry-weight basis) are estimated as follows:

$$A_{glove\ i} = N_{glove\ i} \times WT_{glove\ i} \times 10^6$$

$A_{glove\ i}$: Incineration amount of medical glove *i* (PVC or synthetic rubber examination gloves, or synthetic rubber surgical gloves) [t (dry)]
$N_{glove\ i}$: Domestic shipment quantity of medical glove *i* [pieces]
$WT_{glove\ i}$: Average weight of medical glove *i* (examination gloves: 4.2 g/piece, and surgical gloves: 9.0 g/piece, based on expert judgements)

The domestic shipment quantity of medical gloves (N_{glove}) is estimated by using data from the *Statistics of Production by Pharmaceutical Industry* (MHLW) and the *Domestic Sales Statistics of Gloves* (Japan Glove Industry Association).

- ***Paper/Cardboard***

$$A_{paper} = (IW_{paper} - A_{IMW\ excl.\ plast.}) \times (1 - u_{paper})$$

A_{paper} : Activity data for the incineration of paper/cardboard [t (dry)]
IW_{paper} : Amount of paper/cardboard incinerated in IW [t (wet)]
$A_{IMW\ excl.\ plast.}$: Amount of infectious waste incinerated in SCIW except plastics [t (wet)]
u_{paper} : Percentage of waste content in paper or cardboard in IW [%]

Note: Of the SCIW, infectious waste (except plastics) is assumed to be paper/cardboard. Percentage of water content in paper/cardboard in IW is given the value 15% (see Table 7-11).

Details of the activity data for ISW estimated are shown in the table below.

Table 7-51 Incineration amounts of ISW used for CO_2 emission estimates (activity data)

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Plastics	kt (dry)	789	1,679	1,666	1,692	1,594	1,665	1,710	1,474	1,522	1,517	1,677	1,591
Medical nonwoven masks													
Examination gloves (PVC)													
Examination gloves (Synthetic rubber)													
Paper/cardboard	kt (dry)	285	605	611	274	248	129	97	15	14	13	16	16

Note: For the activity data of fossil-fuel-derived waste oil, see Table 7-54.

- ***Percentage of Industrial Waste Incinerated at Industrial Incineration Facilities for Energy Recovery (by Type)***

Percentage of IW that is incinerated at industrial incineration facilities with energy recovery stands for the one being incinerated at the facilities actually supply electricity or heat outside of them. The values are obtained from the *Survey of Industrial Waste Treatment Facilities* (MOE).

In Japan, industrial incineration facilities are installed mainly by private sector waste disposal enterprises. In comparison with the MW incinerators installed primarily by municipal governments, energy recovery (for use in power generation and as a heat source) has not yet been so popular. The percentage for the IW category is therefore smaller.

Table 7-52 Percentage of IW incinerated at incineration facilities with energy recovery

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Waste oil [1)]	%	0.6	0.7	0.6	2.5	4.1	4.0	4.8	4.0	2.2	4.8	8.1	8.1
Plastics [2)]	%	1.4	1.4	4.1	6.6	13.3	13.3	19.2	25.8	21.4	20.0	24.3	24.3
Wood [3)]	%	0.2	0.8	1.1	1.5	5.9	8.5	10.2	9.5	11.1	11.0	18.8	18.8
Sludge [4)]	%	0.9	0.8	1.0	1.1	2.2	8.3	12.2	14.5	12.0	9.0	12.3	12.3
Other [5)]	%	0.2	0.8	1.1	1.5	1.5	1.9	4.2	11.4	10.4	4.4	9.5	9.5

Note:
1) "Waste oil" includes fossil-fuel-derived/animal and vegetable waste oil.
2) "Plastics" includes plastics and plastic products for infection control.
3) "Wood" includes paper/cardboard and wood.
4) Not applicable for "sewage sludge".
5) "Other" includes textiles (natural fiber), and animal and vegetable residues/animal carcasses.

2) CH_4

- ***Estimation Method***

Emissions of CH_4 from this source have been calculated by multiplying the amount of IW incinerated by Japan's country-specific emission factor and by percentage of IW incinerated at incineration facilities with energy recovery.

$$E = \sum_j \{EF_j \times A_j \times (1 - R_j)\}$$

E : CH_4 emissions from the incineration of IW [kg-CH_4]
EF_j : Emission factor for IW type j [kg-CH_4/t (wet)]
A_j : Amount of IW type j incinerated [t (wet)]
R_j : Percentage of IW j incinerated at IW incineration facilities with energy recovery

- ***Emission Factor***

Based on expert judgment which takes into account the countermeasures against dioxin emissions from incinerators, for the emission factors by waste type for the period FY1990-2001 (MOE, 2006b) and from FY2002 onward (MOE, 2010), respectively, different values are used. These emission factors are established based on the measurement surveys. The air-intake adjustment taking into account CH_4 concentrations in the atmosphere is not made to these emission factors. The emission factor of paper/cardboard or wood in MOE (2006b) and MOE (2010) is used for those of textiles (natural fiber), and animal and vegetable residues/animal carcasses.

Table 7-53 CH_4 emission factors for IW by waste type

Item	Unit	FY1990–2001	FY2002–
Waste oil (fossil-fuel-derived/animal and vegetable)	g-CH_4 /t (wet)	4.8	4.0
Plastics[1)]	g-CH_4 /t (wet)	30	8.0
Paper/cardboard	g-CH_4 /t (wet)	22	225
Wood	g-CH_4 /t (wet)		
Textiles (natural fiber)	g-CH_4 /t (wet)		
Animal and vegetable residues/animal carcasses	g-CH_4 /t (wet)		
Sewage sludge	g-CH_4 /t (wet)	14	1.5
Sludge (excl. sewage sludge)	g-CH_4 /t (wet)		

Note: 1) Emission factors for plastics are applied to plastics including plastic products for infection control.

Reference: Environmental Agency (2000), MOE (2006b), MOE (2010), Ishikawa Pref. et al. (1991-1999), JSAE (1996)

- ***Activity Data***

The amount of waste incinerated (wet basis) by waste type is used as the activity data for CH_4 emissions from the incineration of IW.

➢ ***Waste Oil and Plastics***

The activity data for waste oil and plastics are provided by the *Cyclical Use of Waste Report* (MOE). Because the values provided by this report include the amount of SCIW which is allocated to the category of specially-controlled industrial waste (5.C.1.-), it is subtracted from the total amount to avoid double counting. Unlike the activity data for CO_2 emission estimates, both fossil-fuel-derived waste oil and animal and vegetable waste oil are included in waste oil for the activity data for CH_4 emission estimates.

$$A_{oil-bio} = IW_{oil} \times F_{bio} \times (1 - F_{non-oil})$$

$A_{oil-bio}$: Activity data for the incineration of animal and vegetable waste oil [t (wet)]
IW_{oil} : Amount of waste oil incinerated in IW [t (wet)]
F_{bio} : Fraction of waste oil from animal and vegetable origin[1)] [%]
$F_{non-oil}$: Fraction of non-waste oil element[2)] [%]

Note:
1) From the survey conducted by the MOE
2) Fraction of non-waste oil elements in amount of waste oil data, which include oil containers such as metal barrels (3%: MOE, 2025)

The activity data used to estimate CH_4 and N_2O emissions from the incineration of plastics include the incineration amounts of plastic products for infection control (medical nonwoven masks and examination gloves), unlike the activity data used to estimate CO_2 emissions.

$$A_{plast.} = IW_{plast.} - A_{IMW\ plast.}$$

$A_{plast.}$: Activity data for the incineration of plastics [t (wet)]
$IW_{plast.}$: Incinerated amount of IW plastics [t (wet)]
$A_{IMW\ plast.}$: Incinerated amount of infectious waste plastics classified as SCIW [t (wet)]

➢ ***Paper/Cardboard, Wood, Textiles (natural fiber) and Animal and Plant Residues/Animal Carcasses:***

The amount of waste incinerated for each type is obtained from the *Cyclical Use of Waste Report* (MOE). Animal and vegetable residues/animal carcasses waste is defined as the sum of items “animal and vegetable residues” and “animal carcasses” in the said reference.

➢ ***Sewage Sludge and Sludge (Excluding Sewage Sludge)***

Activity data for sewage sludge is obtained from the amount of incinerated sewage sludge reported in a survey by the Ministry of Land, Infrastructure, Transport and Tourism (MLIT). Activity data for sludges

(excluding sewage sludge) is obtained from the amount of other incinerated organic sludge reported in the *Cyclical Use of Waste Report* (MOE).

Table 7-54 Incinerated IW by waste types (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Fossil-fuel-derived waste oil	kt (wet)	1,221	1,454	1,596	1,448	1,423	1,258	1,155	1,110	1,134	1,178	1,312	1,243
Animal and vegetable waste oil	kt (wet)	39	67	100	112	117	100	97	95	93	95	103	99
Plastics	kt (wet)	842	1,794	1,780	1,808	1,703	1,778	1,826	1,574	1,626	1,620	1,791	1,699
Paper/cardboard	kt (wet)	335	712	718	323	292	152	114	18	16	15	19	19
Wood	kt (wet)	2,679	4,744	3,114	1,865	1,101	1,388	1,120	1,055	958	1,021	1,171	1,108
Textiles (natural fiber)	kt (wet)	31	49	50	43	24	35	27	30	28	29	30	30
Animal and vegetable residues/animal carcasses	kt (wet)	77	125	272	167	190	151	168	170	198	175	122	117
Sewage sludge	kt (wet)	3,214	3,829	4,300	5,174	5,187	5,078	5,046	5,023	4,938	5,009	4,931	4,754
Sludge (excl. sewage sludge)	kt (wet)	1,972	2,023	2,071	2,288	2,010	1,954	1,880	1,790	1,690	1,664	1,658	1,595

3) N_2O

- ***Estimation Method***

Emissions of N_2O from this source are calculated separately for the major emission source, sewage sludge, and the waste other than sewage sludge. With respect to sewage sludge, emission factors are set by type of flocculants and furnaces; and the ones for "high-molecular-weight, flocculant fluidized bed incinerator" are further determined by the incineration temperatures. Emissions from the IW other than sewage sludge are estimated by multiplying the amount of waste incinerated by Japan's country-specific emission factor. Among those emissions, the ones to be reported in the waste sector are calculated by multiplying the percentage of IW incinerated at the IW incineration facilities with energy recovery.

$$E = \sum \{EF_j \times A_j \times (1 - R_j)\}$$

E : Emission of nitrous oxide from the incineration of IW [kg-N_2O]
EF_j : Emission factor for waste type j [kg-N_2O /t (dry) -sewage sludge], [kg-N_2O /t (wet) - other IW]
A_j : Incinerated amount of waste type j [t (dry)- sewage sludge], [t (wet) - other IW]
R_j : Percentage of IW j incinerated at facilities with energy recovery

- ***Emission Factor***

➢ ***Sewage Sludge***

Emission factor for N_2O emissions from sewage sludge incineration are determined by taking a weighted average of actually measured emission factors for N_2O at each incineration facility based on the survey on the amount of sewage sludge incinerated at the facilities conducted by MLIT. Since emission factors are different depending on the types of incinerators, temperatures, and flocculants they are established for each category as given in Table 7-55.

Table 7-55 N_2O emission factors for sewage sludge incineration

#	Incinerator type		Temperature	Flocculant	Emission factor [g-N_2O/t (dry)]
1	Conventional type of FBI		Normal (under 850 ˚C)	Polymer	6,700
2			High (850 ˚C and over)		2,880
3	- Multi-layer FBI, - Pressurized FBI with turbocharger - Other low-N_2O emission FBI	Low-N_2O emission furnace	High (850 ˚C and over)		914
4	- Circulating FBI with two-stage incineration method - Stoker furnace - Gasification furnace				86.0
5	Carbonization furnace for solid fuel production		–		144
6	Multiple hearth furnace		–		4,100
7	–		–	Lime	907

FBI: Fluidized Bed Incinerator

Reference:
Hyogo Pref. (1994), Kanagawa Pref. (1994), National Institute for Land and Infrastructure Management: NILIM (2001), NILIM (2002), Nakamura et al. (1998), Matsubara et al. (1994), Takeishi et al. (1994), Takeishi et al. (1996), MOE (2006b), MOE (2013b), MOE (2015), MOE (2025)

➢ ***Other Industrial Waste***

Based on expert judgment which takes into account the countermeasures against dioxin emissions from incinerators, for the emission factors by waste type for the period FY1990-2001 (MOE, 2006b) and from FY2002 onward (MOE, 2010), respectively, different values are used. These emission factors are established based on the measurement surveys. The air-intake adjustment taking into account CH_4 concentrations in the atmosphere is not made to these emission factors. The emission factor applied for paper/cardboard or wood is also used for textiles (natural fiber) and animal and vegetable residues/animal carcasses in the MOE (2006b) and MOE (2010).

Table 7-56 N_2O Emission factors for IW by type

Item	Unit	FY1990–2001	FY2002–
Waste oil (fossil-fuel-derived/animal and vegetable)	g-N_2O /t (wet)	12	62
Plastics [1)]	g-N_2O /t (wet)	180	15
Paper/cardboard	g-N_2O /t (wet)	21	77
Wood	g-N_2O /t (wet)		
Textiles (natural fiber)	g-N_2O /t (wet)		
Animal and vegetable residues/animal carcasses	g-N_2O /t (wet)		
Sludge (excl. sewage sludge)	g-N_2O /t (wet)	457	99

Note: 1) Emission factors for plastics are applied to waste plastics, including plastic products for infection control.

Reference: MOE (2000), MOE (2010), Ishikawa Pref. et al. (1991-1997), JSAE (1996), Nakamura et al. (1998), Matsubara et al. (1994), Suzuki et al. (2001), Takeishi et al. (1994), Takeishi et al. (1996), Ueno et al. (1995), Yasuda et al. (1994)

● ***Activity Data***

➢ ***Sewage Sludge***

Data in the "amount of incinerated sewage sludge, by incinerator types, by temperature and by flocculants" reported in a survey by MLIT are used as activity data (dry basis).

Table 7-57 Amount of sewage sludge incinerated (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
1. Conventional FBI (Normal)	kt (dry)	220	319	388	719	440	505	384	365	348	332	361	363
2. Conventional FBI (High)	kt (dry)	115	206	325	359	524	492	537	528	507	517	490	449
3. Multi-layer FBI, Pressurized FBI, Other low-N_2O FBI	kt (dry)	NO	NO	NO	NO	NO	15	45	76	85	88	81	113
4. Circulating FBI, Stoker furnace, Gasification furnace	kt (dry)	72	86	105	135	198	135	141	121	129	129	125	109
5. Carbonization furnace	kt (dry)	NO	NO	NO	0.3	1	16	30	54	49	50	50	41
6. Multiple hearth furnace	kt (dry)	152	140	114	23	12	7	NO	NO	NO	NO	NO	NO
7. Lime flocculant	kt (dry)	218	139	91	116	35	8	NO	NO	NO	NO	NO	NO

➢ ***Other Industrial Waste***

Activity data (wet basis) is determined in the same manner as for the CH_4 emissions from IW.

c) Uncertainty Assessment and Time-series Consistency

● ***Uncertainty Assessment***

The uncertainties in CO_2 emission factors are evaluated by using the 95% confidence interval of carbon content data in fossil fuel-based waste. The uncertainties in CH_4 and N_2O emission factors are evaluated by using the 95% confidence interval of the measured data obtained from emission factor surveys. For activity data, the uncertainties in IW data in Table 7-2 are applied. Details of the uncertainty assessment for this category are provided in Table 7-58.

Table 7-58 Uncertainty assessment for IW on the category "waste incineration (5.C.1.-)"

Item	GHGs	Emission factor uncertainty		Activity data uncertainty		Emission uncertainty		Method for assessing emission factor uncertainty	Method for assessing activity data uncertainty	Method for assessing emission uncertainty
		(-)	(+)	(-)	(+)	(-)	(+)			
Waste oil	CO_2	-22%	+22%	-30%	+30%	-37%	+37%	MOE (2025).	The uncertainty in IW statistics is applied.	Combined by using the error-propagation formula.
	CH_4	-100%	+181%	-30%	+30%	-104%	+184%	MOE (2010).		
	N_2O	-76%	+76%	-30%	+30%	-81%	+81%			
Plastics	CO_2	-11%	+11%	-30%	+30%	-32%	+32%	Evaluated by combining the 95% confidence interval of the measured carbon contents of each component with those of the fossil-derived fractions.		Combined by using the error-propagation formula.
	CH_4	-100%	+216%	-30%	+30%	-104%	+218%	MOE (2010).		
	N_2O	-44%	+44%	-30%	+30%	-53%	+53%			
Medical nonwoven masks	CO_2	-1%	＋1%	-30%	+30%	-30%	+30%	MOE (2026).		
Examination gloves	CO_2	-11%	＋11%	-30%	+30%	-32%	+32%	Due to the lack of information on the uncertainty of the emission factor, that for IW plastics is applied based on expert judgment.		
Paper/ cardboard	CO_2	-13%	+13%	-30%	+30%	-104%	+401%	Evaluated by combining the 95% confidence interval in the measured data of carbon content with that of fossil-derived fraction in the carbon.		
Paper/ cardboard or wood	CH_4	-100%	+412%	-30%	+30%	-104%	+413%	MOE (2010).		
	N_2O	-64%	+64%	-30%	+30%	-71%	+71%			
Textiles (Natural fiber)	CH_4	-100%	+412%	-30%	+30%	-104%	+413%	Due to the lack of information on the uncertainty of the emission factors, the uncertainty for paper/cardboard or wood is applied based on expert judgment.		
	N_2O	-64%	+64%	-30%	+30%	-71%	+71%			
Animal and vegetable residues/ animal carcasses	CH_4	-100%	+412%	-30%	+30%	-104%	+413%			
	N_2O	-64%	+64%	-30%	+30%	-71%	+71%			
Sludge (incl. sewage sludge)	CH_4	-100%	+201%	-30%	+30%	-104%	+203%	MOE (2010).		Combined by using the error-propagation formula.
	N_2O	-84%	+84%	-30%	+30%	-89%	+89%			

- ***Time-series Consistency***

  Emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

See section 7.1.5. "Sector-specific QA/QC and Verification".

e) Category-specific Recalculations

By adding the incinerated amounts of medical nonwoven masks and examination gloves to the activity data, CO_2 emissions for the entire time series were recalculated. By revising the estimation methods for CO_2 emissions from incineration of plastics, CO_2 emissions for the whole time series were recalculated. By updating the statistical data, CO_2, CH_4 and N_2O emissions in FY2023 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

7.4.1.3. Specially-Controlled Industrial Waste (5.C.1.-)

a) Category Description

The SCIW includes wastes with properties, such as explosiveness, toxicity and infectivity, that may be harmful to human health or to living environment. Waste types in this category are indicated in the Table 7-59.

Table 7-59 Substance in incineration of SCIW

Waste type		Substance
Waste oil	Flammable waste oil	Gasoline, Kerosene, Gas oil or diesel oil
	Specified hazardous IW oil	Trichlorethylene, tetrachlorethylene, dichloromethane, carbon tetrachloride, 1,2-dichloroethane, 1,1-dichloroethane, cis-1,2-dichloroethylene, 1,1,1-trichloroethane, 1,1,2-trichloroethane, 1,3 dichloropropene, thiuram, simazine, thiobencarb, benzene, selenium, 1,4-dioxane
Infectious waste	Infectious waste plastics	Plastics
	Plastic products (surgical gloves)	Synthetic rubber
	Infectious waste (excl. plastics)	Glasses, Textile, Paper

In this category, CO_2, CH_4, and N_2O emissions from incineration of SCIW are estimated by each waste type and reported in the corresponding category either "Clinical waste (Biogenic) (5.C.1.a.ii.3.)", "Hazardous waste (Non-biogenic) (5.C.1.b.ii.2.)" or "Clinical waste (Non-biogenic) (5.C.1.b.ii.3.)" (see Table 7-27).

Because the actual state of energy recovery from the incineration of SCIW is not sufficiently understood, the emissions from SCIW are reported entirely in "Waste Incineration (Category 5.C.)".

b) Methodological Issues

1) CO_2

- ***Estimation Method***

Emissions of CO_2 from the incineration of flammable waste oil, specified hazardous IW oil, infectious waste plastics and plastic products (surgical gloves) contained in SCIW are estimated in accordance with the decision tree given in the *2006 IPCC Guidelines* (Page 5.9, Fig. 5.1) by using Japan's country-specific emission factors and the amount of waste incinerated.

- ***Emission Factor***

In accordance with the approach taken by the *2006 IPCC Guidelines*, CO_2 emission factors for SCIW are estimated as follows. Note that for the fossil-fuel-derived fraction (*FCF*) and the oxidation factor (*OF*), the default values in the *2006 IPCC Guidelines* are applied (100%, respectively, for each waste type).

- ***Flammable Waste Oil, Infectious Waste Plastics, Surgical gloves***

$$EF_i = CF_i \times FCF_i \times OF \times 44/12$$

EF_i : Emission factor for SCIW *i* [kg-CO_2/t (wet)- incineration of flammable waste oil or infectious plastics], [kg-CO_2/t (dry)- surgical gloves]
CF_i : Carbon content in SCIW *i* [% (wet) for incineration of flammable waste oil or infectious plastics], [% (dry) for surgical gloves]
FCF_i : Fossil-fuel-derived fraction in SCIW *i* [%]
OF : Oxidation factor [%]

- ***Specified Hazardous Industrial Waste Oil***

$$EF = CF \times FCF \times OF \times (1 - u) \times 44/12$$

EF : Emission factor for the incineration of specified hazardous IW oil [kg-CO_2/t (wet)]
CF : Carbon content in specified hazardous IW oil [% (dry)]
FCF : Fossil-fuel-derived fraction in specified hazardous IW oil [%]
OF : Oxidation factor [%]
u : Percentage of water content in specified hazardous IW oil [%] (5%, by expert judgement)

Table 7-60 Carbon content in waste oil and infectious plastics of SCIW

Item	Carbon content (*CF*)	Reference
Flammable waste oil	80% (wet)	Environmental Agency (1992)
Specified hazardous IW oil	29.4% (dry)	The weighted average of carbon contents in substances shown in Table 7-59 estimated by using these chemical formulas and amount of these incinerated in FY2009-FY2010 (MOE, 2010-2011).
Infectious waste plastics	70% (wet)	Environmental Agency (1992).
Surgical gloves	67.6% (dry)	MOE (2026)

Table 7-61 CO_2 emission factors for waste oil and infectious plastics of specially-controlled waste

Item	Unit	Emission factor
Flammable waste oil	kg-CO_2/t (wet)	2,933
Specified hazardous IW oil	kg-CO_2/t (wet)	1,024
Infectious waste plastics	kg-CO_2/t (wet)	2,567
Surgical gloves	kg-CO_2/t (dry)	2,478

- ***Activity Data***

Generally, the amount of SCIW incinerated obtained from the *Cyclical Use of Waste Report* (MOE) is used as the activity data for FY2008 onward. As for the past activity data which the survey data is not available, output amount of waste oil indicated in the *Report on Survey of Organizations in Industrial Waste Administration* (Water Supply Division, Health Service Bureau, the Ministry of Health and Welfare) is used on the assumption that the entire amount of waste oil and infectious plastics contained in SCIW is incinerated. Details are shown below.

- ***Flammable Waste Oil***

The amount of SCIW oil incinerated from the *Cyclical Use of Waste Report* (MOE) is used as the activity data. Since the data includes both incinerated amounts of flammable waste oil and specified hazardous IW oil, the amounts of flammable waste oil are estimated by following equation. All the waste oil in SCIW to be estimated for emissions is waste fossil-fuel-derived oil.

$$A_{flam.oil} = SCIW_{oil} - A_{s-hazard.oil}$$

$A_{flam.\ oil}$: Amount of flammable waste oil incinerated [t (wet)]
$SCIW_{oil}$: Total amount of SCIW oil incinerated [t (wet)]
$A_{s\text{-}hazard.\ oil}$: Amount of specified hazardous IW oil incinerated [t (wet)]

- ***Specified Hazardous Industrial Waste Oil***

The activity data is obtained from following equation using the amount of specified hazardous IW oil reduced in incineration from the *Report on the survey for the estimation of GHG emissions from specially-controlled industrial was*te (MOE) and residual fraction of incinerated waste oil (3%) from the *Cyclical Use of Waste Report* (MOE).

$$A_{s-hazard.oil} = R_{s-hazard.oil} \times (1 + r)$$

$A_{s\text{-}hazard.\ oil}$: Amount of specified hazardous IW oil incinerated [t (wet)]
$R_{s\text{-}hazard.\ oil}$: Amount of specified hazardous IW oil reduced in incineration [t (wet)]
r : Residual fraction of incinerated waste oil [%]

- ***Infectious Waste Plastics Excluding Surgical Gloves***

The activity data is obtained from following equation using the amount of infectious waste incinerated from the *Cyclical Use of Waste Report* (MOE) and the percentage of plastic content in infectious waste ($C_{IMW\ plast.}$: 42.6%) from Japan Society of Waste Management Experts: JSWME (1997). In addition, The CO_2 emissions from the incineration of surgical gloves made of synthetic rubber are estimated separately by applying a specific emission factor.

$$A_{IMW\ plast.excl.gloves} = IMW \times C_{IMW\ plast.} - A_{surgical\ gloves}$$

$A_{IMW\ plast.\ excl.\ gloves}$: Amount of infectious waste plastics excluding surgical gloves incinerated [t (wet)]
IMW : Total amount of infectious waste incinerated [t (wet)]
$C_{IMW\ plast.}$: Percentage of plastic content in infectious waste [%]
$A_{surgical\ gloves}$: Amount of surgical glove incinerated [t (dry)]

Note: The incineration amount of surgical glove on a wet basis [t (wet)] is assumed to be equal to the corresponding dry-basis amount [t (dry)].

- ***Surgical Gloves***

The estimation method for the activity data of surgical gloves is the same as that for examination gloves (see Section 7.4.1.2. “Industrial Waste (5.C.1.-)”).

2) CH_4

- ***Estimation Method***

Emissions of CH_4 from the incineration of waste oil and infectious waste included in the SCIW are calculated by multiplying the amount of incinerated waste by type (wet basis) by Japan’s country-specific emission factor.

- ***Emission Factor***

Because measured data are not available, the emission factors for the incineration of IW are used as substitutes for the emission factor for the SCIW by type. Specifically, the substitute emission factors used are: the waste fossil-fuel-derived oil in IW for the flammable waste oil and specified hazardous waste oil; the plastics in IW for the infectious plastics; and the paper/cardboard and wood in IW for the other infectious waste (biogenic).

- ***Activity Data***

- ***Flammable Waste Oil, Specified Hazardous Industrial Waste Oil***

Activity data is the same as those used for CO_2 emissions.

- ***Infectious Waste Plastics, Infectious Waste Excluding Plastics***

The activity data for incineration of infectious waste plastics and infectious waste excluding plastics are obtained from the equation as shown below.

$$A_{IMW\ i} = IMW \times C_{IMW\ i}$$

$A_{IMW\ i}$: Amount of infectious waste *i* (infectious waste plastics or infectious waste excluding plastics) incinerated [t (wet)]
IMW : Total amount of infectious waste incinerated [t (wet)]
$C_{IMW\ i}$: Percentage of waste *i* content in total amount of infectious waste (infectious waste plastics: 42.6%, infectious waste excluding plastics: 57.4%)

Note that unlike the estimation of CO_2 emissions, the activity data used for estimating CH_4 and N_2O emissions from infectious waste plastics include the incinerated amount of surgical gloves.

3) N_2O

- ***Estimation Method***

Emissions of N_2O from the incineration of waste oil and infectious waste in SCIW are calculated by multiplying the incinerated amount of each type of waste (wet basis) by Japan's country-specific emission factor.

- ***Emission Factor***

Because measured data are not available, the N_2O emission factors for the incineration of IW are used as substitutes for determining the emission factor for each type of SCIW. Specifically, the substitute emission factors used are: the waste oil in IW for the flammable waste oil and specified hazardous IW oil; the plastics in IW for the infectious plastics; and the paper/cardboard and wood in IW for the waste other than infectious plastics.

- ***Activity Data***

The same activity data used for CH_4 emissions is used.

Table 7-62 Amount of incineration of SCIW (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Flammable waste oil	kt (wet)	238	353	520	478	390	271	236	311	301	282	281	257
Specified hazardous IW oil	kt (wet)	18	27	40	37	41	54	145	75	38	39	33	60
Infectious waste (plastics, incl. surgical gloves)	kt (wet)	78	128	167	169	154	133	166	182	175	196	222	231
Infectious waste (excl. plastics)	kt (wet)	105	172	225	228	106	92	114	125	121	135	154	159

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the emission factors, the uncertainty assessment is conducted as well as that for the IW incineration (see Table 7-58). For the activity data, the uncertainties in SCIW data indicated in Table 7-2 are applied. Details of the uncertainty assessment for this category are indicated in Table 7-63.

Table 7-63 Uncertainty assessment for SCIW on the category "waste incineration (5.C.1.-)"

Item	GHGs	Emission factor uncertainty		Activity data uncertainty		Emission uncertainty		Method for assessing emission factor uncertainty	Method for assessing activity data uncertainty	Method for assessing emission uncertainty
		(-)	(+)	(-)	(+)	(-)	(+)			
SCIW	CO_2	-11%	+11%	-60%	+60%	-61%	+61%	Due to the lack of information on the uncertainty of the emission factors, the values for IW plastics are applied based on expert judgment.	The uncertainty for SCIW is applied.	Combined by using the error-propagation formula.
	CH_4	-100%	+216%	-60%	+60%	-117%	+224%			
	N_2O	-44%	+44%	-60%	+60%	-74%	+74%			

- ***Time-series Consistency***

Since some basic data used for calculating activity data are available only for part of time series, consistent data over the time series are developed based on the estimation. The emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

See section 7.1.5. "Sector-specific QA/QC and Verification".

e) Category-specific Recalculations

By updating the statistical data, CO_2, CH_4 and N_2O emissions in FY2023 were recalculated. By adding the CO_2 emission source related to the incineration of surgical gloves, CO_2 emissions for the whole time series were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

7.4.2. Open Burning of Waste (5.C.2.)

7.4.2.1. Municipal Solid Waste (5.C.2.-)

a) Category Description

In Japan, since the Waste Management and Public Cleansing Act prohibits open burning of waste, the emissions from open burning of MSW are reported as "NO".

7.4.2.2. Industrial Waste (5.C.2.-)

a) Category Description

This category covers CO_2, CH_4 and N_2O emissions from illegal open burning of IW (wood, construction and demolition, plastics, and other/unknown), and the emissions are reported in the category "non-biogenic, industrial solid waste (ISW)".

b) Methodological Issues

1) CO_2

- ***Estimation Method***

CO_2 emissions from the open burning of IW plastics are estimated in accordance with the decision tree given in the *2006 IPCC Guidelines* by using Japan's country-specific emission factors and the amount of waste burned in the open air.

- ***Emission Factor***

In accordance with the approach taken by the *2006 IPCC Guidelines*, emission factor is calculated as follows.

$$EF = CF \times FCF \times OF \times 44/12$$

EF : Emission factor for the open burning of IW plastics [kg-CO_2/t (wet)]
CF : Carbon content in IW plastics [% (wet)]
FCF : Fossil-fuel-derived fraction in IW plastics [%]
OF : Oxidation factor [%]

Table 7-64 CO_2 emission factors and relevant parameters of open burning of IW plastics

Item	Value	Reference	Note
EF	1,822 kg-CO_2/t (wet)	–	Calculated by using country-specific parameters
CF	70 %	Environmental Agency (1992)	–.
FCF	100%	*2006 IPCC Guidelines*	Default value
OF	71 %	*2019 Refinement*	Default value

- ***Activity Data***

The amount of plastics as IW burned in the open air, obtained from the *Report on Survey of Organizations in Industrial Waste Administration* (MOE), is used as the activity data for FY1996 onward. As for the past activity data from FY1990 to FY1995, for which the survey data is not available, the data of FY1996 is uniformly used as a substitute since there are no other appropriate ways to estimate activity data prior to FY1995. Since it is unclear that plastics burned in the open air include biogenic fraction, whole of those plastics are assumed to be derived from fossil fuel.

Table 7-65 The amount of fossil-fuel-derived IW burned in the open air (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Plastics	kt (wet)	3.4	3.4	0.9	0.2	0.1	0.1	0.02	0.03	0.02	0.02	0.02	0.02

2) CH_4, N_2O

- ***Estimation Method***

Emissions of CH_4 and N_2O from the open burning of IW are estimated in accordance with the decision tree given in the *2006 IPCC Guidelines* by using the IPCC default emission factors and the Japan's country-specific amount of waste burned in the open air.

- ***Emission Factor***

As no knowledge is obtained for making it possible to set emission factors specific to Japan, the default values given in the *2006 IPCC Guidelines* are applied.

Table 7-66 CH_4 and N_2O emission factors for open burning of IW

Gas	Unit	EFs	Reference
CH_4	kg-CH_4/t (wet)	6.5	*2006 IPCC Guidelines*
N_2O	kg-N_2O/t (dry)	0.15	*2006 IPCC Guidelines*

- ***Activity Data***

The total amount (wet basis) summed up all IW burned in the open air obtained from the *Report on Survey of Organizations in Industrial Waste Administration* (MOE) is used as the activity data for CH_4 emission estimates. As for the activity data for N_2O emission estimates, the amounts (wet basis) mentioned above are converted to dry basis by using water contents for each waste type. To be consistent with the IPCC default emission factor applied in estimations, default water contents of the *2006 IPCC Guidelines* (wood: 15%, plastics: 0%, construction and demolition: 0%, and other/unknown:10%) are applied in this conversion. As for the past activity data from FY1990 to 1995, for which the survey data is not available, the data of FY1996 is uniformly used as a substitute since there are no other appropriate ways to estimate.

Table 7-67 The amount of IW burned in the open air (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Total wet weight amount	kt (wet)	72.2	72.2	28.9	3.5	1.3	1.3	1.0	0.4	0.6	0.2	0.2	0.2
Total dry weight amount	kt (dry)	62.4	62.4	25.5	3.1	1.1	1.2	0.8	0.4	0.5	0.1	0.1	0.1

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

Details of the uncertainty assessment for this category are indicated in Table 7-68.

Table 7-68 Uncertainty assessment for the category "open burning of waste (5.C.2.-)"

Item	GHGs	Emission factor uncertainty		Activity data uncertainty		Emission uncertainty		Method for assessing emission factor uncertainty	Method for assessing activity data uncertainty	Method for assessing emission uncertainty
		(-)	(+)	(-)	(+)	(-)	(+)			
Plastics	CO_2	-11%	+11%	-30%	+30%	-32%	+32%	Due to the lack of information on the uncertainty of the emission factor, the value for IW plastics is applied based on expert judgment (see Table 7-58).	The uncertainty for IW is applied (see Table 7-2).	Combined by using the error-propagation formula.
IW	CH_4	-100%	+100%	-30%	+30%	-104%	+104%	The uncertainties are assessed as those of the *2006 IPCC Guidelines*' default emission factors.		
	N_2O	-100%	+100%	-30%	+30%	-104%	+104%			

- ***Time-series Consistency***

Since activity data based on the survey are available from FY1996 onward, a consistent time series is developed based on the estimation. The emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

See section 7.1.5. "Sector-specific QA/QC and Verification".

e) Category-specific Recalculations

No recalculations are conducted.

f) Category-specific Planned Improvements

No improvements are planned.

7.4.3. Waste Incineration and Energy Use (Reported in Energy Sector) (1.A.)

7.4.3.1. Waste Incineration with Energy Recovery (1.A.)

a) Category Description

In this category, CO_2, CH_4, and N_2O emissions from the incineration of municipal and IW with energy recovery are estimated and reported. The reporting category for the emissions is "Other sectors (Category 1.A.4.)" and the fuel types are classified as "Other fossil fuels" or "Biomass" as shown on the Table 7-28.

b) Methodological Issues

Methodologies similar to the ones used in the sections "7.4.1.1. Municipal Solid Waste (5.C.1.-)" and "7.4.1.2. Industrial Waste (5.C.1.-)" are used. Emissions are calculated using the following equations:

1) CO_2

- ***Estimation Method***

○ Municipal Solid Waste

$$E = \sum_i (EF_i \times A_i \times R)$$

E : CO_2 emissions from incineration of MSW type *i* [kg-CO_2]
EF : Emission factor for incineration of MSW type *i* [kg-CO_2/t (dry)]
A : Amount of waste type *i* incinerated [t (dry)]
R : Percentage of MSW incinerated at incineration facilities with energy recovery

➢ ***Industrial Waste***

$$E = \sum_i (EF_i \times A_i \times R_i)$$

E : CO_2 emissions from IW incineration [kg-CO_2]
EF : Emission factor for incineration of IW type *i*
[kg-CO_2/t (wet) -waste oil], [kg-CO_2/t (dry) -waste other than oil]
A : Amount of incinerated IW type *i* [t (wet) -waste oil], [t (dry) -waste other than oil]
R : Fraction of IW incinerated at IW incineration facilities with energy recovery (by waste type)

2) CH_4, N_2O

- ***Estimation Method***

○ Municipal Solid Waste

$$E = \sum_i (EF_i \times A_i \times R)$$

E : CH_4 or N_2O emissions from incineration of MSW [kg-CH_4], [kg-N_2O]
EF_i : Emission factor for MSW by incineration method (or furnace type) *i* [kg-CH_4/t (wet)], [kg-N_2O/t (wet)]
A_i : Amount of MSW incinerated by incineration method (or furnace type) *i* [t (wet)]
R : Percentage of MSW incinerated at facilities with energy recovery

➢ ***Industrial Waste***

$$E = \sum_j (EF_j \times A_j \times R_j)$$

E : CH_4 or N_2O emissions from incineration of IW [kg-CH_4], [kg-N_2O]
EF_j : Emission factor for IW type *j* [kg-CH_4/t (wet)], [kg-N_2O/t (wet)]
A_j : Amount of IW type *j* incinerated [t (wet)]
R_j : Percentage of IW type *j* incinerated at IW incineration facilities with energy recovery
Note: Sewage sludge is not incinerated at IW incineration facilities with energy recovery.

- ***Activity Data***

➢ ***Amount of Waste Incinerated***

The total amount of waste incinerated with energy recovery ($A \times R$), used for estimating emissions from the incineration of MSW and IW, is shown in the table below.

Table 7-69 Total amount of waste incinerated with energy recovery ($A \times R$)

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
MSW	kt (wet)	19,706	21,976	25,725	27,515	23,591	24,013	22,665	24,296	23,732	23,383	22,504	22,478
IW	kt (wet)	43	95	149	221	419	588	775	838	710	657	990	942

➢ ***Activity Data Converted into Energy Units (Reference Value)***

Activity data converted into energy units to be reported in CRT is estimated as indicated below.

- ***Municipal Solid Waste***

$A_E = A \times GCV \times R/10^6$

A_E : Calorific value of activity data of MSW [TJ]
A : Total amount of MSW incinerated [kg (wet)]
GCV : Gross calorific value of MSW [MJ/kg (wet)]
R : Fraction of MSW incinerated at MSW incineration facility with energy recovery

Based on the actual measurement results obtained at municipality, the GCV of MSW is 9.9 [MJ/kg].

- ***Industrial Waste***

$A_E = \sum_j A_j \times GCV_j \times R/10^6$

A_E : Calorific value of activity data of IW [TJ]
Aj : Amount of IW type j incinerated [kg (wet)]
$GCVj$: Gross calorific value of IW type j [MJ/kg (wet)]
R : Fraction of IW type j incinerated at IW incineration facility with energy recovery

Calorific value of IW is indicated in Table 7-73 (as referred to hereinafter).

c) Uncertainty Assessment and Time-series Consistency

Methodologies similar to the ones used in sections "7.4.1.1. Municipal Solid Waste (5.C.1.-)" and "7.4.1.2. Industrial Waste (5.C.1.-)" are used.

d) Category-specific QA/QC and Verification

See section 7.1.5. "Sector-specific QA/QC and Verification".

e) Category-specific Recalculations

Same recalculations as the category waste incineration (without energy recovery) were conducted. For details, see the paragraphs for category-specific recalculations in sections "7.4.1.1. Municipal Solid Waste (5.C.1.-)" and "7.4.1.2. Industrial Waste (5.C.1.-)".

f) Category-specific Planned Improvements

No improvements are planned.

7.4.3.2. Direct Use of Waste as Alternative Fuel (1.A.)

a) Category Description

In this category, CO_2, CH_4, and N_2O emissions from waste directly used as alternative fuel are estimated and reported. The reporting category for the emissions for each type of waste is included in, according to its use as raw material or fuel, either "Energy industries (Category 1.A.1.)", "Manufacturing industries and Construction (1.A.2.)" or "Other sectors (Category 1.A.4.)" (Table 7-29). The fuel types are classified as "Other fossil fuels" or "Biomass" as indicated in Table 7-28.

GHG emissions during the direct use of waste as a raw material, such as plastics used as reducing agents in blast furnaces or as a chemical material in coking furnaces, or use of intermediate products manufactured using the waste as a raw material, are estimated in this category. The waste used as raw material and the ones used as alternative fuel are combined and expressed as "raw material or fuel (use)" in this section.

b) Methodological Issues

1) CO_2

- ***Estimation Method***

Emissions are estimated by multiplying the incinerated amount of each type of waste used as raw material or fuel by Japan's country-specific emission factor. The wastes included in the estimation are the portions used as raw material or fuel of: plastics in MSW, plastics and fossil-fuel-derived waste oil, recycled oil from used solvent and recycled heavy oil in IW, and waste tires.

- ***Emission Factor***

In this category, the emission factors applied in section "7.4.1. Waste Incineration (without Energy Recovery) (5.C.1.)" are also applied to most emission sources. However, specific emission factors in this category for the plastics from MSW that are used as chemical raw material in coke ovens, recycled oil from used solvent, recycled heavy oil and waste tires are developed specifically. For details, see relevant sections.

- ***Activity Data***

For details of the amount of waste used as raw materials or fuels, see section 7.4.3.2.a-7.4.3.2.c.

Table 7-70 Amount of direct use of waste as alternative fuel (Activity data: wet basis)

Waste type		Application breakdown	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
MSW	Plastics	Liquefaction	kt (wet)	NO	NO	3	7	1	NO	NO	NO	NO	NO	NO	NO
		Blast furnace reducing agent	kt (wet)	NO	NO	25	37	27	30	31	29	31	28	14	14
		Coke oven chemical feedstock	kt (wet)	NO	NO	11	175	177	NO	29	24	24	23	71	70
		Gasification	kt (wet)	NO	NO	1	59	53	58	55	42	35	41	44	43
IW	Fossil-fuel-derived waste oil	(Unclassified)	kt (wet)	1,278	1,407	1,316	1,738	1,600	1,608	1,681	1,662	1,714	1,711	1,899	1,866
	Animal and vegetable waste oil														
	Recycled oil from used solvent														
	Recycled heavy oil														
	Plastics	Blast furnace reducing agent	kt (wet)	NO	NO	57	160	134	107	144	115	147	144	118	53
		Chemical industry	kt (wet)	21	23	118	311	464	533	592	768	798	802	811	837
		Paper industry													
		Cement burning													
		Automobile manufacturer													
		Liquefaction	kt (wet)	NO	NO	1	1	1	1	1	1	1	1	1	6
		Gasification	kt (wet)	NO	NO	NO	11	117	97	81	99	92	71	78	73
	Wood	(Unclassified)	kt (wet)	1,635	1,635	2,061	2,683	3,900	4,425	4,628	4,996	4,986	4,948	5,367	5,277
Waste tire		Cement burning	kt (wet)	111	275	361	181	95	62	59	69	73	81	67	60
		Boiler	kt (wet)	119	126	75	12	8	6	2	2	3	5	5	2
		Iron manufacture	kt (wet)	NO	NO	57	51	30	27	20	16	17	NO	NO	NO
		Gasification	kt (wet)	NO	NO	NO	27	49	44	49	10	1	2	1	3
		Metal refining	kt (wet)	67	37	30	10	1	NO	NO	NO	NO	NO	NO	NO
		Tire manufacture	kt (wet)	NO	32	39	24	23	27	23	2	2	3	2	1
		Paper manufacture	kt (wet)	NO	26	42	210	388	372	439	412	425	433	476	413
		Power generation	kt (wet)	NO	NO	7	9	9	40	51	96	112	136	113	104
RDF		(Unclassified)	kt (wet)	34	39	148	415	380	386	361	310	297	285	266	189
RPF		Petroleum product manufacturer	kt (wet)	NO	8	33	493	845	971	981	1,018	1,085	1,047	1,049	1,127
		Chemical industry													
		Paper industry													
		Cement manufacturer													

Note: The amount of biogenic fraction such as animal and vegetable waste oil and wood are not included in the activity data for the estimation of CO_2 emissions. For the activity data to estimate CO_2 emissions, excluding those for waste oils, the figures in the above table are converted into dry basis amount by subtracting water contents.

2) CH_4, N_2O

- ***Estimation Method***

Emissions are estimated by multiplying the amount of each type of waste used as raw material or fuel by the country-specific emission factor.

- ***Emission Factor***

Emission factors for waste used as raw material or fuel are determined by multiplying the emission factor for applicable types of furnaces by the calorific value of each waste type and converting the result to the weight-based values.

Table 7-71 shows the data used in the estimation.

$$EF_i = EF_{E,i} \times GCV_i / 1000$$

EF_i : Emission factor for waste type i [kg-CH_4 / t (wet)], [kg-N_2O/ t (wet)]
$EF_{E,i}$: Emission factor for waste type i on calorie basis [kg-CH_4/TJ], [kg-N_2O/TJ]
GCV_i : Gross calorific value of waste type i [MJ/kg]

Table 7-71 Data used for the calculation of CH_4 and N_2O emission factors for direct use of waste as alternative fuel

Waste type		Application breakdown	Emission factor for furnaces and ovens (energy sector)		Calorific value
			CH_4	N_2O	
MSW	Plastics	Liquefaction	Boilers (Heavy fuel oil A, diesel oil, kerosene, naphtha, other liquid fuels)		Calorific value of plastics
		Blast furnace reducing agent	NA		NA
		Coke oven chemical feedstock	NA		NA
		Gasification	NA		NA
IW	Waste oil (including valuables)	(Unclassified)	Boilers (Heavy fuel oil A, diesel oil, kerosene, naphtha, other liquid fuels)		Specific gravity of reclaimed oil/waste oil [1]
	Plastics	Blast furnace reducing agent	NA		NA
		Chemical industry	Boilers (wood, charcoal, and other solid fuel)	Fluidized-bed boilers (solid fuel)	Calorific value of plastics
		Paper industry			
		Automobile manufacturer			
		Cement burning	Other industrial furnaces (solid fuel)		
		Liquefaction	Boilers (Heavy fuel oil A, diesel oil, kerosene, naphtha, other liquid fuels)		
		Gasification	NA		NA
	Wood	(Unclassified)	Boilers (wood, charcoal)	Boilers (other than fluidized-bed) (solid fuel)	Calorific value of wood [2]
Waste tire		Iron manufacture	NA		NA
		Cement burning	Other industrial furnaces (solid fuel)		Calorific value of waste tires
		Gasification	Other industrial furnaces (gas fuels) and other industrial furnaces (liquid fuels) [3]		
		Metal refining (pyrolysis)	Boilers (gas fuels)		
		Boiler	Boilers (wood, charcoal, and other solid fuel)	Boilers (other than fluidized-bed) (solid fuel)	
		Tire manufacture			
		Paper manufacture			
		Power generation			
RDF		(Unclassified)	Boilers (wood, charcoal, and other solid fuel)	Boilers (other than fluidized-bed) (solid fuel)	Calorific value of RDF
RPF		Petroleum product manufacturer	Boilers (wood, charcoal, and other solid fuel)	Boilers (other than fluidized-bed) (solid fuel)	Calorific value of RPF
		Chemical industry			
		Paper industry			
		Cement manufacturer	Other industrial furnaces (solid fuel)		

Note:
1) Calorific value per unit volume is determined by dividing by the specific gravity of waste oil (0.9 kg/l) obtained from JSWME (1997).
2) Data from Environmental Agency (1995)
3) The percentage of substances recovered during the gasification of waste tires. A weighted average is calculated by using the proportions of gas and oil (22% and 43%) reported in the Hyogo Pref. (2003).

Table 7-72 CH_4 and N_2O emission factors for the use of waste as raw material or fuel used in the energy sector

Furnace type/Fuel type	CH_4 Emission factor [kg-CH_4/TJ]	N_2O Emission factor [kg-N_2O/TJ]
Boilers (Heavy fuel oil A, diesel oil, kerosene, naphtha, other liquid fuels)	0.26	0.19
Boilers (gaseous fuels)	0.23	0.17
Boilers (steam coal, coke, other solid fuels)	0.13	–
Boilers (wood, charcoal)	74.9	–
Boilers (other than fluidized-bed) (solid fuels)	–	0.85
Normal pressure fluidized-bed boilers (solid fuels)	–	54.39
Other industrial furnaces (liquid fuels)	0.83	1.8
Other industrial furnaces (solid fuels)	13.1	1.1
Other industrial furnaces (gaseous fuels)	2.3	1.2

Reference: MOE (2006a)

Table 7-73 GCV of waste incinerated and used as raw material or fuel

Item		Unit	GCV	Reference
Waste oil (including valuables)		TJ/L	40.2	*General Energy Statistics* (ANRE); estimated with 0.9[kg/L] (JSWME, 1997)
Plastics	FY2022 and before	MJ/kg	29.3	*General Energy Statistics* (ANRE)
	FY2023 and later	MJ/kg	28.7	*General Energy Statistics* (ANRE)
Paper/cardboard		MJ/kg	15.1	JSWME (1997), dry basis; value is obtained by subtracting water content
Wood		MJ/kg	14.4	*General Energy Statistics* (ANRE)
Textiles		MJ/kg	17.9	JSWME (1997), dry basis; value is obtained by subtracting water content
Food waste (Animal and vegetable residues/animal carcasses)		MJ/kg	4.4	JSWME (1997), dry basis; value is obtained by subtracting water content
Sludge (including sewage sludge)		MJ/kg	4.7	*General Energy Statistics* (ANRE), dry basis; value is obtained by subtracting water content
Waste tire	FY2004 and before	MJ/kg	20.9	*General Energy Statistics* (ANRE)
	FY2005 and later	MJ/kg	33.2	*General Energy Statistics* (ANRE)
RDF		MJ/kg	18.0	*General Energy Statistics* (ANRE)
RPF		MJ/kg	29.3	*General Energy Statistics* (ANRE)

ANRE: Agency for Natural Resources and Energy

- ***Activity Data***

➢ ***Amount of Waste Used as Raw Material or Fuel***

Activity data are determined for each category using the wet-basis values (Table 7-70). For more details, see each section.

➢ ***Activity Data Converted into Energy Units (Reference Value)***

Activity data converted into energy units to be reported in CRT are calculated as indicated below.

$$A_{E,i} = N_i \times GCV_i / 10^6$$

$A_{E,i}$: Activity data of waste type *i*, converted into energy units [TJ]
N_i : Amount of waste type *i* used as raw material or fuel [kg (wet)]
GCV_i : Gross calorific value of waste type *i* [MJ/kg]

c) Uncertainty Assessment and Time-series Consistency

See the respective sections.

d) Category-specific QA/QC and Verification

See section 7.1.5. “Sector-specific QA/QC and Verification”.

e) Category-specific Recalculations

See the respective sections.

f) Category-specific Planned Improvements

See the respective sections.

7.4.3.2.a. Municipal Solid Waste (Plastics) Used as Alternative Fuels (1.A.1 and 1.A.2)

a) Category Description

This category covers the emissions from MSW (plastics) used as alternative fuels. Plastics in MSW collected under the Containers and Packaging Recycling Law are processed into liquefaction, blast furnace reducing agent, coke oven chemical feedstock, and gasification to be used as alternative fuel or raw material. Note that PET bottles are not included in MSW in this source.

b) Methodological Issues

1) CO_2

- ***Estimation Method***

Emissions are calculated by multiplying the amount of fossil-fuel-derived plastics in MSW by each usage (liquefaction, blast furnace reducing agent, coke oven chemical feedstock, and gasification) by Japan's country-specific emission factor.

- ***Emission Factor***

For the emission factors for plastics in MSW in the usage of liquefaction, blast furnace reducing agent, and gasification, the same values applied in section "7.4.1.1. Municipal Solid Waste (5.C.1.-)" are applied. The emission factor for plastics used as coke oven chemical feedstock is set as the amount of hydrocarbon that is used as chemical raw material and from which no CO_2 is emitted into the air by subtracting the percentage of carbon in the plastics that migrates to hydrocarbon oil in the coke oven (47.9%) from emission factor for plastics (MSW).

$$EF_{coke} = EF_{plastics} \times (1 - M) \times FCF_{MSW\ plastics}$$

EF_{coke} : Emission factor for plastics used as raw material in coke ovens (dry basis)
$EF_{plastics}$: Emission factor for the incineration of plastics in MSW (dry basis)
M : Fraction of carbon in plastics used as chemical raw material for coke ovens that migrates to hydrocarbon
$FCF_{MSW\ plastics}$: Fossil-fuel-derived fraction of plastics in MSW [%] (See Table 7-35.)

Table 7-74 CO_2 emission factors for plastics in MSW used as alternative fuels

Item	Unit	Emission factor	Note
Liquefaction, blast furnace reducing agent, Gasification	kg-CO_2/t (dry)	2,816	In case of *FCF*=1
Coke oven chemical feedstock	kg-CO_2/t (dry)	1,467	

- ***Activity Data***

The amount of plastics in MSW used as raw material or fuel by usage (wet basis) is estimated by the total amount collected by designated legal bodies and municipalities to be processed as raw material or fuel by usage (wet basis). The methodology to estimate activity data for this category is the same as that in the section "7.4.1.1. Municipal Solid Waste (5.C.1.-) b) 1) CO_2".

$$A_i = WP_i \times (1 - u_{plastics})$$

A_i : Amount of fossil-fuel-derived plastics used as raw material or fuel for usage *i* [t (dry)]
WP_i : Amount of plastics used as raw material or fuel for usage *i* [t (wet)]
$u_{plastics}$: Percentage of water content in plastics [%]

➢ ***The Amount of Plastics in MSW Used as Raw Material or Fuel by Usage (Wet Basis)***

- ***Processing of Plastics Collected by Designated Legal Bodies***

The amount of the plastics in MSW collected by designated legal bodies into raw material or fuel is determined from the amount reported (pyrolytic oil: petrochemical, blast furnace reducing agent, chemical raw material in coke-oven, syngas, and gasification) in the "Plastic Containers and Packaging (Other Plastics, Food Trays)" section of the *Statistics of Commercial Recycling of Plastics (Recycling)* (Japan Containers and Packaging Recycling Association: JCPRA). Usage in products that do not emit CO_2 is deducted.

- ***Processing of Plastics Collected by Municipalities***

The amount of plastics in MSW collected by municipalities and processed into raw material or fuel is calculated as indicated below.

$$P_{LG} = \sum (PR - P_{JCPRA}) \times F_i \times R_i$$

P_{LG} : Amount of plastics in MSW collected by municipalities and processed into raw material or fuel [t (wet)]
PR : Amount of all plastics that are commercially recycled under the Plastic Containers and Packaging Recycling Law [1] [t (wet)]
P_{JCPRA} : Amount of plastics that is commercially recycled through designated legal bodies[2] [t (wet)]
F_i : Percentage of commercially recycled plastics by recycling method i[3] [%]
R_i : Percentage of commercially recycled plastic products by recycling method i[4] [%] (The percentages for designated legal bodies are used for the value for municipalities.)

Note:
1) The amount is determined from the *Annual Recycling Statistics under the Plastic Containers and Packaging Recycling Law* (MOE).
2) The amount is determined from the "Actual Collection of Plastic Containers and Packages" section of the *Statistics of Commercial Recycling of Plastics (Recycling)* (JCPRA).
3) The rates are obtained from the percentages for various methods of commercial recycling of the plastics collected through municipal channels in the Results of the *2001 Questionnaire to Municipalities on Waste Plastic Processing* compiled by the Plastic Waste Management Institute.
4) The values are calculated by using data from the *Annual Recycling Statistics under the Plastic Containers and Packaging Recycling Law* (MOE) and the *Statistics of Commercial Recycling of Plastic (Recycling)* (JCPRA).

➢ ***Water Content Ratio***

Water content ratio of 4% is determined based on the data provided by the JCPRA (MOE, 2006b).

➢ ***Fossil-fuel-derived Fraction of Plastics in MSW***

See Table 7-35 in the section "7.4.1.1. Municipal Solid Waste (5.C.1.-)."

2) CH_4, N_2O

For estimation method and emission factors, see the section "7.4.3.2. Direct Use of Waste as Alternative Fuel (1.A.)". The amount of plastics used as raw material or fuel by usage (wet basis) is determined by the total amount collected by designated legal bodies and municipalities to be processed as raw material or fuel by usage (wet basis); this value includes the amount of biomass-based plastics consumed.

c) Uncertainty Assessment and Time-series Consistency

● ***Uncertainty Assessment***

The uncertainty assessment is conducted as well as assessment in the category of the MSW incineration (see Table 7-45 and Table 7-46). Details of the uncertainty assessment for this category are shown in the Table 7-75.

Table 7-75 Uncertainty assessment for MSW plastics used as alternative fuels (1.A.1 and 1.A.2)

Item	GHGs	Emission factor uncertainty		Activity data uncertainty		Emission uncertainty		Method for assessing emission factor uncertainty	Method for assessing activity data uncertainty	Method for assessing emission uncertainty
		(-)	(+)	(-)	(+)	(-)	(+)			
Plastics	CO_2	-1%	+1%	-10%	+10%	-10%	+10%	The equivalent assessment of the uncertainty in MSW plastics in "5.C.1. Waste Incineration" is applied.	The uncertainty in MW statistics is applied.	Combined by using the error-propagation formula.
	CH_4	-39%	+39%	-10%	+10%	-40%	+40%	The equivalent assessment of the uncertainty in MSW in "5.C.1. Waste Incineration" is applied.		
	N_2O	-34%	+34%	-10%	+10%	-35%	+35%			

● ***Time-series Consistency***

Time-series consistency in emission estimates has been ensured. However, the statistical data for activity data have been available since FY2000 because the use of waste as alternative fuel or raw material was not a common practice prior to FY2000 in Japan.

d) Category-specific QA/QC and Verification

See section 7.1.5. "Sector-specific QA/QC and Verification".

e) Category-specific Recalculations

By updating the statistical data, CO_2 emissions in FY2023 were recalculated. By updating GCV for plastics, CH_4 and N_2O emissions in FY2023 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

7.4.3.2.b. Industrial Waste (Plastics, Waste Oil, and Wood) Used as Alternative Fuels (1.A.2.)

a) Category Description

This category covers GHG emissions from IW (plastics, waste oil, and wood) used as raw material or fuels. Waste oil in this category includes valuables: recycled oil from used solvent and recycled heavy oil.

b) Methodological Issues

1) CO_2

- ***Estimation Method and Emission Factor***

Emissions are estimated by multiplying the amount of plastics, fossil-fuel-derived waste oil, recycled oil from used solvent and recycled heavy oil used as raw material or fuels by emission factor used for incineration of IW (See Table 7-49).

- ***Activity Data***

➢ ***Plastics***

Estimated activity data are the amounts of plastics in IW used as raw material or fuel in steel industry, chemical industry, paper industry, cement manufacturer, automobile manufacturer, and "other industry". The amount of plastics in IW used as raw material or fuel in each industry is provided by the following data sources: for steel industry, the *Current State of Plastics Waste Recycling and Future Tasks* published by the Japan Iron and Steel Federation; for cement manufacturing industry, from the *Cement Handbook* published by the Japan Cement Association; for chemical industry, paper industry, and automobile manufacturer, the amount of plastics used for fluidized bed boiler provided by the Japan Chemical Industry Association, the Japan Paper Association, the Japan Automobile Manufacturers Association. For "other industry", the activity data is obtained from the *Review Report on Improvement of Accuracy and Faster Compilation of Waste Statistics* (Environmental Regeneration and Material Cycles Bureau of MOE) distinguished between plastics liquefaction and gasification. Since these data are obtained on a wet basis, the activity data on a dry basis is estimated by using the water content (6.4%) of IW plastics (see also section 7.4.1.2. "Industrial Waste (5.C.1.-)").

➢ ***Waste Oil (Fossil-fuel-derived Waste Oil, Recycled Oil from Used Solvent, Recycled Heavy Oil)***

- ***Fossil-fuel-derived Waste Oil***

The amount of waste oil indicated as "Fuel Usage" of "Direct Recycle Usage" and "Recycle Usage after Treatment" of IW from the *Cyclical Use of Waste Report* (MOE) is used as the activity data of the waste oil that includes biogenic fraction and non-oil element (e.g. metallic barrel). Hence in the estimation method for CO_2 emissions, the amount of biogenic "animal and vegetable waste oil" and fraction of non-waste oil element is subtracted from this item in the same way as indicated in "7.4.1.2. Industrial Waste (5.C.1.-) 7.4.1.2. b)1) CO_2". The data for FY1997 and before are estimated by using the trend in the amount of incinerated IW oil.

- ***Recycled Oil from Used Solvent***

The data of the amount of used solvent to be used as alternative fuel (valuables-origin), surveyed by the Japan Solvent Recycling Industry Association is used as activity data for recycled oil from used solvent. All recycled oil from used solvent in this category are assumed to be fossil-fuel-derived.

- ***Recycled Heavy Oil***

The amount of recycled heavy oil products [kL] derived from used lubricant (data indicated in the *Lubricant Recycle Handbook,* Japan Lubricating Oil Society and data provided from Japan Oil Recycling Co-operative [JORC]) and recycled heavy oil density (0.8642 [g/cm^3]: surveyed by JORC) are also used to estimate activity data of recycled heavy oil. All recycled heavy oil in this category are assumed to be fossil-fuel-derived.

2) CH_4, N_2O

● ***Estimation Method and Emission Factor***

See the section "7.4.3.2. Direct Use of Waste as Alternative Fuel (1.A.)"

● ***Activity Data***

➢ ***Plastics***

The activity data (wet basis) obtained in estimating CO_2 emissions for this source is used for the estimation of CH_4 and N_2O emissions. Note plastics as blast furnace reducing agent and plastics gasified are not included in the activity data (see also Table 7-29).

➢ ***Waste Oil (Fossil-fuel-derived Waste Oil, Animal and Vegetable Waste Oil, Recycled Oil from Used Solvent, Recycled Heavy Oil)***

The activity data used for CO_2 emission estimates from this source is also used for CH_4 and N_2O emission estimates. Unlike the activity data for CO_2 emissions, animal and vegetable waste oil are also included for the estimation of activity data from this source. Activity data for animal and vegetable waste oil excludes fraction of non-waste oil element (e.g. metallic barrels) by using the same way as indicated in "7.4.1.2. Industrial Waste (5.C.1.-) 7.4.1.2. b)1) CO_2".

➢ ***Wood***

The amount of usage of wood as raw material or fuel is obtained from the "fuel usage" in the "direct recycle usage" and the "fuel usage" in the "recycle usage after treatment" in the *Cyclical Use of Waste Report* (MOE). Values prior to FY1997 are estimated by using the average value for FY1998-2002.

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainty assessment is conducted as well as assessment in the category of the IW incineration (see Table 7-58). Details of the uncertainty assessment for this category are shown in the Table 7-76.

Table 7-76 Uncertainty assessment for IW plastics used as alternative fuels (1.A.2)

Item	GHGs	Emission factor uncertainty		Activity data uncertainty		Emission uncertainty		Method for assessing emission factor uncertainty	Method for assessing activity data uncertainty	Method for assessing emission uncertainty
		(-)	(+)	(-)	(+)	(-)	(+)			
Plastics	CO_2	-11%	+11%	-30%	+30%	-32%	+32%	The equivalent assessment of the uncertainty for IW plastics in "5.C Incineration" is applied.	The uncertainty in IW statistics is applied.	Combined by using the error-propagation formula.
	CH_4	-100%	+216%	-30%	+30%	-104%	+218%			
	N_2O	-44%	+44%	-30%	+30%	-53%	+53%			
Fossil-fuel-derived waste oil	CO_2	-22%	+22%	-30%	+30%	-37%	+37%	The equivalent assessment of the uncertainty for IW oil in "5.C.1. Waste Incineration" is applied.		Combined by using the error-propagation formula.
Recycled oil from used solvent		-14%	+14%	-30%	+30%	-33%	+33%	MOE (2025).		
Recycled heavy oil		-1%	+1%	-30%	+30%	-30%	+30%			
Waste oil	CH_4	-100%	+181%	-30%	+30%	-104%	+184%	The equivalent assessment of the uncertainty in IW oil in "5.C.1. Waste Incineration" is applied.		
	N_2O	-76%	+76%	-30%	+30%	-81%	+81%			
Wood	CH_4	-100%	+412%	-30%	+30%	-104%	+413%	The equivalent assessment of the uncertainty in IW paper/cardboard or wood in "5.C.1. Waste Incineration" is applied.		Combined by using the error-propagation formula.
	N_2O	-64%	+64%	-30%	+30%	-71%	+71%			

- ***Time-series Consistency***

Data on the amount of waste oil and wood used as alternative fuels have been available since FY1998. For waste oil, consistent data over the time series are developed by using the total amount of waste oil incinerated without the use of waste oil as alternative fuel. For wood, the average of FY1998-2002 data is used to estimate the amount of wood for the past years. The emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

See section 7.1.5. "Sector-specific QA/QC and Verification".

e) Category-specific Recalculations

By revising the estimation method for CO_2 emissions for plastics used as fuel, CO_2 emissions for the whole time series were recalculated. By updating GCV for plastics, CH_4 and N_2O emissions in FY2023 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

7.4.3.2.c. Waste Tires Used as Alternative Fuels (1.A.1 and 1.A.2)

a) Category Description

This category covers the emissions from the use of waste tires as raw materials or fuels.

b) Methodological Issues

1) CO_2

- **Estimation Method**

The emissions are calculated by multiplying the incinerated amount of waste tires used as raw materials or fuels by Japan's country-specific emission factor.

- **Emission Factor**

The emission factor for waste tires is calculated by multiplying the fossil-fuel-derived carbon content of the waste tires by the oxidation factor of the waste tires at the facilities that use waste tires as fuel. The amount of the fossil-fuel-derived carbon in the waste tires is calculated by the material contents of new tires reported in the *Tire Industry of Japan* (Japan Automobile Tire Manufacturers Association: JATMA). The oxidation factor for waste tires is set to the default value of 100% indicated in the *2006 IPCC Guidelines*.

$$EF = CF \times OF \times 1000 \times 44/12$$

EF : Emission factor for the incineration of waste tires [kg-CO_2/t (dry)]
CF : Fossil-fuel-derived carbon content in waste tires
OF : Oxidation factor of waste tires

Table 7-77 CO_2 emission factors for waste tires used as alternative fuels

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Waste tires	kg-CO_2/t (dry)	1,867	1,794	1,799	1,746	1,759	1,744	1,698	1,641	1,562	1,563	1,563	1,634

- **Activity Data**

Activity data (dry basis) is calculated by subtracting the water content in the waste tires determined from analyses of three constituents of divided tires (Environmental Sanitation Center, 2001) from the amount of waste tires used as raw material or fuel (wet basis) in the *Tire Industry of Japan* (JATMA).

2) CH_4, N_2O

- **Estimation Method and Emission Factor**

See the section "7.4.3.2. Direct Use of Waste as Alternative Fuel (1.A.)"

- **Activity Data**

The amount of waste tires used as raw material or fuel by usage that is determined during the calculation of the CO_2 emissions from this source is used. For the activity data, the amount of waste tires recorded in the following categories are used: "Cement burning" for use in cement kilns; "Small and medium size boilers", "Tire manufacture", "Paper manufacturer", and "Power generation" for use in boilers; "Metal refining" for use in carbonization; and "Gasification" for use in gasification processes.

c) Uncertainty Assessment and Time-series Consistency

- **Uncertainty Assessment**

The uncertainty assessment is conducted as well as assessment in the category of the IW incineration (see Table 7-58). Details of the uncertainty assessment for this category are shown in the Table 7-78.

Table 7-78 Uncertainty assessment for waste tire used as alternative fuels (1.A.1 and 1.A.2)

Item	GHGs	Emission factor uncertainty		Activity data uncertainty		Emission uncertainty		Method for assessing emission factor uncertainty	Method for assessing activity data uncertainty	Method for assessing emission uncertainty
		(-)	(+)	(-)	(+)	(-)	(+)			
Waste tires	CO_2	-11%	+11%	-30%	+30%	-32%	+32%	Due to the lack of information for the uncertainty of the emission factor, the values for IW plastics are applied based on expert judgment.	The uncertainty in IW statistics is applied.	Combined by using the error-propagation formula.
	CH_4	-100%	+216%	-30%	+30%	-104%	+218%			
	N_2O	-44%	+44%	-30%	+30%	-53%	+53%			

- ***Time-series Consistency***

The emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

See section 7.1.5. “Sector-specific QA/QC and Verification”.

e) Category-specific Recalculations

No recalculations are conducted.

f) Category-specific Planned Improvements

No improvements are planned.

7.4.3.3. Incineration of Waste Processed as Fuel (1.A.)

7.4.3.3.a. Incineration of Refuse-based Solid Fuels (RDF and RPF) (1.A.1 and 1.A.2)

a) Category Description

In this category, CO_2, CH_4, and N_2O emissions from waste that is processed and used as fuel are estimated and reported. Refuse-derived solid fuels (RDF as Refuse Derived Fuel and RPF as Refuse Paper and Plastic Fuel) are used for the estimation of emissions from fuels produced from waste. The reporting categories for the above emissions are included in “Energy industries (1.A.1.)” and “Manufacturing industries and construction (1.A.2)” as indicated in Table 7-29. The fuel types are classified as “Other fossil fuels” or “Biomass” as indicated in Table 7-28.

b) Methodological Issues

1) CO_2

- ***Estimation Method***

Emissions are estimated by multiplying the amount of RDF and RPF incinerated by Japan’s country-specific emission factor.

$$E_{RDF} = EF_{RDF} \times AD_{RDF}$$

E_{RDF} : CO_2 emissions from RDF use [kg-CO_2]
EF_{RDF} : Emission factor for RDF use [kg-CO_2/t (dry)]
AD_{RDF} : Activity data for RDF use [t (dry)]

$$E_{RPF} = EF_{RPF} \times AD_{RPF}$$

E_{RPF} : CO_2 emissions from RPF use [kg-CO_2]
EF_{RPF} : Emission factor for RPF use [kg-CO_2/t (dry)]
AD_{RPF} : Activity data for RPF use [t (dry)]

- ***Emission Factor***

Emission factor associated with the use of RDF and RPF are calculated respectively as shown below.

➢ ***RDF***

By considering fossil-fuel-derived fraction in MSW (paper/cardboard, synthetic fibers and plastics) included in RDF, emission factor for RDF use is estimated by the equation shown below.

$$EF_{RDF} = 1000 \times \sum_i \left(F_{RDF,i} \times CF_i \times FCF_i\right) \times OF_{RDF} \times 44/12$$

$F_{RDF,i}$: Fraction of waste type *i* derived content contained in RDF (dry basis)
CF_i : Fraction of carbon content in waste type *i* in RDF (dry basis)
FCF_i : Fossil-fuel-derived fraction of waste type *i* in RDF
OF_{RDF} : Oxidation factor of RDF at RDF combustion facilities

- ***Fraction of Each Waste Type Derived Content Contained in RDF (F_{RDF}: Dry Basis)***

Fractions of each waste type derived content contained in RDF in wet basis are estimated based on the averages of those from result on the waste composition analysis in MOE (2003), supplemented by information from MOE (2020b) and the *Textile Handbook* (Japan Chemical Fibers Association). Water content in each waste type shown in sections "7.2.1. Managed Waste Disposal Sites (5.A.1.)" and "7.4.1.1. Municipal Solid Waste (5.C.1.-), CO_2" are applied to convert wet basis waste composition into that of dry basis (paper/cardboard: 20%, synthetic textiles: 20% and plastics: 26.1%). Estimated fractions of these wastes in RDF in dry basis are 38.2% of paper/cardboard, 10.3% of synthetic textiles and 28% of plastics respectively. Note that it is assumed that RDF almost does not include PET bottles.

- ***Fraction of Carbon Content Contained in Each Waste Type in RDF (CF: Dry Basis)***

Since RDF is usually made from MSW, the fractions of carbon content in each waste type used in section "7.4.1.1. Municipal Solid Waste (5.C.1.-)" are also applied for this category (paper/cardboard: 40.8%, synthetic textiles: 63.0% and plastics: 76.8%).

- ***Fossil-fuel-derived Fraction of Each Waste Type in RDF (FCF)***

Since RDF is usually made from MSW, fossil-fuel-derived fractions of each waste type used in section "7.4.1.1. Municipal Solid Waste (5.C.1.-)" are also applied for this category (paper/cardboard: 9.6%, synthetic textiles: 100% and plastics: see Table 7-35).

- ***Oxidation Factor for RDF at RDF Combustion Facilities (OF_{RDF})***

The default value provided in the *2006 IPCC Guidelines* (100%) is applied for the oxidation factor for this category.

➢ ***RPF***

Because the quality of RPF is categorized into "coal-equivalent product" and "coke-equivalent product" (Japan RPF Association, 2004), emission factor for RPF is established for each quality of product. However, in the case that the amount of use of each quality of product for estimating activity data is unavailable, emission factor is established by the weighted average of each emission factor for coal-equivalent product and coke-equivalent product with the average fraction of amount of use of each product (see "*Emission Factor for the Use of RPF (Weighted Average) (Dry basis)*" as described herein below.)

Coal-equivalent product

$$EF_{RPF,coal} = 1000 \times P_{RPF,coal} \times C \times OF_{RPF} \times 44/12 \times FCF_{plastics}$$
$$= 1000 \times 0.528 \times 0.737 \times 1.0 \times 44/12 \times FCF_{plastics}$$
$$= 1426\ [\text{kg-}CO_2/\text{t (dry)}] \times FCF_{plastics}$$

Coke-equivalent product

$$EF_{RPF,coke} = 1000 \times P_{RPF,coke} \times C \times OF_{RPF} \times 44 / 12 \times FCF_{plastics}$$
$$= 1000 \times 0.910 \times 0.737 \times 1.0 \times 44 / 12 \times FCF_{plastics}$$
$$= 2457\ [\text{kg-}CO_2/\text{t (dry)}] \times FCF_{plastics}$$

$EF_{RPF,coal}$: Emission factor for the use of coal-equivalent product RPF [kg-CO_2/t (dry)]
$EF_{RPF,coke}$: Emission factor for the use of coke-equivalent product RPF [kg-CO_2/t (dry)]
$P_{RPF,coal}$: Fraction of plastic-derived content contained in coal-equivalent product RPF (dry basis)
$P_{RPF,coke}$: Fraction of plastic-derived content contained in coke-equivalent product RPF (dry basis)
C : Fraction of carbon content contained in plastic (dry basis)
OF_{RPF} : Oxidation factor of RPF at RPF combustion facilities
$FCF_{plastics}$: Fossil-fuel-derived fraction of plastics in RPF

- ***Fraction of Waste Plastic-derived Content Contained in RPF ($P_{RPF,coal/coke}$: Dry Basis)***

The fraction of waste plastic-derived content contained in RPF in wet basis is established at 50% for coal-equivalent product and at 90% for coke-equivalent product based on the results of fact-finding survey conducted by the Japan RPF Industry Association (MOE, 2006b).
The fraction of plastic-derived content in RPF in a dry basis is calculated with the fraction of water content of RPF, to which the average water content of IW plastics used for RPF production is applied; it is established at 5% based on expert judgment.

- ***Fraction of Carbon Content Contained in Plastic (Dry Basis) (C)***

Because most of the plastics contained in RPF originate from IW (Seki, 2004), the carbon content of plastics on a dry basis (73.7%) is calculated by using the carbon content in IW plastics (70%) based on Environmental Agency (1992) together with the water content of IW plastics (5%) assumed in the RPF production process.

- ***Oxidation Factor for RPF at RPF Combustion Facilities (OF_{RPF})***

As applied in section "7.4.1.2. Industrial Waste (5.C.1.-)", the value provided in the *2006 IPCC Guidelines* (100%) is also applied for the oxidation factor for RPF at RPF combustion facilities.

- ***Fossil-fuel-derived Fraction of Plastics in RPF ($FCF_{plastics}$)***

The same values for IW plastics are applied (See Table 7-35).

- ***Emission Factor for RPF Use (Weighted Average) ($EF_{RPF,av}$: Dry Basis)***

In the case that the amount of use of coal-equivalent product RPF and coke-equivalent product RPF for estimating activity data is unavailable, emission factor is determined by the weighted average of each emission factor for coal-equivalent product and coke-equivalent product with the average fraction of the amount of use of each product.

Production percentage of RPF of coal-equivalent product and coke-equivalent product (wet basis) is obtained from the survey results conducted by Japan RPF Industry Association and is converted into the value in dry basis. The fraction of water content of RPF is established at 3% for coal-equivalent product and at 1% for coke-equivalent product based on the RPF quality standards provided by the

Japan RPF Industry Association. The estimated fractions of production percentage in dry basis are applied to all the reporting years because relevant statistics are unavailable.

$$EF_{RPF,av} = EF_{RPF,coal} \times P_{coal} + EF_{RPF,coke} \times P_{coke}$$
$$= (1426 \times FCF_{plastics}) \times 0.797 + (2457 \times FCF_{plastics}) \times 0.203$$
$$= 1636\ [\text{kg-CO}_2/\text{t}] \times FCF_{plastics}$$

$EF_{RPF,av}$: Emission factor for RPF use (weighted average) [kg-CO_2/t (dry)]
P_{coal} : Fraction of the use of coal-equivalent product RPF (dry basis)
P_{coke} : Fraction of the use of coke-equivalent product RPF (dry basis)
$FCF_{plastics}$: Fossil-fuel-derived fraction of plastics in RPF

Table 7-79 CO_2 emission factors for the emissions from the use of RDF and RPF

Item	Unit	Emission Factor
RDF	kg-CO_2/t (dry)	1,081
RPF (coal-equivalent products)	kg-CO_2/t (dry)	1,426
RPF (coke-equivalent products)	kg-CO_2/t (dry)	2,457
RPF (weighted average values)	kg-CO_2/t (dry)	1,636

Note: The emission factors are applied 100% of fossil-fuel-derived fraction of plastics ($FCF_{plastics}$)

- ***Activity Data***

➢ ***RDF***

The amount of RDF production is used as the substitute for the amount of use of RDF. Activity data (dry basis) is calculated by subtracting the water content of RDF from the amount of RDF production at RDF production facilities (wet basis) provided by the *Report on Survey of State of Treatment of Municipal Solid Waste* (MOE). For the fiscal years that the data are unavailable, the activity data are estimated by using the trend on the refuse processing capacity.

$$A_{RDF} = a_{RDF} \times (1 - u_{RDF})$$

A_{RDF} : Activity data for RDF use [t (dry)]
a_{RDF} : Amount for RDF production at RDF production facilities [t (wet)]
u_{RDF} : Fraction of water content in RDF

➢ ***RPF***

The amounts of RPF used in chemical industry, paper industry, cement manufacturer, and petroleum product manufacturer are estimated (See also Table 7-70). The amount of RPF (dry basis) for paper industry is obtained from the survey results conducted by the Japan Paper Association. The amounts of RPF (dry basis) for the chemical industry, cement manufacturers, and petroleum product manufacturers are obtained by using the averaged water content of RPF and the survey results (wet basis) conducted by the *Japan Chemical Industry Association*, the *Japan Cement Association* and the *Petroleum Association of Japan*.

2) CH_4, N_2O

- ***Estimation Method and Emission Factor***

For the estimation method and the emission factors used, see section "7.4.3.2. Direct Use of Waste as Alternative Fuel (1.A.)".

- ***Activity Data***

➢ ***RDF***

The entire amount of RDF production (wet basis) used for CO_2 emission estimates is also used for the amount of use of RDF for boiler.

➢ ***RPF***

Out of the amount of RPF used for CO_2 emission estimates, the amounts of RPF used in chemical industry, paper industry, and petroleum product manufacturers are adopted as the amount of fuel used for boiler (wet basis). The amount of RPF used in cement industry is adopted as the amount of fuel used for cement kiln (wet basis). Because the amount of RPF used in paper industry is on a dry basis, the average water content of RPF is added to obtain the value on a wet basis.

➢ ***Activity Data Converted into Energy Units (Reference Value)***

Activity data converted into energy units to be reported in CRT is calculated as indicated below.

$$A_{E,i} = A_i \times GCV_i / 10^6$$

$A_{E,i}$: Activity data of fuel type i converted into energy units [TJ]
A_i : Amount of consumed fuel type i [kg (wet)]
GCV_i : Gross calorific value of fuel type i [MJ/kg]

c) Uncertainty Assessment and Time-series Consistency

● ***Uncertainty Assessment***

The uncertainty assessment is conducted as well as the assessment for the MSW or IW incineration (see Table 7-45, Table 7-46 and Table 7-58). Details of the uncertainty assessment for this category are indicated in the Table 7-80.

Table 7-80 Uncertainty assessment for incineration of waste refuse-based solid fuels (1.A.1 and 1.A.2)

Item	GHGs	Emission factor uncertainty		Activity data uncertainty		Emission uncertainty		Method for assessing emission factor uncertainty	Method for assessing activity data uncertainty	Method for assessing emission uncertainty
		(-)	(+)	(-)	(+)	(-)	(+)			
RDF	CO_2	-1%	+1%	-10%	+10%	-10%	+10%	Due to the lack of information on the uncertainty of the emission factors, the values for MSW plastics are applied based on expert judgment.	The uncertainty in MW statistics is applied.	Combined by using the error-propagation formula.
	CH_4	-39%	+39%	-10%	+10%	-40%	+40%			
	N_2O	-34%	+34%	-10%	+10%	-35%	+35%			
RPF	CO_2	-11%	+11%	-30%	+30%	-32%	+32%	Due to the lack of information on the uncertainty of the emission factors, the values for IW plastics is applied based on expert judgment.	The uncertainty in IW statistics is applied.	Combined by using the error-propagation formula.
	CH_4	-100%	+216%	-30%	+30%	-104%	+218%			
	N_2O	-44%	+44%	-30%	+30%	-53%	+53%			

● ***Time-series Consistency***

Since data on the amount of RDF produced are not available for the years prior to FY1997, these data are estimated by using the trend on capacity of refuse-based fuel-producing facilities. The emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

See section 7.1.5. “Sector-specific QA/QC and Verification”.

e) Category-specific Recalculations

By updating the statistical data, CO_2 emissions in FY2023 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

7.5. Wastewater Treatment and Discharge (5.D.)

The CH_4 and N_2O emissions from domestic wastewater (DWW) and industrial wastewater (IWW) treatment and discharge are reported under the category "Wastewater Treatment and Discharge (5.D.)". The target categories are shown in Table 7-81. Since an emission factor that takes into account emissions from wastewater and sludge treatment processes is used in Japan, emissions from these processes are reported altogether. Note since this category includes various types of sources, it is difficult to analyze the trend in the IEFs.

Table 7-81 Categories overview for wastewater treatment and discharge (5.D.)

Category	Wastewater type					Treatment type			CH_4	N_2O
5.D.1. (Sec. 7.5.1)	DWW	Plant	Public sewer system	Sewage		Sewage treatment plants (Sec. 7.5.1.1)	Standard activated sludge process		○	○
							Anaerobic-aerobic activated sludge process			○
							Anaerobic-anoxic-oxic process and recycled nitrification-denitrification process			○
							Recycled nitrification-denitrification membrane bioreactor			○
			Other sewer system	Human waste	Miscellaneous wastewater	Domestic sewage treatment plants (mainly *Johkasou*) (Sec. 7.5.1.2)	Community plant		○	○
							Current type *Johkasou*	Advanced type: TN removal type	○	○
								Advanced type: TN and TP removal type		
								Advanced type: BOD removal type		
								Advanced type: Other advanced type	○	○
								Standard type	○	○
							Old type *Johkasou*		○	○
							Vault toilet		○	○
				Collected human waste	Human waste and *Johkasou* sludge (from domestic sewage treatment plants)	Human waste treatment plants (Sec. 7.5.1.3)	High-load denitrification treatment		○	○
							Membrane separation		○	○
							Anaerobic treatment		○	○
							Aerobic treatment		○	
							Standard denitrification treatment		○	
							Other		○	
		Effluent	Wastewater		Untreated wastewater	Natural decomposition of domestic wastewater (Sec. 7.5.1.4)	Discharge of untreated wastewater	From old type *Johkasou*	○	○[2]
								From vault toilet	○	○[2]
								From on-site treatment	○	○[2]
					Treated wastewater		Discharge of treated wastewater	(From each treatment plant)	NA	○[2]
			Sludge		Human waste and *Johkasou* sludge		Ocean dumping of sludge[1]	(From domestic sewage treatment plants)	○	○[2]
					Sewage sludge			(From sewage treatment plants)	○	○[2]
5.D.2. (Sec. 7.5.2)	IWW	Plant	Manufacture of Food			Industrial wastewater treatment (Sec. 7.5.2.1)	(IWW treatment plants)		○	○
			Pulp, paper and paper products						○	○
			Chemical and allied product						○	○
			Iron and steel						○	○
			Beverages, tobacco and feed						○	○
			Textile products							
			Petroleum and coal products							
			Plastic products							
			Rubber products							
			Leather tanning, leather products and fur skins							
		Effluent	Wastewater		Untreated wastewater	Natural decomposition of Industrial wastewater (Sec. 7.5.2.2)	Discharge of untreated wastewater	(from industrial plants/facilities)	○	○[2]
					Treated wastewater		Discharge of treated wastewater	(from IWW treatment plants)	NA	○[2]
	Landfill leachate (plant)					Landfill leachate treatment (Sec. 7.5.2.3)			○	○

Note:

1) Due to legal regulations on sludge disposal at sea, there has been no activity since FY2009.

2) N_2O emissions from category "Natural decomposition of domestic wastewater" and "Natural decomposition of industrial wastewater" are reported under "Effluent" in the CRT Table 5B. Meanwhile, all CH_4 and N_2O emissions from the other sources are included in "Plant" in the CRT.

Estimated GHG emissions from wastewater handling are shown in Table 7-82. In FY2024, emissions from this source category were 3,367 kt-CO_2 eq. and accounted for 0.3% of the national total emissions (excluding LULUCF). The emissions from this source category decreased by 37.8% compared to those in FY1990. This emission decrease is the result of decrease in the amount of CH_4 emissions from "Natural decomposition of domestic wastewater" because the practice of wastewater treatment at wastewater treatment plants increased in Japan.

Table 7-82 GHG emissions from wastewater treatment and discharge (5.D.)

Gas	Category		Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
CH_4	5.D.1. Domestic wastewater	Sewage treatment plant	kt-CH_4	8.6	9.9	11.1	12.1	12.7	12.5	12.4	12.9	12.9	12.6	12.4	12.4
		Domestic sewage treatment plant	kt-CH_4	30.4	35.0	38.8	38.3	36.8	35.3	34.3	30.8	31.5	31.1	30.7	30.4
		Human-waste treatment plant	kt-CH_4	5.2	3.2	1.8	1.0	0.6	0.5	0.4	0.3	0.2	0.2	0.2	0.2
		Natural decomposition of DWW	kt-CH_4	61.7	50.8	39.5	28.7	21.1	18.1	16.4	13.1	11.8	11.1	10.5	10.0
	5.D.2. Industrial wastewater	IWW treatment	kt-CH_4	2.2	2.2	2.1	1.9	1.8	1.6	1.7	1.7	1.7	1.7	1.7	1.7
		Natural decomposition of IWW	kt-CH_4	8.2	7.8	7.9	8.3	4.9	4.1	4.6	3.7	3.7	3.7	3.7	3.7
		Landfill leachate treatment	kt-CH_4	1.2	1.2	1.1	0.8	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.1
	Total		kt-CH_4	117.7	110.0	102.2	91.2	78.1	72.5	70.0	62.6	61.9	60.5	59.4	58.5
			kt-CO_2 eq.	3,295	3,080	2,863	2,553	2,188	2,029	1,959	1,753	1,733	1,695	1,663	1,639
N_2O	5.D.1. Domestic wastewater	Sewage treatment plant	kt-N_2O	1.39	1.55	1.58	1.67	1.67	1.59	1.55	1.47	1.46	1.44	1.44	1.44
		Domestic sewage treatment plant	kt-N_2O	1.52	1.65	1.70	1.57	1.53	1.56	1.55	1.56	1.60	1.61	1.60	1.58
		Human-waste treatment plant	kt-N_2O	0.22	0.26	0.12	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
		Natural decomposition of DWW	kt-N_2O	2.79	2.72	2.49	2.29	2.11	2.08	2.02	1.91	1.88	1.87	1.82	1.81
	5.D.2. Industrial wastewater	IWW treatment	kt-N_2O	1.00	0.96	0.81	1.10	1.09	1.15	1.13	1.13	1.13	1.13	1.13	1.13
		Natural decomposition of IWW	kt-N_2O	1.06	1.02	1.02	0.97	0.66	0.59	0.54	0.55	0.55	0.55	0.55	0.55
		Landfill leachate treatment	kt-N_2O	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.004	0.003	0.004	0.003	0.003
	Total		kt-N_2O	8.01	8.18	7.72	7.65	7.10	6.99	6.80	6.64	6.65	6.61	6.55	6.52
			kt-CO_2 eq.	2,123	2,169	2,046	2,028	1,881	1,851	1,803	1,760	1,762	1,752	1,737	1,729
Total			kt-CO_2 eq.	5,417	5,249	4,909	4,581	4,069	3,880	3,762	3,512	3,495	3,448	3,399	3,367

7.5.1. Domestic Wastewater (5.D.1.)

Domestic and commercial wastewater generated in Japan is treated at various wastewater treatment facilities (e.g., sewage treatment plants, domestic sewage treatment plants, human waste treatment plants) and GHG emissions from these sources are reported under "Domestic and Commercial Wastewater (5.D.1.)". Because the CH_4 and N_2O emission characteristics differ from one wastewater treatment facility to another, a different emission estimation method is established for each facility.

The characteristics, effectiveness, and economic efficiency of wastewater treatment systems are thoroughly reviewed, and the most suitable systems are selected for each area in Japan with care also being taken to avoid excessive expenditure. According to the data from the *Waste Treatment in Japan* (MOE), public sewerage system is spreading from large cities to smaller municipalities and used by 78.5% of the population at the end of FY2024.

Domestic sewage treatment plants (e.g. current type *Johkasou*) are being promoted as an effective means of supplementing sewerage systems in smaller municipalities with low population densities and little flat land. In FY2024, *Johkasou* (including rural sewerage and other facilities) is used by 18.0% of the population, with the remainder being treated after collection or on-site.

Note that activity data are reported as "NA" in the CRT Table 5.B instead of the amount of organic carbon based on BOD values and nitrogen in effluents since country-specific methodology for this category requires various types of activity data by gas and facility type as shown below.

Table 7-83 Various type of activity data for the category "Domestic Wastewater (5.D.1.)"

Emission sources	Activity data for CH_4 estimation	Activity data for N_2O estimation
Sewage treatment plants	Yearly amount of sewage treated at sewage treatment plants [Unit: m^3]	
Domestic sewage treatment plants	Population requiring waste processing at domestic sewage treatment plants [Unit: person]	
Human waste treatment plants	Input volume of human waste and *Johkasou* sludge at human waste treatment plants [Unit: m^3]	Amount of nitrogen in human waste and *Johkasou* sludge input at human waste treatment plants [Unit: kg-N]
Natural decomposition of domestic wastewater	Amount of organic matter in DWW discharged [Unit: kg-BOD]	Amount of nitrogen in DWW discharged [Unit: kg-N]

7.5.1.1. Sewage Treatment Plants (5.D.1.-)

a) Category Description

This category covers CH_4 and N_2O emissions from treatment of wastewater at sewage treatment plants.

b) Methodological Issues

- ***Estimation Method***

Emissions of CH_4 and N_2O from this source are calculated using Japan's country-specific method in accordance with the decision tree of the *2006 IPCC Guidelines* (Page 6.10, Fig. 6.2). Emissions are calculated by multiplying the volume of sewage treated at sewage treatment plants by the emission factor.

$$E = EF \times A$$

E : Amount of CH_4 or N_2O emitted from sewage treatment plants in conjunction with domestic/commercial wastewater treatment [kg-CH_4], [kg-N_2O]
EF : Emission factor [kg-CH_4/m^3], [kg-N_2O/m^3]
A : Yearly amount of sewage treated at sewage treatment plants [m^3]

- ***Emission Factors***

1) CH_4

Emission factors are established by adding the simple averages for each treatment process, having taken the actual volume of CH_4 released from sludge treatment and water treatment processes measured at sewage treatment plants from research studies (sampling surveys) conducted in several different seasons for 8 plants in Japan (MOE, 2006b).

$$EF_{CH4} = EF_{WWTT} + EF_{SSTT}$$
$$= 8.8 \times 10^{-4} \text{ [kg-CH}_4/\text{m}^3\text{]}$$

EF_{CH4} : CH_4 Emission factor
EF_{WWTT} : Average of emission factors for wastewater treatment processes (528.7 [mg-CH_4/m^3])
EF_{SSTT} : Average of emission factors for sludge treatment processes (348.0 [mg-CH_4/m^3])

2) N_2O

Emission factors are established on the basis of measured values of N_2O volume emitted from wastewater and sludge treatment processes at sewage treatment plants which is obtained from research studies (sampling surveys) conducted in several different seasons for 42 plants in Japan; these studies consist of measurements in several plants for each type of wastewater treatment process.

Since the research studies revealed that the amount of N_2O emission varies according to the type of wastewater treatment process at sewage treatment plants, the N_2O emission factor for each wastewater treatment type is developed based on the latest findings in Japan (MOE, 2013b).

$$EF_{N2O} = EF_{WWTTi} + EF_{SSTT}$$

EF_{N2O} : N_2O Emission factor
EF_{WWTTi} : Emission factor for wastewater treatment process *i* (See Table 7-84.)
EF_{SSTT} : Average of emission factor for sludge treatment process (0.6 [mg-N_2O/m^3])

Table 7-84 N_2O Emission factors by wastewater treatment process at sewage treatment plants

Wastewater treatment process	N_2O EF [mg-N_2O/m^3]	
	Wastewater treatment process[3)]	Sludge treatment process
Standard activated sludge process[1)]	142	0.6
Anaerobic-aerobic activated sludge process	29.2	
Anaerobic-anoxic-oxic process and recycled nitrification-denitrification process[2)]	11.7	
Recycled nitrification-denitrification membrane bioreactor	0.5	

Note:
1) Includes all the wastewater treatment processes other than indicated above.
2) Includes all the wastewater treatment processes which remove nitrogen at the same level or greater than Anaerobic-anoxic-oxic process and recycled nitrification-denitrification process, but excludes recycled nitrification-denitrification membrane bioreactor.
3) Since the main purpose of the "Standard activated sludge process" is to remove BOD from wastewater, the nitrification reaction cannot be completed during the process, resulting in more N_2O generated. In the meanwhile, advanced treatment procedures such as "Anaerobic-aerobic activated sludge process", "Anaerobic-anoxic-oxic process and recycled nitrification-denitrification process", and "Recycled nitrification-denitrification membrane bioreactor" allow sufficient nitrification reaction to occur for nitrogen removal etc, and accordingly generate less N_2O.

- ***Activity Data***

Activity data for N_2O emissions by wastewater treatment process at sewage treatment plants are provided by MLIT. Total amounts of wastewater treated used for N_2O emission estimates are also used for the activity data for CH_4 emission estimates.

Table 7-85 Activity data for wastewater treated at sewage treatment plants

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Standard activated sludge process	10^6 m^3	9,761	10,780	10,686	11,405	11,358	10,736	10,401	9,733	9,664	9,479	9,524	9,524
Anaerobic-aerobic activated sludge process	10^6 m^3	73	446	1,523	1,039	909	931	933	1,456	1,456	1,417	1,477	1,477
Anaerobic-anoxic-oxic process and recycled nitrification; denitrification process	10^6 m^3	23	89	487	1,374	2,181	2,629	2,819	3,480	3,533	3,452	3,167	3,167
Recycled nitrification-denitrification membrane bioreactor	10^6 m^3	NO	NO	NO	0.1	2	15	0.2	6	12	15	15	15
Total	10^6 m^3	9,857	11,316	12,696	13,818	14,450	14,311	14,153	14,674	14,665	14,363	14,182	14,182

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainties in emission factors for CH_4 and N_2O in sewage treatment plants are evaluated by using the 95% confidence intervals of measured data which are used for calculation of emission factors. As for the uncertainties in activity data, the uncertainties in sewage data indicated in Table 7-2 are applied. Details of the uncertainty assessment for this category are indicated in Table 7-86.

Table 7-86 Uncertainty assessment for sewage treatment plants on the category "Domestic wastewater (5.D.1.-)"

Item	GHGs	Emission factor uncertainty		Activity data uncertainty		Emission uncertainty		Method for assessing emission factor uncertainty	Method for assessing activity data uncertainty	Method for assessing emission uncertainty
		(-)	(+)	(-)	(+)	(-)	(+)			
Sewage treatment plants	CH_4	-31%	+31%	-5%	+5%	-31%	+31%	Evaluated by using the 95% interval confidence of measured data in MOE (2006b).	The uncertainty in sewage statistics is applied.	Combined by using the error-propagation formula.
	N_2O	-100%	+146%	-5%	+5%	-100%	+146%			

- ***Time-series Consistency***

The emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

See section 7.1.5. "Sector-specific QA/QC and Verification".

e) Category-specific Recalculations

By updating the statistical data, CH_4 and N_2O emissions in FY2023 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

7.5.1.2. Domestic Sewage Treatment Plants (Mainly *Johkasou*) (5.D.1.-)

a) Category Description

A part of domestic and commercial wastewater not processed in the public sewerage in Japan is processed in community plants, current type *Johkasou*, the old type *Johkasou*, and vault toilets. The *Johkasou* means decentralized wastewater treatment facilities installed at an individual home.

Table 7-87 Type of sewage and sewage treatment

Plant type				Sewage type	Description	
Community plant				Human waste and miscellaneous wastewater	Small-scale wastewater treatment facility regionally installed	
Johkasou	Current type	Advanced type	TN removal type		Wastewater treatment unit installed at an individual household	Advanced types under the Building Standards Act mended in FY2001
			TN and TP removal type			
			BOD removal type			
			Other advanced type			
		Standard type				Standard type under the former Building Standards Act
	Old type			Human waste only		Old type which is not allowed to be newly installed under the amended Purification Tank Act since FY2001
Vault toilet					Installed at an individual household	

This category covers CH_4 and N_2O emissions from domestic sewage treatment plants. Emissions from human waste within its residence time in vault toilets are reported under this category, whereas the emissions that occur after the waste is collected from vault toilets are accounted for under section "7.5.1.3. Human Waste Treatment Plants (5.D.1.-)".

b) Methodological Issues

- ***Estimation Method***

Emissions of CH_4 and N_2O from this source are calculated using Japan's country-specific method, in accordance with decision tree the *2006 IPCC Guidelines* (Page 6.10, Fig. 6.2). Emissions are calculated by multiplying the annual population of treatment for each type of domestic sewage treatment plant by the emission factor.

$$E = \sum_i (EF_i \times A_i)$$

E : Emissions of methane and nitrous oxide from the processing of domestic and commercial wastewater at domestic sewage treatment plants (mainly *Johkasou*) [kg-CH_4], [kg-N_2O]
EF_i : Emission factor for domestic sewage treatment plant i [kg-CH_4/person], [kg-N_2O/person]
A_i : Population (persons) requiring waste processing at domestic sewage treatment plant i per year

- ***Emission Factors***

CH_4 and N_2O emission factors for this source are determined from domestic research studies as shown on the Table 7-88.

Table 7-88 Emission factors for CH_4 and N_2O from DWW treatment systems

CH_4 emission factors (Unit: kg-CH_4 /person-year)							
Plant type			FY1990 –1995	FY1996 –2000	FY2001– 2004	FY2005–	Reference
Community plant[1]			0.195	Interpolation		0.062	1990-1995: Tanaka (1998) 2005-: Ike and Soda (2010)
Current type *Johkasou*	Advanced type	TN removal type	NA[2]		1.044		MOE (2012) and MOE (2013c)
		TN and TP removal type					
		BOD removal type					
		Other advanced type			1.984		
	Standard type [3]		2.477				
Old type *Johkasou* [3]			0.46				
Vault toilet [3]			0.062				
N_2O emission factors (Unit: kg-N_2O/person-year)							
Plant type			FY1990 –1995	FY1996 –2000	FY2001– 2004	FY2005–	Reference
Community plant[1]			0.0394	Interpolation		0.0048	1990-1995: Tanaka et al. (1995) [4] 2005-: Ike and Soda (2010)
Current type *Johkasou*	Advanced type	TN removal type	NA[2]		0.123		MOE (2012) and MOE (2013c)
		TN and TP removal type					
		BOD removal type					
		Other advanced type			0.055		
	Standard type [3]		0.0717				
Old type *Johkasou* [3]			0.039				
Vault toilet [3]			0.000022				

Note:
1) For the values from FY2005 onward, the emission factors are applied taking into account the improvement of the plants.
2) The installation of current advanced type *Johkasou* was started under the technical guidelines for *Johkasou* of the Building Standards Act revised in FY2001.
3) The same emission factor is applied for through the reporting years because there is no significant technological advancement
4) The simple mean value of the upper limit and the lower limit of measured values indicated in the reference is applied.

- ***Activity Data***

Annual treatment population by type of domestic sewage treatment plant for community plants, current type *Johkasou,* old type *Johkasou,* and vault toilets given in the *Waste Treatment in Japan* (MOE) is used as the activity data for CH_4 and N_2O emitted in association with domestic sewage treatment plants.

Activity data for current type *Johkasou* are classified as advanced type and standard type by using installation share derived from installation number of each type, which can be assumed as a share of annual treatment population, shown in the *Survey of guidance promotion of Johkasou* (MOE).

Table 7-89 Annual treatment population by type of domestic sewage treatment plant (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Community plant	1000 person	493	398	414	552	293	304	294	259	193	172	163	160
Current type *Johkasou* (Sub total)	1000 person	6,274	8,515	10,806	12,792	14,082	14,492	14,600	14,421	15,206	15,370	15,344	15,260
Advanced type													
TN removal type	1000 person	NO	NO	NO	263	1,433	2,612	3,105	4,772	5,315	5,566	5,728	5,697
TN and TP removal type	1000 person	NO	NO	NO	3	14	35	39	51	58	120	106	105
BOD removal type	1000 person	NO	NO	NO	34	33	25	19	58	35	27	22	22
Other advanced type	1000 person	NO	NO	NO	4,501	6,132	6,123	6,153	5,110	5,273	5,390	5,319	5,290
Standard type	1000 person	6,274	8,515	10,806	7,991	6,471	5,697	5,284	4,429	4,524	4,267	4,168	4,145
Old type *Johkasou*	1000 person	26,828	26,105	23,289	18,303	13,948	12,383	11,415	9,319	8,317	7,755	7,411	7,095
Vault toilet	1000 person	38,920	29,409	20,358	13,920	9,984	8,242	7,197	5,481	5,097	4,846	4,570	4,279
Total	1000 person	72,515	64,427	54,867	45,567	38,307	35,421	33,506	29,480	28,813	28,143	27,488	26,794

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainties in emission factors for CH_4 and N_2O in current type *Johkasou*, old type *Johkasou*, and vault toilet are evaluated by using the 95% confidence intervals of measured data which are used for calculation of emission factors. As for the uncertainties in emission factors for CH_4 and N_2O in community plant, the uncertainties in similar emission sources are used. As for the uncertainties in activity data, the uncertainties in DWW data indicated in Table 7-2 are applied. Details of the uncertainty assessment for this category are indicated in the Table 7-90.

Table 7-90 Uncertainty assessment for domestic sewage treatment plants on the category "Domestic wastewater (5.D.1.-)"

Item	GHGs	Emission factor uncertainty		Activity data uncertainty		Emission uncertainty		Method for assessing emission factor uncertainty	Method for assessing activity data uncertainty	Method for assessing emission uncertainty
		(-)	(+)	(-)	(+)	(-)	(+)			
Community Plant	CH_4	-32%	+32%	-10%	+10%	-33%	+33%	The uncertainties of current type *Johkasou* are applied based on expert judgment. MOE (2013c).	The uncertainty in MW statistics is applied.	Combined by using the error-propagation formula.
	N_2O	-45%	+45%	-10%	+10%	-46%	+46%			
Current type *Johkasou*	CH_4	-32%	+32%	-10%	+10%	-33%	+33%			
	N_2O	-45%	+45%	-10%	+10%	-46%	+46%			
Old type *Johkasou*	CH_4	-84%	+84%	-10%	+10%	-84%	+84%			
	N_2O	-87%	+87%	-10%	+10%	-88%	+88%			
Vault toilet	CH_4	-49%	+49%	-10%	+10%	-50%	+50%			
	N_2O	-72%	+72%	-10%	+10%	-73%	+73%			

- ***Time-series Consistency***

The emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

See section 7.1.5. "Sector-specific QA/QC and Verification".

e) Category-specific Recalculations

By updating the statistical data, CH_4 and N_2O emissions in FY2023 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

7.5.1.3. Human Waste Treatment Plants (5.D.1.-)

a) Category Description

This category includes CH_4 and N_2O emissions from the treatment of collected human waste from vault toilets and sludge from *Johkasou* at human waste treatment plants.

b) Methodological Issues

1) CH_4

- ***Estimation Method***

Emissions of CH_4 from this source are calculated using Japan's country-specific methodology in accordance with decision tree of the *2006 IPCC Guidelines* (Page 6.10, Fig. 6.2). Emissions are calculated by multiplying the volume of DWW treated at human waste treatment plants by the emission factor.

$$E = \sum_i (EF_i \times A_i)$$

E : Emission of methane from the processing of domestic and commercial wastewater at human waste treatment plants [kg-CH_4]

EF_i : Emission factor for human waste treatment plants (for treatment process i) [kg-CH_4/m^3]

A_i : Input volume of human waste and *Johkasou* sludge at human waste treatment plants (for treatment process i) [m^3]

- ***Emission Factors***

Emission factors for CH_4 are determined by treatment processes type, including anaerobic, aerobic, standard denitrification and high-load denitrification treatments as well as membrane separation systems, for each of the human waste treatment plants (MOE, 2006b).

Table 7-91 CH_4 emission factors by each treatment process

Treatment method	Unit	CH_4 Emission factor	Reference
Anaerobic treatment	kg-CH_4/m^3	0.543	Estimated by multiplying the measured methane emissions reported in Japan Environmental Sanitation Center (1990) by 1 – CH_4 recovery rate (90%).
Aerobic treatment	kg-CH_4/m^3	0.00545	Simple average value of standard de-nitrification and high load de-nitrification since the emission profile is not well understood.
Standard de-nitrification treatment	kg-CH_4/m^3	0.0059	Tanaka et al. (1995)
High load de-nitrification treatment	kg-CH_4/m^3	0.005	Tanaka et al. (1995)
Membrane separation	kg-CH_4/m^3	0.00545	Because the emission profile is not well understood, the emission factor for aerobic treatment is applied.
Other	kg-CH_4/m^3	0.00545	Because the emission profile is not well understood, the emission factor for aerobic treatment is applied.

- ***Activity Data***

Activity data for CH_4 emissions associated with the processing of wastewater at human waste treatment plants is determined from the calculated throughput volume for each of the treatment processes (Table 7-94), by multiplying the total volume of human waste and *Johkasou* sludge processed at human waste treatment plants that are indicated in *Waste Treatment in Japan* (MOE) (Table 7-92) by the capacity of each treatment process (Table 7-93).

$$A_i = W_H \times C_i / C_T$$

A_i : Activity data for human waste treatment method i [kL]
W_H : Total amount of human waste and septic tank sludge [kL]
C_i : Capacity of waste treatment method i [kL]
C_T : Total capacity of all waste treatment methods [kL]

Table 7-92 Volume of human waste and *Johkasou* sludge treated at their treatment plants

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Human waste from vault toilets	1000 kL	20,406	18,049	14,673	10,400	7,917	6,771	6,153	4,974	4,781	4,536	4,351	4,173
Johkasou sludge	1000 kL	9,224	11,545	13,234	13,790	13,760	13,726	13,537	13,372	13,260	13,082	13,007	12,950
Total	1000 kL	29,630	29,594	27,907	24,190	21,677	20,497	19,690	18,346	18,041	17,618	17,358	17,123

Table 7-93 Trends in treatment capacity by treatment process

Unit	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Anaerobic treatment	kL/day	34,580	19,869	10,996	6,476	3,891	3,059	2,245	1,330	898	930	650	530
Aerobic treatment	kL/day	26,654	19,716	12,166	8,465	6,753	6,001	5,979	3,666	4,967	4,245	4,110	4,005
Standard de-nitrification treatment	kL/day	25,196	30,157	31,908	29,655	26,173	25,153	24,023	21,322	20,416	19,660	19,187	18,672
High load de-nitrification treatment	kL/day	8,158	13,817	16,498	17,493	16,104	14,529	13,831	12,601	12,330	12,147	11,989	11,464
Membrane separation	kL/day	NO	1,616	2,375	3,055	3,684	4,074	3,373	2,410	2,240	1,910	1,845	1,619
Other	kL/day	13,777	20,028	25,917	30,277	34,577	33,975	33,940	40,882	40,906	44,577	44,234	44,307

Table 7-94 Activity Data for human waste by treatment types

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Anaerobic treatment	1000 kL	9,455	5,589	3,073	1,642	925	722	530	297	198	196	138	113
Aerobic treatment	1000 kL	7,288	5,546	3,400	2,146	1,605	1,417	1,412	818	1,096	896	870	851
Standard de-nitrification treatment	1000 kL	6,889	8,483	8,917	7,518	6,222	5,940	5,672	4,758	4,505	4,150	4,061	3,967
High load de-nitrification treatment	1000 kL	2,231	3,887	4,611	4,435	3,828	3,431	3,266	2,812	2,721	2,564	2,537	2,436
Membrane separation	1000 kL	NO	455	664	774	876	962	796	538	494	403	390	344
Other	1000 kL	3,767	5,634	7,243	7,676	8,220	8,024	8,014	9,123	9,026	9,409	9,362	9,413
Total	1000 kL	29,630	29,594	27,907	24,190	21,677	20,497	19,690	18,346	18,041	17,618	17,358	17,123

2) N_2O

- ***Estimation Method***

Emissions of N_2O from this source are calculated using Japan's country-specific methodology, in accordance with decision tree of the *2006 IPCC Guidelines* (Page 6.10, Fig. 6.2). Emissions are calculated by multiplying the volume of nitrogen treated at human waste treatment plants, by the emission factor.

$$E = \sum_i (EF_i \times A_i)$$

E : Emission of nitrous oxide from the processing of domestic and commercial wastewater at human waste treatment plants [kg-N_2O]
EF_i : Emission factor for human waste treatment plants (by treatment process i) [kg-N_2O/kg-N]
A_i : Amount of nitrogen in human waste and *Johkasou* sludge input at human waste treatment plants (by treatment process i) [kg-N]

- ***Emission Factors***

The emission factors for N_2O are determined for each treatment process including high-load denitrification treatment and membrane separation systems using the results of actual case studies in Japan (MOE, 2006b).

According to the survey studies on the emission factors for human waste treatment facilities conducted in FY1994 (Tanaka et al., 1998) and FY2003 (Ohmura et al., 2004) in Japan, advancements in facility design as well as operation and maintenance technologies have led to improvements in the emission factors for high load de-nitrification treatment and membrane separation. Therefore, different emission factors are applied for FY1994 and earlier, and for FY2003 onwards.

Table 7-95 N_2O emission factors by each treatment process

Treatment method	N_2O emission factors [kg-N_2O/kg-N]		
	FY1990–1994	FY1995–2002	FY2003–
High load de-nitrification treatment	0.033 [1)]	Interpolation	0.0029 [2)]
Membrane separation	0.033 [1)]	Interpolation	0.0024 [2)]
Other (including anaerobic treatment, aerobic treatment, standard de-nitrification treatment)	0.0000045 [3)]		

Note:
1) Median value of measured data from 13 plants reported in Tanaka et al. (1998)
2) Median value of measured data from 13 plants reported in Omura et al. (2004)
3) Referred to Tanaka et al. (1995) (Calculated by dividing upper limit value for standard de-nitrification treatment (1.0×10^{-5} kg-N_2O/m^3) by treated nitrogen concentration in FY1994 (2,211 mg/L)).

- ***Activity Data***

The volume of nitrogen treated at human waste treatment plants is calculated by multiplying treated nitrogen concentration by the volume of human waste treated at these facilities (the sum of collected human waste and sewage in sewerage tank), given in the *Waste Treatment in Japan* (MOE). The treated nitrogen concentration is based on weighted average of the volume of nitrogen contained in collected human waste and sewage in sewerage tank derived using the volume of collected human waste and sewage in sewerage tank treated at human waste treatment plants.

$$A_i = (W_H \times N_H + W_J \times N_J) \times F_i / 1000$$

A_i : Activity data for human waste treatment method i [kg-N]
W_H : Input volume of human waste at human waste treatment plants [m^3]
W_J : Input volume of *Johkasou* sludge at human waste treatment plants [m^3]
N_H : Nitrogen concentration in human waste [mg-N/L]
N_J : Nitrogen concentration in *Johkasou* sludge [mg-N/L]
F_i : Percentage throughput of treatment process i [%]

➢ ***Input Volume of Human Waste and Johkasou Sludge at Human Waste Treatment Plants:***

See the data used for the calculation of CH_4 emissions from human waste treatment plants (Table 7-92).

➢ ***Percentage Throughput of the Human Waste Treatment Processes:***

See the data used for the calculation of CH_4 emission from human waste treatment plants (Table 7-93).

➢ ***Nitrogen Concentration in Human Waste and Johkasou Sludge Input at Treatment Plants:***

For the nitrogen concentration in human waste and *Johkasou* sludge input at treatment plants, the values analyzed for the period FY1989-1991, FY1992-1994, FY1995-1997, and FY1998-2000, respectively, are used based on the research conducted by Okazaki (2001). The values of FY2000 are used for the values from FY2001 onward. (See Table 7-96).

Table 7-96 Concentration of nitrogen contained in collected human waste and *Johkasou* sludge

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Human waste from vault toilets	mg-N/L	3,940	3,100	2,700	2,700	2,700	2,700	2,700	2,700	2,700	2,700	2,700	2,700
Johkasou sludge	mg-N/L	1,060	300	580	580	580	580	580	580	580	580	580	580
Weighted average	mg-N/L	3,043	2,008	1,695	1,491	1,354	1,280	1,242	1,155	1,142	1,126	1,111	1,097

Table 7-97 Amount of nitrogen in human waste and *Johkasou* sludge processed at human waste treatment plants (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Anaerobic treatment	kt-N	28.8	11.2	5.2	2.4	1.3	0.9	0.7	0.3	0.2	0.2	0.2	0.1
Aerobic treatment	kt-N	22.2	11.1	5.8	3.2	2.2	1.8	1.8	0.9	1.3	1.0	1.0	0.9
Standard de-nitrification treatment	kt-N	21.0	17.0	15.1	11.2	8.4	7.6	7.0	5.5	5.1	4.7	4.5	4.4
High load de-nitrification treatment	kt-N	6.8	7.8	7.8	6.6	5.2	4.4	4.1	3.2	3.1	2.9	2.8	2.7
Membrane separation	kt-N	NO	0.9	1.1	1.2	1.2	1.2	1.0	0.6	0.6	0.5	0.4	0.4
Other	kt-N	11.5	11.3	12.3	11.4	11.1	10.3	10.0	10.5	10.3	10.6	10.4	10.3
Total	kt-N	90.2	59.4	47.3	36.1	29.4	26.2	24.5	21.2	20.6	19.8	19.3	18.8

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

As for the uncertainties in emission factors for CH_4 and N_2O in human waste treatment plants, the uncertainties in similar emission sources are used. As for the uncertainties in activity data, the uncertainties in DWW data indicated in Table 7-2 are applied. Details of the uncertainty assessment for this category are indicated in the Table 7-98.

Table 7-98 Uncertainty assessment for human waste treatment plants on the category "Domestic wastewater (5.D.1.-)"

Item	GHGs	Emission factor uncertainty		Activity data uncertainty		Emission uncertainty		Method for assessing emission factor uncertainty	Method for assessing activity data uncertainty	Method for assessing emission uncertainty
		(-)	(+)	(-)	(+)	(-)	(+)			
Human waste treatment plants	CH_4	-84%	+84%	-10%	+10%	-84%	+84%	The uncertaintyies of old type *Johkasou* are applied based on expert judgment.	The uncertainty in MW statistics is applied.	Combined by using the error-propagation formula.
	N_2O	-87%	+87%	-10%	+10%	-88%	+88%			

- ***Time-series Consistency***

For N_2O emission factor, consistent data over the time series are constructed based on the measured data by using the methods described in Table 7-95. For other parameters, data are constructed consistently for the entire time series. The emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

See section 7.1.5. "Sector-specific QA/QC and Verification".

e) Category-specific Recalculations

By updating the statistical data, CH_4 and N_2O emissions from FY2022 onward were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

7.5.1.4. Natural Decomposition of Domestic Wastewater (5.D.1.-)

a) Category Description

Although most of the DWW generated by Japanese households is processed at wastewater treatment plants, treated wastewater which is discharged into public waters contains residual nitrogen. Also, some miscellaneous wastewater is discharged into public waters without any treatment. The CH_4 and N_2O emissions from untreated wastewater and sludge decomposing in public waters and the N_2O from

treated wastewater are reported under this category. The emission sources for this category are shown on Table 7-99.

Table 7-99 Emission sources of category "Natural Decomposition of Domestic Wastewater (5.D.1.-)"

Emission source	Detail
Untreated wastewater (CH_4, N_2O)	Untreated miscellaneous wastewater from households using old type Johkasou
	Untreated miscellaneous wastewater from households using vault toilets
	Untreated miscellaneous wastewater from households using on-site disposal systems
Treated wastewater (N_2O)	Treated wastewater from sewage treatment plants
	Treated wastewater from community plants and current advanced/standard type Johkasou
	Treated wastewater derived from human waste in old type Johkasou
	Treated wastewater from treatment of human waste/Johkasou sludge in human waste treatment plants
Sludge (CH_4, N_2O)	Human waste and Johkasou sludge dumped into the ocean
	Sewage sludge dumped into the ocean

b) Methodological Issues

- ***Estimation Method***

Estimation method is established in accordance with the method described in the *2006 IPCC Guidelines*. In the natural decomposition of wastewater, both the volume of organic matter extracted as sludge and recovered CH_4 are zero. Accordingly, CH_4 emissions are calculated by multiplying the volume of organic matter contained in the untreated DWW that is discharged into public waters by the emission factor. The N_2O emissions are estimated by multiplying the volume of nitrogen contained in the wastewater by the emission factor.

$$E = EF \times A$$

E : Emission of methane or nitrous oxide from the natural decomposition of DWW [kg-CH_4], [kg-N_2O]
EF : Emission factor [kg-CH_4/kg-BOD], [kg-N_2O/kg-N]
A : Amount of organic matter [kg-BOD] or nitrogen [kg-N] in DWW

- ***Emission Factors***

Emission factors are determined in accordance with the *2006 IPCC Guidelines*. The emission factor for CH_4 is established by multiplying the maximum CH_4 generation potential (B_0) by a CH_4 conversion factor (MCF). The maximum CH_4 generation potential is set to 0.6 kg-CH_4/kg-BOD, given in the *2006 IPCC Guidelines*, and the MCF is set to 0.1, a default value for "Sea, river and lake discharge" of "Untreated systems".

$$EF_{CH4} = B_0 \times MCF$$
$$= 0.6 \text{ [kg-}CH_4\text{/kg-BOD]} \times 0.1$$
$$= 0.06 \text{ [kg-}CH_4\text{/kg-BOD]}$$

The emission factor for N_2O is calculated from the default value of 0.005 kg N_2O-N/kg N after conversion of the units.

$$EF_{N2O} = 0.005 \text{ [kg-}N_2O\text{-N/kg-N]} \times 44/28$$
$$= 0.0079 \text{ [kg-}N_2O\text{/kg-N]}$$

- ***Activity Data***

➢ ***Untreated Wastewater***

Activity data for CH_4 and N_2O emissions from untreated wastewater are obtained from the following equation:

$$A = \sum_i P_i \times U$$

A : Activity data of untreated miscellaneous wastewater from households [g-BOD], [g-N]
P_i : User population of treatment system type i (old type *Johkasou*, vault toilet, on-site disposal system) [1] [person]
U : Unit BOD effluent (40 [g-BOD/person-day][2]), or unit nitrogen effluent (2 [g-N/person-day][2]) from untreated miscellaneous wastewater

Reference:
1) *Waste Treatment in Japan* (MOE)
2) JSWA (1999)

Note that a portion of the human waste in on-site disposal systems is utilized as fertilizer on farmlands in Japan. The N_2O emissions from this are already included in the "Direct N_2O emissions from managed soils (3.D.1.)" category in the agriculture sector, and therefore, not included in the calculation for this source.

➢ ***Treated Wastewater***

Activity data for N_2O emissions from treated wastewater are obtained from the following equation:

$$A = A_{sp} + A_{dp} + A_{hp}$$

A : Total nitrogen in treated DWW (activity data) [t-N]
A_{sp} : Total nitrogen in treated wastewater from sewage treatment plants [t-N]
A_{dp} : Total nitrogen in treated wastewater from domestic sewage treatment plants [t-N]
A_{hp} : Total nitrogen in treated wastewater from human waste treatment plants [t-N]

- ***Sewage Treatment Plants***

Total nitrogen in treated wastewater from sewage treatment plants is obtained from the equation below:

$$A_{sp} = \sum_i (W_i \times D_i) \times 10^{-6}$$

W_i : Amount of wastewater treated in sewage treatment plant i [m^3]
D_i : Nitrogen concentration in treated wastewater from sewage treatment plant i [mg-N/L]

References: *Sewage Statistics* (JSWA) for both parameters

- ***Domestic Sewage Treatment Plants***

Total nitrogen in treated wastewater from domestic sewage treatment plants (community plants, current advanced/standard type *Johkasou*, and old type *Johkasou*) are obtained from the equation below:

$$A_{dp} = \sum_i \{TN_i \times d \times P_i \times (1 - R_i)\} \times 10^{-6}$$

TN_i : Unit total nitrogen effluent from domestic sewage plant type i [g-N/person-day] (see Table 7-100)
P_i : User population of domestic sewage treatment plant type i [person] (see Table 7-89)
R_i : Fraction of nitrogen removal in domestic sewage plant type i [%] (see Table 7-101)
d : Annual days [days]

Unit nitrogen effluent from each domestic sewage plant type and fraction of nitrogen removal in these plants are shown in the following tables:

Table 7-100 Unit nitrogen effluent from domestic sewage plants

Treatment system	Sewage type	Unit nitrogen effluent [g-N/person-day]	Reference
Community plant	Human waste and miscellaneous wastewater	10	MOE (2009)
Current type *Johkasou* (both advanced and standard type)			
Old type *Johkasou*	Human waste	8	

Table 7-101 Fraction of nitrogen removal in domestic sewage plants

Treatment system			Fraction of nitrogen removal	Reference
Community plant			20%	Expert judgement based on the result of Tokyo Environmental Public Service Corporation (1996).
Current type *Johkasou*	Advanced type	TN removal type	60%	Estimated by assuming averaged nitrogen concentration in treated wastewater from these systems (20 mg/L), unit nitrogen effluent (10 g-N/person-day) and amount of discharged wastewater (200 L/ person-day).
		TN and TP removal type		
		BOD removal type	20%	Expert judgement based on the result of Tokyo Environmental Public Service Corporation (1996).
		Other advanced type		
	Standard type			
Old type *Johkasou*				

- ***Human Waste Treatment Plants***

Total nitrogen in treated wastewater from human waste treatment plants is obtained from the equation below:

$$A_{hp} = W \times D \times 10^{-6}$$

W : Amount of human waste and *Johkasou* sludge treated in human waste treatment plants [1] [m^3]
D : Nitrogen concentration in treated wastewater from human waste treatment plants [mg-N/L]

References:
1) *Waste Treatment in Japan* (MOE)

Nitrogen concentration in treated wastewater of this subcategory is obtained as weighted averages of those in discharged wastewater from each human waste treatment type (Table 7-102) weighted by treatment capacities by treatment process (Table 7-93).

Table 7-102 Nitrogen concentrations in discharged wastewater from each human waste treatment method

Treatment method	Unit	Nitrogen concentration	Reference
Anaerobic treatment	mg-N/L	98.0	Okazaki et al. (2001)
Aerobic treatment	mg-N/L	32.5	
Standard de-nitrification treatment	mg-N/L	5.5	
High load de-nitrification treatment	mg-N/L	19.0	
Membrane separation	mg-N/L	10.0	

➢ ***Sludge***

Activity data for CH_4 and N_2O emissions from sludge dumped into the ocean are obtained from the equations below:

- ***Human Waste/Johkasou Sludge***

$$A = V_H \times D_H + V_J \times D_J$$

A : Activity data of human waste/*Johkasou* sludge dumped into the ocean [g-BOD], [g-N]
V_H : Human waste dumped into the ocean [1] [kL]
D_H : BOD/Nitrogen concentration in human waste[2] [mg-BOD/L], [mg-N/L]
V_J : *Johkasou* sludge dumped into the ocean [1] [kL]
D_J : BOD/Nitrogen concentration in *Johkasou* sludge [2] [mg-BOD/L], [mg-N/L]

Reference:
1) *Waste Treatment in Japan* (MOE)
2) Okazaki et al. (2001)

- ***Sewage Sludge***

$$A = V \times D$$

A : Activity data of sewage sludge dumped into the ocean [g-BOD], [g-N]
V : Sewage sludge dumped into the ocean [1] [kL]
D : BOD/Nitrogen concentration into sewage sludge [2] [mg-BOD/L], [mg-N/L]

Reference:
1) *Sewage Statistics* (JSWA)

2) The value for *Johkasou* sludge is used by Expert judgement based on Okazaki et al. (2001).

Estimated activity data are shown in Table 7-103.

Table 7-103 Amount of organic material and nitrogen in untreated DWW and discharged into public water zone (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Organic mater in:													
Untreated wastewater (from old type *Johkasou*)	kt-BOD	392	381	341	267	204	181	167	136	121	113	108	104
Untreated wastewater (from Vault toilet)	kt-BOD	568	429	298	203	146	120	105	80	74	71	67	63
Untreated wastewater (from On-site disposal)	kt-BOD	46	21	9	4	2	1	1	1	1	1	1	0
Human waste, *Johkasou* sludge (Ocean dumping)	kt-BOD	22	14	9	4	NO	NO	NO	NO	NO	NO	NO	NO
Sewage sludge (Ocean dumping)	kt-BOD	1	1	0.05	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total	kt-BOD	1,029	846	658	478	351	302	273	218	197	185	176	167
Nitrogen in:													
Untreated wastewater (from old type *Johkasou*)	kt-N	19.6	19.1	17.0	13.4	10.2	9.0	8.3	6.8	6.1	5.7	5.4	5.2
Untreated wastewater (from Vault toilet)	kt-N	28.4	21.5	14.9	10.2	7.3	6.0	5.3	4.0	3.7	3.5	3.3	3.1
Untreated wastewater (from on-site disposal)	kt-N	2.3	1.1	0.5	0.2	0.1	0.1	0.1	0.04	0.04	0.04	0.03	0.02
Treated wastewater	kt-N	297.0	301.2	281.8	267.0	251.6	250.0	243.0	231.8	230.1	229.3	222.5	221.6
Human waste, *Johkasou* sludge (Ocean dumping)	kt-N	7.2	3.2	2.2	0.8	NO	NO	NO	NO	NO	NO	NO	NO
Sewage sludge (Ocean dumping)	kt-N	0.1	0.1	0.01	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total	kt-N	354.6	346.0	316.4	291.5	269.1	265.1	256.7	242.7	239.9	238.5	231.2	230.0

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the emission factors, the uncertainties are assessed by applying those of similar emission sources. For activity data, the uncertainties of MW (DWW excluding sewage) data indicated in Table 7-2 are applied. Details of the uncertainty assessment for this category are indicated in the Table 7-104.

Table 7-104 Uncertainty assessment for natural decomposition of DWW on the category "Domestic wastewater (5.D.1.-)"

Item	GHGs	Emission factor uncertainty		Activity data uncertainty		Emission uncertainty		Method for assessing emission factor uncertainty	Method for assessing activity data uncertainty	Method for assessing emission uncertainty
		(-)	(+)	(-)	(+)	(-)	(+)			
Natural decomposition	CH_4	-58%	+58%	-10%	+10%	-59%	+59%	Since the *2006 IPCC Guidelines* provide the emission factors as default value for this category, the uncertainty is assessed in accordance with the default method in the guidelines.	The uncertainty in MW statistics is applied.	Combined by using the error-propagation formula.
	N_2O	-58%	+58%	-10%	+10%	-59%	+59%	Due to the lack of information on the uncertainty of the emission factor, the value for CH_4 emission factor is applied based on expert judgment.		

- ***Time-series Consistency***

The emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

See section 7.1.5. "Sector-specific QA/QC and Verification".

e) Category-specific Recalculations

By updating the statistical data, N_2O emissions from FY2022 onward were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

7.5.2. Industrial Wastewater (5.D.2.)

CH_4 and N_2O emissions from industrial effluent, which is treated by plants/facilities in accordance with the regulations based on the Water Pollution Prevention Law and the Sewerage Law, are allocated to "Industrial wastewater treatment (5.D.2.-)" , CH_4 and N_2O emissions from untreated/treated industrial effluent discharged from plants/facilities and decomposed in public waters, are allocated to "Natural decomposition of Industrial wastewater (5.D.2.-)", and CH_4 and N_2O emissions from landfill leachate treatment are allocated to "Landfill leachate treatment (5.D.2.-)" under the sub-category of "Industrial Wastewater (5.D.2.)".

7.5.2.1. Industrial Wastewater Treatment (5.D.2.-)

a) Category Description

CH_4 and N_2O emissions from industrial effluent, which is treated by factories and other facilities in accordance with the regulations based on the Water Pollution Prevention Law and the Sewerage Law, are allocated to "Industrial wastewater treatment (5.D.2.-)."

b) Methodological Issues

- ***Estimation Method***

In accordance with the decision tree of the *2006 IPCC Guidelines* (Page 6.19, Fig. 6.3), CH_4 and N_2O emissions are estimated for the industries that release organic-rich wastewater. Since default values given in the *2006 IPCC Guidelines* are considered to be unsuited to Japan's circumstances, CH_4 emissions are estimated based on Japan's country-specific methodology, namely, by multiplying the annual amount of organic matter in IWW subject to report (BOD basis) by the CH_4 emission factor per unit BOD that is based on Japan's country-specific wastewater handling. Because CH_4 is emitted in wastewater biological treatment processes, BOD-based activity data (amount of organic matter in wastewater degraded through biological treatment) is thought to be preferable to COD-based data. For this reason, CH_4 emissions are calculated using BOD in Japan. With regard to N_2O emissions, no estimation methodologies are given in the *2006 IPCC Guidelines*. Therefore, in the same manner for estimating CH_4 emissions, N_2O emissions are estimated by multiplying the amount of nitrogen in IWW by Japan's country-specific N_2O emission factor.

$$E = EF \times A$$

E : Amount of CH_4 or N_2O emissions generated when treating IWW [kg-CH_4], [kg-N_2O]
EF : Emission factor [kg-CH_4/kg-BOD], [kg-N_2O/kg-N]
A : Amount of BOD or nitrogen in IWW [kg-BOD], [kg-N]

- ***Emission Factor***

Country-specific emission factors derived from measured data collected at 8 plants during both summer and winter (MOE, 2018 a) are applied (MOE, 2018 b).

Table 7-105 Emission Factors for IWW treatment facilities

Category of Manufacturing	CH_4 Emission factor [g-CH_4/kg-BOD]	N_2O Emission factor [g-N_2O/kg-N]
Food	1.2	0.47
Pulp, paper and paper products	2.5	0.014
Chemical and allied product	0.92	17
Iron and steel	7.3	4.0
Other (average emission factors for above categories)	3.0	5.3

In Japan, CH_4 emissions generated by anaerobic wastewater treatment are entirely recovered. For a small amount of CH_4 emissions generated under partially anaerobic conditions created during aerobic treatment, a country-specific emission factor is applied for emission estimates because the condition for this particular CH_4 emission differs from that for the use of default value for the CH_4 emissions generated from anaerobic treatment defined in *the 2006 IPCC Guidelines*.

- ***Activity Data***

The activity data for CH_4 emissions are estimated based on the amount of organic matter contained in wastewater using BOD concentrations. The emissions are estimated for the industries which generate large amount of CH_4 emissions with high BOD concentrations from the treatment of wastewater referring to the industry types provided in the *Revised 1996 IPCC Guidelines* (Table 7-106). The amount of organic matter is obtained by sorting and aggregating by industry type according to the middle industrial classification provided by JSWA (2009). In CRT Table 5B, the amount of organic matter is reported on a BOD basis as the activity data.

$$A_{CH4,i} = W_i \times BOD_i / 1000$$

where,

$$W_i = I_i \times F_{CH4,i} \times F_{onsite,i}$$

$A_{CH4,i}$: Amount of BOD in IWW from industry type i (Activity data) [kg-BOD]
W_i : Amount of IWW from industry type i flowing into wastewater treatment facilities [m^3]
BOD_i : BOD concentration of runoff water from industry type i [mg-BOD/L]
I_i : Amount of IWW from industry type i used for product processing and/or washing [m^3]
$F_{CH4,i}$: Percentage of IWW from industry type i treated at treatment facilities emitting CH_4 [%]
$F_{onsite,i}$: Percentage of IWW from industry type i treated on-site [%]

The activity data for N_2O emissions are obtained based on the amount of nitrogen contained in IWW and aggregated by the same industrial sub-category as that applied to the estimation of CH_4 emissions.

$$A_{N2O,i} = W_i \times TN_i / 1000$$

where,

$$W_i = I_i \times F_{\mathrm{N2O,i}} \times F_{\mathrm{onsite,i}}$$

$A_{N2O,i}$: Amount of nitrogen in IWW from industry type i (Activity data) [kg-N]
W_i : Amount of IWW from industry type i flowing into wastewater treatment facilities [m^3]
TN_i : Total nitrogen concentration of runoff water from industry type i [mg-N/L]
I_i : Amount of IWW from industry type i used for product processing and/or washing [m^3]
$F_{N2O,i}$: Percentage of IWW from industry type i treated at treatment facilities emitting N_2O [%]
$F_{onsite,i}$: Percentage of IWW from industry type i treated on-site [%]

➢ ***Amount of Industrial Wastewater Flowing into Wastewater Treatment Facilities***

The amount of water used for the treatment of products by industrial sub-category and the volume of water used for washing given in the *Table of Industrial Statistics - Land and Water* (METI) are used for the amount of IWW treated at wastewater treatment facilities.

➢ ***Percentage of Industrial Wastewater Treated at Facilities Generating CH_4***

Emissions of CH_4 from IWW treatment are believed to be generated from the treatment of wastewater with the activated sludge method and from the anaerobic treatment. IWW treatment percentages for each industry code are set from the percentages of reported wastewater amounts in total wastewater, as given under "active sludge", "other biological treatment", "membrane treatment", "nitrification and denitrification" and "other advanced treatment" in the *Study on the Control of Wastewater Loading* (Water and Air Environment Bureau of MOE).

➢ ***Percentage of Industrial Wastewater Treated at Facilities Generating N_2O***

Emissions of N_2O from IWW treatment are believed to be generated mainly from biological treatment processes such as denitrification. Data on the fraction of IWW treated at facilities generating CH_4 is also used for N_2O emission estimates.

➢ ***Percentage of Industrial Wastewater Treated On-site***

Percentage of IWW treated on-site is set at 1.0 in all industrial sub-categories because there is no statistical information available, making it possible to ascertain this percentage.

➢ ***BOD and Nitrogen Concentrations in Runoff Wastewater***

For the BOD concentrations for industrial sub-categories, the BOD raw water quality for industrial sub-categories given in JSWA (1999) is used. For the nitrogen concentrations for industrial sub-categories, emission intensities (TN: Total Nitrogen) provided by the same survey for industrial sub-categories are used.

Table 7-106 BOD and nitrogen concentrations by industry type used for emission estimates

Industry code	Category of manufacturing	mg-BOD/L	mg-N/L
9	Food	1,470	62
10	Beverages, tobacco and feed	1,138	77
11	Textile products	386	36
14	Pulp, paper and paper products	556	37
16	Chemical and allied product	1,093	191
17	Petroleum and coal products	975	289
18	Plastic products	268	11
19	Rubber products	112	32
20	Leather tanning, leather products and fur skins	1,810	60
22	Iron and steel	246	310

Table 7-107 BOD load and TN load of IWW (Activity data)

Category of manufacturing	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
BOD load													
Food	kt-BOD	297.8	326.2	306.8	289.4	311.7	307.2	348.4	348.4	348.4	348.4	348.4	348.4
Beverages, tobacco and feed	kt-BOD	88.7	100.5	92.0	71.5	58.0	52.8	62.0	62.0	62.0	62.0	62.0	62.0
Textile products	kt-BOD	98.1	94.2	65.5	47.7	40.1	38.2	36.4	36.4	36.4	36.4	36.4	36.4
Pulp, paper and paper products	kt-BOD	471.8	422.7	457.3	423.4	365.4	321.4	324.0	324.0	324.0	324.0	324.0	324.0
Chemical and allied product	kt-BOD	110.2	95.3	103.0	160.1	162.9	154.2	146.1	146.1	146.1	146.1	146.1	146.1
Petroleum and coal products	kt-BOD	0.3	0.3	0.3	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3
Plastic products	kt-BOD	6.2	5.9	6.2	6.9	6.9	7.1	6.2	6.2	6.2	6.2	6.2	6.2
Rubber products	kt-BOD	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Leather tanning, leather products and fur skins	kt-BOD	1.3	1.1	0.8	0.5	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.2
Iron and steel	kt-BOD	1.2	1.3	1.3	1.5	1.8	1.6	1.4	1.4	1.4	1.4	1.4	1.4
TN load													
Food	kt-N	15.5	16.9	16.3	15.0	16.0	15.8	17.4	17.4	17.4	17.4	17.4	17.4
Beverages, tobacco and feed	kt-N	3.8	4.2	4.3	3.9	2.6	2.8	3.3	3.3	3.3	3.3	3.3	3.3
Textile products	kt-N	10.8	10.5	7.4	5.2	4.4	4.3	4.1	4.1	4.1	4.1	4.1	4.1
Pulp, paper and paper products	kt-N	18.4	16.5	17.7	16.2	14.4	11.8	12.0	12.0	12.0	12.0	12.0	12.0
Chemical and allied product	kt-N	40.0	38.8	30.1	48.5	50.8	50.8	49.8	49.8	49.8	49.8	49.8	49.8
Petroleum and coal products	kt-N	0.1	0.1	0.1	0.1	0.03	0.02	0.04	0.04	0.04	0.04	0.04	0.04
Plastic products	kt-N	0.2	0.2	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Rubber products	kt-N	0.04	0.04	0.02	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Leather tanning, leather products and fur skins	kt-N	0.1	0.1	0.05	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Iron and steel	kt-N	57.7	53.9	55.5	54.7	45.6	58.9	57.5	57.5	57.5	57.5	57.5	57.5

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the emission factors, the uncertainties are assessed according to the survey for EFs (MOE, 2018a). For the activity data, the uncertainties in IW (IWW) data indicated in Table 7-2 are applied. Details of the uncertainty assessment for this category are indicated in the Table 7-108.

Table 7-108 Uncertainty assessment for IWW treatment on the category "Industrial wastewater (5.D.2.-)"

Item	GHGs	Emission factor uncertainty		Activity data uncertainty		Emission uncertainty		Method for assessing emission factor uncertainty	Method for assessing activity data uncertainty	Method for assessing emission uncertainty
		(-)	(+)	(-)	(+)	(-)	(+)			
Industrial wastewater treatment	CH_4	-60%	+60%	-30%	+30%	-67%	+67%	MOE (2018a).	The uncertainty in IW statistics is applied.	Combined by using the error-propagation formula.
	N_2O	-95%	+95%	-30%	+30%	-100%	+100%			

- ***Time-series Consistency***

Data on the percentage of IWW treated at CH_4- and N_2O-generating facilities since FY2001 are available only for FY2004. Therefore, data are interpolated and extrapolated for the remaining years. Also, in the *Table of Industrial Statistics* (METI), which had served as the source of activity data, the relevant items were excluded from the scope of the survey. Consequently, the activity data are not changed since FY2014.

d) Category-specific QA/QC and Verification

See section 7.1.5. "Sector-specific QA/QC and Verification".

e) Category-specific Recalculations

No recalculations are conducted.

f) Category-specific Planned Improvements

In the *Table of Industrial Statistics* (METI), which had served as the source of activity data, the relevant items were excluded from the scope of the survey. The use of alternative statistical surveys to estimate activity data is currently being explored.

7.5.2.2. Natural Decomposition of Industrial Wastewater (5.D.2.-)

a) Category Description

Although most of the IWW in Japan generated in industrial plants and facilities is processed at IWW treatment plants, treated wastewater which is discharged into public waters contains residual nitrogen. Also, some IWW is discharged into public waters without any treatment. The CH_4 and N_2O emissions from untreated wastewater decomposed in public waters and the N_2O from treated wastewater are reported under this category.

b) Methodological Issues

- ***Estimation Method***

CH_4 and N_2O emissions from untreated/treated IWW discharged into public waters are estimated in accordance with the method in the *2006 IPCC Guidelines*, as shown below.

$$E = EF \times A$$

E : Emissions of methane or nitrous oxide from the natural decomposition of IWW [kg-CH_4], [kg-N_2O]
EF : Emission factor [kg-CH_4/kg-BOD], [kg-N_2O/kg-N]
A : Volume of organic matter [kg-BOD] or nitrogen [kg-N] in IWW

- ***Emission Factor***

As for CH_4 and N_2O emission factors for both of untreated and treated wastewater discharged into public waters, the default values of the *2006 IPCC Guidelines* are applied in a similar way of section "7.5.1.4. Natural Decomposition of Domestic Wastewater (5.D.1.-)".

Table 7-109 CH_4 and N_2O emission factors for the category natural decomposition of IWW

Gas	Unit	Emission factor	Reference
CH_4	kg-CH_4/ kg-BOD	0.06	*2006 IPCC Guidelines*
N_2O	kg-N_2O/ kg-N	0.0079	*2006 IPCC Guidelines*

- ***Activity Data***

Activity data for this category cover 10 middle industrial classification shown on the Table 7-106 in section "7.5.2.1. Industrial Wastewater Treatment (5.D.2.-).

➢ ***Untreated Wastewater***

Activity data for this category are defined as a sum up of BOD or TN loadings from industrial plants/facilities which directly discharge untreated wastewater into public waters. The BOD or TN loadings in wastewater from each plant/facility are calculated by multiplying amount of wastewater and BOD or TN concentration in wastewater from each plant/facility, which data are obtained from the *Comprehensive Survey on Water Pollutant Discharge* (MOE).

$$A = \sum_i (V_i \times Q_i)$$

A : Activity data of untreated wastewater (BOD or TN loadings) [kg-BOD/L], [kg-N/L]
V_i : Amount of untreated IWW discharged into public waters from industrial plant/facility i [m^3]
Q_i : BOD or TN concentration of untreated IWW discharged from industrial plant/facility i [g-BOD/L], [g-N/L]

Table 7-110 BOD and TN loadings in untreated wastewater discharged into public waters (Activity data)

Category of manufacturing	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
BOD load													
Food	kt-BOD	8.0	8.5	9.0	16.3	6.2	4.3	5.0	5.5	5.5	5.5	5.5	5.5
Beverages, tobacco and feed	kt-BOD	0.6	0.6	0.6	0.6	0.3	0.3	0.2	0.4	0.4	0.4	0.4	0.4
Textile products	kt-BOD	3.4	2.9	2.2	2.2	4.4	5.1	2.5	3.3	3.3	3.3	3.3	3.3
Pulp, paper and paper products	kt-BOD	9.4	8.9	8.9	8.4	3.6	6.9	3.4	4.1	4.1	4.1	4.1	4.1
Chemical and allied product	kt-BOD	49.5	50.6	44.9	46.7	28.3	23.4	27.2	20.8	20.8	20.8	20.8	20.8
Petroleum and coal products	kt-BOD	25.4	20.8	24.6	26.9	11.3	8.5	11.2	9.1	9.1	9.1	9.1	9.1
Plastic products	kt-BOD	0.6	0.6	0.6	0.8	0.7	0.5	0.6	0.1	0.1	0.1	0.1	0.1
Rubber products	kt-BOD	0.2	0.1	0.1	0.1	0.1	0.04	0.1	0.04	0.04	0.04	0.04	0.04
Leather tanning, leather products and fur skins	kt-BOD	0.3	0.3	0.2	0.1	0.001	0.001	0.002	0.0002	0.0002	0.0002	0.0002	0.0002
Iron and steel	kt-BOD	39.7	37.3	40.3	36.5	26.1	19.1	26.0	18.5	18.5	18.5	18.5	18.5
TN load													
Food	kt-N	5.0	5.3	5.6	5.3	3.2	3.3	2.6	2.4	2.4	2.4	2.4	2.4
Beverages, tobacco and feed	kt-N	0.6	0.6	0.6	0.4	0.3	0.3	0.2	0.3	0.3	0.3	0.3	0.3
Textile products	kt-N	0.8	0.7	0.5	0.4	1.7	1.8	1.6	1.6	1.6	1.6	1.6	1.6
Pulp, paper and paper products	kt-N	0.7	0.7	0.7	0.5	0.6	0.4	0.5	0.5	0.5	0.5	0.5	0.5
Chemical and allied product	kt-N	31.4	32.2	28.5	28.2	21.3	16.1	15.5	16.2	16.2	16.2	16.2	16.2
Petroleum and coal products	kt-N	19.6	16.0	18.9	8.8	7.6	7.2	6.7	6.3	6.3	6.3	6.3	6.3
Plastic products	kt-N	0.3	0.3	0.3	0.4	0.3	0.3	0.4	0.1	0.1	0.1	0.1	0.1
Rubber products	kt-N	0.3	0.3	0.2	0.3	0.1	0.1	0.04	0.03	0.03	0.03	0.03	0.03
Leather tanning, leather products and fur skins	kt-N	0.01	0.01	0.01	0.01	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Iron and steel	kt-N	33.3	31.2	33.7	41.8	17.6	14.9	14.2	15.2	15.2	15.2	15.2	15.2

- ***Treated Wastewater***

Activity data are defined as a sum up of TN loadings from industrial plants/facilities which discharge treated wastewater into public waters. The TN loadings in wastewater from each plant/facility are calculated by multiplying amount of wastewater and TN concentration for each plant/facility, which data are obtained from the *Comprehensive Survey on Water Pollutant Discharge* (MOE).

$$A = \sum_i (V_i \times TN_i)$$

A : Activity data of treated wastewater (TN loadings) [kg-N/L]
V_i : Amount of treated IWW discharged into public water from industrial plant/facility i [m^3]
TN_i : TN concentration in treated IWW discharged from industrial plant/facility i [g-N/L]

Table 7-111 TN loadings in treated IWW discharged into public waters (Activity data)

Category of manufacturing	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Food	kt-N	5.8	6.2	6.5	7.0	4.0	7.9	5.3	5.4	5.4	5.4	5.4	5.4
Beverages, tobacco and feed	kt-N	1.1	1.1	1.1	0.7	0.6	0.5	0.4	1.1	1.1	1.1	1.1	1.1
Textile products	kt-N	2.5	2.1	1.6	2.1	1.7	1.5	1.1	1.4	1.4	1.4	1.4	1.4
Pulp, paper and paper products	kt-N	8.4	8.0	8.0	8.0	5.4	3.8	4.4	6.8	6.8	6.8	6.8	6.8
Chemical and allied product	kt-N	17.0	17.4	15.5	14.2	15.9	13.7	12.7	9.7	9.7	9.7	9.7	9.7
Petroleum and coal products	kt-N	2.2	1.8	2.1	1.1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Plastic products	kt-N	0.2	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Rubber products	kt-N	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Leather tanning, leather products and fur skins	kt-N	0.28	0.23	0.18	0.09	0.04	0.01	0.02	0.02	0.02	0.02	0.02	0.02
Iron and steel	kt-N	5.3	5.0	5.4	4.1	3.1	2.1	2.7	2.9	2.9	2.9	2.9	2.9

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the emission factors, the uncertainties in similar emission sources are applied. For the activity data, the uncertainties in IW (IWW) data indicated in Table 7-2 are applied. Details of the uncertainty assessment for this category are indicated in the Table 7-112.

Table 7-112 Uncertainty assessment for natural decomposition of IWW on the category "Industrial wastewater (5.D.2.-)"

Item	GHGs	Emission factor uncertainty		Activity data uncertainty		Emission uncertainty		Method for assessing emission factor uncertainty	Method for assessing activity data uncertainty	Method for assessing emission uncertainty
		(-)	(+)	(-)	(+)	(-)	(+)			
Natural decomposition	CH_4	-58%	+58%	-30%	+30%	-66%	+66%	Since the *2006 IPCC Guidelines* provide the emission factors as default value for this category, the uncertainty is assessed in accordance with the default method in the guidelines.	The uncertainty in IW statistics is applied.	Combined by using the error-propagation formula.
	N_2O	-58%	+58%	-30%	+30%	-66%	+66%	Due to the lack of information on the uncertainty for the emission factor, the uncertainty for that of CH_4 is used based on expert judgment.		

- ***Time-series Consistency***

The emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

See section 7.1.5. "Sector-specific QA/QC and Verification".

e) Category-specific Recalculations

No recalculations are conducted.

f) Category-specific Planned Improvements

No improvements are planned.

7.5.2.3. Landfill Leachate Treatment (5.D.2.-)

a) Category Description

CH_4 and N_2O emissions from landfill leachate treatment in MW and IW landfill sites are estimated and allocated to "Landfill leachate treatment (5.D.2.-)."

b) Methodological Issues

- ***Estimation Method***

Potential BOD load [kg-BOD] and TN load [kg-N] to be remained in leachate percolated through organic waste disposed of in MW and IW landfill sites are applied for its activity data, and the methodology for the natural decomposition of DWW given in *the 2006 IPCC Guidelines* is applied to estimate CH_4 and N_2O emissions from this source as described below:

$$E = EF \times L_i$$

E : CH_4 and N_2O emissions [kg-CH_4], [kg-N_2O]
EF : CH_4 and N_2O emission factor [kg-CH_4/kg-BOD], [kg-N_2O /kg-N]
L_i : Potential BOD load and TN load to be remained in leachate percolated through organic waste disposed of in MW and IW landfill sites [kg-BOD], [kg-N]

- ***Emission Factors***

Emission factors for CH_4 and N_2O are determined in accordance with the methodology for the natural decomposition of DWW given in the *2006 IPCC Guidelines* as described below.

➢ ***CH_4***

According to the *2006 IPCC Guidelines,* the emission factor for CH_4 is established by multiplying the maximum CH_4 generation potential (B_0) by a CH_4 conversion factor (MCF). The B_0 is determined to be 0.6 kg-CH_4/kg-BOD which is a default value for "Domestic wastewater" given in the *2006 IPCC Guidelines*, and MCF is determined to be 0.8 which is also a default value for "Anaerobic reactor" of "Treated systems" given in the *2006 IPCC Guidelines*.

$$EF_{CH4} = B_0 \times MCF$$
$$= 0.6 \quad [\text{kg-CH}_4/\text{kg-BOD}] \quad \times 0.8$$
$$= 0.48 \quad [\text{kg-CH}_4/\text{kg-BOD}]$$

B_0 : Maximum CH_4 generation potential [kg-CH_4/kg-BOD], (IPCC default value:0.6)
MCF : CH_4 conversion factor (IPCC default value: 0.8)

➢ ***N_2O***

The emission factor for N_2O is determined from a default value of 0.005 [kg N_2O-N/kg N] given in the *2006 IPCC Guidelines* after unit conversion.

$$EF_{N2O} = 0.005 \ [\text{kg-N}_2\text{O-N/kg-N}] \ \times 44/28$$
$$= 0.0079 \ [\text{kg-N}_2\text{O /kg-N}]$$

- ***Activity Data***

Based on MOE (2010), the activity data for CH_4 and N_2O emission estimates are determined by establishing the ratio of organic and nitrogen contents to be remained in leachate for the amount of organic waste disposed of in MW and IW landfill sites to obtain potential BOD load and TN load.

➢ ***CH_4***

$$L_{BODi} = F_{BOD} \times W \times T_i$$

L_{BODi} : Potential BOD load to be remained in leachate percolated through organic waste disposed of in MW and IW landfill sites [kg-BOD]
F_{BOD} : Ratio of organic contents for the amount of organic waste landfilled [kg-BOD/t] determined to be 0.188 [kg-BOD/t] based on MOE (2010)
W : Amount of organic waste landfilled with or without intermediate treatments including incineration ash [t] obtained by the *Cyclical Use of Waste Report* (MOE)
T_i : Ratio of leachate to be biologically treated in landfill site [%] determined to be 87.6% based on MOE (2010)

➢ ***N_2O***

$$L_{TNi} = F_{TN} \times W \times T_i$$

L_{TNi} : Potential TN load to be remained in leachate percolated through organic waste disposed of in MW and IW landfill sites [kg-N]
F_{TN} : Ratio of nitrogen contents for the amount of organic waste landfilled [kg-N/t] determined to be 0.254 [kg-N/t] based on MOE (2010)
W : Amount of organic waste landfilled with or without intermediate treatments including incineration ash [t] obtained by the *Cyclical Use of Waste Report* (MOE)
T_i : Ratio of leachate to be biologically treated in landfill site [%] determined to be 87.6% based on MOE (2010)

Table 7-113 BOD load and TN load of landfill leachate (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
BOD load	kt-BOD	2.6	2.5	2.2	1.6	0.8	0.6	0.5	0.4	0.3	0.3	0.3	0.3
TN load	kt-N	3.5	3.3	3.0	2.2	1.1	0.8	0.7	0.5	0.4	0.5	0.4	0.4

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

As for the uncertainties in emission factors for CH_4 and N_2O in landfill leachate treatment (5.D.2.-), the uncertainties in similar emission sources are used. Details of the uncertainty assessment for this category are indicated in the Table 7-114.

Table 7-114 Uncertainty assessment for landfill leachate treatment on the category "Industrial wastewater (5.D.2.-)"

Item	GHGs	Emission factor uncertainty		Activity data uncertainty		Emission uncertainty		Method for assessing emission factor uncertainty	Method for assessing activity data uncertainty	Method for assessing emission uncertainty
		(-)	(+)	(-)	(+)	(-)	(+)			
Landfill leachate treatment	CH_4	-39%	+39%	-100%	+100%	-107%	+107%	MOE (2010).	Due to the lack of information on the uncertainty for the activity data, the value is assessed by expert judgment.	Combined by using the error-propagation formula.
	N_2O	-39%	+39%	-100%	+100%	-107%	+107%	Due to the lack of information on the uncertainty of the emission factor, the value for CH_4 in this category is applied based on expert judgment.		

- ***Time-series Consistency***

As described in detail in the preceding sections, emissions are calculated in a consistent manner.

d) Category-specific QA/QC and Verification

See section 7.1.5. "Sector-specific QA/QC and Verification".

e) Category-specific Recalculations

By updating the statistical data, CH_4 and N_2O emissions from FY2023 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

7.6. Other (5.E.)

In this category, CO_2 emissions as a result of the decomposition of fossil-fuel-derived surfactants are calculated. Estimated GHG emissions from category "Other" are shown in Table 7-116.

Table 7-115 Categories whose emissions are estimated for other (5.E.)

Category	Waste type	Treatment type	CO_2	CH_4	N_2O
5.E.1. (Sec. 7.6.1)	Fossil-fuel-derived Surfactants	Decomposition at wastewater treatment facilities and/or in the environment	○	NA	NA

In FY2024, emissions from this source category were 560 kt-CO_2 eq. and accounted for 0.05% of the national total emissions (excluding LULUCF). The emissions from this category had decreased by 20.3% compared to those in FY1990. This decrease is primarily due to the decrease of the consumption of alkylbenzenes by introduction of the Pollutant Release and Transfer Register (PRTR).

Table 7-116 GHG emissions from category other (5.E.)

Gas	Category	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
CO_2	5.E. Other (Decomposition of fossil-fuel-derived surfactants)	kt-CO_2	703	668	656	507	527	605	625	597	679	654	597	560

7.6.1. Decomposition of Fossil-fuel-derived Surfactants (5.E.-)

a) Category Description

Surfactants are used for various cleaning activities in homes and factories in Japan. Fossil-fuel-derived surfactants discharged into wastewater treatment facilities and into the environment decompose and emit CO_2. As this emission source does not correspond to any of the existing waste categories (5.A. to 5.D.), it is included in the "Other (5.E.)" category. Because "CH_4 and N_2O emissions from wastewater treatment and discharge" and "CO_2 emissions from the decomposition of fossil-fuel-derived surfactants" concern different types of gases, they are unrelated to each other and pose no duplication of accounting.

b) Methodological Issues

- ***Estimation Method***

As the *2006 IPCC Guidelines* do not specify any method for estimating emissions, an estimation method specifically established in Japan is applied. For this category, it is assumed that all carbon contained in surfactants, that are fossil-fuel-derived and domestically consumed, are emitted into wastewater treatment facilities and into the environment and are eventually decomposed and oxidized to CO_2 and emitted into the atmosphere.

In this category, the CO_2 emissions are calculated by multiplying the consumption of the fossil-fuel-derived surfactant for each type of raw material by the carbon content of each of the materials. The calculation covers surfactant materials: synthetic alcohols, alkylbenzenes, alkylphenols, and ethylene oxide. Some of the carbon contained in surfactants discharged into wastewater treatment facilities are adsorbed and assimilated by sludge. However, this portion of carbon is not decomposed biologically. It is released into the atmosphere as CO_2 through incineration and landfilling of sludge. Therefore, the emission is included in these CO_2 emission estimates.

- ***Emission Factor***

Emission factor is determined for each type of material by calculating the amount of CO_2, expressed in kg that is emitted from the decomposition of 1 t of a surfactant using the average carbon content in the molecules.

$EF_i = CF_i \times 1{,}000 \times 44/12$

EF_i : Emission factor for fossil-fuel-derived raw material *i* used in a surfactant
CF_i : Average carbon content of fossil-fuel-derived raw material *i* used in a surfactant

Table 7-117 Average carbon content of surfactants, by fossil-fuel-derived raw material

Raw material	Carbon number	Molecular weight	Carbon content	Basis for determination
Synthetic alcohol	12	186	77.4%	C12-alcohol as the main constituent.
Alkylbenzene	18	246	87.8%	C12-alkylbenzene as the main constituent.
Alkylphenol	15	220	81.8%	C9-alkylphenol as the main constituent.
Ethylene oxide	2	44	54.5%	Based on ethylene oxide molecules (C_2H_4O)

- ***Activity Data***

Activity data is the amount of raw materials consumed for fossil-fuel-derived surfactants. As some of the surfactants produced in Japan are exported, the activity data are determined by multiplying the amount of raw materials used in the surfactants obtained from the statistical data for surfactant consumption by an import/export adjustment factor.

➢ ***Amount of Surfactant Materials Consumed***

The amount of surfactant material consumed is obtained from the consumption of raw materials for surfactants indicated in the *Current Production Statistics - Chemical Industry*. As there is no compilation of consumption since FY2002, the amount of consumption is estimated using the production amount in the statistics and the simple averages (k value) of the ratio of consumption of material to production in the period from FY1990 to FY2001.

➢ ***Export/import Correction Factor***

Correction factor is calculated from the export/import statistics in *Trade Statistics of Japan* by the Ministry of Finance (MOF) for categories of anionic surfactants and non-ionic surfactants, and the amount of surfactant production. As some of the materials for surfactants are used in several different types of surfactants, an average of the export/import correction factor is weighted by surfactant production amount as necessary to calculate the correction factor for each classification of surfactant.

$F_{corr.} = (P + I - E)/P$

$F_{corr.}$: Export/Import correction factor
P : Surfactant production [t]
I : Surfactant imported [t]
E : Surfactant exported [t]

Table 7-118 Activity data associated with decomposition of fossil-fuel-derived surfactants

Item	Unit	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Synthetic alcohol	t	29,239	16,253	28,285	31,609	33,750	43,324	44,299	48,057	53,151	51,216	44,979	41,168
Alkyl benzene	t	105,432	102,794	80,832	47,349	50,519	44,980	44,044	25,309	26,984	27,720	25,711	23,883
Alkyl phenol	t	10,141	8,798	7,454	3,448	2,054	4,318	4,873	3,677	4,363	4,076	3,419	2,659
Ethylene oxide	t	124,984	132,175	146,509	127,150	131,148	161,969	171,380	184,127	214,129	203,761	188,281	179,356

c) Uncertainty Assessment and Time-series Consistency

- ***Uncertainty Assessment***

For the emission factor, the uncertainty is assessed by using molecular weight, which is used for calculation of emission factors, based on expert judgment. For activity data, the same assessment as MW statistics (see Table 7-2) is applied based on expert judgment since information on the uncertainty is not available.

Table 7-119 Uncertainty assessment for decomposition of fossil-fuel-derived surfactants on the category "Other (5.E.-)"

Item	GHGs	Emission factor uncertainty		Activity data uncertainty		Emission uncertainty		Method for assessing emission factor uncertainty	Method for assessing activity data uncertainty	Method for assessing emission uncertainty
		(-)	(+)	(-)	(+)	(-)	(+)			
Decomposition of fossil-fuel-derived surfactants	CO_2	-1%	+1%	-10%	+10%	-10%	+10%	The uncertainty is assessed by using molecular weight data, which is used to establish the EFs based on expert judgment.	Due to the lack of information on the uncertainty of the activity data, the value for MW statistics is applied.	Combined by using the error-propagation formula.

- ***Time-series Consistency***

Consistent methodology is used in the estimation. However, data on the amount of raw materials consumed for surfactants have become unavailable since FY2002 and activity data are estimated from the production amount of the surfactants.

d) Category-specific QA/QC and Verification

See section 7.1.5. "Sector-specific QA/QC and Verification".

e) Category-specific Recalculations

By updating the statistical data, CO_2 emissions in FY2023 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

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Chapter 8. Other (CRT sector 6)

8.1. Overview of Sector

Paragraph 40 of the *MPGs* indicates that each Party shall provide information on any country-specific category that is not included in the *IPCC Guidelines*. According to this requirement, emissions from the Other sector (CRT sector 6) are indicated below.

8.2. CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, and NF_3

Among CO_2, CH_4, N_2O, HFCs, PFCs, SF_6 and NF_3, no emissions or removals are reported in the Other sector.

8.3. NO_X, CO, NMVOC, and SO_X

Among precursors (NO_X, CO, NMVOC) and SO_X, CO and NMVOC emissions from smoking are reported in the Other sector (see Annex 5).

Chapter 9. Indirect Carbon Dioxide and Nitrous Oxide Emissions

9.1. Overview of Sector

a) Category Description

Parties may choose to report indirect CO_2, and should report indirect N_2O in accordance with paragraph 52 of the *MPGs*. Since the estimation method reflecting Japan's actual status has been established, Japan elects to report indirect CO_2 emissions from the atmospheric oxidation of CH_4, CO, and NMVOCs. Japan also reports indirect N_2O emissions arising from sources other than those in the agriculture and LULUCF sectors. However, indirect N_2O emissions arising from sources other than those in the agriculture and LULUCF sectors are not included in the national total emissions in accordance with paragraph 52 of the *MPGs*.

Indirect CO_2 emissions originating from the use and/or evaporation of NMVOCs and CH_4 as well as indirect N_2O emissions originating from NO_X from the sectors/categories indicated in Table 9-1 are estimated and reported. Other than evaporation of CH_4 and NMVOCs, CH_4, CO, and NMVOCs originating from fuel combustion, evaporative fuel emissions from vehicles[1], and CH_4, CO, and NMVOCs from the incineration of fossil-fuel derived waste are oxidized to CO_2 in the atmosphere; these indirect CO_2 emissions are not reported, because these emissions are included in CO_2 emissions from fuel combustion (1.A.), and CO_2 emissions from waste incineration and open burning (5.C.)[2], respectively. Indirect CO_2 emissions originating from biogenic CH_4, CO, and NMVOC emissions were not reported from the viewpoint of avoiding double-counting, in accordance with the *2006 IPCC Guidelines*. Since NH_3 emissions are not estimated, indirect N_2O emissions originating from NH_3 are not estimated.

Table 9-1 Sector/Category of indirect CO_2 and indirect N_2O emissions

Sector/Category	Indirect CO_2			Indirect N_2O
	Originating from CH_4	Originating from CO	Originating from NMVOCs	Originating from NO_X
1.A Fuel combustion	-	-	-	○
1.B Fugitive emissions from fuels	○	NE, NO	○	NO
2. Industrial processes and product use	○	NE	○	○
5. Waste	-	-	-	○

b) Methodological Issues

- ***Estimation Method***

CO_2 emissions occurring from the oxidation of evaporative NMVOCs and CH_4 in the atmosphere are estimated with the following conversion formulae which are mentioned in the *2006 IPCC Guidelines*.

$$E_{CO2} = E_{CH4} \times \frac{44}{16}$$

[1] Emissions are reported in 1.A.3. Transport.
[2] It is assumed that in the CO_2 emission factors that Japan uses, CO_2 inputs to the atmosphere from fossil fuel and fossil-fuel derived waste combustion related emissions of CH_4, CO, and NMVOCs are already accounted for under 1.A. Fuel combustion and in 5.C. Waste incineration and open burning.

$$E_{CO2} = E_{NMVOC} \times C \times \frac{44}{12}$$

E_{CO2} : Indirect CO_2 emissions [kt]
E_{CH4} : CH_4 emissions [kt]
E_{NMVOC} : NMVOC emissions [kt]
C : Average carbon content of NMVOCs for each source

N_2O emissions caused by atmospheric deposition of nitrogen compounds volatilized as NO_X are estimated, referring to the *2019 Refinement* (Vol.1, Equation 7.1).

$$E_{N2O} = E_{Volatilization} \times EF \times \frac{44}{28}$$

E : N_2O emissions caused by atmospheric deposition [kg-N_2O/yr]
$N_{Volatilization}$: Nitrogen amount volatilized as NOx [kg-NO_X-N/yr]
EF : N_2O emission factor [kg-N_2O-N/kg-NO_X-N]

- ***Parameters***

The average carbon content of NMVOCs is calculated by weighting it by the composition ratio of each NMVOC substance emitted from each source. The carbon contents of each substance are obtained from molecular formulae, and the type of substance and composition ratio of NMVOCs were estimated based on the national emission inventory for volatile organic compounds (VOC) by the Ministry of the Environment and other information. The average carbon content is calculated for each emission source. They are set for each year until FY2020, and the FY2020 value is applied for years FY2021 and onward.

For the N_2O emission factor, the default value from the *2019 Refinement,* Vol.4, Page 11.26, Table 11.3, Wet climate (0.014 [kg-N_2O-N/kg-NH_3-N & NO_X-N deposited]) was used.

- ***Activity Data***

Refer to Chapter 3 for information on CH_4 emissions from fugitive emissions from fuels (1.B.). Refer to Chapter 4 for information on CH_4 emissions from the chemical industry (2.B.) and metal industry (2.C.). Refer to Annex 5 for information on emissions from carbon monoxide (CO), non-methane volatile organic compounds (NMVOCs), and oxides of nitrogen (NO_X).

c) Uncertainties Assessment and Time-series Consistency

- ***Uncertainty Assessment***

See Annex 2.

- ***Time-series Consistency***

For average carbon content of NMVOCs, the composition for each substance is calculated using statistics which are consistent throughout the time-series. Refer to the relevant chapter for activity data.

d) Category-specific QA/QC and Verification

General inventory QC procedures are conducted in accordance with the *2006 IPCC Guidelines*. The focus of general inventory QC is on the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Annex 4.

e) Category-specific Recalculations

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

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Chapter 10. Recalculation and Improvements

10.1. Explanations and Justifications for Recalculations

In accordance with the *MPGs* and the *2006 IPCC Guidelines*, each Party shall report recalculations for the starting year and all subsequent years of the inventory time series, together with explanatory information and justifications for recalculations with an indication of relevant changes and their impact on the emission and removal trends in the cases of 1) application of new estimation methods, 2) addition of new categories for emissions and removals, and 3) data updates or refinements, etc.

In Japan, recalculations are performed and reported for all fiscal years from FY1990 in accordance with the above.

The reasons for recalculation related to the calculation methods in 1) above is described in Section 10.4., and the reasons of recalculations including 1) above for each sector are described separately under sections named as “Category-specific Recalculations” in Chapters 3 to 7.

As the case of 3) above, in Japan, it can generally be said that activity data for the latest fiscal year available at the time when the inventory is compiled are often revised in the following year at the time of publication of data. In the inventory submitted this year, the emissions and the removals for FY2023 have been recalculated in many categories.

10.2. Implications for Emission and Removal Levels, Accounting Quantity

The following shows the changes made to the overall emission estimates due to the recalculations indicated in “Section 10.1. Explanations and Justifications for Recalculations”.

10.2.1. GHG Inventory

Compared to the values reported in the previous year’s inventory, total emissions (excluding the LULUCF sector, and including indirect CO_2) in the starting year (FY 1990) decreased by 0.03%, and the total emissions in year FY2023 decreased by 0.39% (Table 10-1).

Comparisons with the previous year's inventory for each sector, by category and by gas are as shown in Table 10-2 to Table 10-6.

Table 10-1 Comparison of emissions and removals in the inventories submitted in 2025 and 2026

[Mt-CO_2 eq.]

		1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023
CO_2	JNGI 2025	1,077.2	1,147.0	1,168.3	1,187.9	1,132.0	1,236.3	1,155.6	978.3	1,000.5	977.2	936.2
with LULUCF	JNGI 2026	1,076.6	1,145.6	1,166.8	1,186.1	1,129.9	1,234.0	1,153.3	976.2	998.3	974.9	935.4
(excl. Indirect CO_2)	*difference*	*-0.06%*	*-0.12%*	*-0.13%*	*-0.15%*	*-0.18%*	*-0.18%*	*-0.20%*	*-0.22%*	*-0.22%*	*-0.24%*	*-0.08%*
CO_2	JNGI 2025	1,154.9	1,235.9	1,260.2	1,286.4	1,211.1	1,311.9	1,220.0	1,037.3	1,058.5	1,029.6	986.9
without LULUCF	JNGI 2026	1,154.2	1,234.5	1,258.7	1,284.7	1,209.3	1,310.0	1,218.0	1,035.6	1,056.6	1,027.6	986.3
(excl. Indirect CO_2)	*difference*	*-0.05%*	*-0.11%*	*-0.12%*	*-0.14%*	*-0.15%*	*-0.14%*	*-0.16%*	*-0.17%*	*-0.18%*	*-0.20%*	*-0.06%*
CH_4	JNGI 2025	50.0	46.9	41.8	38.2	34.9	32.7	31.8	30.4	30.4	29.9	29.5
with LULUCF	JNGI 2026	50.2	47.1	42.0	38.3	35.0	32.8	31.9	30.5	30.6	30.0	29.6
	difference	*0.27%*	*0.31%*	*0.55%*	*0.38%*	*0.35%*	*0.39%*	*0.39%*	*0.34%*	*0.63%*	*0.52%*	*0.40%*
CH_4	JNGI 2025	49.9	46.8	41.7	38.1	34.8	32.6	31.7	30.4	30.3	29.8	29.4
without LULUCF	JNGI 2026	50.0	46.9	41.9	38.2	34.9	32.8	31.8	30.5	30.5	29.9	29.5
	difference	*0.27%*	*0.31%*	*0.56%*	*0.38%*	*0.35%*	*0.39%*	*0.39%*	*0.34%*	*0.63%*	*0.52%*	*0.40%*
N_2O	JNGI 2025	29.7	30.6	27.5	23.4	20.9	20.1	19.3	17.2	17.0	16.5	16.2
with LULUCF	JNGI 2026	29.7	30.6	27.5	23.3	20.8	20.1	19.2	17.3	17.2	16.5	15.6
	difference	*-0.01%*	*-0.01%*	*0.08%*	*-0.36%*	*-0.38%*	*-0.41%*	*-0.44%*	*0.01%*	*1.21%*	*-0.30%*	*-3.86%*
N_2O	JNGI 2025	28.9	29.8	26.8	22.8	20.4	19.7	18.9	16.8	16.6	16.1	15.8
without LULUCF	JNGI 2026	28.9	29.8	26.8	22.7	20.3	19.6	18.8	16.8	16.8	16.0	15.2
	difference	*-0.01%*	*-0.01%*	*0.08%*	*-0.37%*	*-0.39%*	*-0.42%*	*-0.45%*	*0.01%*	*1.23%*	*-0.32%*	*-3.98%*
HFCs	JNGI 2025	13.4	21.5	19.8	10.8	16.7	22.0	26.8	33.2	33.8	33.0	31.7
	JNGI 2026	13.4	21.5	19.8	10.8	16.7	22.0	26.4	30.9	31.0	29.8	28.5
	difference	*0.00%*	*0.00%*	*0.01%*	*0.04%*	*0.08%*	*-0.29%*	*-1.29%*	*-6.99%*	*-8.18%*	*-9.67%*	*-9.96%*
PFCs	JNGI 2025	6.2	16.2	10.5	7.8	3.8	3.0	3.0	3.2	2.9	3.0	3.1
	JNGI 2026	6.2	16.2	10.5	7.8	3.8	3.0	3.0	3.2	2.9	3.0	3.1
	difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-0.01%*
SF_6	JNGI 2025	13.8	17.6	8.2	5.8	2.8	2.3	2.4	2.2	2.2	2.1	2.1
	JNGI 2026	13.8	17.6	8.2	5.8	2.8	2.3	2.4	2.2	2.2	2.1	2.1
	difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.08%*
NF_3	JNGI 2025	0.03	0.17	0.26	1.36	1.42	1.50	0.52	0.29	0.33	0.34	0.21
	JNGI 2026	0.03	0.17	0.26	1.36	1.42	1.50	0.52	0.29	0.33	0.34	0.21
	difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
Indirect CO_2	JNGI 2025	5.5	4.7	4.2	3.3	2.4	2.3	2.2	1.9	1.8	1.8	1.8
	JNGI 2026	5.6	4.8	4.3	3.4	2.5	2.4	2.3	1.9	1.9	1.9	1.9
	difference	*1.37%*	*1.76%*	*1.98%*	*3.14%*	*3.13%*	*3.03%*	*3.04%*	*2.93%*	*2.97%*	*3.12%*	*4.32%*
Total	JNGI 2025	1,267.0	1,368.0	1,367.4	1,373.0	1,291.0	1,393.1	1,303.2	1,123.4	1,144.7	1,114.0	1,069.1
without LULUCF	JNGI 2026	1,266.5	1,366.8	1,366.2	1,371.4	1,289.2	1,391.2	1,301.0	1,119.5	1,140.5	1,108.9	1,064.9
excl. Indirect CO_2	*difference*	*-0.04%*	*-0.09%*	*-0.09%*	*-0.12%*	*-0.14%*	*-0.14%*	*-0.17%*	*-0.35%*	*-0.37%*	*-0.46%*	*-0.40%*
Total	JNGI 2025	1,190.3	1,280.0	1,276.4	1,275.2	1,212.5	1,318.0	1,239.4	1,065.0	1,087.2	1,062.1	1,018.9
with LULUCF	JNGI 2026	1,189.8	1,278.8	1,275.1	1,273.6	1,210.5	1,315.7	1,236.8	1,060.6	1,082.6	1,056.7	1,014.5
excl. Indirect CO_2	*difference*	*-0.04%*	*-0.09%*	*-0.10%*	*-0.13%*	*-0.17%*	*-0.17%*	*-0.21%*	*-0.41%*	*-0.42%*	*-0.51%*	*-0.44%*
Total	JNGI 2025	1,272.5	1,372.7	1,371.7	1,376.3	1,293.4	1,395.4	1,305.4	1,125.3	1,146.6	1,115.9	1,070.9
without LULUCF	JNGI 2026	1,272.1	1,371.6	1,370.5	1,374.7	1,291.7	1,393.5	1,303.2	1,121.4	1,142.4	1,110.8	1,066.7
incl. Indirect CO_2	*difference*	*-0.03%*	*-0.08%*	*-0.08%*	*-0.11%*	*-0.13%*	*-0.13%*	*-0.17%*	*-0.35%*	*-0.36%*	*-0.46%*	*-0.39%*
Total	JNGI 2025	1,195.8	1,284.7	1,280.6	1,278.5	1,214.9	1,320.3	1,241.6	1,066.8	1,089.0	1,063.9	1,020.7
with LULUCF	JNGI 2026	1,195.4	1,283.6	1,279.5	1,276.9	1,213.0	1,318.1	1,239.0	1,062.6	1,084.5	1,058.5	1,016.4
incl. Indirect CO_2	*difference*	*-0.03%*	*-0.09%*	*-0.09%*	*-0.12%*	*-0.16%*	*-0.16%*	*-0.20%*	*-0.40%*	*-0.42%*	*-0.51%*	*-0.43%*

Table 10-2 Comparison of emissions in the inventories submitted in 2025 and 2026
(Energy sector)

1. Energy		[Mt-CO_2 eq.]											
Category	Gas		1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023
A. Fuel Combustion	CO_2	JNGI 2025	368.2	378.5	395.0	449.1	473.2	582.9	526.7	436.1	442.4	434.5	409.7
1. Energy Industries		JNGI 2026	368.2	378.5	395.0	449.1	473.3	582.9	526.7	436.1	442.5	434.5	408.4
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.01%*	*0.01%*	*0.00%*	*-0.30%*
	CH_4	JNGI 2025	0.5	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2
		JNGI 2026	0.5	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.02%*	*0.27%*	*0.22%*	*0.30%*	*0.10%*
	N_2O	JNGI 2025	0.8	1.2	1.4	1.9	1.8	2.1	2.1	1.6	1.7	1.6	1.6
		JNGI 2026	0.8	1.2	1.4	1.8	1.8	2.0	2.1	1.6	1.6	1.6	1.5
		difference	*0.00%*	*0.00%*	*0.00%*	*-3.73%*	*-3.10%*	*-3.25%*	*-3.45%*	*-1.65%*	*-1.87%*	*-4.74%*	*-4.39%*
A. Fuel Combustion	CO_2	JNGI 2025	349.0	356.4	345.5	332.6	299.3	303.1	286.1	231.0	247.9	229.9	222.9
2. Manufacturing Industries		JNGI 2026	349.3	356.7	345.7	332.5	299.0	302.7	285.8	230.9	247.7	229.7	224.0
and Construction		*difference*	*0.07%*	*0.09%*	*0.06%*	*-0.02%*	*-0.11%*	*-0.11%*	*-0.10%*	*-0.04%*	*-0.07%*	*-0.08%*	*0.49%*
	CH_4	JNGI 2025	0.4	0.4	0.4	0.5	0.6	0.6	0.6	0.5	0.5	0.5	0.5
		JNGI 2026	0.4	0.4	0.4	0.5	0.6	0.6	0.6	0.5	0.5	0.5	0.5
		difference	*0.13%*	*0.15%*	*0.11%*	*0.04%*	*0.00%*	*0.10%*	*0.12%*	*0.29%*	*0.25%*	*0.20%*	*3.72%*
	N_2O	JNGI 2025	1.1	1.5	1.7	1.7	1.5	1.6	1.5	1.3	1.3	1.1	1.1
		JNGI 2026	1.1	1.5	1.7	1.7	1.5	1.6	1.5	1.3	1.3	1.1	1.1
		difference	*0.09%*	*0.08%*	*0.06%*	*0.03%*	*0.01%*	*0.05%*	*0.06%*	*0.14%*	*0.13%*	*0.13%*	*0.15%*
A. Fuel Combustion	CO_2	JNGI 2025	202.1	242.8	253.1	238.1	222.0	215.1	208.9	176.6	178.0	184.6	183.6
3. Transport		JNGI 2026	202.1	242.8	253.1	238.1	221.7	215.1	208.9	176.6	178.0	184.6	183.6
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-0.14%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
	CH_4	JNGI 2025	0.3	0.3	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
		JNGI 2026	0.3	0.3	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-0.01%*	*-0.04%*	*-0.07%*	*-0.05%*	*-0.03%*	*-0.02%*	*-0.20%*
	N_2O	JNGI 2025	3.4	3.8	3.7	2.6	1.9	1.7	1.6	1.3	1.3	1.4	1.4
		JNGI 2026	3.4	3.8	3.7	2.6	1.9	1.7	1.6	1.3	1.3	1.4	1.4
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.02%*	*0.06%*	*0.10%*	*0.02%*	*-0.04%*	*-0.10%*	*-0.19%*
A. Fuel Combustion	CO_2	JNGI 2025	158.2	175.4	190.2	196.0	156.8	149.2	139.1	140.8	135.3	128.6	121.8
4. Other Sectors		JNGI 2026	157.9	175.1	189.9	195.6	156.7	148.9	138.5	140.0	134.6	127.9	121.8
		difference	*-0.16%*	*-0.18%*	*-0.19%*	*-0.18%*	*-0.03%*	*-0.24%*	*-0.41%*	*-0.61%*	*-0.57%*	*-0.59%*	*0.01%*
	CH_4	JNGI 2025	0.3	0.3	0.4	0.6	0.5	0.3	0.2	0.3	0.2	0.2	0.2
		JNGI 2026	0.3	0.3	0.4	0.6	0.5	0.3	0.2	0.3	0.2	0.2	0.2
		difference	*-0.31%*	*0.32%*	*0.37%*	*-0.04%*	*-0.16%*	*-0.41%*	*-0.77%*	*-1.24%*	*-1.26%*	*-1.33%*	*-1.03%*
	N_2O	JNGI 2025	0.6	0.7	0.7	0.7	0.6	0.5	0.5	0.5	0.5	0.5	0.4
		JNGI 2026	0.6	0.7	0.7	0.7	0.6	0.5	0.5	0.5	0.5	0.4	0.4
		difference	*0.00%*	*0.04%*	*0.04%*	*0.03%*	*0.42%*	*0.00%*	*-0.47%*	*-2.03%*	*-1.97%*	*-2.53%*	*-2.01%*
B. Fugitive Emissions	CO_2	JNGI 2025	0.006	0.004	0.003	0.002	0.002	0.003	0.003	0.003	0.003	0.000	0.000
1. Solid Fuels		JNGI 2026	0.006	0.004	0.003	0.002	0.002	0.003	0.003	0.003	0.003	0.000	0.000
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
	CH_4	JNGI 2025	5.5	2.8	1.8	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.5
		JNGI 2026	5.5	2.8	1.8	0.8	0.7	0.6	0.6	0.5	0.5	0.5	0.5
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-0.68%*
	N_2O	JNGI 2025	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
		JNGI 2026	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-14.94%*
B. Fugitive Emissions	CO_2	JNGI 2025	0.2	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.3	0.3
2. Oil and Natural Gas		JNGI 2026	0.2	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.3	0.3
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.04%*
	CH_4	JNGI 2025	0.3	0.4	0.4	0.5	0.5	0.4	0.4	0.3	0.3	0.3	0.3
		JNGI 2026	0.4	0.5	0.5	0.6	0.7	0.6	0.5	0.5	0.5	0.4	0.4
		difference	*41.55%*	*37.56%*	*39.67%*	*41.98%*	*43.68%*	*43.53%*	*42.86%*	*41.95%*	*41.32%*	*41.18%*	*40.83%*
	N_2O	JNGI 2025	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		JNGI 2026	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.51%*
1. Total	GHG	JNGI 2025	1,090.9	1,165.5	1,195.5	1,225.9	1,160.4	1,258.9	1,169.3	991.5	1,010.8	984.6	944.5
		JNGI 2026	1,091.0	1,165.6	1,195.5	1,225.6	1,159.8	1,258.3	1,168.5	990.7	1,010.0	983.6	944.5
		difference	*0.01%*	*0.01%*	*0.00%*	*-0.02%*	*-0.05%*	*-0.05%*	*-0.06%*	*-0.08%*	*-0.08%*	*-0.09%*	*-0.01%*

*Excluding Indirect CO_2

Table 10-3 Comparison of emissions in the inventories submitted in 2025 and 2026
(Industrial processes and product use sector) (1/2)

2. Industrial Processes and Product Use
(1/2) [Mt-CO_2 eq.]

Category	Gas		1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023
A. Mineral Industry	CO_2	JNGI 2025	48.7	50.7	43.5	41.1	32.7	34.9	33.5	30.7	31.1	28.9	26.8
		JNGI 2026	48.7	50.7	43.5	41.1	32.7	34.9	33.5	30.7	31.1	28.9	26.8
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-0.08%*
B. Chemical Industry	CO_2	JNGI 2025	6.0	6.0	5.9	5.2	4.8	4.2	4.0	3.1	3.8	3.4	3.2
		JNGI 2026	6.0	6.0	5.9	5.2	4.8	4.2	4.0	3.1	3.8	3.4	3.2
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
	CH_4	JNGI 2025	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.03	0.03	0.03	0.02
		JNGI 2026	0.04	0.04	0.04	0.04	0.04	0.03	0.04	0.03	0.03	0.03	0.02
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
	N_2O	JNGI 2025	8.6	8.6	5.6	2.3	1.6	1.1	0.7	0.6	0.4	0.3	0.3
		JNGI 2026	8.6	8.6	5.6	2.3	1.6	1.1	0.7	0.6	0.4	0.3	0.3
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-19.83%*
	HFCs	JNGI 2025	13.3	18.5	13.4	0.9	0.2	0.1	0.1	0.2	0.2	0.1	0.1
		JNGI 2026	13.3	18.5	13.4	0.9	0.2	0.1	0.1	0.2	0.2	0.1	0.1
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
	PFCs	JNGI 2025	0.3	0.8	1.5	1.0	0.2	0.1	0.1	0.1	0.1	0.1	0.0
		JNGI 2026	0.3	0.8	1.5	1.0	0.2	0.1	0.1	0.1	0.1	0.1	0.0
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
	SF_6	JNGI 2025	3.58	4.63	0.85	0.96	0.20	0.10	0.05	0.05	0.05	0.03	0.02
		JNGI 2026	3.58	4.63	0.85	0.96	0.20	0.10	0.05	0.05	0.05	0.03	0.02
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
	NF_3	JNGI 2025	0.003	0.02	0.11	1.16	1.24	1.39	0.38	0.01	0.02	0.02	0.01
		JNGI 2026	0.003	0.02	0.11	1.16	1.24	1.39	0.38	0.01	0.02	0.02	0.01
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
C. Metal Industry	CO_2	JNGI 2025	7.3	6.9	6.9	6.7	6.4	6.4	6.1	5.1	5.4	5.2	5.0
		JNGI 2026	7.3	6.9	6.9	6.7	6.4	6.4	6.1	5.1	5.4	5.0	4.9
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-2.63%*	*-3.07%*
	CH_4	JNGI 2025	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		JNGI 2026	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
	HFCs	JNGI 2025	NO	NO	NO	NO	NO	0.001	0.001	0.001	0.002	0.001	0.002
		JNGI 2026	NO	NO	NO	NO	NO	0.001	0.001	0.001	0.002	0.001	0.002
		difference	*NA*	*NA*	*NA*	*NA*	*NA*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
	PFCs	JNGI 2025	0.30	0.15	0.04	0.03	0.02	0.01	NO	NO	NO	NO	NO
		JNGI 2026	0.30	0.15	0.04	0.03	0.02	0.01	NO	NO	NO	NO	NO
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*NA*	*NA*	*NA*	*NA*	*NA*
	SF_6	JNGI 2025	0.2	0.1	1.0	1.1	0.3	0.2	0.2	0.3	0.3	0.3	0.2
		JNGI 2026	0.2	0.1	1.0	1.1	0.3	0.2	0.2	0.3	0.3	0.3	0.2
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
D. Non-energy Products from Fuels and Solvent Use	CO_2	JNGI 2025	2.2	2.6	2.9	3.1	3.0	3.0	3.0	2.8	2.8	2.7	2.6
		JNGI 2026	2.2	2.6	2.9	3.1	3.0	3.0	3.0	2.8	2.8	2.7	2.6
		difference	*-0.73%*	*-0.62%*	*-0.54%*	*-0.86%*	*-0.25%*	*-0.20%*	*-0.17%*	*-0.09%*	*-0.10%*	*0.47%*	*1.12%*

*Excluding Indirect CO_2

Table 10-3 Comparison of emissions in the inventories submitted in 2025 and 2026
(Industrial processes and product use sector) (2/2)

2. Industrial Processes and Product Use
(2/2) [Mt-CO_2 eq.]

Category	Gas		1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023
E. Electronic Industry	N_2O	JNGI 2025	0.003	0.01	0.01	0.03	0.04	0.1	0.1	0.1	0.1	0.1	0.1
		JNGI 2026	0.003	0.01	0.01	0.03	0.04	0.1	0.1	0.1	0.1	0.1	0.1
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-0.33%*	*-0.01%*	*-0.01%*
	HFCs	JNGI 2025	0.1	0.4	0.4	0.3	0.2	0.1	0.1	0.2	0.1	0.1	0.1
		JNGI 2026	0.1	0.4	0.4	0.3	0.2	0.1	0.1	0.2	0.1	0.1	0.1
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
	PFCs	JNGI 2025	1.3	3.5	6.1	4.3	2.0	1.5	1.5	1.7	1.5	1.5	1.3
		JNGI 2026	1.3	3.5	6.1	4.3	2.0	1.5	1.5	1.7	1.5	1.5	1.3
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
	SF_6	JNGI 2025	1.0	1.2	2.5	1.9	0.8	0.5	0.6	0.5	0.4	0.4	0.3
		JNGI 2026	1.0	1.2	2.5	1.9	0.8	0.5	0.6	0.5	0.4	0.4	0.3
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
	NF_3	JNGI 2025	0.03	0.2	0.1	0.2	0.2	0.1	0.1	0.3	0.3	0.3	0.2
		JNGI 2026	0.03	0.2	0.1	0.2	0.2	0.1	0.1	0.3	0.3	0.3	0.2
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
F. Product Uses as Substitutes for ODS	HFCs	JNGI 2025	0.001	2.6	5.9	9.6	16.3	21.8	26.5	32.8	33.4	32.8	31.5
		JNGI 2026	0.001	2.6	5.9	9.6	16.3	21.7	26.2	30.5	30.7	29.6	28.3
		difference	*0.00%*	*0.00%*	*0.03%*	*0.04%*	*0.08%*	*-0.30%*	*-1.30%*	*-7.06%*	*-8.26%*	*-9.72%*	*-10.02%*
	PFCs	JNGI 2025	4.2	11.7	2.8	2.5	1.6	1.4	1.4	1.3	1.3	1.4	1.7
		JNGI 2026	4.2	11.7	2.8	2.5	1.6	1.4	1.4	1.3	1.3	1.4	1.7
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
G. Other Product Manufacture and Use	N_2O	JNGI 2025	0.2	0.4	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		JNGI 2026	0.2	0.4	0.3	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
	HFCs	JNGI 2025	0.006	0.005	0.006	0.004	0.003	0.002	0.002	0.005	0.006	0.006	0.006
		JNGI 2026	0.006	0.005	0.006	0.004	0.003	0.002	0.002	0.005	0.006	0.006	0.006
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-2.81%*
	PFCs	JNGI 2025	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.06	0.07	0.07	0.08
		JNGI 2026	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.06	0.07	0.07	0.08
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-0.50%*
	SF_6	JNGI 2025	9.1	11.6	3.8	1.8	1.5	1.6	1.5	1.4	1.4	1.4	1.5
		JNGI 2026	9.1	11.6	3.8	1.8	1.5	1.6	1.5	1.4	1.4	1.4	1.5
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.11%*
H. Other	CO_2	JNGI 2025	0.9	1.0	0.9	1.0	0.9	1.0	1.0	0.9	1.0	0.9	0.9
		JNGI 2026	0.9	1.0	0.9	1.0	0.9	1.0	1.0	0.9	1.0	0.9	0.9
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
2. Total	GHG	JNGI 2025	107.4	131.8	104.9	85.4	74.3	79.6	81.1	82.3	83.9	80.2	76.1
		JNGI 2026	107.4	131.8	104.8	85.4	74.3	79.6	80.8	80.0	81.2	76.9	72.8
		difference	*-0.02%*	*-0.01%*	*-0.01%*	*-0.03%*	*0.01%*	*-0.09%*	*-0.43%*	*-2.82%*	*-3.29%*	*-4.13%*	*-4.42%*

*Excluding Indirect CO_2

Table 10-4 Comparison of emissions in the inventories submitted in 2025 and 2026
(Agriculture sector)

3. Agriculture		[Mt-CO_2 eq.]											
Category	Gas		1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023
A. Enteric Fermentation	CH_4	JNGI 2025	10.6	10.4	10.0	9.6	9.1	8.6	8.4	8.6	8.7	8.7	8.6
		JNGI 2026	10.6	10.4	10.0	9.6	9.1	8.6	8.4	8.6	8.7	8.8	8.6
		difference	*-0.09%*	*-0.09%*	*0.69%*	*-0.46%*	*-0.84%*	*-0.56%*	*-0.43%*	*-0.04%*	*0.05%*	*0.11%*	*0.12%*
B. Manure Management	CH_4	JNGI 2025	3.8	3.6	3.4	3.2	2.9	2.8	2.7	2.7	2.8	2.7	2.6
		JNGI 2026	3.8	3.6	3.4	3.2	2.9	2.8	2.7	2.7	2.7	2.6	2.5
		difference	*0.00%*	*0.00%*	*0.04%*	*-0.09%*	*-0.11%*	*-0.09%*	*-0.07%*	*-1.12%*	*-2.27%*	*-3.38%*	*-4.51%*
	N_2O	JNGI 2025	3.9	3.6	3.5	3.7	3.9	3.6	3.5	3.5	3.5	3.4	3.4
		JNGI 2026	3.9	3.6	3.5	3.7	3.9	3.6	3.5	3.4	3.4	3.3	3.2
		difference	*-0.05%*	*-0.05%*	*0.38%*	*-0.28%*	*-0.46%*	*-0.31%*	*-0.24%*	*-1.65%*	*-3.25%*	*-5.11%*	*-6.89%*
C. Rice Cultivation	CH_4	JNGI 2025	13.6	14.7	13.6	13.7	13.6	13.5	13.4	13.3	13.2	13.0	12.9
		JNGI 2026	13.6	14.7	13.6	13.7	13.6	13.5	13.4	13.3	13.4	13.1	13.0
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.87%*	*0.86%*	*0.82%*
D. Agricultural Soils	N_2O	JNGI 2025	6.7	6.1	5.9	5.5	5.3	5.3	5.3	4.6	4.6	4.4	4.4
		JNGI 2026	6.7	6.1	5.9	5.5	5.3	5.3	5.3	4.7	4.9	4.6	4.1
		difference	*-0.02%*	*-0.02%*	*0.11%*	*-0.09%*	*-0.16%*	*-0.10%*	*-0.08%*	*2.03%*	*7.80%*	*4.82%*	*-6.23%*
F. Field Burning of Agricultural Residues	CH_4	JNGI 2025	0.08	0.07	0.06	0.05	0.03	0.04	0.03	0.03	0.03	0.03	0.03
		JNGI 2026	0.08	0.07	0.06	0.05	0.03	0.04	0.03	0.03	0.03	0.03	0.03
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*1.13%*
	N_2O	JNGI 2025	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		JNGI 2026	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*1.33%*
G. Liming	CO_2	JNGI 2025	0.6	0.3	0.3	0.2	0.2	0.4	0.3	0.2	0.2	0.2	0.2
		JNGI 2026	0.6	0.3	0.3	0.2	0.2	0.4	0.3	0.2	0.2	0.2	0.2
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.88%*
H. Urea Application	CO_2	JNGI 2025	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
		JNGI 2026	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.85%*	*-19.02%*	*-39.23%*	*-15.80%*
3. Total	GHG	JNGI 2025	39.3	39.0	37.0	36.2	35.3	34.5	33.9	33.1	33.2	32.6	32.4
		JNGI 2026	39.3	39.0	37.0	36.1	35.2	34.4	33.8	33.1	33.5	32.6	31.8
		difference	*-0.03%*	*-0.03%*	*0.24%*	*-0.17%*	*-0.30%*	*-0.20%*	*-0.15%*	*0.01%*	*0.81%*	*-0.01%*	*-1.65%*

Table 10-5 Comparison of emissions and removals in the inventories submitted in 2025 and 2026 (Land use, land-use change and forestry sector)

4. Land Use, Land-Use Change and Forestry

[Mt-CO_2 eq.]

Category	Gas		1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023
A. Forest Land	CO_2	JNGI 2025	-97.6	-103.4	-103.8	-106.1	-89.5	-83.6	-73.8	-65.9	-63.6	-59.8	-57.8
		JNGI 2026	-97.6	-103.4	-103.8	-106.1	-89.5	-83.6	-73.8	-65.8	-63.6	-59.8	-57.8
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-0.01%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
	CH_4	JNGI 2025	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.003	0.011	0.004	0.012
		JNGI 2026	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.003	0.011	0.004	0.012
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
	N_2O	JNGI 2025	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		JNGI 2026	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		difference	*0.03%*	*0.03%*	*0.03%*	*0.03%*	*0.03%*	*0.03%*	*0.02%*	*0.06%*	*0.17%*	*0.12%*	*-0.05%*
B. Cropland	CO_2	JNGI 2025	7.3	3.8	3.5	2.3	5.8	4.5	5.3	3.9	4.2	5.1	4.5
		JNGI 2026	7.3	3.8	3.5	2.3	5.8	4.5	5.3	3.9	4.2	5.1	4.5
		difference	*-0.01%*	*-0.05%*	*-0.04%*	*-0.06%*	*-0.01%*	*-0.01%*	*-0.06%*	*0.21%*	*0.35%*	*0.03%*	*-0.32%*
	CH_4	JNGI 2025	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04
		JNGI 2026	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-0.01%*	*-0.04%*	*-0.03%*
	N_2O	JNGI 2025	0.04	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02
		JNGI 2026	0.04	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.01%*	*0.05%*	*0.06%*	*0.06%*	*0.07%*	*0.07%*	*0.08%*
C. Grassland	CO_2	JNGI 2025	1.0	-0.2	-0.9	-0.9	0.3	0.1	1.6	0.2	0.1	0.7	0.7
		JNGI 2026	1.0	-0.2	-0.9	-0.9	0.3	0.1	1.6	0.2	0.1	0.7	0.6
		difference	*0.02%*	*-0.01%*	*0.00%*	*0.10%*	*0.10%*	*0.45%*	*-0.15%*	*-2.03%*	*3.95%*	*0.67%*	*-2.75%*
	CH_4	JNGI 2025	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		JNGI 2026	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
	N_2O	JNGI 2025	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		JNGI 2026	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
D. Wetlands	CO_2	JNGI 2025	-0.5	-0.2	-0.1	-0.4	-0.3	-0.4	-0.3	-0.3	-0.3	-0.3	-0.3
		JNGI 2026	-0.5	-0.2	-0.1	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3
		difference	*0.00%*	*0.00%*	*-1.75%*	*-1.91%*	*-4.46%*	*-6.04%*	*-5.94%*	*-2.36%*	*-8.11%*	*-6.72%*	*-8.62%*
E. Settlements	CO_2	JNGI 2025	10.2	8.0	6.0	4.8	4.1	3.2	3.2	3.5	3.1	3.2	3.0
		JNGI 2026	10.2	8.0	6.0	4.7	4.0	3.1	3.1	3.7	3.2	3.3	3.1
		difference	*-0.01%*	*-0.02%*	*-0.09%*	*-1.25%*	*-1.87%*	*-3.27%*	*-3.30%*	*3.22%*	*3.96%*	*3.93%*	*6.55%*
	CH_4	JNGI 2025	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		JNGI 2026	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.01%*	*0.03%*	*0.02%*	*0.02%*	*0.02%*	*0.03%*	*-0.33%*
	N_2O	JNGI 2025	0.6	0.5	0.5	0.4	0.3	0.3	0.3	0.2	0.2	0.2	0.2
		JNGI 2026	0.6	0.5	0.5	0.4	0.3	0.3	0.3	0.2	0.2	0.2	0.2
		difference	*0.00%*	*0.00%*	*0.00%*	*0.01%*	*0.04%*	*0.06%*	*0.05%*	*0.43%*	*0.61%*	*0.78%*	*0.66%*
F. Other Land	CO_2	JNGI 2025	2.2	2.0	1.6	1.1	0.9	0.7	0.7	0.6	0.5	0.5	0.8
		JNGI 2026	2.2	2.0	1.6	1.1	0.9	0.7	0.7	0.6	0.5	0.5	0.6
		difference	*0.01%*	*0.01%*	*0.01%*	*-0.12%*	*-0.69%*	*-0.11%*	*-0.12%*	*1.29%*	*1.53%*	*1.68%*	*-18.98%*
	N_2O	JNGI 2025	0.10	0.09	0.08	0.07	0.05	0.04	0.04	0.03	0.03	0.03	0.03
		JNGI 2026	0.10	0.09	0.08	0.07	0.05	0.04	0.04	0.03	0.03	0.03	0.03
		difference	*0.00%*	*0.00%*	*0.01%*	*0.01%*	*-0.10%*	*-0.15%*	*-0.15%*	*-0.14%*	*-0.09%*	*-0.04%*	*1.14%*
G. Harvested Wood Products	CO_2	JNGI 2025	-0.4	1.2	1.8	0.6	-0.4	-0.2	-1.1	-1.0	-2.1	-1.8	-1.6
		JNGI 2026	-0.4	1.2	1.8	0.6	-0.6	-0.5	-1.3	-1.5	-2.6	-2.2	-1.8
		difference	*0.23%*	*1.17%*	*0.39%*	*7.65%*	*43.50%*	*119.9%*	*24.00%*	*51.78%*	*27.02%*	*23.54%*	*14.51%*
H. Other	CO_2	JNGI 2025	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.000	0.000
		JNGI 2026	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.000	0.000
		difference	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*0.00%*	*0.00%*
4. Total	GHG	JNGI 2025	-76.6	-88.0	-91.1	-97.8	-78.5	-75.1	-63.9	-58.5	-57.5	-52.0	-50.2
		JNGI 2026	-76.6	-88.0	-91.1	-97.8	-78.7	-75.4	-64.2	-58.8	-57.9	-52.2	-50.4
		difference	*0.00%*	*-0.01%*	*0.00%*	*0.01%*	*0.31%*	*0.48%*	*0.54%*	*0.66%*	*0.65%*	*0.51%*	*0.37%*

Table 10-6 Comparison of emissions in the inventories submitted in 2025 and 2026 (Waste sector)

5. Waste		[Mt-CO_2 eq.]											
Category	Gas		1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023
A. Solid Waste Disposal	CH_4	JNGI 2025	11.2	10.1	8.0	6.0	4.0	3.2	2.7	1.9	1.8	1.6	1.5
		JNGI 2026	11.2	10.1	8.1	6.0	4.0	3.2	2.7	1.9	1.8	1.6	1.5
		difference	*0.18%*	*0.16%*	*0.10%*	*0.06%*	*0.03%*	*0.02%*	*0.02%*	*0.03%*	*0.03%*	*0.04%*	*0.05%*
B. Biological Treatment of Solid Waste	CH_4	JNGI 2025	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		JNGI 2026	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-4.98%*
	N_2O	JNGI 2025	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2
		JNGI 2026	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-5.13%*
C. Incineration and Open Burning of Waste	CO_2	JNGI 2025	10.6	13.9	14.6	12.2	10.5	10.5	10.1	8.9	9.3	9.4	9.1
		JNGI 2026	9.9	12.6	13.3	10.9	9.4	9.3	9.0	8.0	8.4	8.5	8.8
		difference	*-5.80%*	*-9.66%*	*-8.92%*	*-10.61%*	*-10.70%*	*-11.10%*	*-10.97%*	*-9.46%*	*-9.84%*	*-9.98%*	*-3.23%*
	CH_4	JNGI 2025	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		JNGI 2026	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-0.87%*	*2.74%*
	N_2O	JNGI 2025	1.3	1.6	1.7	1.9	1.5	1.5	1.3	1.3	1.2	1.2	1.2
		JNGI 2026	1.3	1.6	1.7	1.9	1.5	1.5	1.3	1.3	1.2	1.2	1.2
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*3.04%*
D. Wastewater Treatment and Discharge	CH_4	JNGI 2025	3.3	3.1	2.9	2.6	2.2	2.0	2.0	1.8	1.7	1.7	1.7
		JNGI 2026	3.3	3.1	2.9	2.6	2.2	2.0	2.0	1.8	1.7	1.7	1.7
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-0.58%*
	N_2O	JNGI 2025	2.1	2.2	2.0	2.0	1.9	1.9	1.8	1.8	1.8	1.8	1.7
		JNGI 2026	2.1	2.2	2.0	2.0	1.9	1.9	1.8	1.8	1.8	1.8	1.7
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.07%*	*-0.43%*
E. Other	CO_2	JNGI 2025	0.7	0.7	0.7	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.6
		JNGI 2026	0.7	0.7	0.7	0.5	0.5	0.6	0.6	0.6	0.7	0.7	0.6
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
5. Total	GHG	JNGI 2025	29.4	31.7	30.2	25.6	21.0	20.1	19.0	16.5	16.8	16.7	16.1
		JNGI 2026	28.8	30.4	28.9	24.3	19.8	18.9	17.9	15.6	15.9	15.7	15.8
		difference	*-2.02%*	*-4.18%*	*-4.29%*	*-5.04%*	*-5.36%*	*-5.77%*	*-5.83%*	*-5.11%*	*-5.45%*	*-5.65%*	*-1.78%*

10.2.2. The Contribution from the LULUCF Sector in the NDC

Compared to the values reported in the previous year's inventory, the contribution from LULUCF sector in the NDC in FY2023 resulted in an increase of removals by 0.34% (Table 10-7).

Table 10-7 Comparison of emissions and removals in the inventories submitted in 2025 and 2026 for the LULUCF sector in the NDC

The LULUCF sector in the NDC [Mt-CO_2 eq.]

Activity	Gas		2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Afforestation and	GHG	JNGI 2025	-1.9	-1.9	-1.6	-1.5	-1.4	-1.6	-1.6	-1.5	-1.5	-1.4
Reforestation		JNGI 2026	-1.9	-1.8	-1.6	-1.5	-1.4	-1.6	-1.6	-1.5	-1.4	-1.4
		difference	*-0.76%*	*-0.68%*	*-0.63%*	*-0.61%*	*-0.58%*	*-0.62%*	*-0.64%*	*-0.61%*	*-0.59%*	*-0.83%*
Deforestation	GHG	JNGI 2025	3.1	3.3	3.3	2.9	2.9	3.6	3.6	3.3	3.3	2.8
		JNGI 2026	3.1	3.3	3.3	2.9	2.9	3.8	3.8	3.6	3.6	3.0
		difference	*-0.06%*	*-0.23%*	*-0.24%*	*1.10%*	*1.13%*	*7.00%*	*7.27%*	*9.28%*	*9.52%*	*5.83%*
Forest Management	GHG	JNGI 2025	-62.3	-58.8	-57.3	-56.7	-55.4	-51.4	-49.1	-49.7	-47.4	-46.6
		JNGI 2026	-62.5	-59.0	-57.5	-57.1	-55.9	-52.1	-49.8	-50.4	-48.0	-46.9
		difference	*0.36%*	*0.29%*	*0.50%*	*0.79%*	*1.03%*	*1.47%*	*1.30%*	*1.42%*	*1.22%*	*0.52%*
Cropland Management	GHG	JNGI 2025	-5.1	-5.4	-5.7	-5.4	-5.3	-5.7	-5.8	-5.6	-5.4	-5.7
		JNGI 2026	-5.1	-5.4	-5.7	-5.4	-5.3	-5.7	-5.8	-5.6	-5.4	-5.7
		difference	*-0.06%*	*-0.06%*	*-0.27%*	*0.06%*	*-0.05%*	*-0.05%*	*-0.09%*	*-0.02%*	*0.04%*	*0.03%*
Grazing Land Managemen	GHG	JNGI 2025	-0.8	-0.9	-1.0	-1.0	-1.0	-1.1	-1.2	-1.2	-1.2	-1.2
		JNGI 2026	-0.8	-0.9	-1.0	-1.1	-1.0	-1.1	-1.2	-1.2	-1.2	-1.2
		difference	*-0.02%*	*-0.02%*	*0.00%*	*1.62%*	*0.00%*	*-0.03%*	*0.01%*	*0.00%*	*0.01%*	*0.16%*
Urban Greening	GHG	JNGI 2025	-1.7	-1.7	-1.7	-1.6	-1.6	-1.6	-1.5	-1.5	-1.4	-1.3
		JNGI 2026	-1.8	-1.8	-1.8	-1.8	-1.7	-1.7	-1.6	-1.6	-1.5	-1.5
		difference	*5.86%*	*6.09%*	*6.44%*	*6.90%*	*7.26%*	*8.03%*	*8.59%*	*9.39%*	*10.24%*	*11.29%*
Coastal Wetlands	GHG	JNGI 2025	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.3	-0.3	-0.3
		JNGI 2026	-0.4	-0.4	-0.3	-0.3	-0.3	-0.4	-0.3	-0.3	-0.3	-0.3
		difference	*-4.59%*	*-4.93%*	*-5.25%*	*-5.59%*	*-5.91%*	*-6.64%*	*-2.12%*	*-7.69%*	*-6.37%*	*-10.45%*
Other	GHG	JNGI 2025	NO	NO	NO	NO	NO	NO	NO	NO	0.000	0.000
		JNGI 2026	NO	NO	NO	NO	NO	NO	NO	NO	0.000	0.000
		difference	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*0.00%*	*0.00%*
Total	GHG	JNGI 2025	-69.0	-65.7	-64.2	-63.7	-62.2	-58.2	-56.0	-56.6	-53.8	-53.7
		JNGI 2026	-69.3	-66.0	-64.6	-64.2	-62.8	-58.8	-56.4	-57.1	-54.2	-53.9
		difference	*0.42%*	*0.37%*	*0.55%*	*0.82%*	*1.00%*	*1.01%*	*0.87%*	*0.88%*	*0.70%*	*0.34%*

10.3. Implication for Emission Trends, Including Time-series Consistency

Table 10-8 shows the changes made to the emission trends due to the recalculations indicated in "Section 10.1. Explanation and Justification for Recalculations". The comparison between the 2025 submission and the 2026 submission is made through the comparison of changes between FY1990 and FY2023.

The change between FY1990 and FY2023 total emissions (excluding the LULUCF sector and including indirect CO_2) in the 2026 submission decreased by approximately 3.8 million tonnes (in CO_2 equivalents) and decreased by 0.30 percentage points, compared to the data reported in the previous submission.

Table 10-8 Comparison of change between 1990 and 2023 total emissions (excluding the LULUCF sector, and including indirect CO_2) between the inventories submitted in 2025 and 2026

	Emissions (2023) - Emissions (1990) [Mt-CO_2 eq.]			Emissions (2023) / Emissions (1990) - 1 [%]		
	JNGI 2025	JNGI 2026	Difference	JNGI 2025	JNGI 2026	Difference
CO_2	-167.9	-167.9	0.01	-14.5%	-14.5%	-0.01%
CH_4	-20.5	-20.5	-0.02	-41.1%	-41.0%	0.08%
N_2O	-13.1	-13.7	-0.63	-45.2%	-47.4%	-2.17%
HFCs	18.3	15.1	-3.16	136.4%	112.8%	-23.54%
PFCs	-3.1	-3.1	-0.0004	-50.4%	-50.4%	-0.01%
SF_6	-11.7	-11.7	0.002	-85.0%	-85.0%	0.01%
NF_3	0.2	0.2	0	636.8%	636.8%	0%
Indirect CO_2	-3.7	-3.7	0.003	-67.1%	-66.1%	0.96%
Total	-201.5	-205.3	-3.78	-15.84%	-16.14%	-0.30%

10.4. Areas of Improvement and Planned Improvements

10.4.1. Improvements After the Previous Submission of the Inventory

The major improvements carried out after the previous submission of the inventory are listed below.

10.4.1.1. Improvements Identified by Japan

Calculation methods changed are provided in Table 10-9. For details, see the relevant description of each category.

Table 10-9 Changes in estimation methods

Sector and category		Changes in estimation methods
1.A	Fuel combustion (Other fossil fuels)	The gross calorific value of "Waste plastics" was revised since FY2023.
1.B.2.a.v	Distribution of Oil Products	NMVOC emissions from distribution of Jet fuel, kerosene and diesel oil were newly estimated.
1.B.2.c.i.1 1.B.2.c.ii.1	Venting (Oil) Flaring (Oil)	NMVOC emissions during oil production were newly estimated.
1.B.2.c.i.2	Venting (Gas)	CH_4 emissions during natural gas production were newly estimated.
1.B.2.c.i.2 1.B.2.c.ii.2	Venting (Gas) Flaring (Gas)	NMVOC emissions during natural gas production were newly estimated.
1.B.2.c.ii.2	Flaring (Gas)	Estimation methodology of NMVOC emissions from exploration was revised.
1.A.2.f. 2.H.3.	Environmentally Friendly Concreate	The specifications have been added, and a new product has also been added.
2.D.3	Use of Oil Extraction Solvents	NMVOC emissions were newly estimated.
2.F.1.a.	Commercial Refrigeration	The refrigerant contained (during manufacturing and installation) has been revised.
2.F.1.f.	Stationary Air-Conditioning (Household)	The fugitive refrigerant ratio during use has been revised.
3.A.1. 3.B.1. 3.B.5. 3.D.a.2. 3.D.b.1. 3.D.b.2.	Enteric Fermentation -Non-dairy cattle, Manure Management –Non-dairy cattle, Manure Management -Indirect emissions - Atmospheric Deposition, Agricultural Soils - Direct N_2O Emissions - Organic Fertilizer, Agricultural Soils - Indirect N_2O Emissions – Atmospheric Deposition, Agricultural Soils - N mineralization associated with loss of soil organic matter	Application of equations to estimate weight, dry matter intake (DMI) and crude protein (CP) of the *Japanese Feeding Standard for Beef Cattle* have been revised.
4.B.1	Cropland remaining cropland	Correction of parameter values used to estimate carbon sequestration associated with biochar amendment
4.D.1	Wetlands remaining wetlands – other wetlands – coastal wetlands	Environment data and estimation algorithm used for estimating areas of seagrass meadows and macroalgal beds were revised.
4.G	Harvested Wood Products Plywood and LVL	Addition of items related to the input of "plywood and LVL", revision of the estimation methodology, and the accompanying change in the data sources used for setting domestic wood ratio.
4.G	Harvested Wood Products wooden board	A processing yield was set in the estimation for the amount of wooden boards input into buildings.
4.G	Harvested Wood Products Other	Carbon stock changes in underground buried logs were newly estimated.

Sector and category		Changes in estimation methods
5.C.1./1.A.	Waste incineration/ Waste Incineration and Energy Use (Reported on Energy Sector)	The estimation method for CO_2 emissions from industrial waste plastics incineration, including use as fuel, were updated.
5.C.1./1.A.	Waste incineration/ Waste Incineration and Energy Use (Reported on Energy Sector)	Activity data for the incineration of sanitary pads and plastic products for infection control (including nonwoven masks and examination/surgical gloves) and for incineration with energy recovery were added to the estimation methodology as CO_2 emission sources.

10.4.1.2. Improvements in Response to the Technical Expert Review Process

Actions taken in response to recommendations from the technical expert review are summarized below. See relative sections of each category for details.

The Committee for Greenhouse Gas Estimation Methods (see "Committee for Greenhouse Gas Estimation Methods" (Chapter 1.2.1.2.)) addresses the recommendations that need revision of estimation methods, and efforts have been made to tackle the issues and improve the national GHG inventory with due consideration of priority.

Table 10-10 Summary of improvements made to the national inventory in response to recommendations from the technical expert review

Sector/Category	Recommendations	Actions taken	NID/CRT
Energy/ Fuel combustion (1.A)	Provide information on the CO_2 capture processes in Japan and explain the trend in captured CO_2 in the NID. (TERR.1, 3.E.1)	Tables on CO_2 capture by usage are provided and the trend is explained in the NID.	NID Chapter 3 (3.2.4.b)
IPPU/ General	Revise the reporting of AD and recovery for unspecified mixes of HFCs in CRT 2(II).B-H by reporting these values in t-CO_2 eq., ensuring that the calculated IEFs are meaningful and comparable. (TERR.1, 4.I.1)	The AD and recovery values for unspecified mixes of HFCs in the CRT were reported in t-CO_2 eq.	CRT2(II).B-H
IPPU/ Glass production (2.A.3)	Correct the AD for glass production reported in CRT 2(I).A-H. (TERR.1, 4.I.2)	The AD values in the CRT for glass production were corrected.	CRT2(I).A-H
IPPU/ Iron and steel production (2.C.1)	Revise NID table 4-43 to ensure consistency with the units used in CRT 2(I).A-H and with the Estimation Method section (NID p.4-52), and to clearly indicate information on imports, production, exports, domestic consumption of carbon electrodes (t-C), CO_2 emissions from subcategory 2.C.3, and emissions in t-CO_2 for subcategory 2.C.1.a. (TERR.1, 4.I.3)	The table 4-52 was revised in NID.	NID Chapter 4 (4.4.1.2)
IPPU/ Product uses as substitutes for ozone-depleting substances (2.F)	Revise the reporting in CRT 2(II).B-Hs2 to ensure consistent and accurate AD reporting by reflecting the actual average refrigerant charge at end of life instead of the operational average, and present in NID table 4-63 the average GWPs used to report manufacturing, stock and disposal emissions in CRT 2(II).B-Hs2 for all years. (TERR.1, 4.I.4)	Remaining in products at decommissioning in CRT was revised to reflect the actual average refrigerant at end-of-life. The table 4-65 was revised in NID.	CRT2(II).B-Hs2, NID Chapter 4 (4.7.1.1.a)
Agriculture/ Cattle – CH_4 (3.A)	Use the updated values from the Japanese feeding standard for beef cattle for 2022 to estimate daily gain and cattle weight for 2000 onward by using, for example, the splicing techniques set out in the 2006 IPCC Guidelines (vol. 1, chap. 5). (TERR.1, 5.A.2)	The estimation methodology has been revised.	NID Chapter 5 (5.2.)

Sector/Category	Recommendations	Actions taken	NID/CRT
Agriculture/ Manure Management – N_2O (3.B)	Correct the following information reported in CRT 3.B(b): total Nex for dairy and non-dairy cattle, buffalo and poultry; N2O emissions from pit storage, which were missing (reported as "NO"); where emissions from deep bedding are included; and the values for Nex on pasture, range and paddock. (TERR.1, 5.A.4)	Reported in CRT	CRT 3.B(b)
Agriculture/ Direct and indirect N_2O emissions from agricultural soils – N_2O (3.D)	Report values for $Frac_{GASPRP}$, $Frac_{LEACH}$ and $Frac_{GASM}$ in CRT 3.D and that the weighted mean values for $Frac_{GASF}$ used in the calculations across the entire time series be reported. (TERR.1, 5.A.5)	Reported in CRT	CRT 3.D
LULUCF/ Cropland remaining cropland (4.B.1)	Provide in the NID detailed information on how the CSCs for land converted from annual to perennial crops and vice versa are estimated. (TERR.1, 6.L.3)	The information was added in NID.	NID Chapter 6 (6.5.1.a))
sLULUCF/Cropland remaining cropland (4.B.1)	Provide in the NID the dry matter biomass weights and root-to-shoot ratios by orchard tree species used for estimating CSCs in perennial crops. (TERR.1, 6.L.4)	The information was added in NID.	NID Chapter6 (6.5.1 b) 1), Table 6-30)
LULUCF/ Cropland (4.B)	explain in the NID why it used the same value for biomass stock and annual increment for the pasture land, grazed meadow and wild land subcategories of the grassland category. (TERR.1, 6.L.5)	The information was added in NID.	NID Chapter 6 (Table 6-8)
Waste/ Waste incineration (5.C.1.)	Report in the NID the AD on the amount of waste incinerated (in tonnes) used for estimating emissions from waste incineration with energy recovery. (TERR.1, 7.W.1)	Corresponded AD was reported in the NID.	NID Chapter 7 (Table 7-69)
Waste/ Industrial Wastewater (5.D.2.)	Update the AD used for estimating CH4 and N2O emissions from industrial wastewater treatment and recalculate the emissions for 2014 onward. (TERR.1, 7.W.2)	It was reported in the NID that this issue will be included in future improvement plan.	NID Chapter 7 (7.5.2.1.)

*TERR: Technical Expert Review Report

10.4.2. Planned Improvements

The following improvements are continuously performed and reflect in an inventory preparation process accordingly. See relative sections for details.

1. Review of estimation methods, activity data, emission/removal factors and other elements
   Japan holds meetings of a Committee for Greenhouse Gas Emission Estimation Methods and considers improvements of estimation methods, activity data, emission/removal factors and other elements used in the current inventory. In case of implementation, Japan prioritizes highly important issues such as those relevant to key-categories and those pointed out in the past review reports.

2. Improvement of transparency
   Japan will further improve transparency of the inventory by examining descriptions of methodologies, assumptions, data, and other elements in NID, and by adding necessary information.

Annex 1. Key Categories

A1.1. Outline of Key Category Analysis

The *Modalities, Procedures and Guidelines for the Transparency Framework for Action and Support Referred to in Article 13 of the Paris Agreement* (Decision 18/CMA.1 Annex) require parties to identify key categories by implementing a key category analysis consistent with the *2006 IPCC Guidelines*. The key category analyses were done for both data of FY2024 (the latest year of the inventory time series) and of FY1990 (the starting year). Their results are presented here.

A1.2. Results of Key Category Analysis

A1.2.1 Key Categories

Key categories were assessed in accordance with the *2006 IPCC Guidelines* assessment methods (Approach 1 level assessment, Approach 1 trend assessment, Approach 2 level assessment, and Approach 2 trend assessment), using all of the inventory categories and for both cases of including and excluding the LULUCF sector.

As a result, in the case of including the LULUCF sector, 47 and 41 sources and sinks were identified as the key categories for FY2024 and FY1990, respectively (Table A1-1 and Table A1-2). On the other hand, in the case of excluding the LULUCF sector, 38 and 37 sources were identified as the key categories for FY2024 and FY1990, respectively (Table A1-3 and Table A1-4).

Table A1-1 Japan's key categories (FY2024, including the LULUCF sector)

	A Code	B Category		C GHGs	Ap1-L	Ap1-T	Ap2-L	Ap2-T
#1	1.A.1.	Energy Industries	Solid Fuels	CO_2	#1	#1	#1	#1
#2	1.A.3.	Transport	b. Road Transportation	CO_2	#2	#14	#6	
#3	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	#3	#7	#2	#6
#4	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	#4	#4	#8	#17
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	#5	#6	#21	#20
#6	4.A.	Forest Land	1. Forest Land Remaining Forest Land	CO_2	#6	#5	#3	#3
#7	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	#7	#3	#26	#16
#8	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	#8	#9	#27	#28
#9	1.A.1.	Energy Industries	Liquid Fuels	CO_2	#9	#2	#32	#8
#10	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	#10	#10	#33	
#11	2.F.	Product Uses as Substitutes for ODS	1. Refrigeration and Air Conditioning Equipment	HFCs	#11	#8	#11	#11
#12	2.A.	Mineral Industry	1. Cement Production	CO_2	#12	#11	#25	#24
#13	3.C.	Rice Cultivation		CH_4	#13		#29	
#14	1.A.3.	Transport	a. Domestic Aviation	CO_2	#14	#21		
#15	1.A.3.	Transport	d. Domestic Navigation	CO_2	#15			
#16	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	#16	#23	#13	#23
#17	5.C.	Incineration and Open Burning of Waste		CO_2	#17		#14	
#18	3.A.	Enteric Fermentation		CH_4	#18		#7	
#19	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	#19	#19	#17	#19
#20	1.A.4.	Other Sectors	Solid Fuels	CO_2	#20	#17		
#21	2.C.	Metal Industry	1. Iron and Steel Production	CO_2	#21			
#22	4.E.	Settlements	2. Land Converted to Settlements	CO_2	#22	#20	#10	#5
#23	2.A.	Mineral Industry	2. Lime Production	CO_2	#23			
#24	4.B.	Cropland	1. Cropland Remaining Cropland	CO_2			#23	
#25	3.B.	Manure Management		N_2O			#4	
#26	2.D.	Non-energy Products from Fuels and Solvent Use		CO_2			#15	
#27	2.F.	Product Uses as Substitutes for ODS	2. Foam Blowing Agents	HFCs			#16	#14
#28	3.D.	Agricultural Soils	1. Direct Emissions	N_2O			#12	#22
#29	2.B.	Chemical Industry	Other Production Except Ammonia	CO_2			#18	#29
#30	5.D.	Wastewater Treatment and Discharge		N_2O			#30	
#31	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O			#5	#12
#32	5.A.	Solid Waste Disposal		CH_4		#15		#9
#33	2.G.	Other Product Manufacture and Use		SF_6		#16	#9	#2
#34		Indirect CO_2	from IPPU Sector	Ind CO_2			#28	#13
#35	2.E.	Electronics Industry		PFCs			#22	
#36	5.C.	Incineration and Open Burning of Waste		N_2O			#24	
#37	1.A.3.	Transport	b. Road Transportation	N_2O			#19	#10
#38	4.F.	Other Land	2. Land Converted to Other Land	CO_2				#21
#39	4.A.	Forest Land	2. Land Converted to Forest Land	CO_2		#13		#18
#40	1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	CH_4		#22		#4
#41	4.(III)	N_2O Emissions from N Mineralization/Immobilization		N_2O			#31	#26
#42	2.E.	Electronics Industry		SF_6			#20	#15
#43	2.B.	Chemical Industry	2. Nitric Acid Production	N_2O				#27
#44	2.B.	Chemical Industry	9. Fluorochemical Production	HFCs		#12		
#45	2.B.	Chemical Industry	9. Fluorochemical Production	SF_6		#24		
#46	2.B.	Chemical Industry	3. Adipic Acid Production	N_2O		#18		#25
#47	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O				#7

Note: Ap1-L: Approach1-Level Assessment, Ap1-T: Approach1-Trend Assessment,
Ap2-L: Approach2-Level Assessment, Ap2-T: Approach2-Trend Assessment
Figures recorded in the Level and Trend columns indicate the ranking of individual level and trend assessments.

Table A1-2 Japan's key categories (FY1990, including the LULUCF sector)

	A Code	B Category		C GHGs	Ap1-L	Ap2-L
#1	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	#1	#2
#2	1.A.3.	Transport	b. Road Transportation	CO_2	#2	#11
#3	1.A.1.	Energy Industries	Liquid Fuels	CO_2	#3	#12
#4	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	#4	#18
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	#5	#19
#6	1.A.1.	Energy Industries	Solid Fuels	CO_2	#6	#4
#7	4.A.	Forest Land	1. Forest Land Remaining Forest Land	CO_2	#7	#3
#8	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	#8	#24
#9	2.A.	Mineral Industry	1. Cement Production	CO_2	#9	#22
#10	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	#10	
#11	1.A.3.	Transport	d. Domestic Navigation	CO_2	#11	
#12	3.C.	Rice Cultivation		CH_4	#12	
#13	2.B.	Chemical Industry	9. Fluorochemical Production	HFCs	#13	
#14	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	#14	
#15	4.E.	Settlements	2. Land Converted to Settlements	CO_2	#15	#7
#16	5.A.	Solid Waste Disposal		CH_4	#16	#14
#17	3.A.	Enteric Fermentation		CH_4	#17	#10
#18	5.C.	Incineration and Open Burning of Waste		CO_2	#18	#23
#19	4.A.	Forest Land	2. Land Converted to Forest Land	CO_2	#19	#32
#20	2.G.	Other Product Manufacture and Use		SF_6	#20	#1
#21	2.C.	Metal Industry	1. Iron and Steel Production	CO_2	#21	
#22	1.A.3.	Transport	a. Domestic Aviation	CO_2	#22	
#23	2.A.	Mineral Industry	2. Lime Production	CO_2	#23	
#24	4.B.	Cropland	1. Cropland Remaining Cropland	CO_2	#24	#21
#25	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	#25	#28
#26	2.B.	Chemical Industry	3. Adipic Acid Production	N_2O	#26	
#27	1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	CH_4	#27	#8
#28		Indirect CO_2	from IPPU Sector	Ind CO_2	#28	#15
#29	3.D.	Agricultural Soils	1. Direct Emissions	N_2O		#17
#30	3.B.	Manure Management		N_2O		#6
#31	2.B.	Chemical Industry	Other Production Except Ammonia	CO_2		#20
#32	1.A.3.	Transport	b. Road Transportation	N_2O		#9
#33	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O		#5
#34	4.F.	Other Land	2. Land Converted to Other Land	CO_2		#26
#35	2.D.	Non-energy Products from Fuels and Solvent Use		CO_2		#27
#36	5.D.	Wastewater Treatment and Discharge		N_2O		#31
#37	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O		#16
#38	2.E.	Electronics Industry		PFCs		#29
#39	5.C.	Incineration and Open Burning of Waste		N_2O		#30
#40	2.E.	Electronics Industry		SF_6		#13
#41	4.(III)	N_2O Emissions from N Mineralization/Immobilization		N_2O		#25

Note: Ap1-L: Approach1-Level Assessment, Ap2-L: Approach2-Level Assessment
Figures recorded in the Level columns indicate the ranking of individual level assessments.

Table A1-3 Japan's key categories (FY2024, excluding the LULUCF sector)

	A Code	B Category		C GHGs	Ap1-L	Ap1-T	Ap2-L	Ap2-T
#1	1.A.1.	Energy Industries	Solid Fuels	CO_2	#1	#1	#1	#1
#2	1.A.3.	Transport	b. Road Transportation	CO_2	#2	#10	#5	
#3	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	#3	#6	#2	#7
#4	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	#4	#4	#7	#15
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	#5	#5	#19	#17
#6	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	#6	#3	#23	#14
#7	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	#7	#8	#24	#22
#8	1.A.1.	Energy Industries	Liquid Fuels	CO_2	#8	#2	#28	#5
#9	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	#9	#9		
#10	2.F.	Product Uses as Substitutes for ODS	1. Refrigeration and Air Conditioning Equipment	HFCs	#10	#7	#9	#9
#11	2.A.	Mineral Industry	1. Cement Production	CO_2	#11	#11	#22	#21
#12	3.C.	Rice Cultivation		CH_4	#12		#26	
#13	1.A.3.	Transport	a. Domestic Aviation	CO_2	#13	#18		
#14	1.A.3.	Transport	d. Domestic Navigation	CO_2	#14			
#15	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	#15	#20	#11	#19
#16	5.C.	Incineration and Open Burning of Waste		CO_2	#16		#12	
#17	3.A.	Enteric Fermentation		CH_4	#17		#6	
#18	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	#18	#17	#15	#16
#19	1.A.4.	Other Sectors	Solid Fuels	CO_2	#19	#15		
#20	3.B.	Manure Management		N_2O			#3	
#21	2.D.	Non-energy Products from Fuels and Solvent Use		CO_2			#13	
#22	2.F.	Product Uses as Substitutes for ODS	2. Foam Blowing Agents	HFCs			#14	#11
#23	3.D.	Agricultural Soils	1. Direct Emissions	N_2O			#10	#18
#24	2.B.	Chemical Industry	Other Production Except Ammonia	CO_2			#16	#24
#25	5.D.	Wastewater Treatment and Discharge		N_2O			#27	
#26	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O			#4	#10
#27	5.A.	Solid Waste Disposal		CH_4		#13		#6
#28	2.G.	Other Product Manufacture and Use		SF_6		#14	#8	#2
#29		Indirect CO_2	from IPPU Sector	Ind CO_2			#25	#12
#30	2.E.	Electronics Industry		PFCs			#20	
#31	5.C.	Incineration and Open Burning of Waste		N_2O			#21	
#32	1.A.3.	Transport	b. Road Transportation	N_2O			#17	#8
#33	1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	CH_4		#19		#3
#34	2.E.	Electronics Industry		SF_6			#18	#13
#35	2.B.	Chemical Industry	2. Nitric Acid Production	N_2O				#23
#36	2.B.	Chemical Industry	9. Fluorochemical Production	HFCs		#12		
#37	2.B.	Chemical Industry	3. Adipic Acid Production	N_2O		#16		#20
#38	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O				#4

Note: Ap1-L: Approach1-Level Assessment, Ap1-T: Approach1-Trend Assessment,
Ap2-L: Approach2-Level Assessment, Ap2-T: Approach2-Trend Assessment
Figures recorded in the Level and Trend columns indicate the ranking of individual level and trend assessments.

Table A1-4 Japan's key categories (FY1990, excluding the LULUCF sector)

	A Code	B Category		C GHGs	Ap1-L	Ap2-L
#1	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	#1	#1
#2	1.A.3.	Transport	b. Road Transportation	CO_2	#2	#7
#3	1.A.1.	Energy Industries	Liquid Fuels	CO_2	#3	#8
#4	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	#4	#14
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	#5	#15
#6	1.A.1.	Energy Industries	Solid Fuels	CO_2	#6	#3
#7	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	#7	#21
#8	2.A.	Mineral Industry	1. Cement Production	CO_2	#8	#19
#9	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	#9	
#10	1.A.3.	Transport	d. Domestic Navigation	CO_2	#10	
#11	3.C.	Rice Cultivation		CH_4	#11	#26
#12	2.B.	Chemical Industry	9. Fluorochemical Production	HFCs	#12	
#13	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	#13	
#14	5.A.	Solid Waste Disposal		CH_4	#14	#11
#15	3.A.	Enteric Fermentation		CH_4	#15	#10
#16	5.C.	Incineration and Open Burning of Waste		CO_2	#16	#20
#17	2.G.	Other Product Manufacture and Use		SF_6	#17	#2
#18	2.C.	Metal Industry	1. Iron and Steel Production	CO_2	#18	
#19	1.A.3.	Transport	a. Domestic Aviation	CO_2	#19	
#20	2.A.	Mineral Industry	2. Lime Production	CO_2	#20	
#21	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	#21	#23
#22	2.B.	Chemical Industry	3. Adipic Acid Production	N_2O	#22	
#23	1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	CH_4	#23	#6
#24		Indirect CO_2	from IPPU Sector	Ind CO_2	#24	#18
#25	3.D.	Agricultural Soils	1. Direct Emissions	N_2O		#17
#26	3.B.	Manure Management		N_2O		#5
#27	2.B.	Chemical Industry	Other Production Except Ammonia	CO_2		#16
#28	5.D.	Wastewater Treatment and Discharge		CH_4		#29
#29	1.A.3.	Transport	b. Road Transportation	N_2O		#13
#30	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O		#4
#31	2.D.	Non-energy Products from Fuels and Solvent Use		CO_2		#22
#32	5.D.	Wastewater Treatment and Discharge		N_2O		#27
#33	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O		#12
#34	2.E.	Electronics Industry		PFCs		#24
#35	5.C.	Incineration and Open Burning of Waste		N_2O		#25
#36	2.E.	Electronics Industry		SF_6		#9
#37	2.B.	Chemical Industry	2. Nitric Acid Production	N_2O		#28

Note: Ap1-L: Approach1-Level Assessment, Ap2-L: Approach2-Level Assessment
Figures recorded in the Level columns indicate the ranking of individual level assessments.

A1.2.2 Level Assessment

Level assessment involves an identification of categories as a key by calculating the proportion of emissions and removals in each category to the total or net emissions. The calculated values of proportion are added from the category that accounts for the largest proportion, until the sum reaches 95% for Approach 1 and 90% for Approach 2. Approach 1 level assessment uses emissions and removals from each category directly and Approach 2 level assessment analyzes the emissions and removals of each category, multiplied by the uncertainty of each category.

Approach 1 level assessment of emissions and removals in FY2024 gives the following 23 sub-categories as the key categories and that of excluding LULUCF gives the following 19 sub-categories as the key categories (Table A1-5). Approach 2 level assessment of the emissions and removals gives the following 33 sub-categories as the key categories and that of excluding LULUCF gives the following 28 sub-categories as the key categories (Table A1-6).

Table A1-5 Results of Approach 1 level assessment (FY2024)

	A Code	B Category		C GHGs	F Current Year Estimate [Gg-CO_2 eq.]	H Ap1-L	I Ap1-L Contrib. [%]	Cumulative contrib. [%]
	Including LULUCF							
#1	1.A.1.	Energy Industries	Solid Fuels	CO_2	249,662.31	0.223	22.3%	22.3%
#2	1.A.3.	Transport	b. Road Transportation	CO_2	160,161.86	0.143	14.3%	36.7%
#3	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	133,668.33	0.120	12.0%	48.6%
#4	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	117,326.61	0.105	10.5%	59.1%
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	62,664.92	0.056	5.6%	64.7%
#6	4.A.	Forest Land	1. Forest Land Remaining Forest Land	CO_2	-56,525.64	0.051	5.1%	69.8%
#7	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	47,143.92	0.042	4.2%	74.0%
#8	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	42,138.55	0.038	3.8%	77.8%
#9	1.A.1.	Energy Industries	Liquid Fuels	CO_2	37,667.65	0.034	3.4%	81.2%
#10	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	29,620.10	0.027	2.7%	83.8%
#11	2.F.	Product Uses as Substitutes for ODS	1. Refrigeration and Air Conditioning Equipment	HFCs	24,427.46	0.022	2.2%	86.0%
#12	2.A.	Mineral Industry	1. Cement Production	CO_2	20,174.91	0.018	1.8%	87.8%
#13	3.C.	Rice Cultivation		CH_4	11,841.15	0.011	1.1%	88.9%
#14	1.A.3.	Transport	a. Domestic Aviation	CO_2	10,302.91	0.009	0.9%	89.8%
#15	1.A.3.	Transport	d. Domestic Navigation	CO_2	9,717.06	0.009	0.9%	90.6%
#16	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	8,552.60	0.008	0.8%	91.4%
#17	5.C.	Incineration and Open Burning of Waste		CO_2	8,467.90	0.008	0.8%	92.2%
#18	3.A.	Enteric Fermentation		CH_4	8,458.65	0.008	0.8%	92.9%
#19	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	7,773.34	0.007	0.7%	93.6%
#20	1.A.4.	Other Sectors	Solid Fuels	CO_2	5,669.44	0.005	0.5%	94.1%
#21	2.C.	Metal Industry	1. Iron and Steel Production	CO_2	4,770.85	0.004	0.4%	94.6%
#22	4.E.	Settlements	2. Land Converted to Settlements	CO_2	4,707.90	0.004	0.4%	95.0%
#23	2.A.	Mineral Industry	2. Lime Production	CO_2	4,372.29	0.004	0.4%	95.4%
	Excluding LULUCF							
#1	1.A.1.	Energy Industries	Solid Fuels	CO_2	249,662.31	0.239	23.86%	23.9%
#2	1.A.3.	Transport	b. Road Transportation	CO_2	160,161.86	0.153	15.31%	39.2%
#3	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	133,668.33	0.128	12.77%	51.9%
#4	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	117,326.61	0.112	11.21%	63.2%
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	62,664.92	0.060	5.99%	69.1%
#6	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	47,143.92	0.045	4.51%	73.6%
#7	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	42,138.55	0.040	4.03%	77.7%
#8	1.A.1.	Energy Industries	Liquid Fuels	CO_2	37,667.65	0.036	3.60%	81.3%
#9	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	29,620.10	0.028	2.83%	84.1%
#10	2.F.	Product Uses as Substitutes for ODS	1. Refrigeration and Air Conditioning Equipment	HFCs	24,427.46	0.023	2.33%	86.4%
#11	2.A.	Mineral Industry	1. Cement Production	CO_2	20,174.91	0.019	1.93%	88.4%
#12	3.C.	Rice Cultivation		CH_4	11,841.15	0.011	1.13%	89.5%
#13	1.A.3.	Transport	a. Domestic Aviation	CO_2	10,302.91	0.010	0.98%	90.5%
#14	1.A.3.	Transport	d. Domestic Navigation	CO_2	9,717.06	0.009	0.93%	91.4%
#15	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	8,552.60	0.008	0.82%	92.2%
#16	5.C.	Incineration and Open Burning of Waste		CO_2	8,467.90	0.008	0.81%	93.0%
#17	3.A.	Enteric Fermentation		CH_4	8,458.65	0.008	0.81%	93.8%
#18	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	7,773.34	0.007	0.74%	94.6%
#19	1.A.4.	Other Sectors	Solid Fuels	CO_2	5,669.44	0.005	0.54%	95.1%

Table A1-6 Results of Approach 2 level assessment (FY2024)

	A Code	B Category		C GHGs	F Current Year Estimate [Gg-CO_2 eq.]	L Source/Sink Uncertainty [%]	N Ap2-L Contrib. [%]	Cumulative contrib. [%]
	Including LULUCF							
#1	1.A.1.	Energy Industries	Solid Fuels	CO_2	249,662.31	6%	19.1%	19.1%
#2	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	133,668.33	6%	10.2%	29.3%
#3	4.A.	Forest Land	1. Forest Land Remaining Forest Land	CO_2	-56,525.64	9%	6.2%	35.5%
#4	3.B.	Manure Management		N_2O	3,066.04	141%	5.4%	40.9%
#5	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O	1,649.37	244%	5.1%	45.9%
#6	1.A.3.	Transport	b. Road Transportation	CO_2	160,161.86	2%	3.5%	49.4%
#7	3.A.	Enteric Fermentation		CH_4	8,458.65	30%	3.2%	52.6%
#8	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	117,326.61	2%	2.8%	55.4%
#9	2.G.	Other Product Manufacture and Use		SF_6	1,437.74	143%	2.6%	58.0%
#10	4.E.	Settlements	2. Land Converted to Settlements	CO_2	4,707.90	43%	2.6%	60.6%
#11	2.F.	Product Uses as Substitutes for ODS	1. Refrigeration and Air Conditioning	HFCs	24,427.46	6%	1.9%	62.4%
#12	3.D.	Agricultural Soils	1. Direct Emissions	N_2O	2,399.59	60%	1.8%	64.2%
#13	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	8,552.60	16%	1.8%	66.0%
#14	5.C.	Incineration and Open Burning of Waste		CO_2	8,467.90	16%	1.7%	67.7%
#15	2.D.	Non-energy Products from Fuels and Solvent Use		CO_2	2,589.23	51%	1.7%	69.3%
#16	2.F.	Product Uses as Substitutes for ODS	2. Foam Blowing Agents	HFCs	2,570.28	50%	1.6%	71.0%
#17	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	7,773.34	16%	1.6%	72.6%
#18	2.B.	Chemical Industry	Other Production Except Ammonia	CO_2	2,206.83	55%	1.5%	74.1%
#19	1.A.3.	Transport	b. Road Transportation	N_2O	1,072.71	107%	1.4%	75.5%
#20	2.E.	Electronics Industry		SF_6	376.51	300%	1.4%	76.9%
#21	1.A.4.	Other Sectors	Liquid Fuels	CO_2	62,664.92	2%	1.4%	78.3%
#22	2.E.	Electronics Industry		PFCs	1,322.04	81%	1.3%	79.6%
#23	4.B.	Cropland	1. Cropland Remaining Cropland	CO_2	4,103.81	25%	1.3%	80.9%
#24	5.C.	Incineration and Open Burning of Waste		N_2O	1,195.61	78%	1.2%	82.1%
#25	2.A.	Mineral Industry	1. Cement Production	CO_2	20,174.91	4%	1.0%	83.2%
#26	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	47,143.92	2%	1.0%	84.2%
#27	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	42,138.55	2%	1.0%	85.2%
#28		Indirect CO_2	from IPPU Sector	Ind CO_2	1,388.00	56%	1.0%	86.2%
#29	3.C.	Rice Cultivation		CH_4	11,841.15	6%	0.9%	87.1%
#30	5.D.	Wastewater Treatment and Discharge		N_2O	1,728.60	42%	0.9%	88.0%
#31	4.(III)	N_2O Emissions from N Mineralization/Immobilization		N_2O	413.55	159%	0.8%	88.8%
#32	1.A.1.	Energy Industries	Liquid Fuels	CO_2	37,667.65	2%	0.8%	89.6%
#33	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	29,620.10	2%	0.7%	90.3%
	Excluding LULUCF							
#1	1.A.1.	Energy Industries	Solid Fuels	CO_2	249,662.31	6%	21.80%	21.8%
#2	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	133,668.33	6%	11.67%	33.5%
#3	3.B.	Manure Management		N_2O	3,066.04	141%	6.20%	39.7%
#4	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O	1,649.37	244%	5.78%	45.5%
#5	1.A.3.	Transport	b. Road Transportation	CO_2	160,161.86	2%	3.99%	49.4%
#6	3.A.	Enteric Fermentation		CH_4	8,458.65	30%	3.63%	53.1%
#7	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	117,326.61	2%	3.24%	56.3%
#8	2.G.	Other Product Manufacture and Use		SF_6	1,437.74	143%	2.96%	59.3%
#9	2.F.	Product Uses as Substitutes for ODS	1. Refrigeration and Air Conditioning Equipment	HFCs	24,427.46	6%	2.13%	61.4%
#10	3.D.	Agricultural Soils	1. Direct Emissions	N_2O	2,399.59	60%	2.05%	63.4%
#11	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	8,552.60	16%	2.02%	65.5%
#12	5.C.	Incineration and Open Burning of Waste		CO_2	8,467.90	16%	1.90%	67.4%
#13	2.D.	Non-energy Products from Fuels and Solvent Use		CO_2	2,589.23	51%	1.90%	69.3%
#14	2.F.	Product Uses as Substitutes for ODS	2. Foam Blowing Agents	HFCs	2,570.28	50%	1.84%	71.1%
#15	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	7,773.34	16%	1.84%	72.9%
#16	2.B.	Chemical Industry	Other Production Except Ammonia	CO_2	2,206.83	55%	1.74%	74.7%
#17	1.A.3.	Transport	b. Road Transportation	N_2O	1,072.71	107%	1.65%	76.3%
#18	2.E.	Electronics Industry		SF_6	376.51	300%	1.62%	78.0%
#19	1.A.4.	Other Sectors	Liquid Fuels	CO_2	62,664.92	2%	1.56%	79.5%
#20	2.E.	Electronics Industry		PFCs	1,322.04	81%	1.53%	81.0%
#21	5.C.	Incineration and Open Burning of Waste		N_2O	1,195.61	78%	1.35%	82.4%
#22	2.A.	Mineral Industry	1. Cement Production	CO_2	20,174.91	4%	1.19%	83.6%
#23	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	47,143.92	2%	1.17%	84.8%
#24	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	42,138.55	2%	1.16%	85.9%
#25		Indirect CO_2	from IPPU Sector	Ind CO_2	1,388.00	56%	1.11%	87.0%
#26	3.C.	Rice Cultivation		CH_4	11,841.15	6%	1.03%	88.1%
#27	5.D.	Wastewater Treatment and Discharge		N_2O	1,728.60	42%	1.03%	89.1%
#28	1.A.1.	Energy Industries	Liquid Fuels	CO_2	37,667.65	2%	0.94%	90.0%

Approach 1 level assessment of emissions and removals in FY1990 gives the following 28 sub-categories as the key categories and that of excluding LULUCF gives the following 24 sub-categories as the key categories (Table A1-7). Approach 2 level assessment of the emissions and removals gives the following 32 sub-categories as the key categories and that of excluding LULUCF gives the following 29 sub-categories as the key categories (Table A1-8).

Table A1-7 Results of Approach 1 level assessment (FY1990)

	A Code	B Category		C GHGs	D FY1990 Estimate [Gg-CO_2 eq.]	H Ap1-L	I Ap1-L Contrib. [%]	Cumulative contrib. [%]
	Including LULUCF							
#1	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	199,517.80	0.143	14.3%	14.3%
#2	1.A.3.	Transport	b. Road Transportation	CO_2	180,367.42	0.129	12.9%	27.2%
#3	1.A.1.	Energy Industries	Liquid Fuels	CO_2	178,585.88	0.128	12.8%	40.1%
#4	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	134,401.55	0.096	9.6%	49.7%
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	128,801.57	0.092	9.2%	58.9%
#6	1.A.1.	Energy Industries	Solid Fuels	CO_2	109,537.93	0.079	7.9%	66.8%
#7	4.A.	Forest Land	1. Forest Land Remaining Forest Land	CO_2	-87,980.64	0.063	6.3%	73.1%
#8	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	80,030.95	0.057	5.7%	78.8%
#9	2.A.	Mineral Industry	1. Cement Production	CO_2	38,701.10	0.028	2.8%	81.6%
#10	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	22,241.56	0.016	1.6%	83.2%
#11	1.A.3.	Transport	d. Domestic Navigation	CO_2	13,674.88	0.010	1.0%	84.2%
#12	3.C.	Rice Cultivation		CH_4	13,584.76	0.010	1.0%	85.2%
#13	2.B.	Chemical Industry	9. Fluorochemical Production	HFCs	13,347.05	0.010	1.0%	86.1%
#14	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	11,894.05	0.009	0.9%	87.0%
#15	4.E.	Settlements	2. Land Converted to Settlements	CO_2	11,261.02	0.008	0.8%	87.8%
#16	5.A.	Solid Waste Disposal		CH_4	11,188.70	0.008	0.8%	88.6%
#17	3.A.	Enteric Fermentation		CH_4	10,553.65	0.008	0.8%	89.3%
#18	5.C.	Incineration and Open Burning of Waste		CO_2	9,949.02	0.007	0.7%	90.0%
#19	4.A.	Forest Land	2. Land Converted to Forest Land	CO_2	-9,576.73	0.007	0.7%	90.7%
#20	2.G.	Other Product Manufacture and Use		SF_6	9,084.65	0.007	0.7%	91.4%
#21	2.C.	Metal Industry	1. Iron and Steel Production	CO_2	7,233.95	0.005	0.5%	91.9%
#22	1.A.3.	Transport	a. Domestic Aviation	CO_2	7,162.41	0.005	0.5%	92.4%
#23	2.A.	Mineral Industry	2. Lime Production	CO_2	6,674.45	0.005	0.5%	92.9%
#24	4.B.	Cropland	1. Cropland Remaining Cropland	CO_2	6,659.68	0.005	0.5%	93.4%
#25	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	6,523.49	0.005	0.5%	93.8%
#26	2.B.	Chemical Industry	3. Adipic Acid Production	N_2O	6,412.36	0.005	0.5%	94.3%
#27	1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	CH_4	5,482.08	0.004	0.4%	94.7%
#28		Indirect CO_2	from IPPU Sector	Ind CO_2	4,479.62	0.003	0.3%	95.0%
	Excluding LULUCF							
#1	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	199,517.80	0.157	15.7%	15.7%
#2	1.A.3.	Transport	b. Road Transportation	CO_2	180,367.42	0.142	14.2%	29.9%
#3	1.A.1.	Energy Industries	Liquid Fuels	CO_2	178,585.88	0.140	14.0%	43.9%
#4	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	134,401.55	0.106	10.6%	54.5%
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	128,801.57	0.101	10.1%	64.6%
#6	1.A.1.	Energy Industries	Solid Fuels	CO_2	109,537.93	0.086	8.6%	73.2%
#7	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	80,030.95	0.063	6.3%	79.5%
#8	2.A.	Mineral Industry	1. Cement Production	CO_2	38,701.10	0.030	3.0%	82.5%
#9	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	22,241.56	0.017	1.7%	84.3%
#10	1.A.3.	Transport	d. Domestic Navigation	CO_2	13,674.88	0.011	1.1%	85.4%
#11	3.C.	Rice Cultivation		CH_4	13,584.76	0.011	1.1%	86.4%
#12	2.B.	Chemical Industry	9. Fluorochemical Production	HFCs	13,347.05	0.010	1.0%	87.5%
#13	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	11,894.05	0.009	0.9%	88.4%
#14	5.A.	Solid Waste Disposal		CH_4	11,188.70	0.009	0.9%	89.3%
#15	3.A.	Enteric Fermentation		CH_4	10,553.65	0.008	0.8%	90.1%
#16	5.C.	Incineration and Open Burning of Waste		CO_2	9,949.02	0.008	0.8%	90.9%
#17	2.G.	Other Product Manufacture and Use		SF_6	9,084.65	0.007	0.7%	91.6%
#18	2.C.	Metal Industry	1. Iron and Steel Production	CO_2	7,233.95	0.006	0.6%	92.2%
#19	1.A.3.	Transport	a. Domestic Aviation	CO_2	7,162.41	0.006	0.6%	92.8%
#20	2.A.	Mineral Industry	2. Lime Production	CO_2	6,674.45	0.005	0.5%	93.3%
#21	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	6,523.49	0.005	0.5%	93.8%
#22	2.B.	Chemical Industry	3. Adipic Acid Production	N_2O	6,412.36	0.005	0.5%	94.3%
#23	1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	CH_4	5,482.08	0.004	0.4%	94.7%
#24		Indirect CO_2	from IPPU Sector	Ind CO_2	4,479.62	0.004	0.4%	95.1%

Table A1-8 Results of Approach 2 level assessment (FY1990)

	A Code	B Category		C GHGs	D FY1990 Estimate [Gg-CO_2 eq.]	L Source/Sink Uncertainty [%]	N Ap2-L Contrib. [%]	Cumulative contrib. [%]
	Including LULUCF							
#1	2.G.	Other Product Manufacture and Use		SF_6	9,084.65	143%	10.9%	10.9%
#2	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	199,517.80	6%	10.2%	21.1%
#3	4.A.	Forest Land	1. Forest Land Remaining Forest Land	CO_2	-87,980.64	9%	6.4%	27.5%
#4	1.A.1.	Energy Industries	Solid Fuels	CO_2	109,537.93	6%	5.6%	33.1%
#5	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O	2,655.41	244%	5.4%	38.5%
#6	3.B.	Manure Management		N_2O	3,865.02	141%	4.6%	43.0%
#7	4.E.	Settlements	2. Land Converted to Settlements	CO_2	11,261.02	43%	4.1%	47.1%
#8	1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	CH_4	5,482.08	84%	3.9%	51.0%
#9	1.A.3.	Transport	b. Road Transportation	N_2O	3,074.39	107%	2.8%	53.8%
#10	3.A.	Enteric Fermentation		CH_4	10,553.65	30%	2.6%	56.4%
#11	1.A.3.	Transport	b. Road Transportation	CO_2	180,367.42	2%	2.6%	59.0%
#12	1.A.1.	Energy Industries	Liquid Fuels	CO_2	178,585.88	2%	2.6%	61.6%
#13	2.E.	Electronics Industry		SF_6	950.73	300%	2.4%	64.0%
#14	5.A.	Solid Waste Disposal		CH_4	11,188.70	24%	2.2%	66.2%
#15		Indirect CO_2	from IPPU Sector	Ind CO_2	4,479.62	56%	2.1%	68.3%
#16	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O	1,487.61	162%	2.0%	70.3%
#17	3.D.	Agricultural Soils	1. Direct Emissions	N_2O	4,002.46	60%	2.0%	72.3%
#18	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	134,401.55	2%	2.0%	74.3%
#19	1.A.4.	Other Sectors	Liquid Fuels	CO_2	128,801.57	2%	1.9%	76.2%
#20	2.B.	Chemical Industry	Other Production Except Ammonia	CO_2	3,601.24	55%	1.7%	77.8%
#21	4.B.	Cropland	1. Cropland Remaining Cropland	CO_2	6,659.68	25%	1.4%	79.2%
#22	2.A.	Mineral Industry	1. Cement Production	CO_2	38,701.10	4%	1.3%	80.6%
#23	5.C.	Incineration and Open Burning of Waste		CO_2	9,949.02	16%	1.3%	81.9%
#24	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	80,030.95	2%	1.3%	83.2%
#25	4.(III)	N_2O Emissions from N Mineralization/Immobilization		N_2O	847.48	159%	1.1%	84.3%
#26	4.F.	Other Land	2. Land Converted to Other Land	CO_2	2,247.47	53%	1.0%	85.3%
#27	2.D.	Non-energy Products from Fuels and Solvent Use		CO_2	2,229.39	51%	1.0%	86.2%
#28	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	6,523.49	16%	0.9%	87.1%
#29	2.E.	Electronics Industry		PFCs	1,314.38	81%	0.9%	88.0%
#30	5.C.	Incineration and Open Burning of Waste		N_2O	1,274.33	78%	0.8%	88.9%
#31	5.D.	Wastewater Treatment and Discharge		N_2O	2,122.77	42%	0.7%	89.6%
#32	4.A.	Forest Land	2. Land Converted to Forest Land	CO_2	-9,576.73	9%	0.7%	90.3%
	Excluding LULUCF							
#1	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	199,517.80	5%	12.1%	12.1%
#2	2.G.	Other Product Manufacture and Use		SF_6	9,084.65	83%	9.0%	21.1%
#3	1.A.1.	Energy Industries	Solid Fuels	CO_2	109,537.93	5%	6.7%	27.8%
#4	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O	2,655.41	164%	5.2%	33.0%
#5	3.B.	Manure Management		N_2O	3,865.02	94%	4.3%	37.3%
#6	1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	CH_4	5,482.08	63%	4.1%	41.4%
#7	1.A.3.	Transport	b. Road Transportation	CO_2	180,367.42	2%	3.5%	44.9%
#8	1.A.1.	Energy Industries	Liquid Fuels	CO_2	178,585.88	2%	3.5%	48.4%
#9	2.E.	Electronics Industry		SF_6	950.73	300%	3.4%	51.8%
#10	3.A.	Enteric Fermentation		CH_4	10,553.65	27%	3.4%	55.2%
#11	5.A.	Solid Waste Disposal		CH_4	11,188.70	24%	3.2%	58.4%
#12	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O	1,487.61	162%	2.9%	61.3%
#13	1.A.3.	Transport	b. Road Transportation	N_2O	3,074.39	72%	2.6%	63.9%
#14	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	134,401.55	2%	2.6%	66.5%
#15	1.A.4.	Other Sectors	Liquid Fuels	CO_2	128,801.57	2%	2.5%	69.0%
#16	2.B.	Chemical Industry	Other Production Except Ammonia	CO_2	3,601.24	55%	2.4%	71.4%
#17	3.D.	Agricultural Soils	1. Direct Emissions	N_2O	4,002.46	50%	2.4%	73.7%
#18		Indirect CO_2	from IPPU Sector	Ind CO_2	4,479.62	43%	2.3%	76.1%
#19	2.A.	Mineral Industry	1. Cement Production	CO_2	38,701.10	4%	1.9%	78.0%
#20	5.C.	Incineration and Open Burning of Waste		CO_2	9,949.02	16%	1.9%	79.8%
#21	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	80,030.95	2%	1.8%	81.6%
#22	2.D.	Non-energy Products from Fuels and Solvent Use		CO_2	2,229.39	51%	1.4%	83.0%
#23	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	6,523.49	16%	1.3%	84.3%
#24	2.E.	Electronics Industry		PFCs	1,314.38	81%	1.3%	85.6%
#25	5.C.	Incineration and Open Burning of Waste		N_2O	1,274.33	78%	1.2%	86.8%
#26	3.C.	Rice Cultivation		CH_4	13,584.76	6%	1.0%	87.8%
#27	5.D.	Wastewater Treatment and Discharge		N_2O	2,122.77	38%	1.0%	88.7%
#28	2.B.	Chemical Industry	2. Nitric Acid Production	N_2O	654.55	112%	0.9%	89.6%
#29	5.D.	Wastewater Treatment and Discharge		CH_4	3,294.53	21%	0.8%	90.4%

A1.2.3 Trend Assessment

The difference between the rate of change in emissions and removals in a category and the rate of change in total or net emissions is calculated. The trend assessment is calculated by multiplying this value by the ratio of contribution of the relevant category to total or net emissions. The calculated results, regarded as trend assessment values, are added from the category whose proportion to the total of trend assessment values is the largest, until the total reaches 95% for Approach 1 and 90% for Approach 2. At this point, these categories are defined as the key categories. Approach 1 trend assessment uses emissions and removals from each category directly and Approach 2 trend assessment analyzes the emissions and removals of each category, multiplied by the uncertainty of each category.

Approach 1 trend assessment of emissions and removals in FY2024 gives the following 24 sub-categories as the key categories and that of excluding LULUCF gives the following 20 sub-categories as the key categories (Table A1-9). Approach 2 trend assessment of the emissions and removals gives the following 29 sub-categories as the key categories and that of excluding LULUCF gives the following 24 sub-categories as the key categories (Table A1-10).

Table A1-9 Results of Approach 1 trend assessment (FY2024)

	A Code	B Category		C GHGs	D FY1990 Estimate [Gg-CO_2 eq.]	F Current Year Estimate [Gg-CO_2 eq.]	J Ap1-T	K Ap1-T Contrib. [%]	Cumulative contrib. [%]
	Including LULUCF								
#1	1.A.1.	Energy Industries	Solid Fuels	CO_2	109537.93	249662.31	0.114	22.5%	22.5%
#2	1.A.1.	Energy Industries	Liquid Fuels	CO_2	178585.88	37667.65	0.080	15.8%	38.4%
#3	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	134401.55	47143.92	0.047	9.2%	47.6%
#4	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	80030.95	117326.61	0.036	7.2%	54.8%
#5	4.A.	Forest Land	1. Forest Land Remaining Forest Land	CO_2	-87980.64	-56525.64	0.033	6.6%	61.4%
#6	1.A.4.	Other Sectors	Liquid Fuels	CO_2	128801.57	62664.92	0.032	6.4%	67.7%
#7	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	199517.80	133668.33	0.023	4.7%	72.4%
#8	2.F.	Product Uses as Substitutes for ODS	1. Refrigeration and Air Conditioning Equipment	HFCs	NO	24427.46	0.018	3.5%	75.9%
#9	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	22241.56	42138.55	0.017	3.4%	79.2%
#10	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	11894.05	29620.10	0.014	2.8%	82.0%
#11	2.A.	Mineral Industry	1. Cement Production	CO_2	38701.10	20174.91	0.009	1.7%	83.7%
#12	2.B.	Chemical Industry	9. Fluorochemical Production	HFCs	13347.05	63.65	0.008	1.6%	85.3%
#13	4.A.	Forest Land	2. Land Converted to Forest Land	CO_2	-9576.73	-499.41	0.008	1.5%	86.8%
#14	1.A.3.	Transport	b. Road Transportation	CO_2	180367.42	160161.86	0.007	1.4%	88.2%
#15	5.A.	Solid Waste Disposal		CH_4	11188.70	1447.14	0.006	1.1%	89.3%
#16	2.G.	Other Product Manufacture and Use		SF_6	9084.65	1437.74	0.004	0.9%	90.2%
#17	1.A.4.	Other Sectors	Solid Fuels	CO_2	353.86	5669.44	0.004	0.8%	91.0%
#18	2.B.	Chemical Industry	3. Adipic Acid Production	N_2O	6412.36	17.42	0.004	0.8%	91.7%
#19	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	3459.35	7773.34	0.004	0.7%	92.4%
#20	4.E.	Settlements	2. Land Converted to Settlements	CO_2	11261.02	4707.90	0.003	0.7%	93.1%
#21	1.A.3.	Transport	a. Domestic Aviation	CO_2	7162.41	10302.91	0.003	0.6%	93.7%
#22	1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	CH_4	5482.08	486.37	0.003	0.6%	94.3%
#23	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	6523.49	8552.60	0.002	0.4%	94.7%
#24	2.B.	Chemical Industry	9. Fluorochemical Production	SF_6	3577.34	41.45	0.002	0.4%	95.2%
	Excluding LULUCF								
#1	1.A.1.	Energy Industries	Solid Fuels	CO_2	109,537.93	249,662.31	0.125	25.3%	25.3%
#2	1.A.1.	Energy Industries	Liquid Fuels	CO_2	178,585.88	37,667.65	0.086	17.3%	42.6%
#3	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	134,401.55	47,143.92	0.050	10.0%	52.6%
#4	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	80,030.95	117,326.61	0.040	8.2%	60.8%
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	128,801.57	62,664.92	0.034	6.9%	67.6%
#6	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	199,517.80	133,668.33	0.024	4.8%	72.4%
#7	2.F.	Product Uses as Substitutes for ODS	1. Refrigeration and Air Conditioning Equipment	HFCs	NO	24,427.46	0.019	3.9%	76.3%
#8	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	22,241.56	42,138.55	0.019	3.8%	80.1%
#9	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	11,894.05	29,620.10	0.016	3.1%	83.2%
#10	1.A.3.	Transport	b. Road Transportation	CO_2	180,367.42	160,161.86	0.009	1.9%	85.1%
#11	2.A.	Mineral Industry	1. Cement Production	CO_2	38,701.10	20,174.91	0.009	1.8%	86.9%
#12	2.B.	Chemical Industry	9. Fluorochemical Production	HFCs	13,347.05	63.65	0.009	1.7%	88.7%
#13	5.A.	Solid Waste Disposal		CH_4	11,188.70	1,447.14	0.006	1.2%	89.9%
#14	2.G.	Other Product Manufacture and Use		SF_6	9,084.65	1,437.74	0.005	1.0%	90.8%
#15	1.A.4.	Other Sectors	Solid Fuels	CO_2	353.86	5,669.44	0.004	0.9%	91.7%
#16	2.B.	Chemical Industry	3. Adipic Acid Production	N_2O	6,412.36	17.42	0.004	0.8%	92.5%
#17	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	3,459.35	7,773.34	0.004	0.8%	93.3%
#18	1.A.3.	Transport	a. Domestic Aviation	CO_2	7,162.41	10,302.91	0.003	0.7%	94.0%
#19	1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	CH_4	5,482.08	486.37	0.003	0.6%	94.6%
#20	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	6,523.49	8,552.60	0.003	0.5%	95.1%

Table A1-10 Results of Approach 2 trend assessment (FY2024)

	A Code	B Category		C GHGs	D FY1990 Estimate [Gg-CO_2 eq.]	F Current Year Estimate [Gg-CO_2 eq.]	L Source/Sink Uncertainty [%]	O Ap2-T	P Ap2-T Contrib. [%]	Cumulative contrib. [%]
	Including LULUCF									
#1	1.A.1.	Energy Industries	Solid Fuels	CO_2	109,537.93	249,662.31	6%	6.91	16.3%	16.3%
#2	2.G.	Other Product Manufacture and Use		SF_6	9,084.65	1,437.74	143%	6.31	14.9%	31.3%
#3	4.A.	Forest Land	1. Forest Land Remaining Forest Land	CO_2	-87,980.64	-56,525.64	9%	2.88	6.8%	38.1%
#4	1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	CH_4	5,482.08	486.37	84%	2.48	5.9%	43.9%
#5	4.E.	Settlements	2. Land Converted to Settlements	CO_2	11,261.02	4,707.90	43%	1.45	3.4%	47.4%
#6	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	199,517.80	133,668.33	6%	1.43	3.4%	50.7%
#7	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O	1,487.61	17.05	162%	1.42	3.4%	54.1%
#8	1.A.1.	Energy Industries	Liquid Fuels	CO_2	178,585.88	37,667.65	2%	1.39	3.3%	57.4%
#9	5.A.	Solid Waste Disposal		CH_4	11,188.70	1,447.14	24%	1.35	3.2%	60.6%
#10	1.A.3.	Transport	b. Road Transportation	N_2O	3,074.39	1,072.71	107%	1.14	2.7%	63.3%
#11	2.F.	Product Uses as Substitutes for ODS	1. Refrigeration and Air Conditioning Equipment	HFCs	NO	24,427.46	6%	1.06	2.5%	65.8%
#12	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O	2,655.41	1,649.37	244%	0.99	2.3%	68.1%
#13		Indirect CO_2	from IPPU Sector	Ind CO_2	4,479.62	1,388.00	56%	0.94	2.2%	70.3%
#14	2.F.	Product Uses as Substitutes for ODS	2. Foam Blowing Agents	HFCs	1.22	2,570.28	50%	0.92	2.2%	72.5%
#15	2.E.	Electronics Industry		SF_6	950.73	376.51	300%	0.90	2.1%	74.6%
#16	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	134,401.55	47,143.92	2%	0.81	1.9%	76.5%
#17	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	80,030.95	117,326.61	2%	0.70	1.6%	78.2%
#18	4.A.	Forest Land	2. Land Converted to Forest Land	CO_2	-9,576.73	-499.41	9%	0.67	1.6%	79.8%
#19	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	3,459.35	7,773.34	16%	0.58	1.4%	81.1%
#20	1.A.4.	Other Sectors	Liquid Fuels	CO_2	128,801.57	62,664.92	2%	0.56	1.3%	82.5%
#21	4.F.	Other Land	2. Land Converted to Other Land	CO_2	2,247.47	646.39	53%	0.47	1.1%	83.6%
#22	3.D.	Agricultural Soils	1. Direct Emissions	N_2O	4,002.46	2,399.59	60%	0.40	0.9%	84.5%
#23	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	6,523.49	8,552.60	16%	0.37	0.9%	85.4%
#24	2.A.	Mineral Industry	1. Cement Production	CO_2	38,701.10	20,174.91	4%	0.36	0.8%	86.2%
#25	2.B.	Chemical Industry	3. Adipic Acid Production	N_2O	6,412.36	17.42	9%	0.35	0.8%	87.1%
#26	4.(III)	N_2O Emissions from N Mineralization/Immobilization		N_2O	847.48	413.55	159%	0.33	0.8%	87.9%
#27	2.B.	Chemical Industry	2. Nitric Acid Production	N_2O	654.55	129.89	112%	0.33	0.8%	88.6%
#28	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	22,241.56	42,138.55	2%	0.33	0.8%	89.4%
#29	2.B.	Chemical Industry	Other Production Except Ammonia	CO_2	3,601.24	2,206.83	55%	0.31	0.7%	90.2%
	Excluding LULUCF									
#1	1.A.1.	Energy Industries	Solid Fuels	CO_2	109,537.93	249,662.31	6%	7.64	19.7%	19.7%
#2	2.G.	Other Product Manufacture and Use		SF_6	9,084.65	1,437.74	143%	6.80	17.6%	37.3%
#3	1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	CH_4	5,482.08	486.37	84%	2.67	6.9%	44.2%
#4	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O	1,487.61	17.05	162%	1.54	4.0%	48.2%
#5	1.A.1.	Energy Industries	Liquid Fuels	CO_2	178,585.88	37,667.65	2%	1.49	3.9%	52.0%
#6	5.A.	Solid Waste Disposal		CH_4	11,188.70	1,447.14	24%	1.46	3.8%	55.8%
#7	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	199,517.80	133,668.33	6%	1.46	3.8%	59.5%
#8	1.A.3.	Transport	b. Road Transportation	N_2O	3,074.39	1,072.71	107%	1.22	3.2%	62.7%
#9	2.F.	Product Uses as Substitutes for ODS	1. Refrigeration and Air Conditioning Equipment	HFCs	NO	24,427.46	6%	1.16	3.0%	65.7%
#10	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O	2,655.41	1,649.37	244%	1.03	2.7%	68.4%
#11	2.F.	Product Uses as Substitutes for ODS	2. Foam Blowing Agents	HFCs	1.22	2,570.28	50%	1.01	2.6%	71.0%
#12		Indirect CO_2	from IPPU Sector	Ind CO_2	4,479.62	1,388.00	56%	1.01	2.6%	73.6%
#13	2.E.	Electronics Industry		SF_6	950.73	376.51	300%	0.96	2.5%	76.0%
#14	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	134,401.55	47,143.92	2%	0.87	2.2%	78.3%
#15	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	80,030.95	117,326.61	2%	0.78	2.0%	80.3%
#16	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	3,459.35	7,773.34	16%	0.64	1.6%	81.9%
#17	1.A.4.	Other Sectors	Liquid Fuels	CO_2	128,801.57	62,664.92	2%	0.59	1.5%	83.5%
#18	3.D.	Agricultural Soils	1. Direct Emissions	N_2O	4,002.46	2,399.59	60%	0.42	1.1%	84.6%
#19	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	6,523.49	8,552.60	16%	0.41	1.1%	85.6%
#20	2.B.	Chemical Industry	3. Adipic Acid Production	N_2O	6,412.36	17.42	9%	0.38	1.0%	86.6%
#21	2.A.	Mineral Industry	1. Cement Production	CO_2	38,701.10	20,174.91	4%	0.38	1.0%	87.6%
#22	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	22,241.56	42,138.55	2%	0.36	0.9%	88.5%
#23	2.B.	Chemical Industry	2. Nitric Acid Production	N_2O	654.55	129.89	112%	0.36	0.9%	89.4%
#24	2.B.	Chemical Industry	Other Production Except Ammonia	CO_2	3,601.24	2,206.83	55%	0.33	0.8%	90.3%

A1.2.4 Data Utilized for the Key Category Analysis

Data utilized for the key category analysis are shown in Table A1-11 and Table A1-12 as references.

Table A1-11 Data used for the key category analysis (FY2024)

A Code	B Category		C GHGs	E Absolute Value of FY1990 Estimate [Gg-CO_2 eq.]	G Absolute Value of Current Year Estimate [Gg-CO_2 eq.]	H Ap1-L	I Ap1-L Contrib. [%]	J Ap1-T	K Ap1-T Contrib. [%]	L Source/Sink Uncertainty [%]	M Ap2-L	N Ap2-L Contrib. [%]	O Ap2-T	P Ap2-T Contrib. [%]
1.A.1.	Energy Industries	Liquid Fuels	CO_2	178,585.88	37,667.65	0.034	3.4%	0.0798	15.8%	2%	0.008	0.8%	1.39	3.3%
1.A.1.	Energy Industries	Solid Fuels	CO_2	109,537.93	249,662.31	0.223	22.3%	0.1135	22.5%	6%	0.191	19.1%	6.91	16.3%
1.A.1.	Energy Industries	Gaseous Fuels	CO_2	80,030.95	117,326.61	0.105	10.5%	0.0363	7.2%	2%	0.028	2.8%	0.70	1.6%
1.A.1.	Energy Industries	Other Fossil Fuels	CO_2	0.00	96.29	0.000	0.0%	0.0001	0.0%	16%	0.000	0.0%	0.01	0.0%
1.A.1.	Energy Industries		CH_4	514.47	195.56	0.000	0.0%	0.0002	0.0%	62%	0.002	0.2%	0.10	0.2%
1.A.1.	Energy Industries		N_2O	790.98	1,409.40	0.001	0.1%	0.0005	0.1%	30%	0.005	0.5%	0.16	0.4%
1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	134,401.55	47,143.92	0.042	4.2%	0.0466	9.2%	2%	0.010	1.0%	0.81	1.9%
1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	199,517.80	133,668.33	0.120	12.0%	0.0235	4.7%	6%	0.102	10.2%	1.43	3.4%
1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	11,894.05	29,620.10	0.027	2.7%	0.0141	2.8%	2%	0.007	0.7%	0.27	0.6%
1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	3,459.35	7,773.34	0.007	0.7%	0.0035	0.7%	16%	0.016	1.6%	0.58	1.4%
1.A.2.	Manufacturing Industries and Construction		CH_4	403.48	524.34	0.000	0.0%	0.0001	0.0%	62%	0.004	0.4%	0.08	0.2%
1.A.2.	Manufacturing Industries and Construction		N_2O	1,121.33	1,052.52	0.001	0.1%	0.0001	0.0%	30%	0.004	0.4%	0.03	0.1%
1.A.3.	Transport	a. Domestic Aviation	CO_2	7,162.41	10,302.91	0.009	0.9%	0.0031	0.6%	2%	0.002	0.2%	0.05	0.1%
1.A.3.	Transport	a. Domestic Aviation	CH_4	6.31	1.69	0.000	0.0%	0.0000	0.0%	52%	0.000	0.0%	0.00	0.0%
1.A.3.	Transport	a. Domestic Aviation	N_2O	56.93	79.22	0.000	0.0%	0.0000	0.0%	141%	0.001	0.1%	0.03	0.1%
1.A.3.	Transport	b. Road Transportation	CO_2	180,367.42	160,161.86	0.143	14.3%	0.0070	1.4%	2%	0.035	3.5%	0.12	0.3%
1.A.3.	Transport	b. Road Transportation	CH_4	282.90	87.86	0.000	0.0%	0.0001	0.0%	104%	0.001	0.1%	0.11	0.3%
1.A.3.	Transport	b. Road Transportation	N_2O	3,074.39	1,072.71	0.001	0.1%	0.0011	0.2%	107%	0.014	1.4%	1.14	2.7%
1.A.3.	Transport	c. Railways	CO_2	935.40	448.59	0.000	0.0%	0.0002	0.0%	2%	0.000	0.0%	0.00	0.0%
1.A.3.	Transport	c. Railways	CH_4	1.50	0.71	0.000	0.0%	0.0000	0.0%	151%	0.000	0.0%	0.00	0.0%
1.A.3.	Transport	c. Railways	N_2O	97.77	46.19	0.000	0.0%	0.0000	0.0%	200%	0.001	0.1%	0.05	0.1%
1.A.3.	Transport	d. Domestic Navigation	CO_2	13,674.88	9,717.06	0.009	0.9%	0.0012	0.2%	2%	0.002	0.2%	0.02	0.0%
1.A.3.	Transport	d. Domestic Navigation	CH_4	7.11	4.93	0.000	0.0%	0.0000	0.0%	52%	0.000	0.0%	0.00	0.0%
1.A.3.	Transport	d. Domestic Navigation	N_2O	192.20	133.30	0.000	0.0%	0.0000	0.0%	141%	0.002	0.2%	0.03	0.1%
1.A.4.	Other Sectors	Liquid Fuels	CO_2	128,801.57	62,664.92	0.056	5.6%	0.0321	6.4%	2%	0.014	1.4%	0.56	1.3%
1.A.4.	Other Sectors	Solid Fuels	CO_2	353.86	5,669.44	0.005	0.5%	0.0039	0.8%	6%	0.004	0.4%	0.23	0.6%
1.A.4.	Other Sectors	Gaseous Fuels	CO_2	22,241.56	42,138.55	0.038	3.8%	0.0169	3.4%	2%	0.010	1.0%	0.33	0.8%
1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	6,523.49	8,552.60	0.008	0.8%	0.0022	0.4%	16%	0.018	1.8%	0.37	0.9%
1.A.4.	Other Sectors		CH_4	266.46	217.73	0.000	0.0%	0.0000	0.0%	62%	0.002	0.2%	0.00	0.0%
1.A.4.	Other Sectors		N_2O	613.08	423.97	0.000	0.0%	0.0001	0.0%	30%	0.002	0.2%	0.02	0.0%
1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	CO_2	5.90	0.39	0.000	0.0%	0.0000	0.0%	22%	0.000	0.0%	0.00	0.0%
1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	CH_4	5,482.08	486.37	0.000	0.0%	0.0029	0.6%	84%	0.005	0.5%	2.48	5.9%
1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	N_2O	1.76	0.35	0.000	0.0%	0.0000	0.0%	163%	0.000	0.0%	0.00	0.0%
1.B.	Fugitive Emissions from Fuels	2.a. Oil	CO_2	0.00	0.00	0.000	0.0%	0.0000	0.0%	87%	0.000	0.0%	0.00	0.0%
1.B.	Fugitive Emissions from Fuels	2.a. Oil	CH_4	20.25	12.41	0.000	0.0%	0.0000	0.0%	79%	0.000	0.0%	0.00	0.0%
1.B.	Fugitive Emissions from Fuels	2.b. Natural Gas	CO_2	0.73	0.77	0.000	0.0%	0.0000	0.0%	16%	0.000	0.0%	0.00	0.0%
1.B.	Fugitive Emissions from Fuels	2.b. Natural Gas	CH_4	215.88	216.86	0.000	0.0%	0.0000	0.0%	28%	0.001	0.1%	0.01	0.0%
1.B.	Fugitive Emissions from Fuels	2.c. Venting & Flaring	CO_2	91.68	127.57	0.000	0.0%	0.0000	0.0%	13%	0.000	0.0%	0.00	0.0%
1.B.	Fugitive Emissions from Fuels	2.c. Venting & Flaring	CH_4	184.76	154.96	0.000	0.0%	0.0000	0.0%	11%	0.000	0.0%	0.00	0.0%
1.B.	Fugitive Emissions from Fuels	2.c. Venting & Flaring	N_2O	0.13	0.09	0.000	0.0%	0.0000	0.0%	378%	0.000	0.0%	0.00	0.0%
1.B.	Fugitive Emissions from Fuels	2.d. Other (Geothermal)	CO_2	104.42	191.86	0.000	0.0%	0.0001	0.0%	17%	0.000	0.0%	0.01	0.0%
1.B.	Fugitive Emissions from Fuels	2.d. Other (Geothermal)	CH_4	5.84	10.68	0.000	0.0%	0.0000	0.0%	17%	0.000	0.0%	0.00	0.0%
2.A.	Mineral Industry	1. Cement Production	CO_2	38,701.10	20,174.91	0.018	1.8%	0.0087	1.7%	4%	0.010	1.0%	0.36	0.8%
2.A.	Mineral Industry	2. Lime Production	CO_2	6,674.45	4,372.29	0.004	0.4%	0.0009	0.2%	4%	0.002	0.2%	0.03	0.1%
2.A.	Mineral Industry	3. Glass Production	CO_2	312.93	156.02	0.000	0.0%	0.0001	0.0%	6%	0.000	0.0%	0.00	0.0%
2.A.	Mineral Industry	4. Other Process Uses of Carbonates	CO_2	3,025.31	1,463.98	0.001	0.1%	0.0008	0.2%	6%	0.001	0.1%	0.04	0.1%
2.B.	Chemical Industry	1. Ammonia Production	CO_2	2,445.29	649.41	0.001	0.1%	0.0010	0.2%	2%	0.000	0.0%	0.02	0.1%
2.B.	Chemical Industry	Other Production Except Ammonia	CO_2	3,601.24	2,206.83	0.002	0.2%	0.0006	0.1%	55%	0.015	1.5%	0.31	0.7%
2.B.	Chemical Industry	2. Nitric Acid Production	N_2O	654.55	129.89	0.000	0.0%	0.0003	0.1%	112%	0.002	0.2%	0.33	0.8%
2.B.	Chemical Industry	3. Adipic Acid Production	N_2O	6,412.36	17.42	0.000	0.0%	0.0038	0.8%	9%	0.000	0.0%	0.35	0.8%
2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid	N_2O	1,487.61	17.05	0.000	0.0%	0.0009	0.2%	162%	0.000	0.0%	1.42	3.4%
2.B.	Chemical Industry	9. Fluorochemical Production	HFCs	13,347.05	63.65	0.000	0.0%	0.0079	1.6%	2%	0.000	0.0%	0.16	0.4%
2.B.	Chemical Industry	9. Fluorochemical Production	PFCs	303.84	32.14	0.000	0.0%	0.0002	0.0%	2%	0.000	0.0%	0.00	0.0%
2.B.	Chemical Industry	9. Fluorochemical Production	SF_6	3,577.34	41.45	0.000	0.0%	0.0021	0.4%	2%	0.000	0.0%	0.04	0.1%
2.B.	Chemical Industry	9. Fluorochemical Production	NF_3	2.61	12.17	0.000	0.0%	0.0000	0.0%	47%	0.000	0.0%	0.00	0.0%
2.B.	Chemical Industry	Whole of Chemical Industries	CH_4	41.99	12.80	0.000	0.0%	0.0000	0.0%	58%	0.000	0.0%	0.01	0.0%
2.C.	Metal Industry	1. Iron and Steel Production	CO_2	7,233.95	4,770.85	0.004	0.4%	0.0009	0.2%	4%	0.002	0.2%	0.03	0.1%
2.C.	Metal Industry	1. Iron and Steel Production	CH_4	20.63	13.61	0.000	0.0%	0.0000	0.0%	163%	0.000	0.0%	0.00	0.0%
2.C.	Metal Industry	2. Ferroalloys Production	CH_4	5.18	1.32	0.000	0.0%	0.0000	0.0%	163%	0.000	0.0%	0.00	0.0%
2.C.	Metal Industry	3. Aluminium Production	CO_2	57.97	0.00	0.000	0.0%	0.0000	0.0%	10%	0.000	0.0%	0.00	0.0%
2.C.	Metal Industry	3. Aluminium Production	PFCs	301.48	0.00	0.000	0.0%	0.0000	0.0%	5%	0.000	0.0%	0.00	0.0%
2.C.	Metal Industry	4. Magnesium Production	HFCs	0.00	0.98	0.000	0.0%	0.0000	0.0%	5%	0.000	0.0%	0.00	0.0%
2.C.	Metal Industry	4. Magnesium Production	SF_6	151.04	150.85	0.000	0.0%	0.0000	0.0%	100%	0.002	0.2%	0.02	0.0%
2.D.	Non-energy Products from Fuels and Solvent Use		CO_2	2,229.39	2,589.23	0.002	0.2%	0.0005	0.1%	51%	0.017	1.7%	0.27	0.6%
2.E.	Electronics Industry		N_2O	3.39	56.10	0.000	0.0%	0.0000	0.0%	5%	0.000	0.0%	0.00	0.0%
2.E.	Electronics Industry		HFCs	55.22	64.64	0.000	0.0%	0.0000	0.0%	100%	0.001	0.1%	0.01	0.0%
2.E.	Electronics Industry		PFCs	1,314.38	1,322.04	0.001	0.1%	0.0002	0.0%	81%	0.013	1.3%	0.13	0.3%
2.E.	Electronics Industry		SF_6	950.73	376.51	0.000	0.0%	0.0003	0.1%	300%	0.014	1.4%	0.90	2.1%
2.E.	Electronics Industry		NF_3	25.36	167.48	0.000	0.0%	0.0001	0.0%	71%	0.001	0.1%	0.07	0.2%
2.F.	Product Uses as Substitutes for ODS	1. Refrigeration and Air Conditioning Equipment	HFCs	0.00	24,427.46	0.022	2.2%	0.0175	3.5%	6%	0.019	1.9%	1.06	2.5%
2.F.	Product Uses as Substitutes for ODS	2. Foam Blowing Agents	HFCs	1.22	2,570.28	0.002	0.2%	0.0018	0.4%	50%	0.016	1.6%	0.92	2.2%
2.F.	Product Uses as Substitutes for ODS	3. Fire Protection	HFCs	0.00	9.44	0.000	0.0%	0.0000	0.0%	16%	0.000	0.0%	0.00	0.0%
2.F.	Product Uses as Substitutes for ODS	4. Aerosols	HFCs	0.00	309.98	0.000	0.0%	0.0002	0.0%	10%	0.000	0.0%	0.02	0.1%
2.F.	Product Uses as Substitutes for ODS	5. Solvents	HFCs	0.00	125.24	0.000	0.0%	0.0001	0.0%	11%	0.000	0.0%	0.01	0.0%
2.F.	Product Uses as Substitutes for ODS	5. Solvents	PFCs	4,228.36	1,072.32	0.001	0.1%	0.0018	0.3%	10%	0.001	0.1%	0.18	0.4%
2.G.	Other Product Manufacture and Use		N_2O	245.40	93.69	0.000	0.0%	0.0001	0.0%	5%	0.000	0.0%	0.00	0.0%
2.G.	Other Product Manufacture and Use		HFCs	6.46	5.34	0.000	0.0%	0.0000	0.0%	200%	0.000	0.0%	0.00	0.0%
2.G.	Other Product Manufacture and Use		PFCs	14.62	54.82	0.000	0.0%	0.0000	0.0%	35%	0.000	0.0%	0.01	0.0%
2.G.	Other Product Manufacture and Use		SF_6	9,084.65	1,437.74	0.001	0.1%	0.0044	0.9%	143%	0.026	2.6%	6.31	14.9%
2.H.	Other		CO_2	880.34	921.22	0.001	0.1%	0.0001	0.0%	2%	0.000	0.0%	0.00	0.0%
3.A.	Enteric Fermentation		CH_4	10,553.65	8,458.65	0.008	0.8%	0.0002	0.0%	30%	0.032	3.2%	0.07	0.2%
3.B.	Manure Management		CH_4	3,786.09	2,476.74	0.002	0.2%	0.0005	0.1%	16%	0.005	0.5%	0.08	0.2%
3.B.	Manure Management		N_2O	3,865.02	3,066.04	0.003	0.3%	0.0001	0.0%	141%	0.054	5.4%	0.16	0.4%
3.C.	Rice Cultivation		CH_4	13,584.76	11,841.15	0.011	1.1%	0.0004	0.1%	6%	0.009	0.9%	0.02	0.1%
3.D.	Agricultural Soils	1. Direct Emissions	N_2O	4,002.46	2,399.59	0.002	0.2%	0.0007	0.1%	60%	0.018	1.8%	0.40	0.9%
3.D.	Agricultural Soils	2. Indirect Emissions	N_2O	2,655.41	1,649.37	0.001	0.1%	0.0004	0.1%	244%	0.051	5.1%	0.99	2.3%
3.F.	Field Burning of Agricultural Residues		CH_4	77.94	26.06	0.000	0.0%	0.0000	0.0%	296%	0.001	0.1%	0.08	0.2%
3.F.	Field Burning of Agricultural Residues		N_2O	22.74	7.16	0.000	0.0%	0.0000	0.0%	300%	0.000	0.0%	0.03	0.1%
3.G.	Liming		CO_2	550.24	205.00	0.000	0.0%	0.0002	0.0%	50%	0.001	0.1%	0.09	0.2%
3.H.	Urea Application		CO_2	181.77	148.30	0.000	0.0%	0.0000	0.0%	50%	0.001	0.1%	0.00	0.0%
4.A.	Forest Land	1. Forest Land Remaining Forest Land	CO_2	87,980.64	56,525.64	0.051	5.1%	0.0330	6.6%	9%	0.062	6.2%	2.88	6.8%
4.A.	Forest Land	2. Land Converted to Forest Land	CO_2	9,576.73	499.41	0.000	0.0%	0.0076	1.5%	9%	0.001	0.1%	0.67	1.6%
4.B.	Cropland	1. Cropland Remaining Cropland	CO_2	6,659.68	4,103.81	0.004	0.4%	0.0010	0.2%	25%	0.013	1.3%	0.26	0.6%
4.B.	Cropland	2. Land Converted to Cropland	CO_2	626.33	137.15	0.000	0.0%	0.0003	0.1%	12%	0.000	0.0%	0.03	0.1%
4.C.	Grassland	1. Grassland Remaining Grassland	CO_2	539.00	517.29	0.000	0.0%	0.0000	0.0%	10%	0.001	0.1%	0.00	0.0%
4.C.	Grassland	2. Land Converted to Grassland	CO_2	455.65	60.10	0.000	0.0%	0.0002	0.0%	21%	0.000	0.0%	0.05	0.1%
4.D.	Wetlands	1. Wetlands Remaining Wetlands	CO_2	520.71	323.07	0.000	0.0%	0.0002	0.0%	19%	0.001	0.1%	0.04	0.1%
4.D.	Wetlands	2. Land Converted to Wetlands	CO_2	70.36	6.00	0.000	0.0%	0.0000	0.0%	23%	0.000	0.0%	0.01	0.0%
4.E.	Settlements	1. Settlements Remaining Settlements	CO_2	1,013.18	1,399.88	0.001	0.1%	0.0002	0.0%	15%	0.003	0.3%	0.02	0.1%
4.E.	Settlements	2. Land Converted to Settlements	CO_2	11,261.02	4,707.90	0.004	0.4%	0.0034	0.7%	43%	0.026	2.6%	1.45	3.4%
4.F.	Other Land	2. Land Converted to Other Land	CO_2	2,247.47	646.39	0.001	0.1%	0.0009	0.2%	53%	0.004	0.4%	0.47	1.1%
4.G.	Harvested Wood Products		CO_2	404.48	1,546.37	0.001	0.1%	0.0008	0.2%	30%	0.006	0.6%	0.23	0.5%
4.H.	Other		CO_2	0.00	0.10	0.000	0.0%	0.0000	0.0%	6%	0.000	0.0%	0.00	0.0%

Table A1-11 Data used for the key category analysis (FY2024) (Continued)

A Code	B Category		C GHGs	E Absolute Value of FY1990 Estimate [Gg-CO_2 eq.]	G Absolute Value of Current Year Estimate [Gg-CO_2 eq.]	H Ap1-L	I Ap1-L Contrib. [%]	J Ap1-T	K Ap1-T Contrib. [%]	L Source/Sink Uncertainty [%]	M Ap2-L	N Ap2-L Contrib. [%]	O Ap2-T	P Ap2-T Contrib. [%]
4.(I)	N_2O Emissions from N Inputs to Managed Soils		N_2O	1.24	0.57	0.000	0.0%	0.0000	0.0%	101%	0.000	0.0%	0.00	0.0%
4.(II)	CH_4 Emissions from Drainage of Organic Soils		CH_4	63.63	45.24	0.000	0.0%	0.0000	0.0%	49%	0.000	0.0%	0.00	0.0%
4.(II)	N_2O Emissions from Drainage of Organic Soils		N_2O	2.62	1.25	0.000	0.0%	0.0000	0.0%	48%	0.000	0.0%	0.00	0.0%
4.(III)	N_2O Emissions from N Mineralization/Immobilization		N_2O	847.48	413.55	0.000	0.0%	0.0002	0.0%	159%	0.008	0.8%	0.33	0.8%
4.(IV)	Biomass Burning		CH_4	53.09	206.81	0.000	0.0%	0.0001	0.0%	32%	0.001	0.1%	0.04	0.1%
4.(IV)	Biomass Burning		N_2O	19.71	27.58	0.000	0.0%	0.0000	0.0%	52%	0.000	0.0%	0.00	0.0%
5.A.	Solid Waste Disposal		CH_4	11,188.70	1,447.14	0.001	0.1%	0.0057	1.1%	24%	0.004	0.4%	1.35	3.2%
5.B.	Biological Treatment of Soild Waste		CH_4	60.47	71.98	0.000	0.0%	0.0000	0.0%	84%	0.001	0.1%	0.01	0.0%
5.B.	Biological Treatment of Soild Waste		N_2O	160.75	189.81	0.000	0.0%	0.0000	0.0%	170%	0.004	0.4%	0.07	0.2%
5.C.	Incineration and Open Burning of Waste		CO_2	9,949.02	8,467.90	0.008	0.8%	0.0001	0.0%	16%	0.017	1.7%	0.02	0.0%
5.C.	Incineration and Open Burning of Waste		CH_4	31.18	9.36	0.000	0.0%	0.0000	0.0%	50%	0.000	0.0%	0.01	0.0%
5.C.	Incineration and Open Burning of Waste		N_2O	1,274.33	1,195.61	0.001	0.1%	0.0001	0.0%	78%	0.012	1.2%	0.07	0.2%
5.D.	Wastewater Treatment and Discharge		CH_4	3,294.53	1,638.87	0.001	0.1%	0.0008	0.2%	21%	0.004	0.4%	0.16	0.4%
5.D.	Wastewater Treatment and Discharge		N_2O	2,122.77	1,728.60	0.002	0.2%	0.0000	0.0%	42%	0.009	0.9%	0.01	0.0%
5.E.	Other		CO_2	702.83	560.45	0.001	0.1%	0.0000	0.0%	10%	0.001	0.1%	0.00	0.0%
	Indirect CO_2	from Energy Sector	Ind CO_2	1,085.39	472.53	0.000	0.0%	0.0003	0.1%	39%	0.002	0.2%	0.12	0.3%
	Indirect CO_2	from IPPU Sector	Ind CO_2	4,479.62	1,388.00	0.001	0.1%	0.0017	0.3%	56%	0.010	1.0%	0.94	2.2%
Absolute Figure Total (including LULUCF)				1,394,400.62	1,117,574.46	1.000	100.0%	0.5039	100.0%		1.000	100.0%	42.32	100.0%

Table A1-12 Data used for the key category analysis (FY1990)

A Code	B Category		C GHGs	E Absolute Value of FY1990 Estimate [Gg-CO_2 eq.]	H Ap1-L	I Ap1-L Contrib. [%]	L Source/Sink Uncertainty [%]	M Ap2-L	N Ap2-L Contrib. [%]
1.A.1.	Energy Industries	Liquid Fuels	CO_2	178,585.88	0.128	12.8%	2%	0.026	2.6%
1.A.1.	Energy Industries	Solid Fuels	CO_2	109,537.93	0.079	7.9%	6%	0.056	5.6%
1.A.1.	Energy Industries	Gaseous Fuels	CO_2	80,030.95	0.057	5.7%	2%	0.013	1.3%
1.A.1.	Energy Industries	Other Fossil Fuels	CO_2	0.00	0.000	0.0%	16%	0.000	0.0%
1.A.1.	Energy Industries		CH_4	514.47	0.000	0.0%	62%	0.003	0.3%
1.A.1.	Energy Industries		N_2O	790.98	0.001	0.1%	30%	0.002	0.2%
1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	134,401.55	0.096	9.6%	2%	0.020	2.0%
1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	199,517.80	0.143	14.3%	6%	0.102	10.2%
1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	11,894.05	0.009	0.9%	2%	0.002	0.2%
1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	3,459.35	0.002	0.2%	16%	0.005	0.5%
1.A.2.	Manufacturing Industries and Construction		CH_4	403.48	0.000	0.0%	62%	0.002	0.2%
1.A.2.	Manufacturing Industries and Construction		N_2O	1,121.33	0.001	0.1%	30%	0.003	0.3%
1.A.3.	Transport	a. Domestic Aviation	CO_2	7,162.41	0.005	0.5%	2%	0.001	0.1%
1.A.3.	Transport	a. Domestic Aviation	CH_4	6.31	0.000	0.0%	52%	0.000	0.0%
1.A.3.	Transport	a. Domestic Aviation	N_2O	56.93	0.000	0.0%	141%	0.001	0.1%
1.A.3.	Transport	b. Road Transportation	CO_2	180,367.42	0.129	12.9%	2%	0.026	2.6%
1.A.3.	Transport	b. Road Transportation	CH_4	282.90	0.000	0.0%	104%	0.002	0.2%
1.A.3.	Transport	b. Road Transportation	N_2O	3,074.39	0.002	0.2%	107%	0.028	2.8%
1.A.3.	Transport	c. Railways	CO_2	935.40	0.001	0.1%	2%	0.000	0.0%
1.A.3.	Transport	c. Railways	CH_4	1.50	0.000	0.0%	151%	0.000	0.0%
1.A.3.	Transport	c. Railways	N_2O	97.77	0.000	0.0%	200%	0.002	0.2%
1.A.3.	Transport	d. Domestic Navigation	CO_2	13,674.88	0.010	1.0%	2%	0.002	0.2%
1.A.3.	Transport	d. Domestic Navigation	CH_4	7.11	0.000	0.0%	52%	0.000	0.0%
1.A.3.	Transport	d. Domestic Navigation	N_2O	192.20	0.000	0.0%	141%	0.002	0.2%
1.A.4.	Other Sectors	Liquid Fuels	CO_2	128,801.57	0.092	9.2%	2%	0.019	1.9%
1.A.4.	Other Sectors	Solid Fuels	CO_2	353.86	0.000	0.0%	6%	0.000	0.0%
1.A.4.	Other Sectors	Gaseous Fuels	CO_2	22,241.56	0.016	1.6%	2%	0.004	0.4%
1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	6,523.49	0.005	0.5%	16%	0.009	0.9%
1.A.4.	Other Sectors		CH_4	266.46	0.000	0.0%	62%	0.001	0.1%
1.A.4.	Other Sectors		N_2O	613.08	0.000	0.0%	30%	0.002	0.2%
1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	CO_2	5.90	0.000	0.0%	22%	0.000	0.0%
1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	CH_4	5,482.08	0.004	0.4%	84%	0.039	3.9%
1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	N_2O	1.76	0.000	0.0%	163%	0.000	0.0%
1.B.	Fugitive Emissions from Fuels	2.a. Oil	CO_2	0.00	0.000	0.0%	87%	0.000	0.0%
1.B.	Fugitive Emissions from Fuels	2.a. Oil	CH_4	20.25	0.000	0.0%	79%	0.000	0.0%
1.B.	Fugitive Emissions from Fuels	2.b. Natural Gas	CO_2	0.73	0.000	0.0%	16%	0.000	0.0%
1.B.	Fugitive Emissions from Fuels	2.b. Natural Gas	CH_4	215.88	0.000	0.0%	28%	0.001	0.1%
1.B.	Fugitive Emissions from Fuels	2.c. Venting & Flaring	CO_2	91.68	0.000	0.0%	13%	0.000	0.0%
1.B.	Fugitive Emissions from Fuels	2.c. Venting & Flaring	CH_4	184.76	0.000	0.0%	11%	0.000	0.0%
1.B.	Fugitive Emissions from Fuels	2.c. Venting & Flaring	N_2O	0.13	0.000	0.0%	378%	0.000	0.0%
1.B.	Fugitive Emissions from Fuels	2.d. Other (Geothermal)	CO_2	104.42	0.000	0.0%	17%	0.000	0.0%
1.B.	Fugitive Emissions from Fuels	2.d. Other (Geothermal)	CH_4	5.84	0.000	0.0%	17%	0.000	0.0%
2.A.	Mineral Industry	1. Cement Production	CO_2	38,701.10	0.028	2.8%	4%	0.013	1.3%
2.A.	Mineral Industry	2. Lime Production	CO_2	6,674.45	0.005	0.5%	4%	0.002	0.2%
2.A.	Mineral Industry	3. Glass Production	CO_2	312.93	0.000	0.0%	6%	0.000	0.0%
2.A.	Mineral Industry	4. Other Process Uses of Carbonates	CO_2	3,025.31	0.002	0.2%	6%	0.001	0.1%
2.B.	Chemical Industry	1. Ammonia Production	CO_2	2,445.29	0.002	0.2%	2%	0.000	0.0%
2.B.	Chemical Industry	Other Production Except Ammonia	CO_2	3,601.24	0.003	0.3%	55%	0.017	1.7%
2.B.	Chemical Industry	2. Nitric Acid Production	N_2O	654.55	0.000	0.0%	112%	0.006	0.6%
2.B.	Chemical Industry	3. Adipic Acid Production	N_2O	6,412.36	0.005	0.5%	9%	0.005	0.5%
2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O	1,487.61	0.001	0.1%	162%	0.020	2.0%
2.B.	Chemical Industry	9. Fluorochemical Production	HFCs	13,347.05	0.010	1.0%	2%	0.002	0.2%
2.B.	Chemical Industry	9. Fluorochemical Production	PFCs	303.84	0.000	0.0%	2%	0.000	0.0%
2.B.	Chemical Industry	9. Fluorochemical Production	SF_6	3,577.34	0.003	0.3%	2%	0.001	0.1%
2.B.	Chemical Industry	9. Fluorochemical Production	NF_3	2.61	0.000	0.0%	47%	0.000	0.0%
2.B.	Chemical Industry	Whole of Chemical Industries	CH_4	41.99	0.000	0.0%	58%	0.000	0.0%

Table A1-12 Data used for the key category analysis (FY1990) (Continued)

A Code	B Category		C GHGs	E Absolute Value of FY1990 Estimate [Gg-CO_2 eq.]	H Ap1-L	I Ap1-L Contrib. [%]	L Source/Sink Uncertainty [%]	M Ap2-L	N Ap2-L Contrib. [%]
2.C.	Metal Industry	1. Iron and Steel Production	CO_2	7,233.95	0.005	0.5%	4%	0.002	0.2%
2.C.	Metal Industry	1. Iron and Steel Production	CH_4	20.63	0.000	0.0%	163%	0.000	0.0%
2.C.	Metal Industry	2. Ferroalloys Production	CH_4	5.18	0.000	0.0%	163%	0.000	0.0%
2.C.	Metal Industry	3. Aluminium Production	CO_2	57.97	0.000	0.0%	10%	0.000	0.0%
2.C.	Metal Industry	3. Aluminium Production	PFCs	301.48	0.000	0.0%	5%	0.000	0.0%
2.C.	Metal Industry	4. Magnesium Production	HFCs	0.00	0.000	0.0%	5%	0.000	0.0%
2.C.	Metal Industry	4. Magnesium Production	SF_6	151.04	0.000	0.0%	100%	0.001	0.1%
2.D.	Non-energy Products from Fuels and Solvent Use		CO_2	2,229.39	0.002	0.2%	51%	0.010	1.0%
2.E.	Electronics Industry		N_2O	3.39	0.000	0.0%	5%	0.000	0.0%
2.E.	Electronics Industry		HFCs	55.22	0.000	0.0%	100%	0.000	0.0%
2.E.	Electronics Industry		PFCs	1,314.38	0.001	0.1%	81%	0.009	0.9%
2.E.	Electronics Industry		SF_6	950.73	0.001	0.1%	300%	0.024	2.4%
2.E.	Electronics Industry		NF_3	25.36	0.000	0.0%	71%	0.000	0.0%
2.F.	Product Uses as Substitutes for ODS	1. Refrigeration and Air Conditioning Equipment	HFCs	0.00	0.000	0.0%	6%	0.000	0.0%
2.F.	Product Uses as Substitutes for ODS	2. Foam Blowing Agents	HFCs	1.22	0.000	0.0%	50%	0.000	0.0%
2.F.	Product Uses as Substitutes for ODS	3. Fire Protection	HFCs	0.00	0.000	0.0%	16%	0.000	0.0%
2.F.	Product Uses as Substitutes for ODS	4. Aerosols	HFCs	0.00	0.000	0.0%	10%	0.000	0.0%
2.F.	Product Uses as Substitutes for ODS	5. Solvents	HFCs	0.00	0.000	0.0%	11%	0.000	0.0%
2.F.	Product Uses as Substitutes for ODS	5. Solvents	PFCs	4,228.36	0.003	0.3%	10%	0.004	0.4%
2.G.	Other Product Manufacture and Use		N_2O	245.40	0.000	0.0%	5%	0.000	0.0%
2.G.	Other Product Manufacture and Use		HFCs	6.46	0.000	0.0%	200%	0.000	0.0%
2.G.	Other Product Manufacture and Use		PFCs	14.62	0.000	0.0%	35%	0.000	0.0%
2.G.	Other Product Manufacture and Use		SF_6	9,084.65	0.007	0.7%	143%	0.109	10.9%
2.H.	Other		CO_2	880.34	0.001	0.1%	2%	0.000	0.0%
3.A.	Enteric Fermentation		CH_4	10,553.65	0.008	0.8%	30%	0.026	2.6%
3.B.	Manure Management		CH_4	3,786.09	0.003	0.3%	16%	0.005	0.5%
3.B.	Manure Management		N_2O	3,865.02	0.003	0.3%	141%	0.046	4.6%
3.C.	Rice Cultivation		CH_4	13,584.76	0.010	1.0%	6%	0.007	0.7%
3.D.	Agricultural Soils	1. Direct Emissions	N_2O	4,002.46	0.003	0.3%	60%	0.020	2.0%
3.D.	Agricultural Soils	2. Indirect Emissions	N_2O	2,655.41	0.002	0.2%	244%	0.054	5.4%
3.F.	Field Burning of Agricultural Residues		CH_4	77.94	0.000	0.0%	296%	0.002	0.2%
3.F.	Field Burning of Agricultural Residues		N_2O	22.74	0.000	0.0%	300%	0.001	0.1%
3.G.	Liming		CO_2	550.24	0.000	0.0%	50%	0.002	0.2%
3.H.	Urea Application		CO_2	181.77	0.000	0.0%	50%	0.001	0.1%
4.A.	Forest Land	1. Forest Land Remaining Forest Land	CO_2	87,980.64	0.063	6.3%	9%	0.064	6.4%
4.A.	Forest Land	2. Land Converted to Forest Land	CO_2	9,576.73	0.007	0.7%	9%	0.007	0.7%
4.B.	Cropland	1. Cropland Remaining Cropland	CO_2	6,659.68	0.005	0.5%	25%	0.014	1.4%
4.B.	Cropland	2. Land Converted to Cropland	CO_2	626.33	0.000	0.0%	12%	0.001	0.1%
4.C.	Grassland	1. Grassland Remaining Grassland	CO_2	539.00	0.000	0.0%	10%	0.000	0.0%
4.C.	Grassland	2. Land Converted to Grassland	CO_2	455.65	0.000	0.0%	21%	0.001	0.1%
4.D.	Wetlands	1. Wetlands Remaining Wetlands	CO_2	520.71	0.000	0.0%	19%	0.001	0.1%
4.D.	Wetlands	2. Land Converted to Wetlands	CO_2	70.36	0.000	0.0%	23%	0.000	0.0%
4.E.	Settlements	1. Settlements Remaining Settlements	CO_2	1,013.18	0.001	0.1%	15%	0.001	0.1%
4.E.	Settlements	2. Land Converted to Settlements	CO_2	11,261.02	0.008	0.8%	43%	0.041	4.1%
4.F.	Other Land	2. Land Converted to Other Land	CO_2	2,247.47	0.002	0.2%	53%	0.010	1.0%
4.G.	Harvested Wood Products		CO_2	404.48	0.000	0.0%	30%	0.001	0.1%
4.H.	Other		CO_2	0.00	0.000	0.0%	6%	0.000	0.0%
4.(I)	N_2O Emissions from N Inputs to Managed Soils		N_2O	1.24	0.000	0.0%	101%	0.000	0.0%
4.(II)	CH_4 Emissions from Drainage of Organic Soils		CH_4	63.63	0.000	0.0%	49%	0.000	0.0%
4.(II)	N_2O Emissions from Drainage of Organic Soils		N_2O	2.62	0.000	0.0%	48%	0.000	0.0%
4.(III)	N_2O Emissions from N Mineralization/Immobilization		N_2O	847.48	0.001	0.1%	159%	0.011	1.1%
4.(IV)	Biomass Burning		CH_4	53.09	0.000	0.0%	32%	0.000	0.0%
4.(IV)	Biomass Burning		N_2O	19.71	0.000	0.0%	52%	0.000	0.0%
5.A.	Solid Waste Disposal		CH_4	11,188.70	0.008	0.8%	24%	0.022	2.2%
5.B.	Biological Treatment of Soild Waste		CH_4	60.47	0.000	0.0%	84%	0.000	0.0%
5.B.	Biological Treatment of Soild Waste		N_2O	160.75	0.000	0.0%	170%	0.002	0.2%
5.C.	Incineration and Open Burning of Waste		CO_2	9,949.02	0.007	0.7%	16%	0.013	1.3%
5.C.	Incineration and Open Burning of Waste		CH_4	31.18	0.000	0.0%	50%	0.000	0.0%
5.C.	Incineration and Open Burning of Waste		N_2O	1,274.33	0.001	0.1%	78%	0.008	0.8%
5.D.	Wastewater Treatment and Discharge		CH_4	3,294.53	0.002	0.2%	21%	0.006	0.6%
5.D.	Wastewater Treatment and Discharge		N_2O	2,122.77	0.002	0.2%	42%	0.007	0.7%
5.E.	Other		CO_2	702.83	0.001	0.1%	10%	0.001	0.1%
	Indirect CO_2	from Energy Sector	Ind CO_2	1,085.39	0.001	0.1%	39%	0.004	0.4%
	Indirect CO_2	from IPPU Sector	Ind CO_2	4,479.62	0.003	0.3%	56%	0.021	2.1%
Total (including LULUCF)				1,394,400.62	1.000	100.0%		1.000	100.0%

References

1. IPCC, *2006 IPCC Guidelines for National Greenhouse Inventories,* 2006.
2. UNFCCC, *Modalities, Procedures and Guidelines for the Transparency Framework for Action and Support Referred to in Article 13 of the Paris Agreement*, Decision 18/CMA.1 Annex, FCCC/PA/CMA/2018/3/Add.2, 2019.

Annex 2. Assessment of Uncertainty

A2.1. Methodology of Uncertainty Assessment

"Uncertainty" is a conceptual framework which represents the differences between emissions/ removals inventory estimates and true underlying values, resulting from lack of data or representativeness, sampling error, or, errors in measurement values, etc. In the paragraph 29 and 44 in the *Modalities, Procedures and Guidelines for the Transparency Framework for Action and Support Referred to in Article 13 of the Paris Agreement,* (Decision 18/CMA.1 Annex), it is noted that Annex I Parties shall quantitatively estimate and report the uncertainty of inventories. The assessment of uncertainties is intended to contribute to improve the accuracy of national inventories continuously and to guide decisions on methodological choice but not to evaluate justification of inventories nor make a comparison of accuracy of inventories among the parties.

The fundamental methodological issues of uncertainties assessment are provided in the IPCC guidelines; however, uncertainty assessment for specific emission sources and removal sinks is mainly subject to country-specific method determined by each party depending on country's own circumstances. In Japan, the uncertainties were assessed based on the country-specific guidelines (MOE, 2013).

A2.2. Results of Uncertainty Assessment

A2.2.1 Uncertainty of Japan's Total Emissions

In FY2024, total net emissions in Japan were approximately 997 million tonnes (carbon dioxide equivalents). Uncertainty of total net emissions in FY2024 was assessed at -3% to +2% and uncertainty introduced into the trend in total net emissions was assessed at -3% to +2%. Thus, the uncertainty level was low in Japan, mainly because CO_2 emissions from low-uncertainty fuel combustion (1.A.) accounted for 93% of the net emissions.

Table A2-1 Uncertainty of Japan's total net emissions

A	B	C	D	G-1990		G-2024		I	J	
Category	GHGs	FY1990 emissions / removals	FY2024 emissions / removals	Combined uncertainty in FY1990		Combined uncertainty in FY2024		Inventory trend in national emissions for FY2024 increase with respect to FY1990	Uncertainty introduced into the trend in total national emissions	
		kt-CO_2 eq.	kt-CO_2 eq.	(-) %	(+) %	(-) %	(+) %	%	(-) %	(+) %
1A. Fuel Combustion (CO_2)	CO_2	1,077,488	922,614	-2%	+1%	-3%	+2%	-14.4%	-2.9%	+1.9%
1A. Fuel Combustion (Stationary:CH_4,N_2O)	CH_4, N_2O	3,710	3,824	-22%	+28%	-24%	+27%	3.1%	0.0%	+0.0%
1A. Fuel Combustion (Transport:CH_4,N_2O)	CH_4, N_2O	3,719	1,427	-30%	+89%	-28%	+82%	-61.6%	0.0%	+0.0%
1B. Fugitive Emissions from Fuels	CO_2, CH_4, N_2O	6,113	1,202	-36%	+76%	-17%	+35%	-80.3%	0.0%	+0.0%
2. IPPU (CO_2,CH_4,N_2O)	CO_2, CH_4, N_2O	74,033	37,647	-5%	+5%	-5%	+5%	-49.1%	-0.1%	+0.1%
2. IPPU (HFCs,PFCs,SF_6,NF_3)	HFCs, PFCs, SF_6, NF_3	33,364	32,245	-11%	+40%	-8%	+10%	-3.4%	-0.3%	+0.3%
3. Agriculture	CO_2, CH_4, N_2O	39,280	30,278	-11%	+25%	-10%	+22%	-22.9%	-0.1%	+0.1%
4. LULUCF	CO_2, CH_4, N_2O	-76,648	-49,421	-12%	12%	-11%	+11%	-35.5%	-0.4%	+0.4%
5. Waste	CO_2, CH_4, N_2O	28,785	15,310	-11%	+11%	-12%	+12%	-46.8%	-0.2%	+0.2%
Indirect CO_2	Ind CO_2	5,565	1,861	-25%	+46%	-24%	+43%	-66.6%	0.0%	+0.0%
Total Net Emissions		1,195,409	996,986	-2.1%	+2.2%	-2.6%	+2.0%	-16.6%	-2.9%	+2.0%

Data used for estimating emissions in each category are as follows:

Table A2-2 Data used for uncertainty assessment (Energy Sector)

A		B	C	D	E		F		G		H-1990		H-2024		T	I	J	K		L		M	
Category		GHG	FY1990 emissions / removals	FY2024 emissions / removals	Activity data uncertainty		Emission factor/ estimation parameter uncertainty		Combined uncertainty		Combined Uncertainty as % of Total National Emissions in FY1990		Combined Uncertainty as % of Total National Emissions in FY2024		Emission increase rate	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor/ estimation parameter uncertainty		Uncertainty in trend in national emissions introduced by activity data uncertainty		Uncertainty introduced into the trend in total national emissions	
			Input Data	Input Data	Input Data		Input Data		$(E^2+F^2)^{1/2}$		G*C/ ΣC		G*D/ ΣD		D/C	Note*	D/ ΣC	I*F		J*E*√2		$(K^2+L^2)^{1/2}$	
			kt-CO_2 eq.	kt-CO_2 eq.	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	%	%	%	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %
Total			1,195,409	996,986							-2.1%	+2.2%	-2.6%	+2.0%	-16.6%							-2.9%	+2.0%
1.A. Fuel Combustion	Liquid Fuels	CO_2	643,856	328,052	-1%	+1%	-	-	-2%	+2%	-0.9%	0.8%	-0.6%	0.5%	-49.0%	0.2%	27.4%	0.0%	0.0%	-0.4%	0.2%	0.4%	0.2%
1.A. Fuel Combustion	Solid Fuels	CO_2	309,482	389,025	-6%	+4%	-	-	-6%	+4%	-1.6%	1.1%	-2.4%	1.6%	25.7%	0.1%	32.5%	0.0%	0.0%	-2.8%	1.9%	2.8%	1.9%
1.A. Fuel Combustion	Gaseous Fuels	CO_2	114,167	189,116	-1%	+1%	-	-	-2%	+2%	-0.2%	0.2%	-0.4%	0.4%	65.6%	0.1%	15.8%	0.0%	0.0%	-0.3%	0.3%	0.3%	0.3%
1.A. Fuel Combustion	Other Fossil Fuels	CO_2	9,983	16,422	-	-	-	-	-16%	+16%	-0.1%	0.1%	-0.3%	0.3%	64.5%	0.0%	1.4%	0.0%	0.0%	-0.3%	0.3%	0.3%	0.3%
1.A. Stationary Combustion		CH_4	1,184	938	-	-	-	-	-29%	+62%	0.0%	0.1%	0.0%	0.1%	-20.8%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.A. Stationary Combustion		N_2O	2,525	2,886	-	-	-	-	-30%	+30%	-0.1%	0.1%	-0.1%	0.1%	14.3%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.A.3. Transport	a. Domestic Aviation	CH_4	6	2	-5%	+5%	-57%	+100%	-57%	+100%	0.0%	0.0%	0.0%	0.0%	-73.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.A.3. Transport	a. Domestic Aviation	N_2O	57	79	-5%	+5%	-70%	+150%	-70%	+150%	0.0%	0.0%	0.0%	0.0%	39.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.A.3. Transport	b. Road Transportation	CH_4	283	88	-	-	-	-	-36%	+104%	0.0%	0.0%	0.0%	0.0%	-68.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.A.3. Transport	b. Road Transportation	N_2O	3,074	1,073	-	-	-	-	-37%	+107%	-0.1%	0.3%	0.0%	0.1%	-65.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.A.3. Transport	c. Railways	CH_4	2	1	-5%	+5%	-60%	+151%	-60%	+151%	0.0%	0.0%	0.0%	0.0%	-52.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.A.3. Transport	c. Railways	N_2O	98	46	-5%	+5%	-50%	+200%	-50%	+200%	0.0%	0.0%	0.0%	0.0%	-52.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.A.3. Transport	d. Domestic Navigation	CH_4	7	5	-13%	+13%	-50%	+50%	-52%	+52%	0.0%	0.0%	0.0%	0.0%	-30.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.A.3. Transport	d. Domestic Navigation	N_2O	192	133	-13%	+13%	-41%	+140%	-43%	+141%	0.0%	0.0%	0.0%	0.0%	-30.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.B. Fugitive Emission from Fuel	1. Solid Fuels	CO_2	6	0	-	-	-	-	-15%	+22%	0.0%	0.0%	0.0%	0.0%	-93.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.B. Fugitive Emission from Fuel	1. Solid Fuels	CH_4	5,482	486	-	-	-	-	-41%	+84%	-0.2%	0.4%	0.0%	0.0%	-91.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.B. Fugitive Emission from Fuel	1. Solid Fuels	N_2O	2	0	-2%	+2%	-75%	+163%	-75%	+163%	0.0%	0.0%	0.0%	0.0%	-80.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.B. Fugitive Emission from Fuel	2.a. Oil	CO_2	0	0	-	-	-	-	-87%	+87%	0.0%	0.0%	0.0%	0.0%	-30.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.B. Fugitive Emission from Fuel	2.a. Oil	CH_4	20	12	-	-	-	-	-79%	+79%	0.0%	0.0%	0.0%	0.0%	-38.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.B. Fugitive Emission from Fuel	2.b. Natural Gas	CO_2	1	1	-	-	-	-	-16%	+16%	0.0%	0.0%	0.0%	0.0%	5.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.B. Fugitive Emission from Fuel	2.b. Natural Gas	CH_4	216	217	-	-	-	-	-15%	+28%	0.0%	0.0%	0.0%	0.0%	0.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.B. Fugitive Emission from Fuel	2.c. Venting & Flaring	CO_2	92	128	-	-	-	-	-13%	+13%	0.0%	0.0%	0.0%	0.0%	39.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.B. Fugitive Emission from Fuel	2.c. Venting & Flaring	CH_4	185	155	-	-	-	-	-11%	+11%	0.0%	0.0%	0.0%	0.0%	-16.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.B. Fugitive Emission from Fuel	2.c. Venting & Flaring	N_2O	0	0	-	-	-	-	-7%	+378%	0.0%	0.0%	0.0%	0.0%	-24.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.B. Fugitive Emission from Fuel	2.d. Other (Geothermal)	CO_2	104	192	-15%	+15%	-7%	+7%	-17%	+17%	0.0%	0.0%	0.0%	0.0%	83.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.B. Fugitive Emission from Fuel	2.d. Other (Geothermal)	CH_4	6	11	-15%	+15%	-7%	+7%	-17%	+17%	0.0%	0.0%	0.0%	0.0%	83.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table A2-3 Data used for uncertainty assessment (Industrial Processes and Product Use Sector)

A		B	C	D	E		F		G		H-1990		H-2024		T	I	J	K		L		M	
Category		GHG	FY1990 emissions / removals	FY2024 emissions / removals	Activity data uncertainty		Emission factor/ estimation parameter uncertainty		Combined uncertainty		Combined Uncertainty as % of Total National Emissions in FY1990		Combined Uncertainty as % of Total National Emissions in FY2024		Emission increase rate	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor/ estimation parameter uncertainty		Uncertainty in trend in national emissions introduced by activity data uncertainty		Uncertainty introduced into the trend in total national emissions	
			Input Data	Input Data	Input Data		Input Data		$(E^2+F^2)^{\wedge}1/2$		G*C/ΣC		G*D/ΣD		D/C	Note*	D/ΣC	I*F		J*E*√2		$(K^2+L^2)^{\wedge}1/2$	
			kt-CO_2 eq.	kt-CO_2 eq.	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	%	%	%	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %
2.A. Mineral Industry	1. Cement Production	CO_2	38,701	20,175	-2%	+2%	-4%	+4%	-4%	+4%	-0.1%	0.1%	-0.1%	0.1%	-47.9%	0.0%	1.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.A. Mineral Industry	2. Lime Production	CO_2	6,674	4,372	-3%	+3%	-2%	+2%	-4%	+4%	0.0%	0.0%	0.0%	0.0%	-34.5%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.A. Mineral Industry	3. Glass Production	CO_2	313	156	-3%	+3%	-5%	+5%	-6%	+6%	0.0%	0.0%	0.0%	0.0%	-50.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.A. Mineral Industry	4. Other Process Uses of Carbonates	CO_2	3,025	1,464	-3%	+3%	-5%	+5%	-6%	+6%	0.0%	0.0%	0.0%	0.0%	-51.6%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.B. Chemical Industry	1. Ammonia Production	CO_2	2,445	649	-	-	-	-	-2%	+1%	0.0%	0.0%	0.0%	0.0%	-73.4%	0.0%	0.1%	NA	NA	NA	NA	0.0%	0.0%
2.B. Chemical Industry	Other Production Except Ammonia	CO_2	3,601	2,207	-	-	-	-	-55%	+55%	-0.2%	0.2%	-0.1%	0.1%	-38.7%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.B. Chemical Industry	2. Nitric Acid Production	N_2O	655	130	-2%	+2%	-112%	+112%	-112%	+112%	-0.1%	0.1%	0.0%	0.0%	-80.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.B. Chemical Industry	3. Adipic Acid Production	N_2O	6,412	17	-2%	+2%	-9%	+9%	-9%	+9%	0.0%	0.0%	0.0%	0.0%	-99.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.B. Chemical Industry	4. Caprolactam Production	N_2O	1,488	17	-2%	+2%	-162%	+162%	-162%	+162%	-0.2%	0.2%	0.0%	0.0%	-98.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.B. Chemical Industry	Whole of Chemical Industries	CH_4	42	13	-	-	-	-	-58%	+51%	0.0%	0.0%	0.0%	0.0%	-69.5%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
2.C. Metal Industry	1. Iron and Steel Production	CO_2	7,234	4,771	-	-	-	-	-4%	+4%	0.0%	0.0%	0.0%	0.0%	-34.0%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.C. Metal Industry	1. Iron and Steel Production	CH_4	21	14	-5%	+5%	-163%	+163%	-163%	+163%	0.0%	0.0%	0.0%	0.0%	-34.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.C. Metal Industry	2. Ferroalloys Production	CH_4	5	1	-5%	+5%	-163%	+163%	-163%	+163%	0.0%	0.0%	0.0%	0.0%	-74.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.C. Metal Industry	3. Aluminium Production	CO_2	58	NO	-2%	+2%	-10%	+10%	-10%	+10%	0.0%	0.0%	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.0%	0.0%
2.D. Non-energy Products from Fuels and Solvent Use		CO_2	2,229	2,589	-	-	-	-	-51%	+51%	-0.1%	0.1%	-0.1%	0.1%	16.1%	0.0%	0.2%	NA	NA	NA	NA	0.0%	0.0%
2.E. Electronics Industry		N_2O	3	56	-10%	+10%	-120%	+120%	-120%	+120%	0.0%	0.0%	0.0%	0.0%	1553.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.G. Other Product Manufacture and Use		N_2O	245	94	-	-	-	-	-5%	+5%	0.0%	0.0%	0.0%	0.0%	-61.8%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
2.H. Other		CO_2	880	921	-	-	-	-	-2%	+2%	0.0%	0.0%	0.0%	0.0%	4.6%	0.0%	0.1%	NA	NA	NA	NA	0.0%	0.0%
2.B. Chemical Industry	9.a. Fluorochemical Production (By-product emissions)	HFCs	13,346	4	-	-	-	-	-2%	+2%	0.0%	0.0%	0.0%	0.0%	-100.0%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
2.B. Chemical Industry	9.b. Fluorochemical Production (Fugitive Emissions)	HFCs	1	60	-	-	-	-	-2%	+2%	0.0%	0.0%	0.0%	0.0%	4308.6%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
2.B. Chemical Industry	9.b. Fluorochemical Production (Fugitive Emissions)	PFCs	304	32	-	-	-	-	-2%	+2%	0.0%	0.0%	0.0%	0.0%	-89.4%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
2.B. Chemical Industry	9.b. Fluorochemical Production (Fugitive Emissions)	SF_6	3,577	41	-	-	-	-	-2%	+2%	0.0%	0.0%	0.0%	0.0%	-98.8%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
2.B. Chemical Industry	9.b. Fluorochemical Production (Fugitive Emissions)	NF_3	3	12	-	-	-	-	-2%	+2%	0.0%	0.0%	0.0%	0.0%	366.2%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
2.C. Metal Industry	3. Aluminium Production	PFCs	301	NO	-2%	+2%	-47%	+28%	-47%	+28%	0.0%	0.0%	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.0%	0.0%
2.C. Metal Industry	4. Magnesium Production	HFCs	NO	1	-	-	-	-	-5%	+5%	NA	NA	0.0%	0.0%	NA	NA	NA	NA	NA	NA	NA	0.0%	0.0%
2.C. Metal Industry	4. Magnesium Production	SF_6	151	151	-	-	-	-	-5%	+5%	0.0%	0.0%	0.0%	0.0%	-0.1%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
2.E. Electronics Industry		HFCs	55	65	-10%	+10%	-100%	+100%	-100%	+100%	0.0%	0.0%	0.0%	0.0%	17%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.E. Electronics Industry		PFCs	1,314	1,322	-10%	+10%	-80%	+80%	-81%	+81%	-0.1%	0.1%	-0.1%	0.1%	0.6%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.E. Electronics Industry		SF_6	951	377	-10%	+10%	-300%	+300%	-300%	+300%	-0.2%	0.2%	-0.1%	0.1%	-60.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.E. Electronics Industry		NF_3	25	167	-10%	+10%	-70%	+70%	-71%	+71%	0.0%	0.0%	0.0%	0.0%	560.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.F. Product uses as substitutes for ODS	1. Refrigeration and Air Conditioning Equipment	HFCs	NO	24,427	-	-	-	-	-6%	+6%	NA	NA	-0.1%	0.1%	NA	NA	2.0%	NA	NA	-0.3%	0.3%	0.3%	0.3%
2.F. Product uses as substitutes for ODS	2. Foam Blowing Agents	HFCs	1	2,570	-	-	-	-	-50%	+50%	0.0%	0.0%	-0.1%	0.1%	210423%	0.0%	0.2%	NA	NA	NA	NA	0.0%	0.0%
2.F. Product uses as substitutes for ODS	3. Fire Protection	HFCs	NO	9	-	-	-	-	-16%	+16%	NA	NA	0.0%	0.0%	NA	NA	0.0%	NA	NA	NA	NA	0.0%	0.0%
2.F. Product uses as substitutes for ODS	4. Aerosols	HFCs	NO	310	-	-	-	-	-10%	+10%	NA	NA	0.0%	0.0%	NA	NA	0.0%	NA	NA	NA	NA	0.0%	0.0%
2.F. Product uses as substitutes for ODS	5. Solvents	HFCs	NO	125	-10%	+10%	-5%	+5%	-11%	+11%	NA	NA	0.0%	0.0%	NA	NA	0.0%	NA	NA	0.0%	0.0%	0.0%	0.0%
2.F. Product uses as substitutes for ODS	5. Solvents	PFCs	4,228	1,072	-10%	+10%	-	-	-10%	+10%	0.0%	0.0%	0.0%	0.0%	-74.6%	0.0%	0.1%	NA	NA	0.0%	0.0%	0.0%	0.0%
2.G. Other Product Manufacture and Use		HFCs	6	5	-5%	+5%	-200%	+200%	-200%	+200%	0.0%	0.0%	0.0%	0.0%	-17.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.G. Other Product Manufacture and Use		PFCs	15	55	-	-	-	-	-35%	+35%	0.0%	0.0%	0.0%	0.0%	274.8%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
2.G. Other Product Manufacture and Use		SF_6	9,085	1,438	-	-	-	-	-22%	+143%	-0.2%	1.1%	0.0%	0.2%	-84.2%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table A2-4 Data used for uncertainty assessment (Agriculture Sector)

A		B	C	D	E		F		G		H-1990		H-2024		T	I	J	K		L		M	
Category		GHG	FY1990 emissions / removals	FY2024 emissions / removals	Activity data uncertainty		Emission factor/ estimation parameter uncertainty		Combined uncertainty		Combined Uncertainty as % of Total National Emissions in FY1990		Combined Uncertainty as % of Total National Emissions in FY2024		Emission increase rate	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor/ estimation parameter uncertainty		Uncertainty in trend in national emissions introduced by activity data uncertainty		Uncertainty introduced into the trend in total national emissions	
			Input Data	Input Data	Input Data		Input Data		$(E^2+F^2)^{\wedge}1/2$		G*C/ΣC		G*D/ΣD		D/C	Note*	D/ΣC	I*F		J*E*√2		$(K^2+L^2)^{\wedge}1/2$	
			kt-CO_2 eq.	kt-CO_2 eq.	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	%	%	%	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %
3.A.Enteric Fermentation	1.a. Dairy Cattle	CH_4	5,379	3,652	-1%	+1%	-26%	+32%	-26%	+32%	-0.1%	0.1%	-0.1%	0.1%	-32.1%	0.0%	0.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.A.Enteric Fermentation	1.b. Non-dairy Cattle	CH_4	4,663	4,414	-1%	+1%	-40%	+49%	-40%	+49%	-0.2%	0.2%	-0.2%	0.2%	-5.3%	0.0%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.A.Enteric Fermentation	2. Sheep	CH_4	5	5	-9%	+9%	-50%	+50%	-51%	+51%	0.0%	0.0%	0.0%	0.0%	10.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.A.Enteric Fermentation	3. Swine	CH_4	444	345	-1%	+1%	-69%	+69%	-72%	+157%	0.0%	0.1%	0.0%	0.1%	-22.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.A.Enteric Fermentation	4. Other Livestock	CH_4	62	42	-9%	+9%	-50%	+50%	-51%	+51%	0.0%	0.0%	0.0%	0.0%	-32.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B. Manure Management	1.1.a. Dairy Cattle	CH_4	2,995	1,956	-1%	+1%	-20%	+20%	-20%	+20%	-0.1%	0.1%	0.0%	0.0%	-34.7%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B. Manure Management	1.1.a. Dairy Cattle	N_2O	562	473	-50%	+50%	-71%	+112%	-87%	+123%	0.0%	0.1%	0.0%	0.1%	-15.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B. Manure Management	1.1.b. Non-dairy Cattle	CH_4	103	238	-1%	+1%	-20%	+20%	-20%	+20%	0.0%	0.0%	0.0%	0.0%	131.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B. Manure Management	1.1.b. Non-dairy Cattle	N_2O	639	518	-50%	+50%	-71%	+112%	-87%	+123%	0.0%	0.1%	0.0%	0.1%	-19.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B. Manure Management	2. Sheep	CH_4	0	0	-9%	+9%	-30%	+30%	-31%	+31%	0.0%	0.0%	0.0%	0.0%	10.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B. Manure Management	2. Sheep	N_2O	NO	NO	-9%	+9%	-71%	+112%	-72%	+112%	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	0.0%	0.0%
3.B. Manure Management	3. Swine	CH_4	621	210	-1%	+1%	-20%	+20%	-20%	+20%	0.0%	0.0%	0.0%	0.0%	-66.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B. Manure Management	3. Swine	N_2O	978	928	-50%	+50%	-71%	+112%	-87%	+123%	-0.1%	0.1%	-0.1%	0.1%	-5.1%	0.0%	0.1%	0.0%	0.0%	-0.1%	0.1%	0.1%	0.1%
3.B. Manure Management	4. Other Livestock (Poultry)	CH_4	56	68	-9%	+9%	-20%	+20%	-22%	+22%	0.0%	0.0%	0.0%	0.0%	22.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B. Manure Management	4. Other Livestock (Poultry)	N_2O	303	215	-51%	+51%	-71%	+112%	-87%	+123%	0.0%	0.0%	0.0%	0.0%	-28.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B. Manure Management	4. Other Livestock	CH_4	11	5	-9%	+9%	-30%	+30%	-31%	+31%	0.0%	0.0%	0.0%	0.0%	-50.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B. Manure Management	4. Other Livestock	N_2O	7	1	-9%	+9%	-71%	+112%	-72%	+112%	0.0%	0.0%	0.0%	0.0%	-82.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B. Manure Management	5. Indirect N2O Emissions	N_2O	1,376	930	-9%	+9%	-106%	+447%	-106%	+447%	-0.1%	0.5%	-0.1%	0.4%	-32.4%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.C. Rice Cultivation	1. Irrigated	CH_4	13,585	11,841	-1%	+1%	-6%	+6%	-6%	+6%	-0.1%	0.1%	-0.1%	0.1%	-12.8%	0.0%	1.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.D. Agricultural Soils	1.a. Inorganic N Fertilizers	N_2O	1,639	746	-1%	+1%	-113%	+113%	-113%	+113%	-0.2%	0.2%	-0.1%	0.1%	-54.4%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.D. Agricultural Soils	1.b. Organic N Fertilizers	N_2O	1,453	917	-	-	-	-	-42%	+110%	-0.1%	0.1%	0.0%	0.1%	-36.9%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.D. Agricultural Soils	1.c. Urine and Dung Deposited by Grazing Animals	N_2O	24	21	-1%	+1%	-65%	+200%	-65%	+200%	0.0%	0.0%	0.0%	0.0%	-13.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.D. Agricultural Soils	1.d. Crop Residue	N_2O	375	269	-1%	+1%	-70%	+200%	-70%	+200%	0.0%	0.1%	0.0%	0.1%	-28.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.D. Agricultural Soils	1.e. Mineralization	N_2O	403	339	-	-	-	-	-2%	+2%	0.0%	0.0%	0.0%	0.0%	-15.8%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
3.D. Agricultural Soils	1.f. Cultivation of Organic Soils	N_2O	109	107	-1%	+1%	-75%	+200%	-75%	+200%	0.0%	0.0%	0.0%	0.0%	-1.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.D. Agricultural Soils	2.a. Atomospheric Deposition	N_2O	956	593	-9%	+9%	-106%	+447%	-106%	+447%	-0.1%	0.4%	-0.1%	0.3%	-38.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.D. Agricultural Soils	2.b. N Leaching and Run-off	N_2O	1,699	1,057	-9%	+9%	-115%	+287%	-115%	+287%	-0.2%	0.4%	-0.1%	0.3%	-37.8%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.F. Field Burning of Agricultural Residues		CH_4	78	26	-1%	+1%	-296%	+296%	-296%	+296%	0.0%	0.0%	0.0%	0.0%	-66.6%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.F. Field Burning of Agricultural Residues		N_2O	23	7	-1%	+1%	-300%	+300%	-300%	+300%	0.0%	0.0%	0.0%	0.0%	-68.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.G. Liming		CO_2	550	205	-1%	+1%	-50%	+50%	-50%	+50%	0.0%	0.0%	0.0%	0.0%	-62.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.H. Urea Application		CO_2	182	148	-1%	+1%	-50%	+50%	-50%	+50%	0.0%	0.0%	0.0%	0.0%	-18.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table A2-5 Data used for uncertainty assessment (LULUCF Sector)

A		B	C	D	E		F		G		H-1990		H-2024		T	I	J	K		L		M	
Category		GHG	FY1990 emissions / removals	FY2024 emissions / removals	Activity data uncertainty		Emission factor/ estimation parameter uncertainty		Combined uncertainty		Combined Uncertainty as % of Total National Emissions in FY1990		Combined Uncertainty as % of Total National Emissions in FY2024		Emission increase rate	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor/ estimation parameter uncertainty		Uncertainty in trend in national emissions introduced by activity data uncertainty		Uncertainty introduced into the trend in total national emissions	
			Input Data	Input Data	Input Data		Input Data		$(E^2+F^2)^{\wedge}1/2$		G*C/ΣC		G*D/ΣD		D/C	Note*	D/ΣC	I*F		J*E*√2		$(K^2+L^2)^{\wedge}1/2$	
			kt-CO_2 eq.	kt-CO_2 eq.	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	%	%	%	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %
4.A. Forest Land	1. Forest Land Remaining Forest Land	CO_2	-87,981	-56,526	-	-	-	-	-9%	+9%	-0.6%	0.6%	-0.5%	0.5%	-35.8%	0.0%	4.7%	0.0%	0.0%	-0.4%	0.4%	0.4%	0.4%
4.A. Forest Land	2. Land Converted to Forest Land	CO_2	-9,577	-499	-	-	-	-	-9%	+9%	-0.1%	0.1%	0.0%	0.0%	-94.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
4.B. Cropland	1. Cropland Remaining Cropland	CO_2	6,660	4,104	-	-	-	-	-25%	+25%	-0.1%	0.1%	-0.1%	0.1%	-38.4%	0.0%	0.3%	NA	NA	NA	NA	0.0%	0.0%
4.B. Cropland	2. Land Converted to Cropland	CO_2	626	137	-	-	-	-	-12%	+12%	0.0%	0.0%	0.0%	0.0%	-78.1%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
4.C. Grassland	1. Grassland Remaining Grassland	CO_2	539	517	-	-	-	-	-10%	+10%	0.0%	0.0%	0.0%	0.0%	-4.0%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
4.C. Grassland	2. Land Converted to Grassland	CO_2	456	60	-	-	-	-	-21%	+21%	0.0%	0.0%	0.0%	0.0%	-86.8%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
4.D. Wetlands	1. Wetland Remaining Wetland	CO_2	-521	-323	-	-	-	-	-19%	+19%	0.0%	0.0%	0.0%	0.0%	-38.0%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
4.D. Wetlands	2. Land Converted to Wetlands	CO_2	70	6	-	-	-	-	-23%	+23%	0.0%	0.0%	0.0%	0.0%	-91.5%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
4.E. Settlements	1. Settlements Remaining Settlements	CO_2	-1,013	-1,400	-	-	-	-	-15%	+15%	0.0%	0.0%	0.0%	0.0%	38.2%	0.0%	0.1%	NA	NA	NA	NA	0.0%	0.0%
4.E. Settlements	2. Land Converted to Settlements	CO_2	11,261	4,708	-	-	-	-	-43%	+43%	-0.4%	0.4%	-0.2%	0.2%	-58.2%	0.0%	0.4%	NA	NA	NA	NA	0.0%	0.0%
4.F. Other Land	2. Land Converted to Other Land	CO_2	2,247	646	-	-	-	-	-53%	+53%	-0.1%	0.1%	0.0%	0.0%	-71.2%	0.0%	0.1%	NA	NA	NA	NA	0.0%	0.0%
4.G. Harvested Wood Products		CO_2	-404	-1,546	-	-	-	-	-30%	30%	0.0%	0.0%	0.0%	0.0%	282.3%	0.0%	0.1%	NA	NA	NA	NA	0.0%	0.0%
4.H. Other		CO_2	NO	0	-5%	+5%	-2%	+4%	-5%	6%	NA	NA	0.0%	0.0%	NA	NA	0.0%	NA	NA	0.0%	0.0%	0.0%	0.0%
4.(I) N_2O Emissions from N Inputs to Managed Soils		N_2O	1	1	-	-	-	-	-38%	101%	0.0%	0.0%	0.0%	0.0%	-54.5%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
4.(II) CH_4 Emissions from Drainage of Organic Soils		CH_4	64	45	-	-	-	-	-49%	+49%	0.0%	0.0%	0.0%	0.0%	-28.9%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
4.(II) N_2O Emissions from Drainage of Organic Soils		N_2O	3	1	-	-	-	-	-26%	+48%	0.0%	0.0%	0.0%	0.0%	-52.3%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
4.(III) N_2O Emissions from N Mineralization/Immobilization		N_2O	847	414	-	-	-	-	-59%	+159%	0.0%	0.1%	0.0%	0.1%	-51.2%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
4.(IV) Biomass Burning		CH_4	53	207	-	-	-	-	-32%	+32%	0.0%	0.0%	0.0%	0.0%	289.6%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
4.(IV) Biomass Burning		N_2O	20	28	-	-	-	-	-52%	+52%	0.0%	0.0%	0.0%	0.0%	39.9%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%

Table A2-6 Data used for uncertainty assessment (Waste Sector, Indirect CO_2)

A		B	C	D	E		F		G		H-1990		H-2024		T	I	J	K		L		M	
Category		GHG	FY1990 emissions / removals	FY2024 emissions / removals	Activity data uncertainty		Emission factor/ estimation parameter uncertainty		Combined uncertainty		Combined Uncertainty as % of Total National Emissions in FY1990		Combined Uncertainty as % of Total National Emissions in FY2024		Emission increase rate	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor/ estimation parameter uncertainty		Uncertainty in trend in national emissions introduced by activity data uncertainty		Uncertainty introduced into the trend in total national emissions	
			Input Data	Input Data	Input Data		Input Data		$(E^2+F^2)^{\wedge}1/2$		G*C/ ΣC		G*D/ ΣD		D/C	Note*	D/ ΣC	I*F		J*E*√2		$(K^2+L^2)^{\wedge}1/2$	
			kt-CO_2 eq.	kt-CO_2 eq.	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	%	%	%	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %
5.A. Solid Waste Disposal	1. Managed Waste Disposal Site (MW)	CH_4	6,681	875	-	-	-	-	-36%	+36%	-0.2%	0.2%	0.0%	0.0%	-86.9%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.A. Solid Waste Disposal	1. Managed Waste Disposal Site (IW)	CH_4	4,506	564	-	-	-	-	-23%	+23%	-0.1%	0.1%	0.0%	0.0%	-87.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.A. Solid Waste Disposal	3. Uncategorized Disposal Site (Inappropriate Disposal)	CH_4	2	8	-60%	+60%	-42%	+41%	-74%	+73%	0.0%	0.0%	0.0%	0.0%	258.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.B. Biological Treatment of Solid Waste	1. Composting	CH_4	60	72	-30%	+30%	-79%	+79%	-84%	+84%	0.0%	0.0%	0.0%	0.0%	19.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.B. Biological Treatment of Solid Waste	1. Composting	N_2O	161	190	-30%	+30%	-167%	+167%	-170%	+170%	0.0%	0.0%	0.0%	0.0%	18.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C. Incineration and Open Burning of Waste	1. Waste Incineration (MSW)	CO_2	5,587	2,927	-	-	-	-	-7%	+7%	0.0%	0.0%	0.0%	0.0%	-47.6%	0.0%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C. Incineration and Open Burning of Waste	1. Waste Incineration (IW Oil)	CO_2	1,913	1,801	-30%	+30%	-22%	+22%	-37%	+37%	-0.1%	0.1%	-0.1%	0.1%	-5.9%	0.0%	0.2%	0.0%	0.0%	-0.1%	0.1%	0.1%	0.1%
5.C. Incineration and Open Burning of Waste	1. Waste Incineration (ISW)	CO_2	1,527	2,331	-	-	-	-	-32%	-32%	0.0%	0.0%	-0.1%	-0.1%	52.7%	0.0%	0.2%	0.0%	0.0%	-0.1%	0.1%	0.1%	0.1%
5.C. Incineration and Open Burning of Waste	1. Waste Incineration (SCIW)	CO_2	916	1,409	-60%	+60%	-11%	+11%	-61%	+61%	0.0%	0.0%	-0.1%	0.1%	53.7%	0.0%	0.1%	0.0%	0.0%	-0.1%	0.1%	0.1%	0.1%
5.C. Incineration and Open Burning of Waste	2. Open burning of Waste (IW)	CO_2	6	0	-30%	+30%	-11%	+11%	-32%	+32%	0.0%	0.0%	0.0%	0.0%	-99.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C. Incineration and Open Burning of Waste	1. Waste Incineration (MSW)	CH_4	13	1	-	-	-	-	-37%	+166%	0.0%	0.0%	0.0%	0.0%	-92.5%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
5.C. Incineration and Open Burning of Waste	1. Waste Incineration (IW Oil)	CH_4	0	0	-30%	+30%	-100%	+181%	-104%	+184%	0.0%	0.0%	0.0%	0.0%	-18%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C. Incineration and Open Burning of Waste	1. Waste Incineration (IW Sludge)	CH_4	2	0	-30%	+30%	-100%	+201%	-104%	+203%	0.0%	0.0%	0.0%	0.0%	-87.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C. Incineration and Open Burning of Waste	1. Waste Incineration (ISW)	CH_4	3	7	-	-	-	-	-54%	+54%	0.0%	0.0%	0.0%	0.0%	161.9%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
5.C. Incineration and Open Burning of Waste	1. Waste Incineration (SCIW)	CH_4	0	1	-60%	+60%	-100%	+216%	-117%	+224%	0.0%	0.0%	0.0%	0.0%	559.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C. Incineration and Open Burning of Waste	2. Open burning of Waste (IW)	CH_4	13	0	-30%	+30%	-100%	+100%	-104%	+104%	0.0%	0.0%	0.0%	0.0%	-99.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C. Incineration and Open Burning of Waste	1. Waste Incineration (MSW)	N_2O	272	84	-	-	-	-	-27%	+28%	0.0%	0.0%	0.0%	0.0%	-69.1%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
5.C. Incineration and Open Burning of Waste	1. Waste Incineration (IW Oil)	N_2O	4	20	-30%	+30%	-76%	+76%	-81%	+81%	0.0%	0.0%	0.0%	0.0%	417.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C. Incineration and Open Burning of Waste	1. Waste Incineration (IW Sludge)	N_2O	934	1,056	-30%	+30%	-84%	+84%	-89%	+89%	-0.1%	0.1%	-0.1%	0.1%	13.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C. Incineration and Open Burning of Waste	1. Waste Incineration (ISW)	N_2O	57	26	-	-	-	-	-54%	54%	0.0%	0.0%	0.0%	0.0%	-53.5%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
5.C. Incineration and Open Burning of Waste	1. Waste Incineration (SCIW)	N_2O	5	9	-60%	+60%	-44%	+44%	-74%	+74%	0.0%	0.0%	0.0%	0.0%	84.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C. Incineration and Open Burning of Waste	2. Open burning of Waste (IW)	N_2O	2	0	-30%	+30%	-100%	+100%	-104%	+104%	0.0%	0.0%	0.0%	0.0%	-99.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	1. DWW (Sewage Treatment Plants)	CH_4	242	348	-5%	+5%	-31%	+31%	-31%	+31%	0.0%	0.0%	0.0%	0.0%	43.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	1. DWW (Domestic Sewage Treatment Plants)	CH_4	851	851	-	-	-	-	-31%	+31%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.1%	NA	NA	NA	NA	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	1. DWW (Human Waste Treatment Plants)	CH_4	147	4	-10%	+10%	-84%	+84%	-84%	+84%	0.0%	0.0%	0.0%	0.0%	-97.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	1. DWW (Natural Decomposition)	CH_4	1,728	281	-10%	+10%	-58%	+58%	-59%	+59%	-0.1%	0.1%	0.0%	0.0%	-83.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	2. IWW (IWW Treatment)	CH_4	62	47	-30%	+30%	-60%	+60%	-67%	+67%	0.0%	0.0%	0.0%	0.0%	-24.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	2. IWW (Natural Decomposition)	CH_4	230	104	-30%	+30%	-58%	+58%	-66%	+66%	0.0%	0.0%	0.0%	0.0%	-54.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	2. IWW (Landfill Leachate Treatment)	CH_4	34	4	-100%	+100%	-39%	+39%	-107%	+107%	0.0%	0.0%	0.0%	0.0%	-88.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	1. DWW (Sewage Treatment Plants)	N_2O	370	382	-5%	+5%	-100%	+146%	-100%	+146%	0.0%	0.0%	0.0%	0.1%	3.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	1. DWW (Domestic Sewage Treatment Plants)	N_2O	403	419	-	-	-	-	-42%	42%	0.0%	0.0%	0.0%	0.0%	4.1%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	1. DWW (Human Waste Treatment Plants)	N_2O	59	2	-10%	+10%	-87%	+87%	-88%	+88%	0.0%	0.0%	0.0%	0.0%	-96.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	1. DWW (Natural Decomposition)	N_2O	738	479	-10%	+10%	-58%	+58%	-59%	+59%	0.0%	0.0%	0.0%	0.0%	-35.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	2. IWW (IWW Treatment)	N_2O	265	299	-30%	+30%	-95%	+95%	-100%	+100%	0.0%	0.0%	0.0%	0.0%	12.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	2. IWW (Natural Decomposition)	N_2O	281	147	-30%	+30%	-58%	+58%	-66%	+66%	0.0%	0.0%	0.0%	0.0%	-47.7%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	2. IWW (Landfill Leachate Treatment)	N_2O	7	1	-100%	+100%	-39%	+39%	-107%	+107%	0.0%	0.0%	0.0%	0.0%	-88.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.E. Other	Decomposition of Fossil-Fuel-Derived Surfactants	CO_2	703	560	-10%	+10%	-1%	+1%	-10%	+10%	0.0%	0.0%	0.0%	0.0%	-20.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

A		B	C	D	E		F		G		H-1990		H-2024		T	I	J	K		L		M	
Indirect CO_2	from Energy Sector	Ind CO_2	1,085	473	-	-	-	-	-22%	+39%	0.0%	0.0%	0.0%	0.0%	-56.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Indirect CO_2	from IPPU Sector	Ind CO_2	4,480	1,388	-	-	-	-	-31%	+56%	-0.1%	0.2%	0.0%	0.1%	-69.0%	0.0%	0.1%	NA	NA	NA	NA	0.0%	0.0%

Note*: Type A sensitivity $= \frac{0.01\times D_x+\sum D_i-(0.01\times C_x+\sum C_i)}{(0.01\times C_x+\sum C_i)} \times 100 - \frac{\sum D_i-\sum C_i}{\sum C_i} \times 100$

Where: C_x, D_x = entry of row x of column C and D respectively in Table A2

ΣC_i, ΣD_i = sum of column C and D respectively

References

1. IPCC, *2006 IPCC Guidelines for National Greenhouse Inventories,* 2006.
2. UNFCCC, *Modalities, Procedures and Guidelines for the Transparency Framework for Action and Support Referred to in Article 13 of the Paris Agreement,* Decision 18/CMA.1 Annex, FCCC/PA/CMA/2018/3/Add.2, 2019.
3. Ministry of the Environment, *Guidelines for Uncertainty Assessment of GHG Inventories in Japan*, 2013.

Annex 3. National Energy Balance

According to "Outline of the national inventory document" (decision 5/CMA.3 Annex V), Parties to the Paris Agreement are encouraged to provide a detailed description of the reference approach (including inputs to the reference approach such as the national energy balance) and the results of the comparison of national estimates of emissions with those obtained using the reference approach in Annex 3 of the national inventory document (NID). Simultaneously, according to the same outline, Parties are encouraged to provide the results of the comparison of the sectoral approach with the reference approach in Chapter 3, Section 3.2.1 of the NID. In order to avoid the occurrence of duplication and/or discrepancies between Chapter 3 and Annex 3, those descriptions are collectively described in Chapter 3, Section 3.2.1 of this NID. This Annex describes topics related to the Japan's national energy balance.

A3.1. Discrepancies Between the Figures Reported in the CRT and the IEA Statistics

There are some discrepancies between the reference approach figures reported in CRT Table 1.A(b) and the figures reported in the IEA statistics. In this section, the main differences are explained using the FY2023 results. The IEA statistical data used in the explanation were extracted from the *World Energy Statistics*, July 2025 Edition, OECD/IEA.

In summary, these discrepancies occurred; because (a) the CRT and the IEA statistics treat international aviation and marine bunker fuels (bonded exports) differently, and (b) fuel oil A is classified in a different way. The figures for imports and exports of fuels reported in the CRT include the bonded exports, whereas the figures for imports and exports of fuels in the IEA statistics do not. With respect to fuel oil A, Japan includes it under "heavy fuel oil" in its energy balances but reports it to the IEA under gas/diesel oil according to the classifications used in Europe and the United States.

According to Japanese definition, fuel oil A has a flash point of more than 60 °C, kinematic viscosity of below 20 mm^2/s, carbon residue content of below 4% and sulfur content of below 2.0 %. Fuel oil B has a flash point of more than 60 °C, kinematic viscosity of below 50 mm^2/s, carbon residue content of below 8% and sulfur content of below 3.0 %. Fuel oil B is rarely used nowadays in Japan, for this reason, fuel oil B is treated as "fuel oil B/C" together with fuel oil C in Japanese statistics. Fuel oil C has a flash point of more than 70 °C, kinematic viscosity of less than 1,000 mm^2/s and sulfur content of less than 3.5%.

In addition, the preliminary figures of reporting year (y) based on the *General Energy Statistics* are used for reporting to the IEA in fall of the next fiscal year (y+1), which starts in April and ends in March; on the other hand, the final figures based on the *General Energy Statistics* are used for reporting to the UNFCCC since the final figures are available in the CRT submission period in spring of the next year (y+2). Therefore, there are discrepancies of the reported values between the IEA statistics (preliminary figures) and the CRT (final figures) at the time of review under the UNFCCC in summer of the next year (y+2). The preliminary figures reported to the IEA are updated to the final figures in fall of the next year (y+2) and are published in the IEA statistics in summer of the year after next (y+3); the discrepancies between the data in the CRT and the IEA statistics are dissolved at the time, except for discrepancies resulted from the definitions or different estimation methods mentioned below.

Further explanations are provided below.

a) Differences in exports of jet kerosene and residual fuel oil

<Explanation 1: Exports of jet kerosene>

The figures for jet kerosene exports reported in the CRT are different from those in the IEA statistics because the CRT figures include bonded exports whereas the export figures in the IEA statistics do not. The IEA statistics accounted the consumption of jet kerosene by international aviation bunkers as an aggregate of the bonded exports and imports. (See Chapter 3, for bonded exports and imports.)

Table A 3-1 Exports of jet kerosene in FY2023 (reference)

CRT Table 1.A(b)
Exports: 8,067.26 × 10^3 kL
IEA statistics
Exports: 721.67 × 10^3 t [8,067.26 × 10^3 kL (exports) - 7,146.06 × 10^3 kL (bonded exports) = 921.20 × 10^3 kL. 921.20 × 10^3 kL × 0.7834 t/kL (density) = 721.67 × 10^3 t] <Remarks> International aviation: 6,903.16×10^3 t [7,146.06 × 10^3 kL (bonded exports) + 1,665.74 × 10^3 kL (bonded imports) = 8,811.80 × 10^3 kL. 8,811.80 × 10^3 kL × 0.7834 t/kL (density) = 6,903.16 × 10^3 t]

<Explanation 2: Exports of residual fuel oil>

The figures for exports of residual fuel oil reported in the CRT are different from those in the IEA statistics because the CRT figures for residual fuel oil include the bonded exports, whereas the export figures for fuel oil in the IEA statistics do not. The bonded exports portion of the fuel oil was reported in the IEA statistics as an aggregate of the bonded exports and imports of fuel oil under international marine bunkers. (See Chapter 3, for bonded exports and imports.)

Further, the figures for exports of residual fuel oil reported in the CRT include fuel oil A, whereas the figures reported under fuel oil in the IEA statistics do not. The IEA reports fuel oil A together with gas oil under gas/diesel oil in its statistics. Because fuel oil A, which is treated as a fuel oil that is distinguished from diesel oil in Japan, is grouped together with diesel oil in Europe and the United States, the fuel oil A data have been included in the diesel oil data in Japan's report to the IEA.

Table A 3-2 Exports of residual fuel oil in FY2023 (reference)

CRT Table 1.A(b)
Exports: 7,920.75 × 10^3 kL [90.89×10^3 kL (fuel oil A) + 0.00×10^3 kL (fuel oil B) + 7,829.86×10^3 kL (fuel oil C for general use) + 0.00 × 10^3 kL (fuel oil C for power generation)= 7,920.75 × 10^3 kL]
IEA statistics
Exports: 2,910.92×10^3 t [0.00×10^3 kL (fuel oil B) + 7,829.86×10^3 kL (fuel oil C for general use) + 0.00×10^3 kL (fuel oil C for power generation) - 4,595.51×10^3 kL (bonded exports of fuel oils B and C) = 3,234.35×10^3 kL. 3,234.35 × 10^3 kL × 0.9000 t/kL (density) = 2,910.92 × 10^3 t] <Remarks> International marine bunkers: 4,176.33×10^3 t [4,595.51 × 10^3 kL (bonded exports of fuel oils B and C) + 44.86 × 10^3 kL (bonded imports of fuel oils B and C) = 4,640.37 × 10^3 kL. 4,640.37 × 10^3 kL × 0.9000 t/kL (density) = 4,176.33 × 10^3 t]

b) Differences in imports of jet kerosene and gas/diesel oil

<Explanation 1: Imports of jet kerosene>

The figures for jet kerosene imports reported in the CRT are different from those in the IEA statistics because the CRT figures are the sums of imports including bonded imports and bonded exports while the IEA statistics figures are the imports including bonded imports. (See Chapter 3, for bonded exports and imports.)

Table A 3-3 Imports of jet kerosene in FY2023 (reference)

CRT Table 1.A(b)
Imports: 8,853.62 × 10^3 kL [41.82 × 10^3 kL (imports) + 1,665.74 × 10^3 kL (bonded imports) + 7,146.06 × 10^3 kL (bonded exports) = 8,853.62×10^3 kL]
IEA statistics
Imports: 1,337.70 × 10^3 t [41.82 × 10^3 kL (imports) + 1,665.74 × 10^3 kL (bonded imports) = 1,707.56 × 10^3 kL. 1,707.56×10^3 kL × 0.7834 t/kL (density) = 1,337.70×10^3 t]

<Explanation 2: Imports of gas/diesel oil>

The figures for imports of gas/diesel oil reported in the CRT are different from those in the IEA statistics, because the CRT figures are the sums of imports (including bonded imports) and bonded exports of diesel oil, which excludes fuel oil A, while the figures for imports of gas/diesel oil in the IEA statistics are the aggregate of imports of diesel oil and fuel oil A, both of which included the bonded imports.

Table A 3-4 Imports of gas/diesel oil in FY2023 (reference)

CRT Table 1.A(b)
Imports: 1,259.92 × 10^3 kL [1,245.76 × 10^3 kL (imports of gas/diesel oil) + 0.00 × 10^3 kL (bonded imports of gas/diesel oil) + 14.15 × 10^3 kL (bonded exports of gas/diesel oil) = 1,259.92 × 10^3 kL]
IEA statistics
Imports: 1,060.39 × 10^3 t [1,245.76 × 10^3 kL (imports of gas/diesel oil) + 0.00×10^3 kL (bonded imports of gas/diesel oil) + 12.11×10^3 kL (imports of fuel oil A) + 0.00×10^3 kL (bonded imports of fuel oil A) = 1,257.88×10^3 kL. 1,257.88 × 10^3 kL × 0.8430 t/kL (density) = 1,060.39×10^3 t]

c) Differences in imports of coking coal

<Explanation: Imports of coking coal>

The imported amounts of coking coal in the CRT and the IEA statistics in physical units are basically the same.

Table A 3-5 Imports of coking coal in FY2023 (reference)

CRT Table 1.A(b)
Imports: 39,681.60×10^3 t
IEA statistics
Imports: 39,681.60×10^3 t

d) Differences in stock changes in liquid and gaseous fuels

It should be noted that the plus-minus signs of stock changes in the CRT differ from those of the IEA. The changes in the CRT are defined as plus for stock increase and as minus for stock release, while the changes in the IEA are defined as minus for stock increase and as plus for stock release.

<Explanation 1: Changes in crude oil stock>

The difference between the CRT and the IEA statistics with respect to changes in crude oil stock occurred because the figures reported in the CRT were calculated using the stock of crude oil after customs clearance (or more precisely, after inspection in the presence of customs officers). The stock changes reported in the IEA statistics were calculated based on stock that included crude oil carried by oil tankers in Japanese territorial waters, but which was yet to clear customs as well as the crude oil in the national stockpile. This discrepancy arose because the UNFCCC and the IEA had different objectives.

Table A 3-6 Changes in crude oil stock in FY2023 (reference)

CRT Table 1.A(b)
Stock changes: 86.41 × 10^3 kL [85.27 × 10^3 kL (crude oil for refining) + 1.15 × 10^3 kL (crude oil for power generation) = 86.41×10^3 kL]
IEA statistics
Stock changes: 741.91×10^3 t [(9,893.04 × 10^3 kL (opening stock) + 43,323.00 ×10^3 kL (opening national stockpile) + 2,277.00 × 10^3 kL (opening stock carried by oil tankers) - 1,013.00 × 10^3 kL (opening joint stockpile with Abu Dhabi)) - (9,978.30 × 10^3 kL (closing stock) + 42,534.00 ×10^3 kL (closing national stockpile) + 2,115.00 × 10^3 kL (closing stock carried by oil tankers) - 1,015.00 × 10^3 kL (closing joint stockpile with Abu Dhabi)) = 867.74 × 10^3 kL. 867.74 × 10^3 kL × 0.8550 t/kL (density) = 741.91×10^3 t]

<Explanation 2: Changes in NGL stock>

Stock changes concerning NGL in FY2023 were reported as 0 in the CRT and the IEA Statistics. The NGL stock changes reported in the IEA statistics were 0 because the NGL stock figure in the Monthly Oil Statistics (MOS) of the IEA was 0. This discrepancy resulted from the direction given by the IEA that the figures in the IEA statistics must be consistent with the MOS figures. Furthermore, the MOS requires figures for opening stock and closing stock, but Japan does not collect such statistical data for NGL. As a result, Japan reported 0 values to the IEA for both opening stock and closing stock data for the MOS. Due to lack of statistical data for stock changes in NGL, the estimated value calculated as a difference between supply and consumption amount is reported as stock change in the CRT. The estimated value is 0 in FY2023.

<Explanation 3: Changes in gasoline stock>

The figures for stock of gasoline reported in the CRT are changes of gasoline stock only, whereas the values relating to the stock of gasoline in the IEA statistics are changes of gasoline stock plus national stockpile minus other gasoline stock. Other gasoline stock is reported as stock change of white spirit in the IEA statistics.

Table A 3-7 Changes in gasoline stock in FY2023 (reference)

CRT Table 1.A(b)
Stock changes: -62.60 × 10^3 kL
IEA statistics
Stock changes: 50.97 × 10^3 t [(1,616.36 × 10^3 kL (opening stock) + 585.42 × 10^3 kL (opening national stockpile) - 11.82 × 10^3 kL (opening gasoline inventories for others (*Monthly Report of Current Production Statistics*, METI) - 4.59 × 10^3 kL (opening gasoline inventories for others (*Mineral Resources and Petroleum Products Statistics*, METI)) - (1,553.76 × 10^3 kL (closing stock) + 582.00 × 10^3 kL (closing national stockpile) - 7.46 × 10^3 kL (closing gasoline inventories for others (*Monthly Report of Current Production Statistics*, METI) - 12.08 × 10^3 kL (closing gasoline inventories for others *(Mineral Resources and Petroleum Products Statistics*, METI)) = 69.16 × 10^3 kL. 69.16×10^3 kL × 0.7370 t/kL (density) = 50.97 × 10^3 t]

<Explanation 4: Changes in jet kerosene stock>

The figures for changes in jet kerosene stock reported in the CRT are basically the same as the figures in the IEA statistics.

Table A 3-8 Changes in jet kerosene stock in FY2023 (reference)

CRT Table 1.A(b)
Stock changes: 84.43 × 10^3 kL
IEA statistics
Stock changes: -66.14 × 10^3 t [633.14 × 10^3 kL (opening stock) - 717.56 × 10^3 kL (closing stock) = -84.43 × 10^3 kL. -84.43×10^3 kL × 0.7834 t/kL (density) = -66.14 × 10^3 t]

<Explanation 5: Changes in kerosene stock>

The figures reported in the CRT are changes in kerosene stock only, while the figures in the IEA statistics are the sum of the changes in kerosene stock and national stockpile of kerosene.

Table A 3-9 Changes in kerosene stock in FY2023 (reference)

CRT Table 1.A(b)
Stock changes: -121.48 × 10^3 kL
IEA statistics
Stock changes: 99.15 × 10^3 t [(1,273.17 × 10^3 kL (opening stock) + 317.33 × 10^3 kL (opening national stockpile)) - (1,151.69 × 10^3 kL (closing stock) + 317.00 × 10^3 kL (closing national stockpile)) = 121.81×10^3 kL. 121.81 × 10^3 kL × 0.8140 t/kL (density) = 99.15×10^3 t]

<Explanation 6: Changes in gas/diesel oil stock>

The figures for gas/diesel stock reported in the CRT did not include stock changes in fuel oil A, while the figures in the IEA statistics included stock changes in fuel oil A and change of national stockpile of gas/diesel oil and fuel oil A.

Table A 3-10 Changes in gas/diesel oil stock in FY2023 (reference)

CRT Table 1.A(b)
Stock changes: 204.21×10^3 kL
IEA statistics
Stock changes: -112.16×10^3 t [(1,161.63 × 10^3 kL (gas/diesel oil, opening stock) + 702.16 × 10^3 kL (fuel oil A, opening stock) + 374.16×10^3 kL (gas/diesel oil, opening national stockpile) + 152.18×10^3 kL (fuel oil A, opening national stockpile)) - (1,365.85 × 10^3 kL (gas/diesel oil, closing stock) + 631.33 × 10^3 kL (fuel oil A, closing stock) + 374.00 × 10^3 kL (gas/diesel oil, closing national stockpile) +152.00 × 10^3 kL (fuel oil A, closing national stockpile)) = -133.05 × 10^3 kL. -133.05 × 10^3 kL × 0.8430 t/kL (density) = -112.16×10^3 t]

<Explanation 7: Changes in residual fuel oil stock>

The figures for residual fuel oil stock reported in the CRT were different from those in the IEA statistics because the CRT figures included changes in fuel oil A stock, whereas stock change data under

fuel oil in the IEA statistics did not include fuel oil A. (See the explanation for the gas/diesel oil data above.)

Table A 3-11 Changes in residual fuel oil stock in FY2023 (reference)

CRT Table 1.A(b)
Stock changes: -65.57 × 10^3 kL [-70.83 × 10^3 kL (fuel oil A) + 0.00 × 10^3 kL (fuel oil B) + 5.26 × 10^3 kL (fuel oil C for general use) + 0.00 × 10^3 kL (fuel oil C for power generation) = -65.57 × 10^3 kL]
IEA statistics
Stock changes: -4.74×10^3 t [1,120.06 × 10^3 kL (fuel oil B and C, opening stock) - 1,125.32 × 10^3 kL (fuel oil B and C, closing stock) = -5.26 × 10^3 kL. -5.26×10^3 kL × 0.9000 t/kL (density) = -4.74 × 10^3 t]

<Explanation 8: Changes in LPG stock>

The figures for changes in LPG stock reported in the CRT may differ from those reported in IEA statistics, because the LPG stock in IEA includes the national stock.

Table A 3-12 Changes in LPG stock in FY2023 (reference)

CRT Table 1.A(b)
Stock changes: -133.16 × 10^3 t
IEA statistics
Stock changes: 133.16 × 10^3 t [(1,736.64 × 10^3 t (opening stock) + 1,394.00 × 10^3 t (opening national stockpile)) - (1,603.48 × 10^3 t (closing stock) + 1,394.00 × 10^3 t (closing national stockpile)) = 133.16×10^3 t]

<Explanation 9: Changes in naphtha stock>

The figures for changes in naphtha stock reported in the CRT are the same as the figures in the IEA statistics.

Table A 3-13 Changes in naphtha stock in FY2023 (reference)

CRT Table 1.A(b)
Stock changes: 15.07 × 10^3 kL
IEA statistics
Stock changes: -11.11 × 10^3 t [1,408.21 × 10^3 kL (opening stock) - 1,423.28 × 10^3 kL (closing stock) = -15.07 × 10^3 kL. -15.07 × 10^3 kL × 0.7370 t/kL (density) = -11.11 × 10^3 t]

<Explanation 10: Changes in bitumen stock>

The figures for changes in bitumen stock reported in the CRT were slightly different from the figures reported under bitumen in the IEA statistics because the bitumen data in the CRT included “asphalt” and “miscellaneous heavy oil products”. The IEA statistics reported figures for only “asphalt” under bitumen, and the figures for “miscellaneous heavy oil products” reported in the CRT under bitumen were included in the figures reported under paraffin waxes in the IEA statistics.

Table A 3-14 Changes in bitumen stock in FY2023 (reference)

CRT Table 1.A(b)
Stock changes: -29.05×10^3 t [-25.67×10^3 t (asphalt) + -3.38×10^3 t (miscellaneous heavy oil products ($0454)) = -29.05×$10^3$ t]
IEA statistics
Stock changes: 25.67×10^3 t [218.65×10^3 t (opening stock) - 192.98×10^3 t (closing stock) = 25.67×10^3 t]

<Explanation 11: Changes in lubricants stock>

The figures for changes in lubricants stock reported in the CRT are basically the same as the figures in the IEA statistics.

Table A 3-15 Changes in lubricants stock in FY2023 (reference)

CRT Table 1.A(b)
Stock changes: -65.47×10^3 kL
IEA statistics
Stock changes: 58.33×10^3 t [492.95×10^3 kL (opening stock) - 427.49×10^3 kL (closing stock) = 65.47×10^3 kL. 65.47×10^3 kL × 0.8910 t/kL (density) = 58.33×10^3 t]

<Explanation 12: Changes in petroleum coke stock>

The figures for changes in petroleum coke stock reported in the CRT are the same as the figures in the IEA statistics.

Table A 3-16 Changes in petroleum coke stock in FY2023 (reference)

CRT Table 1.A(b)
Stock changes: 24.82×10^3 t
IEA statistics
Stock changes: -24.82×10^3 t [13.22×10^3 t (opening stock) - 38.04×10^3 t (closing stock) = -24.82×10^3 t]

<Explanation 13: Changes in refinery feedstock stock>

The figures for changes in refinery feedstock stock reported in the CRT were different from those in the IEA statistics because the IEA statistics included the figures for stock changes in slack wax and slack coke in addition to the semi-refined products reported in the CRT.

The changes in slack wax and coke stocks were not reported in the CRT because both items were solids used as raw materials for the production of paraffin and petroleum coke, and unlikely to be returned to oil refining processes. In addition, shipments of paraffin and petroleum coke produced using slack wax and slack coke were separately accounted for.

Table A 3-17 Changes in refinery feedstock stock in FY2023 (reference)

CRT Table 1.A(b)
Stock changes: 527.24×10^3 kL [256.70×10^3 kL (slack gasoline) + -49.42×10^3 kL (slack kerosene) + 72.78×10^3 kL (slack diesel oil or gas oil) + 247.17×10^3 kL (slack fuel oil) + 0.00×10^3 kL (feedstock oil for refinery and mixing) = 527.24×10^3 kL]
IEA statistics
Stock changes: -418.54×10^3 t [(1,858.18×10^3 kL (slack gasoline, opening stock) - 2,114.88×10^3 kL (slack gasoline, closing stock)) × 0.7370 t/kL (density) + (374.68×10^3 kL (slack kerosene, opening stock) - 325.26×10^3 kL (slack kerosene, closing stock)) × 0.8140 t/kL(density) + (645.96×10^3 kL (slack diesel oil or gas oil, opening stock) - 718.74×10^3 kL (slack diesel oil or gas oil, closing stock)) × 0.8430 t/kL (density) + (3,454.84×10^3 kL (slack fuel oil, opening stock) - 3,729.42 × 10^3 kL (slack fuel oil, closing stock)) × 0.9000 t/kL (density) + (460.59×10^3 kL (slack lubricant, opening stock) - 433.18 × 10^3 kL (slack lubricant, closing stock)) × 0.8910 t/kL (density) + (25.55×10^3 kL (slack wax, opening stock) - 14.88 × 10^3 kL (slack wax, closing stock)) × 0.8160 t/kL (density) + (34.82×10^3 kL (slack coke, opening stock) - 28.72 × 10^3 kL (slack coke, closing stock)) × 0.9436 t/kL (density) = -418.54×10^3 t]

<Explanation 14: Changes in natural gas stock>

The figures for changes in natural gas stock (imported natural gas (LNG) and domestic natural gas) reported in the CRT were different from those in the IEA statistics because of the treatment of changes in the LNG stock and the city gas stock. The source figures for the domestic natural gas stock were the same for reporting of the CRT and the IEA statistics because the statistical data existed in Japan. The figures for stock changes in natural gas reported to the CRT do not include the changes in LNG stock. On the other hand, the figures for stock changes in natural gas reported to the IEA includes the stock change in LNG (estimates) calculated as the difference between the stock volume at the end of the previous year and the stock volume at the end of the current year in the *Electric Power Statistics* and the *Current Survey of Production Concerning Gas Industry*. The figures for stock of natural gas reported in the CRT include the city gas stock, whereas the figures for stock of natural gas in the IEA statistics do not.

Table A 3-18 Changes in natural gas stock in FY2023 (reference)

CRT Table 1.A(b)
Stock changes: -449.05 TJ [-10.253×10^6 m^3-SATP (indigenous natural gas) × 38.36 MJ/m^3-SATP (GCV) + -1.393×10^6 m^3-SATP (city gas) ×40.02 MJ/m^3-SATP (GCV) = -449.05 TJ]
IEA statistics
Stock changes: 83,545.69 TJ [(2,818.78×10^3 t (LNG, opening stock (*Electric Power Statistics*)) + 2,649.28×10^3 t (LNG, opening stock (*Current Survey of Production Concerning Gas Industry*))} × 54.71 MJ/kg (GCV in previous year) + 252.042×10^6 Sm^3 (natural gas, opening stock) / 1.0759 Sm^3/Nm^3 × 1.1060 m^3 - SATP/Nm^3 × 38.38 MJ/m^3-SATP (GCV in previous year) = 309,102.74 TJ (opening stock). {1,784.49×10^3 t (LNG, closing stock (*Electric Power Statistics*)) + 2,162.68×10^3 t (LNG, closing stock (*Current Survey of Production Concerning Gas Industry*))} ×54.72 MJ/kg (GCV in current year) + 242.068×10^6 Sm^3 (natural gas, closing stock) / 1.0759 Sm^3/Nm^3 × 1.1060 m^3-SATP/Nm^3 × 38.38 MJ/m^3-SATP (GCV in current year) = 225,557.04 TJ (closing stock). 309,102.74 TJ (opening stock) - 225,557.04 TJ (closing stock) = 83,545.69 TJ]

A3.2. General Energy Statistics

A3.2.1 General Energy Statistics Overview

The data given in the *General Energy Statistics* compiled by the Agency for Natural Resources and Energy (ANRE) were used for the activity data of fuel combustion (1.A) in energy sector.

The *General Energy Statistics* (Japan's Energy Balance Tables) provides a comprehensive overview of domestic energy supply and demand to grasp what are converted from energy sources, such as coal, oil, natural gas and others, provided in Japan and what are consumed in what sectors. The objective of this *General Energy Statistics* is to help to quantitatively understand energy supply and demand and to make judgments about the situation, in addition to helping with planning for energy and environmental policy, and with measuring, assessing, and otherwise gauging policy effectiveness. The supply/conversion and consumption data in *General Energy Statistics* use official statistics and are structured with the minimum of estimation and adjustment.

The *General Energy Statistics* indicates an overview of domestic energy supply and demand, shows the main energy sources used in Japan as "Columns" and the supply, conversion and consumption sectors as "Rows", in a matrix. Specifically, the columns comprise 13 major categories (coal [$0100[1]], coal products [$0200], crude oil [$0300], oil products [$0400], natural gas [$0500], city gas [$0600], renewable energy (excl. hydro) [$0700], hydraulic power generation (excl. pumped) [$0800], pumped storage [$0900], effective recovery use of wasted energy [$1000], nuclear power generation [$1100], electricity [$1200], and heat [$1300]) and the necessary sub-categories and a more detailed breakdown of the sub-categories. The rows comprise 3 major sectors — primary energy supply [#100000], energy transformation & own use [#200000], and final energy consumption [#500000] — plus the necessary sub-categories and a more detailed breakdown of the sub-categories.

In calculating the energy supply and demand amounts for the *General Energy Statistics*, it is assumed that each energy source, such as gasoline or electricity, is homogeneous in terms of gross calorific value per original unit (MJ/kg, MJ/L, MJ/m^3), and that homogeneous energy sources are supplied, converted and consumed. The values for supply, transformation and consumption in original units as determined from official statistical sources are multiplied by the gross calorific value per original unit to obtain energy supply and demand amounts.

The calculation process in the *General Energy Statistics* is as follows:

1. Setting calorific values and carbon emission factors.
2. Building an energy supply and demand module.
3. Preparing original unit tables (preparing a detailed table, a main table and a summary table through the module from relevant official statistics) (units in t, kL, 10^3 m^3, etc.).
4. Preparing energy unit tables (unit in J).
5. Preparing energy-derived carbon tables (carbon content).

The *General Energy Statistics* is available on the following internet site (Japanese only):
https://www.enecho.meti.go.jp/statistics/total_energy/results.html#headline2

The energy balance simplified tables are shown as follows.

[1] Code number of the *General Energy Statistics*

Table A 3-19 Energy balance simplified table (General Energy Statistics, FY1990, 2013)

1990FY	Row $	$0100	$0200	$0300	$0400	$0500	$0600	$0700	$0800	$0900	$1000	$1100	$1200	$1300	$1400	$1401	$1402
	<< General Energy Statistics >> Simplified energy unit table GCV (gross calorific value) basis Display unit: TJ	Coal	Coal Products	Crude Oil	Oil Products	Natural Gas	City Gas	Renewable (excl. hydro)	Hydraulic Power Generation (excl. pumped)	Pumped Storage	Effective Recovery Use of Wasted Energy	Nuclear Power Generation	Electricity	Heat	Total	Energy Use Total	Non-Energy Use Total
Line #																	
#01	Primary Energy Supply	3,357,112	-39,341	8,981,710	2,026,265	2,056,326	0	267,189	818,519	0	317,978	1,883,500	0	0	19,669,259	18,066,870	1,602,389
#02	Indigenously Produced	193,762	0	24,484	0	89,203	0	266,070	818,519	0	317,978	1,883,500	0	0	3,593,516	0	0
#03	Import	3,161,715	15,352	9,139,187	2,341,006	1,967,475	0	1,119	0	0	0	0	0	0	16,625,854	0	0
#04	Total Primary Energy Supply	3,355,476	15,352	9,163,671	2,341,006	2,056,678	0	267,189	818,519	0	317,978	1,883,500	0	0	20,219,371	18,616,982	1,602,389
#05	Export	-53	-56,644	0	-292,955	0	0	-1	0	0	0	0	0	0	-349,653	0	0
#06	Stockpile Change / Supply (+: withdrawal/ -: build-up)	1,689	1,951	-181,961	-21,786	-352	0	0	0	0	0	0	0	0	-200,458	0	0
#07	Domestic Primary Energy Supply (Supply)	3,357,112	-39,341	8,981,710	2,026,265	2,056,326	0	267,189	818,519	0	317,978	1,883,500	0	0	19,669,259	18,066,870	1,602,389
	(Demand)														19,778,538	18,176,149	1,602,389
#08	Energy Transformation & Own Use	-3,151,561	1,278,447	-8,961,984	5,498,247	-1,980,245	510,901	-210,804	-818,519	0	-317,978	-1,883,500	2,785,405	1,018,386	-6,233,207	-6,170,781	-62,426
#09	Manufacture of Coal Products (+: output/ -: input)	-2,142,047	1,934,969	0	-27,085	0	0	0	0	0	0	0	0	0	-234,162	-234,162	0
#10	Oil Products (+: output/ -: input)	0	0	-8,073,053	8,124,996	5,121	0	0	0	0	0	0	0	-94,149	-37,085	0	-37,085
#11	Gas Conversion and Production (+: output/ -: input)	0	-19,178	0	-161,220	-503,899	683,704	-101	0	0	-445	0	0	0	-1,139	-1,139	0
#12	Power Generation	-673,045	-209,619	-874,209	-1,052,475	-1,529,799	-65	-13,827	-752,524	0	0	-1,882,503	2,679,366	0	-4,308,700	-4,308,700	0
#13	Auto Power Generation	-162,252	-132,541	0	-432,432	-4,367	-27,139	-87,643	-65,995	0	-170,247	-997	407,122	0	-676,491	-676,491	0
#14	Auto Steam Generation	-147,046	-135,509	0	-641,033	-4,241	-61,907	-109,183	0	0	-145,775	0	0	1,106,886	-137,808	-137,808	0
#15	Heat Supply/ Other Energy Transformation	-3,704	2,880	0	4,949	56,636	-62,805	-37	0	0	-1,511	0	-1,229	8,361	3,541	-4,000	7,541
#16	Own Use and Loss	-3,015	-161,697	-1,017	-319,060	-238	-20,889	0	0	0	0	0	-299,854	-2,712	-808,481	-808,481	0
#17	Transformation and Consumption Stockpile Change (+: withdrawal/ -: build-up)	-20,454	-858	-13,705	1,607	542	0	-13	0	0	0	0	0	0	-32,881	0	-32,881
#18	Statistical Discrepancy (+: excess/ -: shortage)	-195,600	12,361	19,725	0	18,443	0	0	0	0	0	0	32,085	3,706	-109,279	-109,279	0
#19	Final Energy Consumption	401,151	1,226,745	0	7,524,512	57,638	510,901	56,385	0	0	0	0	2,753,319	1,014,680	13,545,331	12,005,368	1,539,963
#20	Industry	401,119	1,223,865	0	3,909,149	57,638	167,823	7,989	0	0	0	0	2,077,712	1,013,395	8,858,691	7,359,480	1,499,211
#21	Agriculture, Fishery, Mining and Construction	133	5,090	0	616,237	1,753	2,182	0	0	0	0	0	84,671	2,276	712,343	523,036	189,306
#22	Manufacturing	400,852	1,218,775	0	2,189,457	55,885	100,469	0	0	0	0	0	1,475,333	935,052	6,375,823	5,183,059	1,192,764
#23	Food, Beverages, Tobacco and Feed	48	0	0	53,396	0	8,102	0	0	0	0	0	57,526	49,454	168,526	168,526	0
#24	Textile Mill Products	544	0	0	50,708	0	4,699	0	0	0	0	0	72,141	92,180	220,273	220,273	0
#25	Pulp, Paper and Paper Products	126	0	0	31,995	2	4,731	0	0	0	0	0	131,124	274,119	442,097	442,097	0
#26	Chemical and Allied Products, Oil and Coal Products	6,633	46,779	0	1,457,205	25,021	9,582	0	0	0	0	0	211,987	234,151	1,991,359	812,009	1,179,351
#27	Ceramic, Stone and Clay Products	236,521	37,016	0	203,421	854	13,546	0	0	0	0	0	112,242	42,437	646,038	633,309	12,728
#28	Iron and Steel	156,771	1,121,208	0	212,343	25,309	23,952	0	0	0	0	0	383,523	136,967	2,060,073	2,059,388	685
#29	Non-Ferrous Metals	15,811	11,378	0	56,667	322	9,162	0	0	0	0	0	62,825	17,411	173,575	173,575	0
#30	Machinery	15	13,891	0	172,060	4,698	33,072	0	0	0	0	0	402,666	76,719	703,121	703,121	0
#31	Miscellaneous	194	0	0	37,228	0	6,489	0	0	0	0	0	152,112	38,000	234,024	234,024	0
#32	Commerce, public services and Not elsewhere specified	133	0	0	1,103,455	0	65,172	7,989	0	0	0	0	517,708	76,067	1,770,525	1,653,384	117,140
#33	Residential	0	2,880	0	597,661	0	343,074	48,395	0	0	0	0	615,093	1,284	1,608,388	1,608,388	0
#34	Transportation	33	0	0	3,017,702	0	3	0	0	0	0	0	60,514	0	3,078,252	3,037,500	40,752
#35	Passenger	33	0	0	1,516,269	0	1	0	0	0	0	0	56,610	0	1,572,912	1,540,989	31,923
#36	Freight	0	0	0	1,501,433	0	3	0	0	0	0	0	3,905	0	1,505,340	1,496,511	8,829
#37	Non-energy and Feedstock Use	6,063	26,437	0	1,493,428	13,997	38	0	0	0	0	0	0	0	1,539,963	0	1,539,963

2013FY	Row $	$0100	$0200	$0300	$0400	$0500	$0600	$0700	$0800	$0900	$1000	$1100	$1200	$1300	$1400	$1401	$1402
	<< General Energy Statistics >> Simplified energy unit table GCV (gross calorific value) basis Display unit: TJ	Coal	Coal Products	Crude Oil	Oil Products	Natural Gas	City Gas	Renewable (excl. hydro)	Hydraulic Power Generation (excl. pumped)	Pumped Storage	Effective Recovery Use of Wasted Energy	Nuclear Power Generation	Electricity	Heat	Total	Energy Use Total	Non-Energy Use Total
Line #																	
#01	Primary Energy Supply	5,274,704	28,097	8,036,024	966,605	4,898,871	-527	535,849	679,414	0	553,355	79,612	0	0	21,052,004	19,262,027	1,789,978
#02	Indigenously Produced	31,624	0	24,165	0	119,743	0	517,530	679,414	0	553,355	79,612	0	0	2,005,442	0	0
#03	Import	5,243,135	64,217	8,005,711	2,036,634	4,777,978	0	18,402	0	0	0	0	0	0	20,146,078	0	0
#04	Total Primary Energy Supply	5,274,760	64,217	8,029,876	2,036,634	4,897,721	0	535,932	679,414	0	553,355	79,612	0	0	22,151,520	20,361,543	1,789,978
#05	Export	-56	-35,736	0	-1,173,800	0	0	-83	0	0	0	0	0	0	-1,209,676	0	0
#06	Stockpile Change / Supply (+: withdrawal/ -: build-up)	0	-383	6,148	103,771	1,150	-527	0	0	0	0	0	0	0	110,160	0	0
#07	Domestic Primary Energy Supply (Supply)	5,274,704	28,097	8,036,024	966,605	4,898,871	-527	535,849	679,414	0	553,355	79,612	0	0	21,052,004	19,262,027	1,789,978
	(Demand)														21,091,875	19,301,897	1,789,978
#08	Energy Transformation & Own Use	-4,910,699	1,044,456	-8,070,114	5,926,553	-4,800,224	1,065,862	-518,832	-679,414	0	-530,690	-79,612	3,584,601	940,786	-7,027,327	-6,896,085	-131,242
#09	Manufacture of Coal Products (+: output/ -: input)	-1,645,211	1,554,119	0	-17,890	0	0	0	0	0	-5,598	0	0	0	-114,579	-114,579	0
#10	Oil Products (+: output/ -: input)	0	0	-7,629,955	7,617,491	5,446	0	-9,725	0	0	0	0	0	-131,593	-148,336	0	-148,336
#11	Gas Conversion and Production (+: output/ -: input)	0	0	0	-78,765	-1,662,709	1,741,681	-88	0	0	0	0	0	0	119	119	0
#12	Power Generation	-2,444,764	-199,628	-454,903	-672,861	-3,148,065	-79,217	-53,129	-539,735	0	-6,828	-79,612	3,170,547	0	-4,508,196	-4,508,196	0
#13	Auto Power Generation	-513,415	-99,338	-40	-300,076	-162,729	-141,146	-270,117	-139,679	0	-308,442	0	776,097	0	-1,158,885	-1,158,885	0
#14	Auto Steam Generation	-245,306	-78,181	-79	-371,206	-26,085	-183,704	-184,695	0	0	-206,967	0	0	1,053,416	-242,806	-242,806	0
#15	Heat Supply/ Other Energy Transformation	0	0	0	15,543	208,380	-224,686	-857	0	0	-2,998	0	-3,878	22,902	14,406	-923	15,329
#16	Own Use and Loss	-23,630	-130,316	-470	-290,712	-16,516	-47,066	0	0	0	0	0	-358,165	-3,940	-870,815	-870,815	0
#17	Transformation and Consumption Stockpile Change (+: withdrawal/ -: build-up)	-38,374	-2,199	15,333	25,029	2,054	0	-222	0	0	144	0	0	0	1,765	0	1,765
#18	Statistical Discrepancy (+: excess/ -: shortage)	-91,479	65,012	-34,089	-3	29,362	0	0	0	0	0	0	22,180	-30,854	-39,871	-39,871	0
#19	Final Energy Consumption	455,484	1,007,541	0	6,893,161	69,285	1,065,335	17,017	0	0	22,665	0	3,562,420	971,640	14,064,548	12,405,812	1,658,736
#20	Industry	455,445	1,007,541	0	3,140,948	69,285	645,074	4,815	0	0	22,665	0	2,467,338	970,470	8,783,582	7,161,173	1,622,409
#21	Agriculture, Fishery, Mining and Construction	33	242	0	339,628	5,142	2,789	0	0	0	0	0	39,804	920	388,559	327,002	61,557
#22	Manufacturing	455,172	1,004,168	0	2,125,506	64,143	260,379	396	0	0	22,665	0	1,268,652	927,489	6,128,570	4,619,300	1,509,270
#23	Food, Beverages, Tobacco and Feed	270	83	0	44,451	0	31,703	0	0	0	0	0	93,198	102,135	271,839	271,839	0
#24	Textile Mill Products	0	0	0	9,624	0	4,895	0	0	0	0	0	31,128	45,354	91,001	91,001	0
#25	Pulp, Paper and Paper Products	2,442	0	0	17,693	552	4,508	326	0	0	597	0	118,663	208,866	353,647	353,647	0
#26	Chemical and Allied Products, Oil and Coal Products	805	50,172	0	1,798,358	32,731	25,994	0	0	0	1,305	0	191,753	346,683	2,447,801	938,882	1,508,918
#27	Ceramic, Stone and Clay Products	140,686	13,944	0	97,801	4,224	26,278	70	0	0	17,675	0	67,595	21,834	390,107	389,844	263
#28	Iron and Steel	310,551	937,059	0	100,913	24,464	107,718	0	0	0	3,088	0	355,429	127,371	1,966,593	1,966,504	89
#29	Non-Ferrous Metals	2,162	8,124	0	21,566	975	15,662	0	0	0	815	0	47,075	10,060	106,440	106,440	0
#30	Machinery	17	2,929	0	51,721	2,172	60,542	0	0	0	0	0	345,952	45,020	508,354	508,354	0
#31	Miscellaneous	401	15	0	17,346	0	11,504	0	0	0	0	0	110,427	36,498	176,192	176,192	0
#32	Commerce, public services and Not elsewhere specified	241	3,130	0	675,814	0	381,906	4,419	0	0	0	0	1,158,883	42,061	2,266,453	2,214,871	51,582
#33	Residential	0	0	0	584,366	0	416,311	12,202	0	0	0	0	1,031,286	1,170	2,045,336	2,045,336	0
#34	Transportation	39	0	0	3,167,846	0	3,949	0	0	0	0	0	63,796	0	3,235,630	3,199,304	36,327
#35	Passenger	39	0	0	1,871,820	0	452	0	0	0	0	0	60,725	0	1,933,036	1,905,410	27,626
#36	Freight	0	0	0	1,296,026	0	3,497	0	0	0	0	0	3,071	0	1,302,594	1,293,893	8,701
#37	Non-energy and Feedstock Use	24	18,474	0	1,624,131	16,107	0	0	0	0	0	0	0	0	1,658,736	0	1,658,736

Table A 3-20 Energy balance simplified table (General Energy Statistics, FY2023, 2024)

2023FY	Row $	$0100	$0200	$0300	$0400	$0500	$0600	$0700	$0800	$0900	$1000	$1100	$1200	$1300	$1400	$1401	$1402
<< General Energy Statistics >> Simplified energy unit table GCV (gross calorific value) basis Display unit: TJ		Coal	Coal Products	Crude Oil	Oil Products	Natural Gas	City Gas	Renewable (excl. hydro)	Hydraulic Power Generation (excl. pumped)	Pumped Storage	Effective Recovery Use of Wasted Energy	Nuclear Power Generation	Electricity	Heat	Total	Energy Use Total	Non-Energy Use Total
Line #																	
#01	Primary Energy Supply	4,274,993	12,852	5,510,378	747,516	3,626,868	56	1,458,080	647,815	0	555,094	724,001	0	0	17,557,652	16,387,041	1,170,612
#02	Indigenously Produced	15,117	0	14,323	0	77,993	0	1,330,333	647,815	0	555,094	724,001	0	0	3,364,675	0	0
#03	Import	4,259,947	27,179	5,499,338	1,772,478	3,548,482	0	127,779	0	0	0	0	0	0	15,235,204	0	0
#04	Total Primary Energy Supply	4,275,064	27,179	5,513,661	1,772,478	3,626,475	0	1,458,112	647,815	0	555,094	724,001	0	0	18,599,879	17,429,267	1,170,612
#05	Export	-71	-14,706	0	-1,012,984	0	0	-32	0	0	0	0	0	0	-1,027,793	0	0
#06	Stockpile Change / Supply (+: withdrawal/ -: build-up)	0	379	-3,284	-11,978	393	56	0	0	0	0	0	0	0	-14,434	0	0
#07	Domestic Primary Energy Supply (Supply)	4,274,993	12,852	5,510,378	747,516	3,626,868	56	1,458,080	647,815	0	555,094	724,001	0	0	17,557,652	16,387,041	1,170,612
	(Demand)														17,464,881	16,294,269	1,170,612
#08	Energy Transformation & Own Use	-3,966,197	844,252	-5,510,214	4,628,816	-3,579,857	958,604	-1,449,117	-647,815	0	-523,834	-724,001	3,191,088	822,853	-5,955,422	-6,018,720	63,297
#09	Manufacture of Coal Products (+: output/ -: input)	-1,283,215	1,206,047	0	-13,046	0	0	0	0	0	-3,612	0	0	0	-93,827	-93,827	0
#10	Oil Products (+: output/ -: input)	0	0	-5,508,700	5,503,568	1,483	0	-19,461	0	0	0	0	0	-104,957	-128,067	0	-128,067
#11	Gas Conversion and Production (+: output/ -: input)	0	0	0	-95,790	-1,532,689	1,625,640	0	0	0	0	0	0	0	-2,840	-2,840	0
#12	Power Generation	-2,418,816	-120,152	-1,785	-183,287	-2,167,194	-208,617	-532,840	-625,489	0	-135,352	-724,001	2,961,597	0	-4,155,934	-4,155,934	0
#13	Auto Power Generation	-132,738	-89,037	0	-152,852	-53,331	-99,512	-719,517	-22,326	0	-183,879	0	603,436	0	-849,756	-849,756	0
#14	Auto Steam Generation	-190,898	-53,704	0	-272,224	-23,488	-206,113	-175,641	0	0	-197,431	0	0	902,458	-217,041	-217,041	0
#15	Heat Supply/ Other Energy Transformation	-4,802	0	0	28,245	124,800	-134,765	-756	0	0	-2,956	0	-3,629	31,835	37,971	1,297	36,675
#16	Own Use and Loss	-337	-98,476	-1	-194,687	-11,998	-18,030	-292	0	0	0	0	-370,316	-6,484	-700,620	-700,620	0
#17	Transformation and Consumption Stockpile Change (+: withdrawal/ -: build-up)	64,609	-427	271	8,890	82,560	0	-610	0	0	-603	0	0	0	154,690	0	154,690
#18	Statistical Discrepancy (+: excess/ -: shortage)	-17,174	83,609	163	-57	-9,490	0	0	0	0	0	0	40,136	-4,416	92,771	92,771	0
#19	Final Energy Consumption	325,970	773,495	0	5,376,389	56,502	958,659	8,963	0	0	31,260	0	3,150,952	827,268	11,509,459	10,275,550	1,233,909
#20	Industry	325,941	773,495	0	2,250,361	56,502	573,746	4,166	0	0	31,260	0	2,190,630	826,274	7,032,374	5,834,544	1,197,830
#21	Agriculture, Fishery, Mining and Construction	0	180	0	310,726	4,434	2,246	0	0	0	0	0	42,549	349	360,484	321,733	38,751
#22	Manufacturing	325,934	768,048	0	1,566,545	52,067	240,862	529	0	0	31,260	0	1,113,481	785,107	4,883,833	3,740,761	1,143,072
#23	Food, Beverages, Tobacco and Feed	0	0	0	27,591	0	25,779	0	0	0	0	0	90,712	92,689	236,770	236,770	0
#24	Textile Mill Products	0	0	0	3,386	41	5,272	0	0	0	0	0	25,915	34,768	69,382	69,382	0
#25	Pulp, Paper and Paper Products	0	0	0	12,517	1,304	4,699	152	0	0	435	0	91,488	168,968	279,563	279,563	0
#26	Chemical and Allied Products, Oil and Coal Products	65	40,142	0	1,348,897	22,058	21,023	0	0	0	1,789	0	175,356	304,370	1,913,701	770,914	1,142,787
#27	Ceramic, Stone and Clay Products	94,107	11,769	0	71,951	4,831	23,935	378	0	0	26,659	0	56,844	14,778	305,251	305,053	198
#28	Iron and Steel	231,312	714,624	0	64,112	22,146	104,094	0	0	0	2,377	0	303,742	102,688	1,545,096	1,545,009	87
#29	Non-Ferrous Metals	1,173	6,329	0	14,533	1,215	15,554	0	0	0	1,776	0	42,867	11,530	94,977	94,977	0
#30	Machinery	0	1,518	0	34,351	1,687	60,287	0	0	0	0	0	311,748	31,683	441,274	441,274	0
#31	Miscellaneous	451	0	0	11,376	0	12,064	0	0	0	0	0	99,539	42,057	165,487	165,487	0
#32	Commerce, public services and Not elsewhere specified	7	5,268	0	373,090	0	330,637	3,637	0	0	0	0	1,034,599	40,818	1,788,057	1,772,049	16,008
#33	Residential	0	0	0	405,985	0	384,235	4,797	0	0	0	0	900,865	995	1,696,876	1,696,876	0
#34	Transportation	29	0	0	2,720,043	0	679	0	0	0	0	0	59,458	0	2,780,209	2,744,130	36,079
#35	Passenger	29	0	0	1,546,274	0	27	0	0	0	0	0	57,062	0	1,603,392	1,576,238	27,154
#36	Freight	0	0	0	1,173,769	0	652	0	0	0	0	0	2,396	0	1,176,817	1,167,892	8,925
#37	Non-energy and Feedstock Use	11	16,241	0	1,208,367	9,291	0	0	0	0	0	0	0	0	1,233,909	0	1,233,909

2024FY	Row $	$0100	$0200	$0300	$0400	$0500	$0600	$0700	$0800	$0900	$1000	$1100	$1200	$1300	$1400	$1401	$1402
<< General Energy Statistics >> Simplified energy unit table GCV (gross calorific value) basis Display unit: TJ		Coal	Coal Products	Crude Oil	Oil Products	Natural Gas	City Gas	Renewable (excl. hydro)	Hydraulic Power Generation (excl. pumped)	Pumped Storage	Effective Recovery Use of Wasted Energy	Nuclear Power Generation	Electricity	Heat	Total	Energy Use Total	Non-Energy Use Total
Line #																	
#01	Primary Energy Supply	4,300,507	-8,244	5,138,146	889,968	3,671,805	94	1,475,602	626,015	0	573,930	793,521	0	0	17,461,344	16,200,429	1,260,916
#02	Indigenously Produced	12,449	0	13,887	0	74,435	0	1,342,185	626,015	0	573,930	793,521	0	0	3,436,422	0	0
#03	Import	4,288,115	26,566	5,176,775	1,822,254	3,596,007	0	133,500	0	0	0	0	0	0	15,043,218	0	0
#04	Total Primary Energy Supply	4,300,564	26,566	5,190,662	1,822,254	3,670,442	0	1,475,685	626,015	0	573,930	793,521	0	0	18,479,640	17,218,724	1,260,916
#05	Export	-57	-36,632	0	-927,960	0	0	-83	0	0	0	0	0	0	-964,733	0	0
#06	Stockpile Change / Supply (+: withdrawal/ -: build-up)	0	1,823	-52,516	-4,326	1,362	94	0	0	0	0	0	0	0	-53,563	0	0
#07	Domestic Primary Energy Supply (Supply)	4,300,507	-8,244	5,138,146	889,968	3,671,805	94	1,475,602	626,015	0	573,930	793,521	0	0	17,461,344	16,200,429	1,260,916
	(Demand)														17,358,442	16,097,527	1,260,916
#08	Energy Transformation & Own Use	-4,033,722	815,801	-5,133,312	4,270,992	-3,590,066	989,275	-1,465,034	-626,015	0	-534,197	-793,521	3,219,546	802,248	-6,078,007	-5,943,464	-134,543
#09	Manufacture of Coal Products (+: output/ -: input)	-1,227,712	1,143,002	0	-12,740	0	0	0	0	0	-2,588	0	0	0	-100,038	-100,038	0
#10	Oil Products (+: output/ -: input)	0	0	-5,132,500	5,107,912	1,192	0	-19,578	0	0	0	0	0	-97,951	-140,926	0	-140,926
#11	Gas Conversion and Production (+: output/ -: input)	0	0	0	-91,744	-1,528,342	1,617,201	0	0	0	0	0	0	0	-2,884	-2,884	0
#12	Power Generation	-2,494,790	-107,310	-944	-137,745	-2,097,678	-158,044	-552,187	-605,246	0	-132,900	-793,521	2,986,123	0	-4,094,242	-4,094,242	0
#13	Auto Power Generation	-134,944	-84,135	0	-139,818	-54,622	-93,501	-716,645	-20,769	0	-191,982	0	597,149	0	-839,268	-839,268	0
#14	Auto Steam Generation	-191,436	-49,428	0	-260,714	-25,490	-195,172	-172,086	0	0	-202,180	0	0	871,601	-224,906	-224,906	0
#15	Heat Supply/ Other Energy Transformation	-6,118	0	0	-13,752	151,468	-163,332	-793	0	0	-2,898	0	-3,884	34,902	-4,407	1,409	-5,816
#16	Own Use and Loss	-308	-92,588	0	-194,133	-12,275	-17,878	-207	0	0	0	0	-359,842	-6,303	-683,534	-683,534	0
#17	Transformation and Consumption Stockpile Change (+: withdrawal/ -: build-up)	21,587	6,260	131	13,727	-24,320	0	-3,539	0	0	-1,648	0	0	0	12,198	0	12,198
#18	Statistical Discrepancy (+: excess/ -: shortage)	-42,930	60,167	4,833	-9,571	22,547	0	0	0	0	0	0	48,778	19,078	102,902	102,902	0
#19	Final Energy Consumption	309,715	747,390	0	5,170,532	59,192	989,369	10,568	0	0	39,733	0	3,170,767	783,170	11,280,435	10,154,063	1,126,372
#20	Industry	309,686	747,390	0	2,097,661	59,192	598,600	6,214	0	0	39,733	0	2,203,752	782,177	6,844,404	5,754,274	1,090,130
#21	Agriculture, Fishery, Mining and Construction	0	252	0	306,264	4,348	1,901	0	0	0	0	0	40,703	557	354,024	319,406	34,618
#22	Manufacturing	309,681	742,959	0	1,448,294	54,844	243,228	2,486	0	0	39,733	0	1,107,747	736,673	4,685,646	3,643,291	1,042,355
#23	Food, Beverages, Tobacco and Feed	0	0	0	28,114	0	29,571	0	0	0	0	0	96,217	94,431	248,333	248,333	0
#24	Textile Mill Products	0	0	0	3,441	37	6,317	0	0	0	0	0	24,055	32,072	65,922	65,922	0
#25	Pulp, Paper and Paper Products	0	0	0	11,341	663	6,218	189	0	0	382	0	89,836	157,892	266,520	266,520	0
#26	Chemical and Allied Products, Oil and Coal Products	18	37,029	0	1,234,283	24,402	23,363	0	0	0	1,915	0	176,083	281,528	1,778,621	736,575	1,042,046
#27	Ceramic, Stone and Clay Products	87,706	11,382	0	72,444	4,914	22,586	2,298	0	0	34,817	0	53,468	16,115	305,730	305,530	201
#28	Iron and Steel	221,958	692,705	0	60,764	23,195	98,628	0	0	0	2,618	0	287,967	97,078	1,484,913	1,484,805	108
#29	Non-Ferrous Metals	919	6,060	0	13,255	1,230	15,080	0	0	0	2,051	0	41,471	8,663	88,728	88,728	0
#30	Machinery	0	1,837	0	32,914	1,633	58,051	0	0	0	0	0	320,636	33,424	448,495	448,495	0
#31	Miscellaneous	0	12	0	12,465	0	12,328	0	0	0	0	0	98,435	29,881	153,121	153,121	0
#32	Commerce, public services and Not elsewhere specified	5	4,179	0	343,103	0	353,470	3,728	0	0	0	0	1,055,302	44,947	1,804,734	1,791,577	13,157
#33	Residential	0	0	0	394,102	0	390,172	4,354	0	0	0	0	907,557	993	1,697,179	1,697,179	0
#34	Transportation	29	0	0	2,678,769	0	597	0	0	0	0	0	59,458	0	2,738,853	2,702,610	36,242
#35	Passenger	29	0	0	1,537,946	0	24	0	0	0	0	0	57,062	0	1,595,061	1,567,681	27,381
#36	Freight	0	0	0	1,140,823	0	573	0	0	0	0	0	2,396	0	1,143,791	1,134,930	8,861
#37	Non-energy and Feedstock Use	18	14,218	0	1,101,620	10,517	0	0	0	0	0	0	0	0	1,126,372	0	1,126,372

A3.2.2 General Energy Statistics and CRTs

The following table shows the correspondence of fuels among *General Energy Statistics*, CRT table 1.A(b) 'reference approach' and CRT table 1.A(d) 'non-energy use of fuels'.

Table A 3-21 Correspondence of fuels among *General Energy Statistics*, CRT tables 1.A(b) and (d)

Fuel in CRT tables 1.A(b) and (d)			Fuel in General Energy Statistics	Code
Liquid fossil	Primary fuels	Crude oil	Crude oil for refinery use	$0310
			Crude oil for power generation use	$0320
		Orimulsion	Bituminous mixture fuel	$0321
		Natural gas liquids	Natural gas liquid (NGL) & condensate	$0330
	Secondary fuels	Gasoline	Gasoline	$0431
		Jet kerosene	Jet fuel oil	$0432
		Other kerosene	Kerosene	$0433
		Gas/diesel oil	Gas oil or diesel oil	$0434
		Residual fuel oil	Fuel oil A	$0436
			Fuel oil B	$0438
			Fuel oil C for general use	$0439
			Fuel oil C for power generation use	$0440
		Liquefied petroleum gases	Liquefied petroleum gas (LPG)	$0458
		Naphtha	Pure naphtha	$0420
			Reformate	$0421
		Bitumen	Other heavy oil products	$0452
		Lubricants	Lubricant oil	$0451
		Petroleum coke	Oil coke	$0455
		Refinery feedstocks	Slack gasoline	$0412
			Slack kerosene	$0413
			Slack diesel oil or gas oil	$0414
			Slack fuel oil	$0415
			Cracked gasoline	$0416
			Cracked diesel oil or gas oil	$0417
			Feedstock oil for refinery and mixing	$0418
		Other oil	Refinery gas	$0457
Solid fossil	Primary fuels	Anthracite	Hard coal, anthracite & lignite	$0130
		Coking coal	Steel making coal	$0110
		Other bituminous coal	Imported steam coal for general use	$0121
			Imported steam coal for power generation use	$0123
		Sub-bituminous coal	Indigenous produced steam coal	$0124
	Secondary fuels	BKB and patent fuel	Coal briquette	$0213
		Coke oven/gas coke	Coke	$0211
			Coke oven gas	$0221
			Blast furnace gas	$0222
			Converter furnace gas	$0225
		Coal tar	Coal tar	$0212
Gaseous fossil		Natural gas	Liquefied natural gas (LNG)	$0510
			Indigenous natural gas	$0521
			Coal mining gas	$0522
			Boil off gas from crude oil	$0523
			City gas	$0610
			Small scale community gas	$0620
Biomass		Solid biomass	Woods	$N131
			Waste Woods	$N132
			Thermal Use of Black Liquor	$N136
		Liquid biomass	Bioethanol	$N134
			Biodiesel	$N135
		Gas biomass	Gas Biomass	$N137

A3.3. Carbon Emission Factor for Diesel Oil

The carbon emission factor (CEF) for "Diesel oil" in 1.A.3.b (Road transportation) shown in the Common Reporting Tables (CRTs) is at the level of the lower confidence interval of the default value of "Gas/diesel oil" in the *2006 IPCC Guidelines*. It is because Japan distinguishes between "Gas oil / Diesel oil" (*keiyu*) and "Fuel oil A", but both fuels are classified as "Gas/diesel oil" internationally. Japanese "Gas oil / Diesel oil" is mainly used for road transport and its density and CEF are low. "Fuel oil A" is used for boilers, ships and other purposes, and its density and CEF are high. The carbon balance of Japanese petroleum refineries including "Gas oil / Diesel oil" (*keiyu*) and fuel oil A nearly matches according to statistics, and therefore these CEFs are not irregular.

Table A 3-22 shows the Japanese quality requirement of diesel oil mainly used for automobile engine. In this standard, diesel oil is classified into five types based on the pour point difference. Also, the standard meets with the Japanese law "Act on the Quality Control of Gasoline and Other Fuel" as a matter of course. Please refer to page Annex 3-1 for the required quality of fuel oil.

Table A 3-22 Required quality of diesel oil in Japan

Test item	Unit	Type				
		S1	1	2	3	S3
Flash point	°C	50 or more			45 or more	
90 % distilling temperature	°C	360 or less		350 or less	330 or less [1)]	330 or less
Pour point	°C	+5 or less	-2.5 or less	-7.5 or less	-20 or less	-30 or less
Cold filter plugging point	°C	−	-1 or less	-5 or less	-12 or less	-19 or less
Residual carbon ratio in 10 % residual oil	% in weight	0.1 or less				
Cetane index [2)]	−	50 or more		45 or more		
Kinetic viscosity at 30 °C	mm^2/s	2.5 or more		2.5 or more	2.0 or more	1.7 or more
Sulfur ratio	% in weight	0.0010 or less				
Density at 15 °C	g/cm^3	0.86 or less				

1) 350 or less, if the kinetic viscosity at 30 °C is 4.7 mm^2/s or less.
2) Cetane number is also available for cetane index.
Reference: Japanese Industrial Standards, Diesel Fuel (JIS K 2204:2023)

Table A 3-23 Comparison of density

Item	Density [kg/L]	References
Japanese diesel oil (FY2023 value)	0.8261±0.0064 (mean ± SD)	(ANRE, 2025)
Japanese fuel oil A (FY2023 value)	0.8549±0.0127 (mean ± SD)	(ANRE, 2025)
IEA's typical value of gas/diesel oil	0.8439	(OECD/IEA, 2004)
IEA's typical value of fuel oil, low-sulphur	0.9251	(OECD/IEA, 2004)

SD: Standard deviation

A3.4. Conversion Factors of Calorific Values

For reference, the following table provides the ratio of net calorific values (NCV) to gross calorific values (GCV), which are derived from NCV and GCV obtained from the standard values of FY2023.

Table A 3-24 Ratio of NCV to GCV (for reference)

Fuel	NCV/GCV	Fuel	NCV/GCV
Coal		Oil products (continued)	
Coking coal	0.96	Diesel oil	0.94
PCI coal	0.97	Fuel oil A	0.94
Imported steam coal	0.95	Fuel oil B	0.94
Indigenous produced steam coal	0.94	Fuel oil C	0.95
Imported anthracite	0.97	Lubricants	0.94
Coal products		Other heavy oil products	0.95
Coke	0.98	Petroleum coke	0.98
Coal tar	0.95	Galvanic furnace gas	1.00
Coke oven gas	0.90	Refinery gas	0.92
Blast furnace gas	0.98	Combustible natural gas	
Converter furnace gas	1.00	Imported natural gas (LNG)	0.91
Oil		Indigenous natural gas	0.91
Crude oil	0.94	City gas	
NGL/condensate	0.94	City gas	0.91
Bituminous mixture fuel / Orimulsion	0.95	Direct supply of LPG	0.93
Oil products		Renewable energy	
LPG	0.93	Black liquor	0.87
Naphtha	0.94	Waste woods	0.91
Reformate	0.94	Woods	0.95
Gasoline	0.94	Bioethanol	0.91
Jet fuel oil	0.94	Biodiesel	0.93
Kerosene	0.94	Gas biomass	0.92

Reference: Calculated from ANRE (2025). *2006 IPCC Guidelines* (Vol. 2, page 1.16) for Coal tar and Bituminous mixture fuel/Orimulsion.
Note: Direct supply of LPG corresponds to small-scale community gas in the Energy Balance Tables.

References

1. IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2006.
2. CMA, *Outline of the National Inventory Document, Pursuant to the Modalities, Procedures and Guidelines for the Transparency Framework for Action and Support Referred to in Article 13 of the Paris Agreement*, Decision 5/CMA.3 Annex V, FCCC/PA/CMA/2021/10/Add.2, 2021.
3. OECD/IEA, *World Energy Statistics.*
4. OECD/IEA, *Energy Statistics Manual*, 2004.
5. Agency for Natural Resources and Energy, *General Energy Statistics.*
6. Agency for Natural Resources and Energy, *Explanation on Standard Calorific Values and Carbon Emission Factors for Fuel Combustion Revised in FY2023*, 2025.
7. Japanese Industrial Standards, Diesel Fuel (JIS K 2204:2023).

Annex 4. Quality Assurance/Quality Control (QA/QC) Plan

The following are excerpts from the Quality Assurance/Quality Control (QA/QC) Plan for Japan's National Greenhouse Gas Inventory.

The QA/QC Plan is an internal document that documents, among other things, the specifics of all QA/QC activities in all processes from the start of inventory compilation to the final report, the compilation schedule, and the apportionment of all involved entities' roles. It organizes and systematizes the QA/QC activities of inventory compilation and clarifies what each entity involved in compilation is supposed to do. Additionally, it is prepared for the purpose of guaranteeing the implementation of QA/QC activities.

The QA/QC Plan's scope includes the processes of preparing, reporting, and reviewing the inventory.

A4.1. QA/QC Procedures Applied

When compiling the inventory in Japan, inventory quality is controlled by performing QC activities (such as checking the correctness of calculations and archiving of documents) at each step, in accordance with *2006 IPCC Guidelines*. In Japan, the QC activities relating to inventory compilation performed by personnel belonging to agencies involved in inventory compilation—that is, the MOE (including the GIO and private consultant companies), relevant ministries and agencies, etc—are considered to be QC. External reviews by experts who are outside the inventory compilation system are considered to be QA. They assess data quality from the perspectives of scientific knowledge and data availability with respect to current calculation methods. Table A4-1 summarizes Japan's QA/QC activities.

Table A4-1 Summary of Japan's QA/QC activities

	Implementing entity	Main contents of activity
QC (Quality Control)	Ministry of the Environment (Decarbonized Society Promotion Office, Global Environment Bureau)	・Coordinating QA/QC activities for inventory preparation ・Checking and approving the QA/QC plan ・Checking and approving the inventory improvement plan
	Greenhouse Gas Inventory Office of Japan, Center for Global Environmental Research, Earth System Division, National Institute for Environmental Studies (GIO)	・Conducting general QC checks ・Archiving QA/QC activity records and relevant data and documents ・Developing inventory improvement plan ・Revising QA/QC plan
	Relevant Ministries and Agencies	・Checking data necessary for inventory preparation ・Checking JNGI files and inventory prepared by GIO (Category-specific QC)
	Committee for the Greenhouse Gas Emissions Estimation Methods	・Discussing and assessing estimation methods, EFs, and AD (Category-specific QC)
	Private Consultant Companies	・Checking JNGI files and inventory prepared by GIO (Category-specific QC)
QA (Quality Assurance)	Inventory Quality Assurance Working Group (QAWG)	・Conducting expert peer review of inventory

A4.1.1. QC activity

A4.1.1.1. General QC procedures

In accordance with Table 6.1, Chapter 6, Vol.1 of the *2006 IPCC Guidelines*, general QC procedures include the general items to be confirmed which are related to the calculation, data processing,

completeness, and documentation applicable to all emission source and sink categories. General QC procedures are implemented by each inventory compiler.

Following are the QC activities conducted by GIO's sectoral experts (SEs), who perform the work of compiling the emissions/removals estimation files for each category, the CRT transition files and NID; the National Inventory Compiler (NIC), who integrates the information from the individual SEs and compiles the inventory; and the data providers, who provide the AD and other data used to calculate emissions and removals.

A4.1.1.1.a. Sectoral experts (SEs)

SEs perform mainly the following QC activities.

- Checking for transcription errors in data entry and referencing
- Checking to ensure that emissions are accurately estimated
- Checking to see that parameters and emission units are accurately recorded, and that proper conversion factors are used
- Checking the conformity of databases and/or files
- Checking the consistency of data between categories
- Checking the accuracy of inventory data behavior from one processing step to the next
- Checking completeness
- Checking time series consistency
- Checking trends
- Conducting comparisons with past estimated values
- Checking that uncertainties in emissions and removals are accurately estimated and calculated
- Carrying out reviews of internal documentation
- Checking that the assumptions and criteria for selecting AD and EFs are documented

A4.1.1.1.b. National inventory compiler (NIC)

The NIC performs mainly the following QC activities.

- Confirming that data provided by SEs are imported to the CRT Reporting Tool without omission
- Confirming that the necessary information is properly entered into documentation boxes
- Confirming that the reasons for "NE" and "IE" are correctly entered
- Confirming that the key category analysis results are correctly outputted
- Confirming that the reasons for recalculations are provided for all categories
- Confirming that emissions and removals are correctly aggregated
- Confirming that data are corrected after the coordination with the relevant ministries and agencies

A4.1.1.2. QC procedures for each source and sink category

The following category-specific QC activities are performed in Japan:

A4.1.1.2.a. QC by private consultant companies (External QC)

QC on the estimation files and CRT and NID drafts prepared by the GIO, are performed by mutual checks of estimation results with private consultant companies, through the use of estimation files like those of the GIO, and confirming the data entered into estimation files for each source and sink category

and the equations for calculating emissions and removals.

A4.1.1.2.b. QC through coordination with the relevant ministries and agencies (External QC)

The relevant ministries and agencies are sent the sets of files for estimation, CRT, NID, and the drafts of documents for domestic release showing estimated values for emissions and removals. Through this, category-specific QC is implemented for the content of categories relevant to each ministry or agency.

A4.1.1.2.c. Committee for the Greenhouse Gas Emissions Estimation Methods

Since the Committee considers and selects the methodologies, AD and parameters including EFs, which are actually applied to the estimation of emissions/removals from each category, it also implements category-specific QC activities.

A4.1.1.3. QC activities of the documentation and archiving of inventory information

GIO promptly implements QC activities of the documentation and archiving of inventory information, after the inventory submission to the UNFCCC Secretariat.

A4.1.2. QA activity

QA refers to assessment of inventory quality by third-parties that are not directly involved in inventory compilation. In Japan, the expert peer review is held by the GHG Inventory Quality Assurance Working Group (QAWG) as a QA activity, to assure inventory quality.

A4.1.2.1. GHG Inventory Quality Assurance Working Group (QAWG)

A4.1.2.1.a. Summary

The QAWG performs detailed reviews by experts (expert peer reviews) not directly involved in inventory compilation for each emission source and sink in order to assure inventory quality and to identify areas that need improvement.

The secretariat for the QAWG is established within the GIO. The secretariat and the MOE determine the sectors/categories to be reviewed by the QAWG. The experts for the QAWG are selected by taking the following requirements into account.

<Requirements for QAWG review experts>

a. No direct involvement in the inventory preparation process for estimating emissions/ removals from the sectors/categories to be reviewed (i.e., no involvement in the Committee, the data creation and the data provision for those sectors/categories)
b. No specific interests related to the inventory and the capability to judge objectively without being affected by any specific organizations and/or stakeholders
c. Sufficient skills, knowledge and experience to assure the quality of the inventory

A4.1.2.1.b. Scope of review

The QAWG performs reviews mainly in the following areas. The results are utilized for the preparation of the inventory for the next submission.

- Confirming the appropriateness of estimation methods, AD, EFs, and other items.
- Confirming the appropriateness of content reported in the CRT and NID.

A4.1.2.1.c. Recent activities

The LULUCF sector was reviewed by two experts in FY2021. It was confirmed by the QAWG that the inventory for the LULUCF sector was generally valid. Identified issues by this QAWG were brought up to the Committee and the relevant breakout group in the Committee for discussion, and some issues were improved in the submitted inventory. In addition, the QAWG also identified insufficient explanations in the NID. These findings lead to improved transparency and accuracy of the NID.

The MOE and the secretariat determine the sectors/categories reviewed by the QAWG, and the entire GHG inventory is covered over the course of several years.

A4.2. Verification Activities

Confirmation such as the following have been undertaken in the Breakout groups of the Committee for the Greenhouse Gas Emission Estimation Methods: checking the appropriateness of EFs which were established based on actual measurements in the past against new measurements or checking the appropriateness of applying specific EFs based on models, to the national inventory. Additionally, the inventory emissions are checked against entity-based emission data reported under the Mandatory GHG Accounting and Reporting System[1] - a system that aims to reduce emissions from entities by requiring them to estimate and understand the amount of GHG emissions originating from their own activities. This mutual verification activity is to avoid any possible large omission of emissions.

A4.3. Treatment of Confidential Information

Part of the AD and EFs, other parameters, and emissions obtained from ministries, or the private sector correspond to confidential information. These are listed and archived. At the stage of obtaining and archiving data, and in the QC process, data are protected by using passwords, and confidential files are distinguished from others, and access to them is restricted. When sending data to relevant ministries for checks, confidential data are sent only to the ministry which provided the data. At the stage of UN reporting, a minimum level of aggregation with other sub-categories is performed, and the notation key "C" (confidential) is used.

[1] This system was established in 2006 under the Act on Promotion of Global Warming Countermeasures and requires entities that emit GHGs over a certain amount to estimate and report their emissions to the government. It generally covers all sectors excluding the LULUCF sector and part of the Energy sector (residential and transport (private vehicles)). The methods used to calculate emissions are generally consistent with those used in compiling the inventory.

Annex 5. Detailed Methodological Descriptions for Individual Source or Sink Categories

A5.1. Methodology for Estimating Emissions of Precursors

In addition to the mandatory greenhouse gases (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, NF_3), Japan reports on the emissions of precursors (NO_X, CO, Non-Methane Volatile Organic Compounds [NMVOCs], and SO_X[1]) calculated by established methods. This section explains the categories for which estimation methodologies were established, and emissions are reported.

A5.1.1 Energy Sector

A5.1.1.1 Stationary Combustion (1.A.1., 1.A.2., 1.A.4.: NO_X, CO, NMVOCs, and SO_X)

A5.1.1.1.a. Energy Industries (1.A.1), Manufacturing Industries and Construction (1.A.2), Commercial/institutional (1.A.4.a) and Agriculture/forestry/fishing (1.A.4.c)

a) Category Description

This section provides the estimation methods for emissions of precursors and other substances (NO_X, CO, NMVOCs, and SO_X) from Energy industries (1.A.1), Manufacturing industries and construction (1.A.2), Commercial/institutional (1.A.4.a) and Agriculture/forestry/fishing (1.A.4.c).

b) Methodological Issues

1) NO_X and SO_X

- ***Methodology for Estimating Emissions***

➢ ***Facilities emitting soot and smokes***

General Survey of the Emissions of Air Pollutants by the Ministry of the Environment (MOE) was used as data source for NO_X and SO_X emissions from fuel combustion of the "facilities emitting soot and smokes" specified in laws such as the Air Pollution Control Act. To ensure consistency with the categorization of the common reporting tables (CRTs), the emissions from the energy sector were isolated from the emissions listed in the *General Survey of the Emissions of Air Pollutants* by the following operation:

1. All emissions from the following facilities and industry sectors are reported under Energy sector:

   Facility: [0101–0103: Boilers]; [0601–0618: Metal rolling furnaces, metal furnaces, and metal forge furnaces]; [1101–1106: Drying ovens]; [2901–3202: Gas turbines, diesel engines, gas engines, and gasoline engines]

   Industry sector: [A–D: Accommodation/eating establishments, health care/educational and academic institutions, public bathhouses, laundry services]; [F–L: Agriculture/fisheries, mining, construction, electricity, gas, heat distribution, building heating/other operations]

2. For emissions from the facilities and industry sectors other than the above and [1301–1304: Waste incinerators], after emissions corresponding to the Industrial Processes and Product Use (IPPU)

[1] Most SO_X consists of SO_2. For major sources, SO_2 emissions are estimated.

sector were identified, the emissions from the Energy sector are estimated by subtracting the emissions corresponding to the IPPU sector from the emissions listed in the *General Survey of the Emissions of Air Pollutants.* For estimation method for the emissions corresponding to the IPPU sector, see A5.1.2.1. Mineral Industry, Chemical Industry, Metal Production, and Other Production (2.A., 2.B., 2.C., 2.D.: NO_X, SO_X).

➢ ***Small facilities***

NO_X and SO_X emitted by the "small facilities" (i.e. the facilities in commercial/institutional and manufacturing categories that do not correspond to the facilities emitting soot and smokes) were calculated by multiplying the energy consumption in each facility type by Japan's country-specific emission factor.

● ***Emission factors***

➢ ***Facilities emitting soot and smokes***

Not applicable.

➢ ***Small facilities***

Emission factors were established for each fuel type for [0102: Heating system boilers] for facilities listed in [L: Heating systems for buildings/other places of business] in the *General Survey of the Emissions of Air Pollutants* by aggregating emissions and energy consumption by fuel type.

● ***Activity data***

➢ ***Facilities emitting soot and smokes***

Not applicable.

➢ ***Small facilities***

Energy consumption from small facilities for each fuel type was calculated by subtracting energy consumption for each fuel type, identified by the *General Survey of the Emissions of Air Pollutants*, from energy consumption for each fuel type provided in the *General Energy Statistics* (Agency for Natural Resources and Energy). If the activity data shown in the *General Survey of the Emissions of Air Pollutants* exceeded the activity data provided in the *General Energy Statistics*, the activity data for the specified sources was deemed to be zero. The fuels covered were city gas, LPG, kerosene, and fuel oil A.

2) CO and NMVOCs

● ***Estimation Method***

Emissions of CO and NMVOCs from the specified sources were calculated by multiplying the energy consumption in each facility type by Japan's country-specific emission factor.

● ***Emission factors***

CO emission factors were established based on the summary data of the Japan Society for Atmospheric Environment (1996).

NMVOC emission factors for each facility by fuel type were established by multiplying the CH_4 emission factor by the ratio of the NMVOC emission factor to the CH_4 emission factor (NMVOC/CH_4 ratio). The CH_4 emission factors are elaborated in Chapter 3. The NMVOC/CH_4 ratios were determined from Japan Environmental Sanitation Center (1989), Institute of Behavioral Science (1984), and United

States Environmental Protection Agency (1985).

- ***Activity data***

Energy consumption calculated for estimation of CH_4 and N_2O was used for activity data. (see Chapter 3.)

A5.1.1.1.b. Residential Sector (1.A.4.b)

a) Category Description

This section provides the estimation methods for emissions of precursors and other substances (NO_X, CO, NMVOCs, and SO_X) from fuel combustion of households.

b) Methodological Issues

- ***Estimation Method***

NO_X, CO, NMVOCs, and SO_X emissions from the target source were calculated by multiplying energy consumed of each fuel type by Japan's country-specific emission factors or the default emission factors from *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016*.

- ***Emission factors***

1) NO_X

For solid fuels (coal briquettes), emission factors were established by converting the default values provided in the *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016* to gross calorific values.

For liquid (kerosene) and gaseous (LPG and city gas) fuels, the emission factors by usage by fuel type provided in a report by Air Quality Management Bureau, Environmental Agency (1996) were used. This report calculated the emission factors by taking the average of the concentration of NO_X emissions by product, obtained through questionnaires and interviews in the household gas appliances industry, weighted by the number of products sold.

2) CO

For solid fuels (coal briquettes), emission factors were established by converting the default values provided in the *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016* to gross calorific values.

For liquid (kerosene) and gaseous (LPG and city gas) fuels, the emission factors by usage by fuel type provided in the report by Institute of Behavioral Science (1997) were used. This report tabulated the emission factors by usage by fuel type from the actual values measured in Tokyo, Yokohama City and Chiba Prefecture.

3) NMVOCs

For solid fuels (coal briquettes), liquid fuels (kerosene), gaseous fuels (LPG and city gas), emission factors were established by converting the default values provided in the *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016* to gross calorific values.

4) SO_X

For solid fuels (coal briquettes), emission factors were established by converting the default values provided in the *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016* to gross calorific values.

For liquid fuel (kerosene), emission factors were calculated from energy consumption, specific gravity and sulfur content based on the fuel characteristics of kerosene described in information material compiled by the Petroleum Association of Japan.

- ***Activity data***

Fuel consumption by fuel type for residential use in the *General Energy Statistics* has been taken for the activity data. The fuels covered were coal briquettes, kerosene, LPG, and city gas. For the ratio of consumption by fuel type by type of use in households, the *Handbook of Energy & Economic Statistics in Japan* (Energy Data and Modeling Center) is used.

A5.1.1.1.c. Incineration of Waste for Energy Purposes and With Energy Recovery

Emissions of NO_X, CO, NMVOCs and SO_X from the incineration of waste for energy purposes and from the incineration of waste with energy recovery are reported under the relevant subcategories of 1.A.1, 1.A.2 and 1.A.4. Explanations for estimation method, emission factors, and activity data are all given in the section "A5.1.5 Waste".

A5.1.1.2 Mobile Combustion (NO_X, CO, NMVOCs, and SO_X)

A5.1.1.2.a. Domestic Aviation (1.A.3.a) and International Aviation (NOx, CO, and NMVOCs)

a) Category Description

This section provides the estimation methods for emissions of precursors (NOx, CO, and NMVOCs) from combustion of aviation fuel.

b) Methodological Issues

- ***Estimation Method***

NO_X, CO, and NMVOC emissions from the specified sources are calculated by multiplying the fuel consumption converted to net calorific value by the default emission factors provided in the *2006 IPCC Guidelines* and the *Revised 1996 IPCC Guidelines*.

- ***Emission factors***

Data in the following table are used.

Table A 5-1 IPCC default emission factors for domestic aviation

Gas	EF [g/MJ(NCV)]
NO_X	0.25 [1)]
CO	0.12 [2)]
NMVOCs	0.018 [2)]

Reference: 1) *2006 IPCC Guidelines*, Vol. 2; Page 3.64, Table 3.6.5
2) *Revised 1996 IPCC Guidelines*, Vol. 3; Page 1.89, Table 1-47, Jet and Turboprop Aircraft

- ***Activity data***

For domestic aviation, figures for jet fuel consumption (for domestic scheduled flights and others [commuter, sightseeing and charter flights]) converted to net calorific value from data described in the *Statistical Yearbook of Air Transport* (Ministry of Land, Infrastructure, Transport and Tourism (MLIT)) are used. For international aviation, the totals for bonded imports and bonded exports given in *Yearbook of Mineral Resources and Petroleum Products Statistics* (former *Yearbook of Production, Supply and*

Demand of Petroleum, Coal and Coke) (METI) are used. It is assumed that jet fuel is used by aircrafts.

- ***Completeness***

For aviation gasoline, emissions of NO_X, CO, and NMVOCs are reported as "NE".

A5.1.1.2.b. Road Transportation (1.A.3.b.): Fuel Combustion (NO_X, CO, NMVOCs, and SO_X)

a) Description of emission source categories

This section provides the estimation methods for emissions of precursors and other substances (NO_X, CO, NMVOCs, and SO_X) from fuel combustion of vehicles.

b) Methodological Issues

1) NO_X, CO, and NMVOCs

- ***Estimation Method***

NO_X, CO, and NMVOC emissions from the specified mobile sources are calculated by multiplying the distance traveled per year for each vehicle type per fuel by Japan's country-specific emission factor.

- ***Emission factors***

Emission factors are established for each vehicle class per fuel type based on the *Survey for Estimation of Emission Factors and Total Emissions of Exhaust Gas from Automobiles* (MOE, 2002) and the *Survey for Consideration of Estimation of Emission Factors and Total Emissions of Exhaust Gas from Automobiles* (MOE, 2004, 2007, 2008, and every year after 2011). The NMVOC emission factors, however, are calculated by multiplying the emission factor of total hydrocarbon (THC) of the Survey by the percentage of NMVOCs in the THC emissions (60% for gasoline and LPG vehicles and 99% for diesel vehicles; surveyed by MOE).

The trend of these emission factors over the years includes not only the impact of replacement to vehicles compatible with the latest exhaust gas regulation, but also the impact of the methodological change in the calculation of the emission factors among the survey years.

- ***Activity data***

For the activity data, the travel distance per year for each vehicle class by fuel type, estimated for CH_4 and N_2O emissions, are used. (See Chapter 3)

Table A 5-2 NO_X emission factors for automobiles [g-NOx/km]

Fuel	Vehicle type	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Gasoline	Light passenger vehicles	0.23	0.16	0.16	0.08	0.15	0.10	0.06	0.05	0.05	0.04	0.03	0.02
	Passenger vehicles	0.24	0.20	0.20	0.08	0.14	0.07	0.05	0.06	0.06	0.05	0.04	0.02
	Light cargo trucks	0.87	0.66	0.38	0.20	0.27	0.23	0.18	0.24	0.24	0.18	0.15	0.08
	Small cargo trucks	1.12	0.90	0.48	0.09	0.15	0.08	0.06	0.07	0.06	0.05	0.04	0.02
	Regular cargo trucks	1.83	1.09	0.56	0.16	0.33	0.23	0.20	0.11	0.09	0.08	0.08	0.05
	Buses	4.45	3.65	2.44	0.09	0.15	0.06	0.05	0.07	0.06	0.05	0.05	0.06
	Special-purpose vehicles	1.47	0.87	0.43	0.12	0.32	0.17	0.12	0.14	0.12	0.10	0.11	0.07
Diesel	Passenger vehicles	0.64	0.53	0.44	0.45	0.47	0.38	0.26	0.33	0.34	0.33	0.32	0.30
	Small cargo trucks	1.33	1.10	1.01	1.00	1.06	0.89	0.73	0.94	0.92	0.86	0.80	0.77
	Regular cargo trucks	5.35	4.59	4.33	4.50	3.26	2.73	2.40	1.86	1.72	1.64	1.72	1.64
	Buses	4.23	3.83	3.60	4.07	3.38	3.23	2.96	3.29	2.93	2.83	2.93	2.74
	Special-purpose vehicles	3.38	2.76	2.15	3.63	2.97	2.41	2.05	2.32	2.15	2.05	2.05	2.01
LPG	Taxis	0.24	0.20	0.20	0.08	0.14	0.07	0.05	0.06	0.06	0.05	0.04	0.02
	Others	1.83	1.09	0.56	0.16	0.33	0.23	0.20	0.11	0.09	0.08	0.08	0.05

Table A 5-3 CO emission factors for automobiles [g-CO/km]

Fuel	Vehicle Type	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Gasoline	Light passenger vehicles	1.75	1.55	1.54	0.97	1.51	1.22	0.94	1.31	1.32	1.14	0.98	0.91
	Passenger vehicles	2.32	2.06	2.03	0.94	1.37	0.92	0.75	1.19	1.14	0.90	0.86	0.75
	Light cargo trucks	10.42	8.54	5.51	2.77	2.87	2.76	2.27	1.98	1.98	1.60	1.72	1.17
	Small cargo trucks	9.66	10.08	8.31	2.05	2.73	1.61	1.25	0.98	0.96	0.72	0.73	0.64
	Regular cargo trucks	12.62	10.60	8.95	3.62	7.53	5.04	4.36	2.21	2.02	1.05	1.11	0.98
	Buses	26.21	25.08	21.94	2.07	2.62	1.78	1.57	1.88	1.79	0.98	1.02	0.98
	Special-purpose vehicles	12.47	10.67	8.92	2.30	5.34	3.44	2.76	1.94	1.77	1.18	1.28	1.19
Diesel	Passenger vehicles	0.48	0.43	0.43	0.37	0.39	0.29	0.17	0.10	0.09	0.10	0.08	0.06
	Small cargo trucks	0.98	0.90	0.81	0.59	0.45	0.34	0.25	0.19	0.16	0.14	0.14	0.09
	Regular cargo trucks	3.22	2.99	2.44	2.04	1.10	0.72	0.55	0.18	0.16	0.17	0.21	0.17
	Buses	2.58	2.53	2.20	2.03	1.24	1.05	0.89	0.55	0.46	0.57	0.59	0.49
	Special-purpose vehicles	2.11	1.89	1.30	1.60	0.93	0.58	0.43	0.26	0.22	0.24	0.28	0.23
LPG	Taxis	2.32	2.06	2.03	0.94	1.37	0.92	0.75	1.19	1.14	0.90	0.86	0.75
	Others	12.62	10.60	8.95	3.62	7.53	5.04	4.36	2.21	2.02	1.05	1.11	0.98

Table A 5-4 NMVOC emission factors for automobiles [g-NMVOC/km]

Fuel	Vehicle Type	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Gasoline	Light passenger vehicles	0.08	0.03	0.03	0.03	0.08	0.05	0.04	0.04	0.04	0.03	0.03	0.03
	Passenger vehicles	0.11	0.07	0.06	0.02	0.06	0.04	0.03	0.06	0.06	0.05	0.05	0.04
	Light cargo trucks	0.64	0.37	0.16	0.09	0.14	0.12	0.10	0.08	0.08	0.07	0.08	0.04
	Small cargo trucks	0.71	0.53	0.21	0.04	0.07	0.04	0.03	0.04	0.04	0.04	0.03	0.03
	Regular cargo trucks	0.99	0.58	0.28	0.06	0.17	0.13	0.11	0.06	0.05	0.05	0.05	0.05
	Buses	2.16	1.90	1.32	0.04	0.07	0.04	0.03	0.07	0.06	0.05	0.05	0.05
	Special-purpose vehicles	0.97	0.47	0.19	0.05	0.16	0.10	0.08	0.08	0.07	0.07	0.07	0.07
Diesel	Passenger vehicles	0.11	0.10	0.10	0.09	0.10	0.08	0.05	0.03	0.03	0.02	0.02	0.02
	Small cargo trucks	0.39	0.34	0.26	0.20	0.14	0.09	0.07	0.05	0.04	0.04	0.04	0.02
	Regular cargo trucks	1.62	1.47	1.03	0.75	0.35	0.21	0.15	0.04	0.03	0.03	0.04	0.03
	Buses	1.26	1.24	0.98	0.80	0.43	0.34	0.28	0.17	0.13	0.12	0.13	0.09
	Special-purpose vehicles	1.09	0.96	0.52	0.57	0.27	0.16	0.12	0.05	0.04	0.04	0.05	0.04
LPG	Taxis	0.11	0.07	0.06	0.02	0.06	0.04	0.03	0.06	0.06	0.05	0.05	0.04
	Others	0.99	0.58	0.28	0.06	0.17	0.13	0.11	0.06	0.05	0.05	0.05	0.05

2) SO_X

- ***Estimation Method***

The emissions of SO_X from these sources are calculated by multiplying the fuel consumption of each fuel type by Japan's country-specific emission factors.

- ***Emission factors***

Sulfur content (by weight) by fuel type was used.

Table A 5-5 Sulfur content (by weight) by fuel type

Fuel	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Gasoline	0.008%	0.008%	0.008%	0.005%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%
Diesel	0.350%	0.136%	0.050%	0.005%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%	0.001%
LPG	0.002%	0.002%	0.002%	0.002%	0.002%	0.002%	0.002%	0.002%	0.002%	0.002%	0.002%	0.002%

Reference: Gasoline – The Institute of Behavioral Science (until 2004); Upper limits of regulations (2005 onward),
Diesel oil – Petroleum Association of Japan (until 1997); Upper limits of regulations (1998 onward)
LPG – The Institute of Behavioral Science

- ***Activity data***

Activity data, fuel consumption data of weight value, are calculated by multiplying the fuel consumption of each fuel type, reported in in the *General Energy Statistics* (Agency for Natural Resources and Energy), by the specific gravity of each fuel type.

- ***Completeness***

Emissions of NO_X, CO, NMVOCs, and SO_X from natural gas vehicles and motorcycles are reported as "NE".

A5.1.1.2.c. Road Transportation (1.A.3.b.): Fuel Volatilization (Excluding Motorcycle) (NMVOCs)

a) Description of emission source categories

This section provides the estimation methods for emissions of NMVOCs caused by fuel volatilization of vehicles. NMVOCs are emitted from vehicles which run on gasoline, by volatilization of the gasoline component in the tank. Fuel evaporative emission is classified into the following three types. Evaporating gas in filling gasoline is included in the calculation of fugitive emissions from fuels at gas stations (1.b.2.a.v.).

Table A 5-6 Classification of fuel evaporative gases

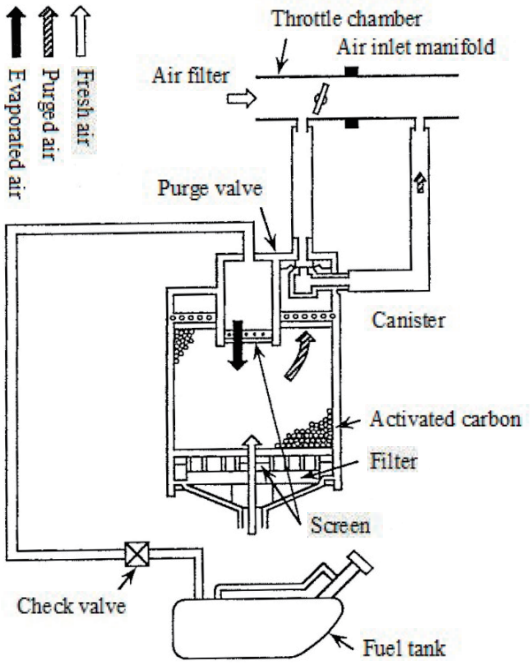
Types	Description
Diurnal Breathing Loss (DBL)	Evaporated gas which is generated when gasoline vapor, generated mainly due to the change in temperature during parking, is vented to the atmosphere after breakthrough[1)] from the canister[2)].
Hot Soak Loss (HSL)	Evaporated gas which is generated from gasoline attached to the induction pipe within one hour after shutdown of an engine.
Running Loss (RL)	Evaporated gas which is generated when the temperature of gasoline rises during driving and it goes beyond the limitation of canister purging[3)].

Note:
1) "Breakthrough" means going through the absorption process without being absorbed when the amount of gas/gasoline goes beyond the absorption capacity of canister.
2) Canister is absorption equipment in which activated carbon and other substances are included to prevent generating

evaporated gas in the fuel system of gasoline car. Evaporated gas during parking is absorbed by the canister; absorbed evaporated gas is delivered to the intake manifold during driving, then, absorption capacity of the canister recovers.

3) Purge means delivering evaporated gas, together with air, to intake manifold.

Reference: *Estimation Methods for Releases from Sources not Required to Report under PRTR (Pollutant Release and Transfer Register)* (Ministry of Economy, Trade and Industry (METI), and Ministry of the Environment (MOE), 2012)



Reference: Society of Automotive Engineers of Japan, Inc. (2008)

Figure A 5-1 Structure of fuel tank and canister

b) Methodological issues

Fuel evaporated emissions are estimated by adjusting THC emission data of DBL, HSL, and RL in 2002 by the annual number of cars owned and annual travel distance. The emissions in 2002 are provided in *Development Research of New Testing Methodology for Emission Gas from Vehicle (Off-road vehicle)* (MOE, FY2003). This methodology is similar to that described in the *Estimation Methods for Releases from Sources not Required to Report under PRTR* (METI and MOE).

In estimating emissions in RL, PRTR emission data is used after 2003.

It was assumed that THC emissions = NMVOC emissions, since methane is not included in fuel evaporated gas[2]. The outline of estimation method for each emission source and used data is shown in Table A 5-7.

[2] Regarding concrete volatile element composition, please refer to Yokota *et al.* (2011) for example.

Table A 5-7 Descriptions for estimating emissions from evaporated gas by mobile fuel combustion

Category	Equation	Data for calculation
DBL	$E_n = \sum_p \sum_q \sum_r \left(E_{2002} \times \frac{N_{n,p,q,r}}{N_{2002,p,q,r}} \right)$ E_n : DBL emissions in fiscal year (FY) n [t-NMVOC] $N_{n,p,q,r}$: Number of gasoline vehicles owned in FY n in a prefecture p, by vehicle type q, by status if regulated or not r	E_{2002}: THC emission amount in FY2002 provided in *Development Research on New Testing Methodology for Emission Gas from Vehicle (Off-road vehicle)* (MOE, FY2003) N: Based on *Monthly Report Statistics of Vehicle*s (Japan Automobile Manufacturers Association, Inc. (JAMA)), *Monthly Report of Number of Motor Vehicles* (Automobile Inspection & Registration Information Association (AIRIA)), and *Statistics of AIRIA/ Number of Motor Vehicles* (AIRIA)
HSL	$E_n = \sum_p \sum_q \left(E_{2002} \times \frac{N_{n,p,q}}{N_{2002,p,q}} \right)$ E_n: DBL emissions in FY n [t-NMVOC] $N_{n,p,q}$: Number of gasoline vehicles owned in FY n in a prefecture p, by usage q	E_{2002}: THC emission amount in FY2002 provided in *Development Research on New Testing Methodology for Emission Gas from Vehicle (Off-road vehicle)* N: Based on *Monthly Report Statistics of Vehicle*s, *Monthly Report of Number of Motor Vehicles*, and *Statistics of AIRIA/ Number of Motor Vehicles*
RL	[1990-2002] $E_n = \sum_p \sum_q \left(E_{2002} \times \frac{N_{n,p,q}}{N_{2002,p,q}} \times \frac{M_{n,p}}{M_{2002,p}} \right)$ E_n: RL emissions in FY n [t-NMVOC] $N_{n,p,q}$: Number of gasoline vehicles owned in FY n in a prefecture p, by status if regulated or not q $M_{n,p}$: Travel distance of gasoline vehicles [km] in FY n in a prefecture p [2003-] PRTR emissions were used.	E_{2002}: THC emission amount in FY2002 provided in *Development Research on New Testing Methodology for Emission Gas from Vehicle (Off-road Vehicle)* N: Based on *Monthly Report Statistics of Vehicle*s, *Monthly Report of Number of Motor Vehicles*, and *Statistics of AIRIA/ Number of Motor Vehicles* M: Based on travel distance by vehicle type from *Monthly Report of Motor Vehicle Transport Statistics,* and number of vehicles owned by prefecture by vehicle type from *Monthly Report Statistics of Vehicle*s or *Monthly Report of Number of Motor Vehicles*.

A5.1.1.2.d. Road Transportation (1.A.3.b.): Fuel Volatilization (Motorcycle) (NMVOCs)

a) Description of emission source categories

This section provides the estimation methods for emissions of NMVOCs by motorcycle caused by fuel volatilization. NMVOCs are emitted from motorcycles which run on gasoline, by volatilization of the gasoline component in the tank due to changes in temperature as described in the above section. This section provides the estimation method for DBL and HSL as described in the *PRTR*.

b) Methodological issues

Fuel evaporated emissions from motorcycle are estimated by using THC emissions in 2001, provided in *Development Research on New Testing Methodology for Emission Gas from Vehicle (Motorcycle)* (MOE, FY2002), which are yearly-adjusted by the activity data, number of motorcycles owned and travel distance, using the same methodology as that in the *Estimation Methods for Releases from Sources not Required to Report under PRTR* (METI and MOE).

Table A 5-8 Description of estimating emissions from evaporated gas by motorcycle fuel combustion

Category	Equation	Data for calculation
DBL	$E_n = \sum_p \sum_q \left(E_{2001} \times \frac{M_{n,p,q}}{M_{2001,p,q}} \right)$ E_n: DBL emissions in FY n [t-NMVOC] $M_{n,p,q}$: travel distance of motorcycle [km] in FY n in a prefecture p, by vehicle type q	E_{2001}: THC emission amount in FY2001 estimated based on *Development Research on New Testing Methodology for Emission Gas from Vehicle (Motorcycle)* (MOE, FY2002) M: Based on *Monthly Report Statistics of Vehicle*s (JAMA), *Monthly Report of Number of Motor Vehicles* (Automobile Inspection & Registration Information Association (AIRIA)), and *Survey of Motorcycle Market Trends* (JAMA)
HSL	$E_n = \sum_p \sum_q \left(E_{2001} \times \frac{M_{n,p}}{M_{2001,p}} \times R_{n,p} \right)$ E_n: DBL emissions in FY n [t-NMVOC] $M_{n,p}$: travel distance of motorcycle [km] in FY n by vehicle type p $R_{n,p}$: Use factor adjustment ratio in FY n by vehicle type p	E_{2001}: THC emission amount in FY2001 estimated based on *Development Research on New Testing Methodology for Emission Gas from Vehicle (Motorcycle)* M: Based on *Monthly Report Statistics of Vehicles*, *Monthly Report of Number of Motor Vehicles*, and *Survey of Motorcycle Market Trends* R: Estimated by multiplying the sales unit for domestic sales of each vehicle type (Website of JAMA) by survival rate of each elapsed year (MOE), by the usage factor of each elapsed year (*Estimation Methods for Releases from Sources not Required to Report under PRTR*)

A5.1.1.2.e. Railways (1.A.3.c.: NO_X, CO, and NMVOCs)

a) Category Description

This section provides the estimation methods for emissions of precursors (NOx, CO, and NMVOCs) caused by combustion of diesel railway fuel.

b) Methodological Issues

NO_X, CO, and NMVOC emissions from the specified sources are calculated by multiplying the fuel consumption converted to net calorific value by the default emission factors provided in the *Revised 1996 IPCC Guidelines*.

- ***Emission factors***

The default emission factors provided for the "Locomotives" category in the *Revised 1996 IPCC Guidelines* are used.

Table A 5-9 IPCC default emission factors for locomotives

Gas	Emission factor [g/MJ(NCV)]
NO_X	1.8
CO	0.61
NMVOCs	0.13

Reference: *Revised 1996 IPCC Guidelines*, Vol. 3; Page 1.89, Table 1-47

- ***Activity data***

The diesel oil consumption by railways in the *General Energy Statistics* (Agency for Natural Resources and Energy) is used.

A5.1.1.2.f. Domestic Navigation (1.A.3.d) and International Navigation (NO_X, CO, NMVOCs, and SO_X)

a) Category Description

This section provides the estimation methods for emissions of precursors (NOx, CO, and NMVOCs) and SO_X from combustion of marine fuel.

b) Methodological Issues

1) NO_X, CO, and NMVOCs

- ***Estimation Method***

NO_X, CO, and NMVOC emissions from the specified sources are calculated by multiplying the fuel consumption converted to net calorific value by the default emission factors provided in the *Revised 1996 IPCC Guidelines*.

- ***Emission factors***

The default emission factors provided in the "Ocean-Going Ships" category in the *Revised 1996 IPCC Guidelines* are used.

Table A 5-10 IPCC default emission factors for ocean-going ships

Gas	Emission factor [g/MJ(NCV)]
NO_X	1.8
CO	0.18
NMVOCs	0.052

Reference: *Revised 1996 IPCC Guidelines*, Vol. 3; Page 1.90, Table 1-48

- ***Activity data***

For domestic navigation, the marine fuel consumption data converted to net calorific value by fuel type (diesel oil, fuel oil A, fuel oil B, and fuel oil C) from the *General Energy Statistics* (Agency for Natural Resources and Energy) are used. For international navigation, the totals for bonded imports and bonded exports given in *Yearbook of Mineral Resources and Petroleum Products Statistics* (former *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*) (METI) are used. It is assumed that fuel oil A, B, C, diesel oil, kerosene and lubricants are used by vessels.

2) SO_X

- ***Estimation Method***

Emissions from the specified sources are calculated by multiplying the fuel consumption by the emission factors.

- ***Emission factors***

Emission factors are calculated by multiplying the specific gravity of each marine fuel by the sulfur ratio of each fuel by the molecular weight ratio of sulfur dioxide[3] versus sulfur. The sulfur ratio of each fuel is restricted by domestic law and *Japanese Industrial Standard*. Therefore, the regulation values are used for the sulfur ratio in the estimation.

[3] Most SO_X consists of SO_2. For major sources, SO_2 emissions are estimated.

Table A 5-11 Specific gravity and sulfur ratio of fuel for ocean-going ships

Fuel	Specific Gravity [kg/L]	Sulfur Ratio [% in weight]
Diesel Oil	0.83	0.5 (1990-1991) 0.2 (1992-1997) 0.05 (1998-2004) 0.005 (2005-2006) 0.001 (2007 onward)
Fuel Oil A	0.84	2.0 (1990-2019) 0.5 (2020 onward)
Fuel Oil B	0.91	3.0 (1990-2019) 0.5 (2020 onward)
Fuel Oil C	0.93	3.5 (1990-2019) 0.5 (2020 onward)

Reference: Sulfur ratio of diesel oil based on Petroleum Association of Japan (2015)
Sulfur ratio of each fuel oil based on *Japanese Industrial Standard* K2205 until 2019, and MARPOL Annex VI for 2020 onward
Specific gravity based on Environmental Research and Control Center (2000)

- ***Activity data***

The marine fuel consumption data of each fuel type (diesel oil, fuel oil A, fuel oil B, and fuel oil C) provided in the *General Energy Statistics* (Agency for Natural Resources and Energy) are used for the activity data.

A5.1.1.3 Fugitive Emissions from Fuel (Oil and Natural Gas) (1.B.2: NMVOCs)

A5.1.1.3.a. Oil Production and Upgrading (1.B.2.a.ii)

a) Category Description

This section provides the estimation methods for NMVOC leaks occurring during production of crude oil in oil fields. The NMVOC emissions from venting and flaring during oil production are reported in the sector "A5.1.1.3.l. Venting (Oil)" (1.B.2.c.i.1) and "A5.1.1.3.m. Flaring (Oil)" (1.B.2.c.ii.1). As for the NMVOC emissions when lowering measuring instruments into operating wells at servicing, the estimation methods are provided in the section "A5.1.1.3.i. Production and Gathering of Natural Gas (1.B.2.b.ii): Servicing".

b) Methodological Issues

The emissions from offshore and onshore oil fields are estimated separately.

- ***Estimation Method***

Using the equation below, the emission amount of NMVOCs in this category is estimated by multiplying the amounts of crude oil production from offshore oil fields and onshore oil fields by the default emission factors for offshore and onshore given in the *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (hereinafter, *2019 Refinement*).

$$E = \sum_i (AD_i \times EF_i)$$

E : NMVOC fugitive emissions caused by crude oil production [kg-NMVOC]
AD_i : Amount of crude oil production (excluding condensate) from offshore oil fields or onshore oil fields [kL]
EF_i : Emission factor for crude oil production from offshore oil fields or onshore oil fields [kg-NMVOC/kL]

- ***Emission factors***

The emission factors are established by multiplying the default emission factors for oil production from

onshore and offshore oil fields, shown in the *2019 Refinement* (Vol.2, Table 4.2.4A), by the disaggregation factor of leaks, venting and flaring in the *2019 Refinement* (Vol.2, Table 4A.2.2). The emission factor of lower-emitting technologies is adopted for onshore oil fields because flaring facilities and vapor recovery units (VRU) have been installed in the most oil fields since FY1990 according to the Japan Natural Gas Association.

Table A 5-12 Emission factor for NMVOC emissions from oil production

Emission source		Emission factor [kg-NMVOC/kL]	Disaggregation factor	Emission factor [kg-NMVOC/kL]
Onshore (lower-emitting technologies)	Leak	1.25	9%	0.11
	Venting		78%	0.98
	Flaring		13%	0.16
Offshore	Leak	1.06	20%	0.21
	Venting		80%	0.85
	Flaring		0%	0

- ***Activity Data***

The amount of crude oil production (excluding condensate) by offshore and onshore oil field is used for activity data.

As for the amount of crude oil production (excluding condensate) in offshore oil fields, the condensate production in offshore gas fields is estimated by multiplying the production amount of condensate by the ratio of natural gas production amount in offshore fields to the total production amount of natural gas, and then subtracted from the crude oil production amount in offshore fields.

The amount of crude oil production (excluding condensate) in offshore fields estimated above is deducted from the total amount of domestic crude oil production (excluding condensate) to obtain the production amount of crude oil (excluding condensate) in onshore oil fields.

Total production volumes of natural gas, crude oil, and condensate are obtained from the data given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* (FY1990-2000), the *Yearbook of Mineral Resources and Petroleum Products* (FY2001-2010), and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* (FY2011 onward), all by METI. The production amounts of natural gas and crude oil from offshore are obtained from *Natural Gas Data Yearbook* compiled by the Japan Natural Gas Association.

A5.1.1.3.b. Oil Transport (1.B.2.a.iii): Distribution of Crude Oil

a) Category Description

This section provides the estimation methods for NMVOC emissions which are, like evaporating gas, emitted in losses from breathing and acceptance for storage tank, and loading to lorry tank during distributing domestic crude oil.

b) Methodological Issues

- ***Estimation Method***

Emission amount of NMVOCs in this category is estimated by multiplying the amount of domestic production of crude oil by the emission factor for NMVOCs per production volume.

$$E = AD \times EF$$

E : NMVOC emissions caused by oil transport [t-NMVOC]
AD : Amount of domestic crude oil production [1000 kL]
EF : Emission factor per crude oil production [t-NMVOC/1000 kL]

- ***Emission factors***

Emission factors for oil transport are established by dividing the emission amount from crude oil (evaporating gas) estimated in *Study to Develop the National Emission Inventory for Volatile Organic Compounds* (hereafter, "*Study on the VOC Emission Inventory*") (MOE) by the activity data (amount of crude oil production). Since emission data indicated in the *Study on the VOC Emission Inventory* is limited only to FY2000 and FY2005 onward, emission factors in and before FY2004 are established by dividing the emissions estimated by Japan Natural Gas Association[4] by the activity data.

- ***Activity Data***

The activity data for this category are the amount of crude oil production (including condensate) which is provided in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

A5.1.1.3.c. Oil Transport (1.B.2.a.iii): Navigation

a) Category Description

NMVOCs are emitted in the process of ocean transportation of liquid cargo including gasoline, gas-free operation, and ship loading. This section provides the estimation methods for NMVOCs which are emitted from cargo operations by two types of tanker, crude oil tanker and product tanker.

Naphtha is also highly volatile and NMVOCs are likely to be emitted. However, naphtha is delivered by chemical tankers, which have high airtightness and pressure resistance, and is prohibited from being delivered by product tankers, which are not enough treated for electrostatic generation which involves the risk of auto-ignition. Therefore, it is considered that naphtha is not emitted into the air during delivering, thus, the naphtha delivery is not subject to the emission estimation. (Although chemical agents are usually delivered by chemical tankers, sometimes they are delivered by product tankers, so all chemical agents are used for estimation to avoid underestimation).

NMVOC emissions from "crude oil" and "oil products (gasoline)" are also included in "1.B.2.a.iv. Refining and storage of oil". Therefore, the emissions are subtracted from the total emissions in "1.B.2.a.iv. Refining and storage of oil" and included and reported in this category.

NMVOC emissions from "chemical agent" are also estimated in "A5.1.2.2.n Chemicals Manufacture" in the IPPU sector. Therefore, the emissions are subtracted from the total emissions in "Chemicals Manufacture" and included and reported in this category.

[4] Japan Natural Gas Association provided the emissions from the following five sources: "breathing and acceptance", "shipping (lorry)", "reboiler vent (GDH)", "gas release" and "CO_2 venting". The first two sources were chosen as the emissions from this subcategory and the rest of the sources were chosen as the emissions from processing of natural gas (1.B.2.b.iii) in accordance with the *Studies on VOC Emission Inventories*.

b) Methodological Issues

- ***Estimation Method***

The NMVOC emissions are estimated by multiplying the amount of exported or domestically transported "crude oil", "oil products (gasoline)", and "chemical agents" which are reported in the tables entitled "Export cargo volume by type of goods, by destination" and "Delivery cargo volume by type of goods, by destination" in the *Statistical Yearbook of Port* (MLIT), by the emission factors.

The following equation is used:

$$E = \sum_i (AD_i \times EF_i)$$

E : Emission amount of NMVOCs from evaporation in vessels [t-NMVOC]
AD_i : Traffic volume of cargo i (export volume + transport volume) [t]
EF_i : Emission factor for cargo i [kg-NMVOC/t]
i : Type of cargo (crude oil, gasoline, chemical agent)

- ***Emission factors***

Emission factors for this category are established as can be seen in Table A 5-13.

Table A 5-13 Emission factors for evaporation from vessels

Activity data		Emission factors [kg-NMVOC/t]
Crude oil	With vapor recovery (only in port of Kiire for FY2007 onward)	0.03
	Without vapor recovery	0.14
Gasoline	During loading	0.12
	During gas-freeing	0.14
Chemical agent	Benzene	0.011
	Methanol	0.006
	Toluene	0.004
	Dichloroethane	0.016
	Acetone	0.023

Reference: Ocean Policy Research Foundation (2006)

- ***Activity Data***

Based on the tables entitled "Export cargo volume by type of goods, by destination" and "Delivery cargo volume by type of goods, by destination" in the *Statistical Yearbook of Port*, the following methods in Table A 5-14 are used for activity data for this category.

Table A 5-14 Activity data for NMVOC emissions from vessels

Activity data	Description
Crude oil	The volume of export and transport of crude oil is used.
Gasoline	Estimated by multiplying the volume of export and transport of crude petroleum products by the percentage of gasoline in the volume of domestic sales and export of petroleum products provided in the *Yearbook of Mineral Resources and Petroleum Products Statistics*.
Chemical agent	Estimated by multiplying the volume of export and transport of chemical agents by the percentage of NMVOCs in chemical agents. The percentage of NMVOCs in chemical agents was established by the percentage of the transport volume in 2003 of five chemical agents (benzene, methanol, toluene, dichloroethane, and acetone), probable emission sources of NMVOCs, to the total chemical agents transported from the *Statistical Yearbook of Port* (Ocean Policy Research Foundation, 2012).

Note: Each activity data is based on calendar year (CY); therefore, CY-based-activity data are converted into FY-based data by combining 75% of the data from corresponding CY and 25% of the data from the subsequent CY.

A5.1.1.3.d. Refining and Storage of Oil (1.B.2.a.iv): Fugitive Emissions From Oil Refineries

a) Category Description

This section provides the estimation methods for NMVOC emissions from fugitive emissions in the process of refining crude oil and producing oil products.

b) Methodological Issues

- ***Estimation Method***

The NMVOC emissions are estimated by multiplying BPSD (Barrel per Stream Day), production amount per stream day of crude oil distillation unit at normal pressure, by stream days per year by the emission factor. Stream days per year are estimated by multiplying the number of days per year (365 days, but 366 days in leap years) by the annual operating rate.

$$E = AD \times D \times R \times EF$$

E : NMVOC emissions from fugitive emissions in refinery [g-NMVOC/year]
AD : Capacity of oil refineries [BPSD]
D : Number of working days in a year (365 days, but 366 days in leap years)
R : Annual operating rate [%]
EF : Emission factor [g-NMVOC/BPSD]

- ***Emission factors***

Emission factor for this category is established at 5.675 [kg/day/10^5BPSD] which is provided in Institute of Behavioral Sciences (2000), in accordance with the *Study on the VOC Emission Inventory*.

- ***Activity Data***

In accordance with the *Study on the VOC Emission Inventory*, the capacity of oil refineries (BPSD) by *Sekiyu Shiryô* (Sekiyu Tsushin) and *Supply and Demand of Crude Oil* (Petroleum Association of Japan) is used for activity data. Stream days in a year are calculated by multiplying 365 days (366 days for leap years such as FY1991) by the annual operating ratio of the crude oil distillation units at normal pressure, which is provided by *Sekiyu Shiryô* and *Supply and Demand of Crude Oil* (=annual processing amount [bbl/year] / annual capacity [bbl/year].

A5.1.1.3.e. Refining and Storage of Oil (1.B.2.a.iv): Production of Lubricant Oil

a) Category Description

This section provides the estimation methods for NMVOC emissions from fugitive emissions in the process of dewaxing and deasphalting during production of lubricants.

b) Methodological Issues

- ***Estimation Method***

NMVOC emissions from the specified sources are calculated by multiplying the amount of domestic gross sales of lubricants to consumers by Japan's country-specific emission factors for toluene and methyl ethyl ketone.

- ***Emission factors***

Based on measurements in Japan shown in Institute of Behavioral Science (1987), emission factors for lubricant oil production are established as 333.2 [g/kL] for toluene and 415.5 [g/kL] for methyl ethyl

ketone.

- ***Activity data***

The activity data for this category are the domestic gross sales amount of lubricants to consumers, provided in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* and the *Yearbook of Mineral Resources and Petroleum Products Statistics*.

A5.1.1.3.f. Refining and Storage of Oil (1.B.2.a.iv): Fugitive Emissions from Storage/Shipping Facilities

a) Category Description

NMVOCs are emitted, with accompanying fuel-evaporated fugitive gases, by storage and shipping of fuel (e.g., gasoline, crude oil, and naphtha) in crude oil transshipment stations, refineries, and oil tank facilities.

NMVOC emissions from storage facilities include losses from breathing and acceptance for fixed-roof type tanks and shipping losses from floating-roof type storage tanks at refineries, and the NMVOC emissions from shipping facilities include shipping losses in loading crude oil or oil products to tanker, tank car, or tank lorry.

b) Methodological Issues

- ***Estimation Method***

NMVOC emissions from storage and shipping of fuel in crude oil transshipment stations, refineries and oil tank facilities are estimated by multiplying the activity data of received amount of crude oil, gasoline and naphtha, by the emission factor per received amount.

$$E = (AD_1 + AD_2 + AD_3) \times EF$$

E : Fugitive NMVOC emissions at fuel storage and shipping facilities [kg-NMVOC]
AD_1 : Received amount of crude oil [kL]
AD_2 : Received amount of gasoline [kL]
AD_3 : Received amount of naphtha [kL]
EF : Emission factor per received amount of petroleum products [kg-NMVOC/kL]

The above-estimated NMVOC emissions include emissions during loading “crude oil” and “oil products (gasoline)” to tankers, which are included and reported in “A5.1.1.3.c. Oil transport (1.B.2.a.iii): Navigation”; therefore, these emissions are subtracted from this category.

- ***Emission factors***

The emission factors are established by dividing the emission amount in fuel storage and shipping in crude oil transshipment stations, refineries, and oil tank facilities, which has been estimated in the *Study on the VOC Emission Inventory*, by the following activity data (the received amounts of crude oil, gasoline and naphtha). The emission amount provided in the *Study on the VOC Emission Inventory* are limited to FY2000 and from FY2005 onward, therefore, the emission factors for the other years are established as follows.

For FY1990-1999, no relevant information is available since no measures based on voluntary action plan on environment had been implemented during the period. Therefore, the emission factor for

FY2000 is adopted for this period.

For FY2001-2003, emission factors are established by interpolating the figures in FY2000 and FY2004 under the assumption of linearly decreasing emissions factors, since member companies of Petroleum Association of Japan had been continuously implementing voluntary measures for reducing emissions.

For FY2004, emission factors are established by dividing the emissions reported in Petroleum Association of Japan's voluntary action plan by the activity data.

- ***Activity Data***

The activity data are the processed amount of crude oil, and the received amounts of gasoline and naphtha provided in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* and the *Yearbook of Mineral Resources and Petroleum Products Statistics*. As for the crude oil, the received amount has not yet been identified, therefore the processed amount is used instead.

A5.1.1.3.g. Distribution of Oil Products (1.B.2.a.v): Fugitive Emissions from Gas Stations (gasoline)

a) Category Description

NMVOCs are emitted by evaporation from underground gasoline storage tanks (loss from acceptance) or by filling gasoline in cars (loss from filling gasoline).

b) Methodological Issues

- ***Estimation Method***

The NMVOC emissions by prefecture and by month in this category are estimated by multiplying the sales volume of each prefecture and month of gasoline by the emission factors per sales volume of each prefecture and month of gasoline. By such estimation by prefecture and by month, the influences of monthly temperature difference and of vapor pressure drop of gasoline for summer season to the emissions are taken into consideration.

$$E = \sum_{i,j} \left(AD_{i,j} \times EF_{i,j} \right)$$

E : NMVOC emissions at gas filling stations [kg-NMVOC]
$AD_{i,j}$: Sales amount of gasoline in prefecture i in month j [kL]
$EF_{i,j}$: Emission factor per sales amount of gasoline in prefecture i in month j (loss from acceptance, loss from filling gas) [kg-NMVOC/kL]

- ***Emission factors***

1) Loss from acceptance

Emission factors are established, taking into consideration the temperature difference among prefectures and months, according to the following equation which is based on Agency for Natural Resources and Energy (1975).

The average monthly temperature in each prefectural capital provided in *Weather Statistics Information* (Japan Meteorological Agency) is used for calculation.

$$EF_{i,j} = (0.46 \times T_{i,j} + 13.92)/21$$

$EF_{i,j}$: Emission factor for loss from acceptance in prefecture i in month j [kg-NMVOC/kL]
$T_{i,j}$: Average of temperature in prefecture i in month j [°C]

As for seven prefectures (Saitama, Tokyo, Kanagawa, Fukui, Aichi, Kyoto and Osaka) where the installation of vapor recovery instrument for acceptance is required by ordinance, the emission factors for losses from acceptance are established by multiplying the emission factors calculated from the equation above by 0.15, under the assumption of the 85% emission reduction by vapor recovery instrument, since the fiscal year when the ordinances are effective, according to the *Study on the VOC Emission Inventory*.

Also, in summer season, the gasoline vapor control action is performed, therefore the emission factors from June to September are consistently multiplied by the value of 0.9, according to the *Study on the VOC Emission Inventory*.

2) Loss from filling gasoline

The NMVOC emission factors for loss from filling gasoline are established by using the formula below which is developed in the *Study on the VOC Emission Inventory* based on the domestic test results. The average temperature by prefecture and by month used for parameter setting are the same as those used for emission factors for loss from acceptance.

$$EF_{i,j} = 0.0359 \times A_{i,j} - 0.0486 \times B_{i,j} - 0.0092 \times C + 0.0149 \times D - 0.1804$$

$EF_{i,j}$: Emission factor for loss from filling gasoline in prefecture i in month j [kg-NMVOC/kL]
$A_{i,j}$: Fuel temperature in car tank in prefecture i in month j (Established as $T_{i,j}$ + 5 [°C])
$B_{i,j}$: $A_{i,j} - E_{i,j}$ [°C]
C : Gasoline filling speed (Established as 35 [L/minute])
D : Reid vapor pressure (Established as 63.2 [kPa] for June to September and 86.0 [kPa] for October to May)
$T_{i,j}$: Average temperature in prefecture i in month j [°C]
$E_{i,j}$: Fuel filling temperature (fuel temperature in underground tank) in prefecture i in month j [°C]

$E_{i,j}$ is established depending on $T_{i,j}$ as follows:

$T_{i,j} < 15$	: $E_{i,j} = T_{i,j} + 5$
$15 \leq T_{i,j} < 20$	: $E_{i,j} = T_{i,j} + 2.5$
$20 \leq T_{i,j} < 25$	: $E_{i,j} = T_{i,j}$
$25 \leq T_{i,j} < 30$	: $E_{i,j} = T_{i,j} - 2.5$
$30 \leq T_{i,j}$	: $E_{i,j} = T_{i,j} - 5$

- ***Activity Data***

The activity data are domestic sales volume of gasoline by prefecture and by month, which are calculated by proportionally dividing the domestic monthly gasoline sales volume, provided in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* and the *Yearbook of Mineral Resources and Petroleum Products Statistics*, by annual gasoline sales volume by prefecture, provided in the *Oil Product Sales Summary by Prefecture* (Petroleum Association of Japan).

A5.1.1.3.h. Distribution of Oil Products (1.B.2.a.v): Jet fuel, kerosene and diesel oil

a) Category Description

This section provides the estimation methods for NMVOCs emissions by evaporation from distribution of oil products to consumers. Main emission sources are evaporation loss in filling and unloading activities and leak from equipment. Evaporation from gasoline in gas station are dealt with in

"A5.1.1.3.g Distribution of Oil Products (1.B.2.a.v): Fugitive Emissions from Gas Stations (gasoline)".

b) Methodological Issues

- ***Estimation Method***

The NMVOC emissions are estimated by the Tier 1 method in the *2019 Refinement*, multiplying consumption of jet fuel, kerosene and diesel oil by the default emission factor.

$$E = \sum_i (AD_i \times EF)$$

E : NMVOC emissions from distribution of oil products other than gasoline [t-NMVOC]
AD_i : Consumption of fuel *i* [kL]
EF : Emission factor of other oil products [t-NMVOC/ thousand kL]

- ***Emission factors***

The emission factor is 0.15 [t-NMVOC/ thousand kL] of Other (e.g. diesel, aviation fuel, jet kerosene) described in the *2019 Refinement*.

- ***Activity Data***

Sum of final energy consumption of jet fuel, kerosene and diesel oil in the *General Energy Statistics* and bonded export of these fuels in the *Yearbook of Mineral Resources and Petroleum Products Statistics* (former *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*) are used.

A5.1.1.3.i. Production and Gathering of Natural Gas (1.B.2.b.ii): Production

a) Category Description

This section provides the estimation methods for NMVOC emissions occurring during production of natural gas in gas fields. The NMVOCs emissions from venting in natural gas production are reported in "Venting (Gas) (1.B.2.c.i.2)". As for the NMVOC emissions when lowering measuring instruments into wells at servicing, the estimation methods are provided in the section "A5.1.1.3.j Production and Gathering of Natural Gas (1.B.2.b.ii): Servicing".

b) Methodological Issues

- ***Estimation Method***

The NMVOC emissions are estimated by multiplying the amounts of natural gas production from offshore gas fields and onshore gas fields by the default emission factors for offshore and onshore gas fields given in the *2019 Refinement*.

$$E = \sum_i (AD_i \times EF_i)$$

E : NMVOC fugitive emissions caused by natural gas production [kt-NMVOC]
AD_i : Amount of natural gas production from offshore gas fields or onshore gas fields [million m^3]
EF_i : Emission factor for natural gas production from offshore gas fields or onshore gas fields [kt-NMVOC/million m^3]

- ***Emission factors***

The default values for leaks and venting of gas production from onshore and offshore gas fields as well

as gas gathering, which are indicated in the *2019 Refinement*, are used.

Table A 5-15 Emission factor for NMVOC emissions from natural gas production

Emission source		Emission factor [kt-NMVOC/million m^3]	Disaggregation factor	Emission factor [kt-NMVOC/million m^3]
Onshore (lower-emitting technologies)	Leak	6.1×10^{-4}	15%	9.5×10^{-5}
	Venting		84%	5.2×10^{-4}
Gas gathering	Leak	7.7×10^{-4}	-	7.7×10^{-4}
Offshore	Leak	7.0×10^{-4}	23%	1.6×10^{-4}
	Venting		77%	5.4×10^{-4}

Reference: *2019 Refinement* Vol. 2, page 4.70, Table 4.2.4G and page 4.132, Table 4A.2.5
Note: As the *2019 Refinement* does not indicate the disaggregation rate of leak, venting and flaring for gas gathering, all NMVOC are regarded as leak.

- ***Activity Data***

The production volume of natural gas from offshore gas fields is taken from the *Natural Gas Data Yearbook*. The production volume of natural gas from onshore gas fields is estimated by subtracting the production volume of natural gas from offshore gas fields above from the total production volume of natural gas in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics* and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*. The activity data for gas gathering are the production volume of natural gas from onshore gas fields in accordance with the *2019 Refinement*.

A5.1.1.3.j. Production and Gathering of Natural Gas (1.B.2.b.ii): Servicing

a) Category Description

This section provides the estimation methods for the NMVOC emissions which occur when lowering measuring instruments into operating wells at servicing.

b) Methodological Issues

- ***Estimation Method***

The NMVOC emissions during well servicing are estimated by multiplying the amount of domestic production of crude oil by the default emission factor, in accordance with the *2006 IPCC Guidelines*.

$$E = AD \times EF$$

E : NMVOC emissions during well servicing [kt-NMVOC]
AD : Amount of domestic crude oil production [1000 kL]
EF : Emission factor per crude oil production [kt-NMVOC/1000 kL]

For the fugitive emissions relating to well servicing, the estimation method of using the crude oil production amount as activity data is indicated in the *2006 IPCC Guidelines*, however, the correlation between the crude oil production amount and the emissions relating to natural gas well servicing is not clear.

- ***Emission factors***

For NMVOC emission factor for flaring and venting during well servicing, the default value per crude oil production amount (1.7×10^{-5} kt-NMVOC/1000 kL), which is indicated in the *2006 IPCC Guidelines*, is used.

- ***Activity Data***

The activity data for this category are the production amount of crude oil in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

A5.1.1.3.k. Processing of Natural Gas (1.B.2.b.iii)

a) Category Description

In the distribution process to the sellers of mined natural gas, NMVOCs originated from natural gas treatment are emitted by vapor from removal device of fluid or impurities (e.g., carbon dioxide gas) contained in natural gas, or, by being released into the air in construction of pipeline relocation.

b) Methodological Issues

- ***Estimation Method***

NMVOC emissions by processing of natural gas are estimated by multiplying the domestic production volume of natural gas by the NMVOC emission factors per production volume.

$$E = AD \times EF$$

E : NMVOC emission amount by processing of natural gas [t-NMVOC]
AD : Production volume of natural gas [million m^3]
EF : Emission factor per production volume of natural gas [t-NMVOC/million m^3]

- ***Emission factors***

Emission factors are established by dividing the emissions related to natural gas, which has been estimated in the *Study on the VOC Emission Inventory* by MOE (based on the reported figures of voluntary action plan by Japan Natural Gas Association), by the later-indicated activity data (domestic production volume of natural gas). Emission factors in and before FY2004 are established by dividing the emissions provided by Japan Natural Gas Association by the activity data, since the emission amounts in the *Study on the VOC Emission Inventory* are limited only to FY2000 and from FY2005 onward (same as shown in "A5.1.1.3.b. Oil transport (1.B.2.a.iii): Distribution of Crude Oil").

- ***Activity data***

The activity data for this category are domestic production volume of natural gas provided by the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products Statistics*, and the *Yearbook of Current Production Statistics - Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics*.

- ***Completeness***

The emissions from this source include the emissions from "transmission and storage of natural gas (1.B.2.b.iv)" and "venting (gas) (1.B.2.c.i.2)".

A5.1.1.3.l. Natural Gas Distribution (1.B.2.b.v): City Gas Production

a) Category Description

NMVOCs are emitted by fugitive emissions from naphtha tanks in the process of city gas production. In Japan, no emission activity in this category has been made since FY2006, because naphtha has not

been used for city gas production due to the completion of shifting raw materials of city gas from low calorific gas made of naphtha to high calorific gas made of LNG in FY2005.

b) Methodological Issues

- ***Estimation Method***

NMVOC emissions from naphtha tank in city gas production are estimated by multiplying the consumption amount of gasoline used as raw material for city gas production by the NMVOC emission factor per consumption amount. The emissions in this category from FY2006 onward are reported as "NO" since no emission activity has been made during this period.

$$E = AD \times EF$$

E : NMVOC emission amount in city gas production [t-NMVOC]
AD : Consumption amount of gasoline used as raw material for city gas production [kL]
EF : NMVOC emission factor per consumption amount [t-NMVOC/kL]

- ***Emission factors***

Emission factors for city gas production are established by dividing the emission amount from "gas production facilities" (estimated based on *Report on Voluntary Action Plan* by the Japan Gas Association) provided in the *Study on the VOC Emission Inventory*, by the activity data (the consumption amount of crude gasoline for city gas production).

Since the emitted amount provided by the *Study on the VOC Emission Inventory* is limited to FY2000 and FY2005 onward, the emission factors for the other years are established as follows. For FY1990-1999, the emission factor for FY2000 is used. For FY2001-2003, emission factors are established by interpolation, using the emission factors for FY2000 and FY2004. For FY2004, the emission factor is established by dividing the emission amount in FY2004 provided in the *Voluntary Action Plan* by the activity data.

- ***Activity data***

The activity data for this category are the consumption amount of gasoline used as raw material for city gas production provided in the *Current Survey of Production Concerning Gas Industry* (Agency for Natural Resources and Energy).

A5.1.1.3.m. Flaring (Gas) (1.B.2.c.ii.2)

a) Category Description

This category provides the estimation method for NMVOC emissions from flaring of exploration in the natural gas industry.

b) Methodological Issues

- ***Estimation Method***

The emissions are estimated by multiplying the number of wells drilled (onshore) of natural gas by the NMVOC default emission factor given in the *2019 Refinement*.

$$E = AD \times EF$$

E : NMVOC emissions from flaring in gas exploration [kt-NMVOC]
AD : Number of wells drilled (onshore) [well]

EF : Emission factor per wells drilled of natural gas [kt-NMVOC/well]

- ***Emission factors***

The NMVOC default emission factor for flaring in gas exploration (0.0087 (0.87×1%) t-NMVOC/well) given in the *2019 Refinement* is used.

- ***Activity Data***

The activity data for this category are the number of wells drilled (onshore) in Japan given in the *Natural Gas Data Yearbook*.

A5.1.2 Industrial Processes and Product Use (IPPU)

A5.1.2.1 Mineral Industry, Chemical Industry, Metal Production, and Other Production (2.A., 2.B., 2.C., 2.D.: NO_X, SO_X)

a) Category Description

This section provides the estimation methods for emissions of precursors and other substances (NO_X and SO_X) from the process of producing mineral products, chemical products, metal production and other production.

b) Methodological Issues

- ***Estimation Method***

NO_X and SO_X emissions from the specified sources, not included in the following facilities or industry sectors, were estimated by isolating the emissions of the IPPU sector from the data in the *General Survey of the Emissions of Air Pollutants* (MOE).

Facility: [0101– 0103: Boilers]; [0601– 0618: Metal rolling furnaces, metal furnaces, and metal forge furnaces]; [1101–1106: Drying ovens]; [1301–1304: Waste incinerators]; [2901–3202: Gas turbines, diesel engines, gas engines, and gasoline engines]

Industry sector: [A–D: Accommodation/eating establishments, health care/educational and academic institutions, public bathhouses, laundry services]; [F–L: Agriculture/fisheries, mining, construction, electricity, gas, heat distribution, building heating/other operations]

➢ ***NO_X***

For raw material falling under either [44: Metallurgical coal] or [45: Metallurgical coke], the following equation is used:

$$E=\Sigma\{EF_{NO_X} \times A \times (1\text{-}R)\}$$

E : NO_X emissions from metallurgical coal or metallurgical coke [t-NO_X]
EF_{NOx} : NO_X emission factor by material [t-NO_X /kcal]
A : Energy consumed by material [kcal]
R : Nitrogen removal rate [%]

For raw material falling under either [41: Iron/ironstone] or [46: Other], the following equation is used:

$$E=\Sigma\{N \times (1\text{-}R)\}$$

E : NO_X emissions from iron/iron ore or other material [t-NO_X]

N : Nitrogen content in each material [t-NO_X]

R : Nitrogen removal rate [%]

However, when the emissions from the IPPU sector calculated by the above equations exceed the emission amount listed in the *General Survey of the Emissions of Air Pollutants*, the total emissions listed in the Survey are considered to be the emissions from the IPPU sector. Materials listed in the categories [42: Sulfide minerals] and [43: Non-ferrous metal ores] are excluded from the calculation due to the lack of data.

➢ ***SO_X***

Emissions from the IPPU sector is calculated from the consumption and sulfur content of the materials in categories [41: Iron/ironstone] to [46: Other materials]. Energy sector emissions are estimated by subtracting IPPU sector emissions from the emissions listed in the *General Survey of the Emissions of Air Pollutants* to determine SO_X emissions.

$$E = \Sigma \{S \times (1 - R)\}$$

E : SO_X emissions [t-SO_X]

S : Sulfur content in each material [t-SO_X]

R : Desulfurization rate [%]

● ***Emission factors***

➢ ***NO_X emission factors for metallurgical coal and coke***

NO_X emission factors for the materials used in calculation of NO_X emissions from metallurgical coal and coke (in the IPPU sector) were established for each facility and material type based on the *General Survey of the Emissions of Air Pollutants*.

➢ ***Nitrogen removal rate***

The nitrogen removal rate was calculated by the following equation:

$$R = RE \times (O_{removal} / O_{furnace}) \times (P / E)$$

R : Nitrogen removal rate [%]
RE : Nitrogen removal efficiency
$O_{removal}$: Hours of operation of nitrogen removal unit [h/yr]
$O_{furnace}$: Hours of operation of furnace [h/yr]
P : Processing capacity of nitrogen removal unit [m^3/yr]
E : Maximum exhaust gas emissions [m^3/yr]

$$RE = (V_{before} - V_{after}) / V_{SS}$$

RE : Nitrogen removal efficiency
V_{before} : NO_X volume before treatment
V_{after} : NO_X volume after treatment
V_{SS} : Volume of smoke and soot

The *General Survey of the Emissions of Air Pollutants* data was used for all items.

➢ ***Desulfurization rate***

The desulfurization rate was calculated by the following equation:

$$R = DE \times (O_{removal} / O_{furnace}) \times (P / E)$$

R : Desulfurization rate [%]
DE : Desulfurization efficiency
$O_{removal}$: Hours of operation of desulfurization unit [h/yr]
$O_{furnace}$: Hours of operation of furnace [h/yr]
P : Processing capacity of desulfurization unit [m^3/yr]
E : Maximum exhaust gas emissions [m^3/yr]

$$DE = (V_{before} - V_{after}) / V_{SS}$$

DE	: Desulfurization efficiency
V_{before}	: SOx volume before treatment
V_{after}	: SOx volume after treatment
V_{SS}	: Volume of smoke and soot

The *General Survey of the Emissions of Air Pollutants* data were used for all items.

- ***Activity data***

➢ ***Energy consumption of metallurgical coal or coke***

The activity data was calculated by multiplying the consumption of materials (under [44: Metallurgical coal] and [45: Metallurgical coke]) provided in the *General Survey of the Emissions of Air Pollutants* by the gross calorific value.

➢ ***Nitrogen content of iron/ironstone and other materials***

The activity data was calculated by multiplying the weighted average of nitrogen content, calculated from the nitrogen content and consumption of the materials (under [41: Iron/ironstone] and [46: Other raw materials]) provided in the *General Survey of the Emissions of Air Pollutants*, by the consumption amount of the materials.

➢ ***Sulfur content of various materials***

The activity data was calculated by multiplying the weighted average of sulfur content, calculated on the basis of sulfur content and consumption of the materials (under [41: Iron/ironstone] through [46: Other materials]) provided in the *General Survey of the Emissions of Air Pollutants*, by the consumption amount of the materials.

A5.1.2.2 Non-energy Products From Fuels and Solvent Use (2.D.3.) (NMVOCs)

A5.1.2.2.a. Use of Paint

a) Category Description

NMVOCs are emitted from paint containing solvent and diluent, in the process of using paint including painting industrial products or buildings[5].

b) Methodological Issues

- ***Estimation Method***

Emissions were estimated by multiplying the sales amount of paint by the emission factors per sales amount of paint.

$$E = AD \times EF$$

E	: NMVOC emissions from use of paint [kt -NMVOC]
AD	: Sales amount of paint [kt]
EF	: Emission factors per sales amount of paint [t-NMVOC/t]

[5] The emissions in the process of manufacturing were estimated in "A5.1.2.2.n Chemicals Manufacture"

- ***Emission factors***

The annual survey on VOC emissions from use of paint by Japan Paint Manufacturers Association has been conducted since FY2000 (excluding FY2002). The NMVOC emissions per sales amount of paint which was calculated by dividing the emissions provided in the survey by the sales amount of paints are used for emission factor. For FY2002, the emission factor was established by interpolating between the FY2001 and FY2003 emission factors that were each established by dividing emissions by activity data.

Due to the lack of quantified data for establishing emission factors for FY1999 and before, emission factors for these periods were established by extrapolation based on the trend during FY2000-FY2010. A decreasing trend was obvious during FY2000-FY2010, and FY2010 was the target year of voluntary action plan based on the Air Pollution Control Act; it was assumed, similarly, that during FY1990-1999 emissions might have decreased because of a possible shift to aqueous paint and installation of VOC processing instruments.

- ***Activity Data***

The sales amount of paint provided in the *Yearbook of Current Production Statistics - chemical industry* (METI) (hereafter, *Yearbook of chemical industry*) was used for activity data.

A5.1.2.2.b. Dry-Cleaning

a) Category Description

NMVOCs are emitted from dry-cleaning laundry equipment by using solvent for dry cleaning of clothes.

b) Methodological Issues

NMVOC emissions from dry-cleaning were estimated by deducting "weight as waste" (including residual weights in cartridge and distilling sludge) from "used weight of dry cleaning solvents"

$$E = AD - A - B$$

E : NMVOC emissions from use of dry-cleaning solvent [t -NMVOC]
AD : Used weight of dry-cleaning solvent (Industrial gasoline No.5, Tetrachloroethylene) [t]
A : Absorbed residual solvent in cartridge filter to be disposed as waste (Transferred weight of absorption solution during the changing of cartridge filters) [t]
B : Residual solvent containing distilling sludge to be disposed as waste (Transferred weight of residual solvents during the distilling of sludge) [t]

- ***Emission factors***

No emission factor was established, as all the solvents used in dry cleaning were assumed to be discharged into the atmosphere.

- ***Activity data***

1) Used weight of dry-cleaning solvent

Estimated according to the below tables, based on data in the *Study on the VOC Emission Inventory*.

Table A 5-16 Method of estimating activity data for dry-cleaning solvent (Industrial gasoline No.5)

Fiscal year (FY)	Method of estimating activity data
1990, 1991	Estimated by multiplying the used weight of industrial gasoline No.5 in FY1992 by the installation ratio of laundry machines which use petroleum dissolution in FY1992, provided in *The survey on usage of dry-cleaning solvent* (Ministry of Health, Labour and Welfare (hereafter, MHLW))
1992-1999	Estimated by multiplying the shipping weight of petroleum dry-cleaning solvent in FY2000, provided in *Shipping weight of solvents* by Japan Cleaning Chemicals Association, by the used weight of industrial gasoline no.5 in FY2000
2000, 2005-	Used the result of the survey on the shipping weight of dry-cleaning solvent by petroleum solvent manufacturer, indicated in the *Study on the VOC Emission Inventory*.
2001-2004	Estimated by interpolating the values in FY2000 and FY2005.

Table A 5-17 Method of estimating activity data for dry-cleaning solvent (Tetrachloroethylene)

Fiscal year (FY)	Method of estimating activity data
1990, 1991	Estimated by multiplying the total consumption weight of the solvent in FY1990 and FY1991 by the percentage for dry-cleaning in FY1992 which was calculated based on *Demand by end-use* by Japan Association for Hygiene of Chlorinated Solvents (hereafter, JAHCS), since the data for FY1990 and 1991 was not available.
1992, 1995-	Used weight of tetrachloroethylene provided in *Demand by end-use* by JAHCS was used for activity data.
1993, 1994	Estimated by interpolating the value provided in *Demand by end-use* by JAHCS for FY1992 and FY1995.

2) Weight transferred as waste

The weight of waste transfer (including residual weights in cartridge and distilling sludge) was estimated using the equations in Table A 5-18, in accordance with the method of the *Study on the VOC Emission Inventory*; the weight was deducted from the used weight of dry-cleaning solvent. Values used for the *Study on the VOC Emission Inventory* based on hearings and other surveys were used as parameters for estimation.

As for installed units of dry-cleaning laundry, values provided in the *Survey on usage and management of solvent for dry-cleaning* (MHLW) were used. However, the survey has been conducted biennially after FY2001; therefore, the same values as those in the previous fiscal year were used for years in which the survey was not conducted.

Table A 5-18 Method of estimation for weight of waste transfer in dry-cleaning solvent

Type of waste	Method of estimation for weight of waste transfer in dry-cleaning solvent
Transfer weight of absorbed solvent in changing cartridge filter	Since 2L solvent per 1kg of laundry is absorbed in changing cartridge on average, the estimated annual weight is calculated according to the following formula. $A = A_{unit} \times L \times D \times (W_{ave.} / T) \times N$ A : Absorbed weight in cartridge [kg/year] A_{unit} : Absorbed VOC weight [L/time/kg] in each changing of cartridge per 1kg of loading weight by washer L : Standard load of washer per washing [kg] D : Density [kg/L] $W_{ave.}$: Annual average of operating washer [time/year] T : Average washer times per changing cartridge filter [time/time] N : Number of laundry units installed [unit]
Transfer weight of residual solvent in distilling sludge	Transferred weight of solvent in distilling was estimated according to the following formula. $R = L \times T \times F \times N \times I$ R : Contained residual solvent in distilling sludge [kg/year] L : Standard load of washer [kg/unit] T : Annual average of operating times of washer [time/year] F : Factors by type of filter [kg/kg] N : Unit of installation of laundry [unit] I : Installation rate of distilling [%]

Reference: *Study on the VOC Emission Inventory*

A5.1.2.2.c. Metallic Cleaning

a) Category Description

NMVOCs are emitted from cleaning of metallic components by industrial cleaners in the process of manufacturing electrical/electronic products or metallic components.

b) Methodological Issues

- ***Estimation Method***

1) Chlorine Cleaners

NMVOC emissions from the use of chlorine cleaners were estimated by multiplying the used amount of chlorine cleaners by the emission rate. Since some chlorine cleaners are recycled, the emissions were adjusted for the recycling.

$$E = AD \times R \times EF$$

E : NMVOC emissions from the use of chlorine cleaners [kt -NMVOC]
AD : Sales amount of chlorine cleaners [kt]
R : Adjustment rate for recycling (x 1.1)[6]
EF : Atmospheric emission rate by use of chlorine cleaners [%]

2) Non-chlorine cleaners

NMVOC emissions from the use of non-chlorine cleaners (semi-aquatic, hydrocarbon system, alcohol system, fluorinated, and other types of cleaners) were estimated by multiplying the used weight of

[6] The research by the Japan Industrial Conference on Cleaning at Japan Solvent Recycling Industry Association found that approximately 10 % of the sales amount of chlorine cleaners were recycled and resupplied by recycling companies. (*Studies to develop the national emissions inventory for volatile organic compounds (VOC), FY 2011*, Ministry of the Environment)

cleaners by the atmospheric emission rate.

$$E = AD \times EF$$

E : NMVOC emissions from the use of each non-chlorine cleaner [kt-NMVOC]
AD : Used weight of each non-chlorine cleaner [kt]
EF : Atmospheric emission rate from the use of each non-chlorine cleaner [%]

- ***Emission factors***

Emission factors provided in the *Study on the VOC Emission Inventory*, as shown in Table A 5-19, were used for chlorine cleaners and non-chlorine cleaners.

Table A 5-19 NMVOC emission factors for use of each type of cleaner

Type of cleaner	Atmospheric emission rate	Reference
Chlorine cleaner	75%	*Commission report on manual for promoting voluntary approach for emission control of VOCs in FY2005* (Japan Industrial Conference on Cleaning (hereafter, JICC))
Semi-aquatic cleaner	0.4%	The result of the survey by JICC
Hydrocarbon system cleaner	31.3%	
Alcohol system cleaner	60% (45% for FY2010 and thereafter)	
Fluorinated cleaner	84%	
Other types of cleaners	75%	

- ***Activity Data***

1) Chlorine cleaners

Activity data for chlorine cleaner was established as shown in the following Table A5-20 which was based on the *Study on the VOC Emission Inventory* by the Ministry of the Environment and data provided by JAHCS. According to the *Study on the VOC Emission Inventory*, about 10% of the sales amount of chlorine cleaners are recycled and resupplied; therefore, this was taking into consideration, by multiplying the estimates of the amount of cleaners used by 110%, to adjust for recycling and to use as activity data.

Table A 5-20 Activity data for the use of chlorine cleaners (dichloromethane, trichloroethylene, tetrachloroethylene)

Fiscal Year (FY)	Activity data
1990-1994	Estimated by multiplying the total consumption amount in each fiscal year by the proportion of metallic cleaners in FY1995 (calculated based on the *Demand by use* (JAHCS), (hereafter *Demand by use*)) since data was not available for FY1990-1994.
1995-	The sales amount of dichloromethane, trichloroethylene, and tetrachloroethylene for metallic cleaning provided in the *Demand by use* was adopted for activity data.

Table A 5-21 Activity data for the use of chlorine cleaners (other types of chlorine cleaner)

Fiscal Year (FY)	Activity data
1990-1999	Estimated by multiplying the total consumption amount for three major chlorine cleaners (*Demand by use*) for 2000 by the ratio in FY1990-1999 to the activity data in FY2000.
2000, 2005-	The sales amount provided in the *Study on the VOC Emission Inventory* was used for activity data. (the results of research by JICC).
2001-2004	Estimated by interpolating the activity data for FY2000 and FY2005.

2) Non-chlorine cleaner

Activity data for non-chlorine cleaners was established as shown in Table A 5-22 based on the

information provided in the *Study on the VOC Emission Inventory*.

Table A 5-22 Activity data for non-chlorine cleaner

Fiscal year (FY)	Activity data
1990-1999	Total amount of raw materials by type of cleaner was estimated by multiplying the proportion for each type of manufacturer provided in the *Study on the VOC Emission Inventory* (Table A 5-23) by the corresponding used weight of raw material; then, the activity data (the used weight) for each year was estimated by multiplying the estimated total weight by the ratio from FY2000.
2000	Used weight of each type of cleaner in the *Study on the VOC Emission Inventory* was adopted for activity data.
2001-2004	Estimated by interpolating the activity data for FY2000 and FY2005.
2005-	Used weight of each type of cleaner in the *Study on the VOC Emission Inventory* was adopted for activity data. As for values in the *Study on the VOC Emission Inventory*, the results of a sampling survey were used after an adjustment. The survey has not been conducting every year. Therefore, for years when the survey was not conducted, data has been supplemented by using the interpolation method.

Table A 5-23 Proportion by type of manufacturer in VOC emissions from non-chlorine cleaner

Manufacture	n-Methyl-pyrrolidone admixture	Glycol ether admixture	n-Paraffin cleaner	Isoparaffin cleaner	Naphthene cleaner	Other carbon hydride cleaner	Isopropyl alcohol cleaner	Other alcohol cleaner	HFC cleaner	Other fluorine cleaner	Bromine cleaner	Other cleaner
Plastic Products			3%	6%	4%			12%				
Iron and Steel			3%	0.1%	5%				1%	2%		
Non-Ferrous Metals and Products			16%	0.05%	7%				1%	2%		
Fabricated Metal Products		2%	17%	30%	26%	8%					4%	
Machinery			11%	8%	15%	11%			1%	2%		
Communications		19%					1%					
Electric device	70%	49%	17%	15%	7%	13%	25%	28%	28%	38%	30%	33%
Transport		2%	16%	26%	36%	10%		12%	7%	19%	18%	67%
Precision apparatus	30%	18%	17%	15%		18%	74%	46%	61%	37%	48%	
Other		10%	0.1%		1%	41%		3%				
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Reference: The *Study on the VOC Emission Inventory*

A5.1.2.2.d. Use of Thinner for Cleaning of Manufacturing Equipment

a) Category Description

NMVOCs are emitted from the use of thinner for cleaning of manufacturing equipment.

b) Methodological Issues

- ***Estimation Method***

NMVOC emissions from the use of thinner for cleaning of manufacturing equipment were estimated by multiplying the sales volume of thinner excluding that for painting by the emission factor for NMVOC per sales volume.

$$E = AD \times EF$$

E : NMVOC emissions from the use of cleaning thinner [t-NMVOC]
AD : The sales volume of thinner excluding that for painting [kL]
EF : Emission factor per sales volume of cleaning thinner [t-NMVOC/kL]

- ***Emission factors***

Emission factor was established by using the emissions from "thinner for cleaning of manufacturing equipment" provided in the *Study on the VOC Emission Inventory* and later-described activity data.

Although the emission factor has a slightly decreasing trend after FY2000, the emission factor for FY2000 is applied for fiscal years FY1990 to FY1999, since there are no quantitative data for estimating emission factors in the related organization and that difficulties have been faced for implementation of technical measures for reduction of emissions from thinner cleaning (Table A5-24).

Table A 5-24 The Method of establishing emission factors of cleaning thinner for manufacturing equipment

Fiscal Year (FY)	Method of establishing emission factor
1990-1999	Emission factor for FY2000 was applied for all fiscal years.
2000, 2005-	Estimated by dividing the emissions for each fiscal year provided in the *Study on the VOC Emission Inventory* by the activity data for each fiscal year.
2001-2004	Estimated by interpolating the activity data for FY2000 and FY2005.

- ***Activity data***

Established based on the sales amount of thinner, etc. in the *Yearbook of chemical industry* as shown in the below table.

Table A 5-25 Method of estimating activity data for the use of cleaning thinner for manufacturing equipment

Fiscal Year (FY)	Activity data
1990-2004	Since data on the consumption amount of diluent thinner in and before FY2004 was unidentified, the consumption amount of diluent thinner for this period, was estimated by multiplying the proportion of the amount of diluent thinner to the sales volume of thinner in FY2005 by the sales volume of thinner in and before FY2004, and, and then subtracted from the total sales volume of thinner, to be used as activity data.
2005-	Estimated by subtracting the consumption amount of diluent thinner for painting provided in *Summary of estimation for the current status of VOC emissions from painting* (Japan Paint Manufacturers Association) from the sales amount of thinner given in the *Yearbook of chemical industry*, where the whole time series data from FY1990 were available.

A5.1.2.2.e. Use of Printing Ink Solvents

a) Category Description

VOCs are emitted from printing ink solvent or other types of diluents in the process of printing. Ink included in stationaries, solvent for cleaning of printing machine (estimated as "A5.1.2.2.d Use of thinner for cleaning of manufacturing equipment"), and emissions at the stage of production of printing ink (estimated as "A5.1.2.2.n Chemicals Manufacture") were excluded from emissions in this category.

b) Methodological Issues

- ***Estimation Method***

VOC emissions were estimated by multiplying the used weight of VOCs in the process of printing, which was provided in the *Study on the VOC Emission Inventory*, by the atmospheric emission rate.

$$E = AD \times EF$$

E : NMVOC emissions from the use of printing ink solvents [t-NMVOC]
AD : Used weight of VOCs in the process of printing [t]
EF : Atmospheric emission rate per used weight of VOCs [%]

- ***Emission factors***

Atmospheric emission rate by type of ink, provided in the *Study on the VOC Emission Inventory* was adopted for emission factor. As for printing ink other than planographic and photogravure ink, the same atmospheric emission rate was adopted for the emission factor for FY2000 and thereafter; in a similar way, the atmospheric emission rate in FY2000 was adopted for and before FY1999.

As for emissions from planographic ink and photogravure ink, the atmospheric emission rate for FY1990-1999 was estimated by extrapolation, using the trend in FY2000-2010: the decreasing trend after FY2000 suggested that some measures aimed at reducing emissions might have been implemented during this period. (Table A 5-26) However, as for photogravure ink, the emission factor was established by interpolating between of the FY1983 value from the *Study of Establishment of Methodology for Estimation of Hydrocarbon Emissions* (Institute of Behavioral Science, 1984) and the FY2000 value, since the atmospheric emission rate in FY1990 would surpass 100% by a simple extrapolating calculation.

Table A 5-26 The method of establishing emission factor for the use of printing ink solvents (Planographic ink, photogravure ink)

Fiscal Year (FY)	The method of establishing of emission factor	
	Planographic ink	Photogravure ink
1990-1999	Estimated by extrapolation, using the trend in FY2000-2010.	Interpolated between the 1983 value from the *Study of Establishment of Methodology for Estimation of Hydrocarbon Emissions* (Institute of Behavioral Science, 1984) and the 2000 value.
2000	Established based on the *Study on the VOC Emission Inventory* in FY2000.	
2001-2004	Established by interpolating the figures in FY2000 and FY2005.	
2005-	Emission factors in each fiscal year provided in the *Study on the VOC Emission Inventory*.	

Note: The same emission factor was applied for resin anastatic ink, metallic printing ink, news ink, and other inks for all time-series, in accordance with the *Study on the VOC Emission Inventory*.

- ***Activity data***

The used amount of VOCs, provided in the *Study on the VOC Emission Inventory* (estimated based on the results of the survey by Japan Printing Ink Makers Association and voluntary action plan of Japan Federation of Printing Industries) was used for activity data and was estimated as shown in Table A 5-27.

Table A 5-27 Method of estimating activity data

Fiscal Year (FY)	Activity data
1990-1999	Estimated by multiplying the ratio of sales amount of print ink for each product type in each year to that in FY2000, provided in the *Yearbook of Chemical Industry*, by the activity data of FY2000.
2000, 2005-	Used amount of VOCs in the process of printing, provided in the *Study on the VOC Emission Inventory*, was used.
2001-2004	Estimated by interpolating the activity data of FY2000 and 2005.

A5.1.2.2.f. Use of Adhesive Agent for Laminate

a) Category Description

VOC are emitted from lamination, caused by solvent contained in adhesive agents for bonding base material and laminate. VOC emissions from producing adhesive agents for laminate are estimated in

"A5.1.2.2.n Chemicals Manufacture".

b) Methodological Issues

- ***Estimation Method***

NMVOC emissions from polyethylene laminate were estimated by multiplying the sales amount of film for laminate, which was adopted for activity data, by the NMVOC emission factor per sales amount of film for laminate.

$$E = AD \times EF$$

E	: NMVOC emissions from lamination [t-NMVOC]
AD	: Sales amount of film for laminate [t]
EF	: Emission factor per sales amount of film for laminate [t-NMVOC/t]

- ***Emission factors***

Emission factor was established by dividing VOC emissions, which was estimated based on reported values in voluntary action plan in the *Study on the VOC emission inventory*, by the sales amount of film for laminating for FY2000, and FY2005 and thereafter. For fiscal years which were not subject to the voluntary action plan, emission factor in FY2000 was adopted for FY1990-1999. The emission factor for FY2001-2004 was established by interpolating between the emission factors for FY2000 and FY2005.

- ***Activity data***

The sales amount of film for laminate provided in the *Yearbook of Current Production Statistics - paper, printing, plastics products and rubber products* (METI), (hereafter, *Yearbook of Paper, Printing, Plastics Products and Rubber Products Statistics*) was used for activity data.

A5.1.2.2.g. Use of Solvent-Type Adhesives

a) Category Description

VOCs are emitted from the use of solvent-type adhesive.

b) Methodological issues

- ***Estimation Method***

As for VOC emissions from the use of solvent-type adhesive, the atmospheric emission rate was regarded as 100%; the total amount was used for estimating emissions.

$$E = AD$$

E	: NMVOC emissions from the use of adhesive [t-NMVOC]
AD	: The used amount of VOCs from the use of adhesive [t]

- ***Emission factors***

No emission factors were established since it was assumed that the total amount of the solvent used for adhesive were emitted into the air.

- ***Activity Data***

Activity data was estimated as shown in the following table, and based on the *Study on the VOC Emission Inventory* and the *Current Survey Report on Adhesives* (Japan Adhesive Industry Association).

Table A 5-28 Method of establishing activity data for the use of adhesives

Fiscal year (FY)	Activity data
1990-1999	Estimated by multiplying the used amount of VOCs in FY2000 by the ratio of the total of shipping weight of each type of adhesive in each year to the 2000 level.
2000, 2005-	Used amount of VOC emissions provided in the *Study on the VOC Emission Inventory* (estimated by the Committee for the VOC Emission Inventory).
2001-2004	Estimated by interpolation, using activity data for FY2000 and FY2005.

A5.1.2.2.h. Use of Gum Solvents

a) Category Description

VOCs are emitted from gum solvent in the manufacturing of gum products.

b) Methodological Issues

- ***Estimation Method***

NMVOC emissions from gum solvents for gum production were estimated by multiplying the consumption of volatile oil for solvent use for gum production by the NMVOC emission factor per consumption of volatile oil for solvent use, which was estimated based on the *Study on the VOC Emission Inventory*.

$$E = AD \times EF$$

E : NMVOC emissions from gum production [t-NMVOC]
AD : Consumption of volatile oil for solvent use for gum production [t]
EF : Emission factor per consumption of volatile oil for solvent use [t-NMVOC/t]

- ***Emission Factors***

VOC emissions per consumption of volatile oil for solvent use, which was calculated by dividing emissions based on reported values in the voluntary action plan by the Japan Rubber Manufacturers Association in the *Study on the VOC Emission inventory*, by the consumption of volatile oil for solvent use, were adopted as emission factors for gum production for FY2000, and FY2005 and thereafter. For fiscal years which were not subject to the voluntary action plan, emission factor in FY2000 was applied for FY1990-1999 and the median value of FY2000 and FY2005 was applied for FY2001-2004.

- ***Activity data***

Consumption of volatile oil for solvent use, which was obtained from the *Yearbook of Rubber Products Statistics* by the Ministry of Economy, Trade and Industry and the survey results by the Japan Rubber Manufacturers Association, was applied for activity data. The consumption was converted from volume to mass using the solvent density. As for FY2006-2010, the activity data was adjusted using interpolation since the business entities surveyed for this period was possibly different from before/after this period.

A5.1.2.2.i. Use of Adhesive Solvents and Detachment Solvents

a) Category Description

NMVOCs are emitted from the use of adhesive solvent and detachment solvent in manufacturing adhesive tape or adhesive label. This source category does not deal with the NMVOC emissions in manufacturing adhesive solvent and detachment solvent since the emissions are included in “A5.1.2.2.n

Chemicals Manufacture".

b) Methodological Issues

- ***Estimation Method***

The shipping amount of adhesive tape was used for activity data. NMVOC emissions from the use of adhesive solvent and detachment solvent were estimated by multiplying the activity data by the emission factor per shipping amount.

$$E = AD \times EF$$

E : NMVOC emissions from the use of adhesive and detachment solvent [t-NMVOC]
AD : Shipping amount of adhesive tape [million m^2]
EF : Emission factor per shipping amount of adhesive tape [t-NMVOC/million m^2]

- ***Emission factors***

Emission factors for FY2000, and FY2005 and thereafter per adhesive for use of solvent and detachment solvent were established by dividing emissions, which were based on the reported values in voluntary action plan by four business associations including Japan Paper Association, by the shipping amount of adhesive tape. For fiscal years which were not subject to the voluntary action plan, emission factor in FY2000 was applied for FY1990-1999 and emission factors in FY2001-2004 were established by interpolating between the FY2000 and FY2005 EFs.

- ***Activity data***

The shipping amount provided by Japan Adhesive Tape Manufacturers Association was adopted for activity data.

A5.1.2.2.j. Use of Repellents and Air Fresheners

a) Category Description

NMVOCs are emitted from the sublimation of chemical agents during the use of repellents or air fresheners such as at home. The major substance in the emissions is p-dichlorobenzene.

b) Methodological Issues

- ***Estimation Method***

Repellents and air fresheners are mainly used in general households, and therefore it is considered that the total amount of them are released into the atmosphere. Therefore, the atmospheric emission rate was regarded as 100% and the amount of p-dichlorobenzene contained in repellents or air fresheners was applied for VOC emissions.

- ***Emission factors***

It was assumed that the total amount of p-dichlorobenzene contained in repellent and air fresheners was released into the atmosphere. Therefore, no emission factor has been established.

- ***Activity data***

Total amount of p-dichlorobenzene shipped as repellent and air fresheners, which was provided by Japan Moth Repellent Association and indicated in *Estimation Methods for Releases from Sources not Required to Report under PRTR* (METI and MOE) was applied for activity data.

The shipping amount provided by Japan Moth Repellent Association was not available for and before FY2000; therefore, for this period, the shipping amount was estimated by multiplying the amount in FY 2001 by the growth rate of market size from FY2001. However, because information on market size is limited to FY1992 onwards, for FY1990 and 1991, it was estimated by extrapolation from the shipping amount.

A5.1.2.2.k. Use of Aerosols Inhalers

a) Category Description

NMVOCs are emitted from inhalers by the use of aerosols products including pesticide, lacquer, and hair spray. NMVOC emissions from content fluid including paint solvent are estimated in other categories such as the use of paint or cosmetic products. Therefore, to avoid double counting, only NMVOC emissions from liquefied gas in inhalers are included in this category. As for inhalers for aerosols products, propane (LPG) and dimethyl ether (DME) are mainly used.

b) Methodological Issues

- ***Estimation Method***

The emissions were estimated based on the estimation method provided in the *Research Report on VOC emissions from private sector* by the Institute of Behavioral Science (hereafter, Survey by Tokyo Metropolitan Government*)*, in March in 2010. The emissions were estimated as shown in the following equation, by multiplying the production amount for each type of product, by the emission factors for LPG and DME.

$$E = \sum (AD_i \times EF_{LPG,DME})$$

E	: NMVOC emissions from the use of aerosols products [g]
AD_i	: Production capacity of aerosols product *i* [cc]
$EF_{LPG,\ DME}$	: LPG and DME emission factor [g/cc]

- ***Emission factors***

Based on each parameter which was used by the Survey by Tokyo Metropolitan Government, the LPG and DME emission amount per aerosols production capacity was applied using the following equation.

$$EF_{LPG,DME} = R_{LPG,DME} \times R_P \times C_{LPG,DME} \times d_{LPG,DME}$$

$EF_{LPG,\ DME}$	: LPG and DME emission factor per aerosols production capacity [g/cc]
$R_{LPG,\ DME}$	: Percentage of LPG and DME aerosols products [%]
R_P	: Percentage of aerosols propellant in can [%]
C_{LPG}, C_{DME}	: Percentage of LPG and DME in propellant [%]
d_{LPG}, d_{DME}	: Specific gravity of LPG and DME [g/cc]

Emission factors for LPG and DME by aerosols products were shown in Table A 5-29.

Table A 5-29 Emission factors for aerosols products (g/cc)

Type of products		LPG	DME
Pesticide	For fly and mosquito	0.223	0.0296
	Other pesticides	0.223	0.0296
Paint	Paint	0.227	0.0151
Household product	Room air freshener	0.236	-
	Cleaner	0.236	-
	Wax and polish	0.236	-
	Laundry articles	0.236	-
	Other household products	0.236	-
Body care products	Hair spray	0.202	0.0269
	Other hair care products	-	0.269
	Shaving cream	0.202	0.0269
	Perfume and cologne	0.112	0.134
	Pharmaceutical products	0.176	0.0905
	Deodorizing and antiperspirant agents	0.225	-
	Other body care products	0.112	0.134
Car-related items	Anti-fog	0.213	-
	Other car-related products	0.213	-
Others	Handy extinguisher	-	-
	Others	0.221	-

Reference: Established based on the *Survey by Tokyo Metropolitan Government*

1) Percentage of aerosol products which used LPG and DME as propellent

As for the percentage of aerosols products which used LPG and DME as propellant, it was calculated by deducting the percentages indicated in Table A 5-30 (established by Tokyo Metropolitan Government research) from 100% for each product and was adapted to each use. As for paint and pharmaceutical products, 100% was applied since no data was available. (Table A 5-31)

Table A 5-30 Percentage of aerosols products which used compressed gas as propellant

Product	Percentage
Pesticide	1.8%
Household product	6.2%
Cosmetic items	10.8%
Industrial goods	2.3%
Car-related items	15.3%
Others	12.5%

Reference: *Survey by Tokyo Metropolitan Government*

Table A 5-31 Percentage of aerosol products which used LPG and DME as propellants

Type of product		Percentage
Pesticide	For fly and mosquito	98.2%
	Other pesticides	98.2%
Paint	Paint	100.0%
Household product	Room air freshener	93.8%
	Cleaner	93.8%
	Wax and polish	93.8%
	Laundry articles	93.8%
	Other household products	93.8%
Body care products	Hair spray	89.2%
	Other hair care products	89.2%
	Shaving cream	89.2%
	Perfume and cologne	89.2%
	Pharmaceutical products	100.0%
	Deodorizing and antiperspirant agents	89.2%
	Other body care products	89.2%
Car-related items	Anti-fog	84.7%
	Other car-related products	84.7%
Others	Handy extinguisher	87.5%
	Others	87.5%

Note: Established based on the *Survey by the Tokyo Metropolitan Government*

2) Percentage of propellant gas contained in aerosols cans

According to the Survey by Tokyo Metropolitan Government, the percentage of propellant gas contained in aerosols cans was estimated to be 45%.

3) Percentage of LPG and DME in propellant gas

According to the Survey by Tokyo Metropolitan Government, the percentage of LPG and DME in propellant gas was estimated as shown in Table A 5-32.

Table A 5-32 Percentage of LPG and DME in propellant

Type of product		LPG	DME
Pesticide	For fly and mosquito	90%	10%
	Other pesticides	90%	10%
Paint	Paint	90%	5%
Household products	Room air freshener	100%	0%
	Cleaner	100%	0%
	Wax and polish	100%	0%
	Laundry articles	100%	0%
	Other household products	100%	0%
Body care products	Hair spray	90%	10%
	Other hair care products	0%	100%
	Shaving cream	90%	10%
	Perfume and cologne	50%	50%
	Pharmaceutical products	70%	30%
	Deodorizing and antiperspirant agents	100%	0%
	Other body care products	50%	50%
Car-related products	Anti-fog	100%	0%
	Other car-related products	100%	0%
Others	Handy extinguisher	0%	0%
	Others	100%	0%

Note: Established based on the *Survey by Tokyo Metropolitan Government*

4) Specific gravity of LPG and DME

Based on the Survey by Tokyo Metropolitan Government, specific gravity of LPG and DME was

established as 0.56 and 0.67, respectively.

- ***Activity data***

Following the Survey by Tokyo Metropolitan Government, production volume of aerosols products was adopted as activity data; it was estimated by multiplying the production volume of aerosols products for each type of container and capacity, by the average capacity per a can for each type of container and capacity, which converts it to capacity base.

$$AD_i = \sum (N_{i,k} \times P_{ave,k})$$

AD_i : Production capacity of aerosols product i [cc]
$N_{i,k}$: Production amount of aerosols Product i, Container capacity k [can]
$P_{ave,k}$: Average capacity of aerosol cans with container capacity k [cc/can]

As for "Production volume for each type of container and capacity", the results of the *Survey of Production Amounts of Aerosols* which has been annually conducted by the Aerosols Industry Association of Japan were used. As for "average capacity", the values were set by the type of container and capacity which was provided in the Survey by Tokyo Metropolitan Government, based on the hearing survey of the Aerosols Industry Association of Japan (shown in Table A 5-33 and TableA5-34).

Table A 5-33 Average capacity by capacity class (tinplate container, aluminum container)

Tinplate container	Capacity class [cc]	100-	150-	180-	220-	280-	420-
	Average capacity[cc]	125	165	200	250	350	420
Aluminum container	Capacity class [cc]	-49	50-	100-	150-	200-	300-
	Average capacity[cc]	25	75	125	175	250	300

Table A 5-34 Average capacity by capacity class (synthetic resin container)

Capacity class [cc]	*
Average capacity[cc]	210

Note: * Same for all capacity classes
Reference: Survey by Tokyo Metropolitan Government (TableA5-33 and TableA5-34)

A5.1.2.2.l. Use of Cosmetic Products

a) Category Description

VOCs contained in various types of cosmetic products are emitted to the atmosphere by the use of cosmetics.

b) Methodological Issues

- ***Estimation Method***

Following the methodology of the *Survey by Tokyo metropolitan government*, VOC emissions were estimated by multiplying the sales amount of cosmetic products for each type by the VOC content for each type of cosmetic product, by the atmospheric emission rate for each type of cosmetic product.

$$E = \sum_i (AD_i \times C_i \times EF_i)$$

E : NMVOC emissions from the use of cosmetic product [t-NMVOC]
AD_i : Sales amount of cosmetic items i [t]
C_i : VOC content in cosmetic products i [%]
EF_i : Atmospheric emission rate of cosmetic products i [%]

- ***Emission factors***

The VOC content of products was classified according to the *Yearbook of chemical industry* from the VOC content which was provided in the *Survey by Tokyo Metropolitan Government* based on some reports. (Table A5-35)

The smaller classified categories in the *Survey by Tokyo Metropolitan Government* than those in *Yearbook of chemical industry* were integrated by weighted average using shipping amount allocated ratio provided in *Cosmetic Products Marketing Directory* (Fuji Keizai CO., Ltd.), to make them correspond to the categories in the *Yearbook of chemical industry*.

Table A 5-35 VOC content and atmospheric emission rate based on classification in the *Yearbook of Chemical Industry*

Cosmetic products		VOC content	Atmospheric emission rate
Skin care	Massage and cold cream	7.5%	100%
	Moisturizing cream	7.5%	100%
	Cleansing foam	10.0%	0%
	Cleansing cream	10.0%	0%
	Lotion	10.0%	100%
	Milk	6.0%	100%
	Beauty essence	8.5%	100%
	Facial mask[1)]	4.4%	100%
	Other skincare products	7.5%	100%
Makeup	Foundation[1)]	2.6%	100%
	Face powder	0.0%	100%
	Eye makeup	4.0%	100%
	Eyebrow and eyelash cosmetics	0.0%	100%
	Cheek rouge	0.0%	100%
	Lip rouge	0.0%	100%
	Nail cosmetics (including nail-polish remover) [1)]	76.8%	100%
Body care	Lip balm	7.5%	100%
	Sunscreen and cosmetics for sun-burns	10.0%	100%
Fragrance	Perfume and cologne	83.5%	100%
Hair care in bath	Shampoo	1.5%	0%
	Rinse	1.5%	0%
	Hair conditioner	1.5%	0%
Hair making	Pomade, hair oil, hair dress, perfume oil[1)] Hairdressing[1)], Setting lotion[1)]	10.6%	100%
	Hair spray	27.5%	100%
	Other items for hair (including permanent wave lotion)	1.5%	100%
Hair color	Hair color (Including hair bleach) [1)]	22.1%	100%
For men	Products for shaving or bath	25.0%	100%
	Skin care products	7.5%	100%
	Hair tonic (including hair growing agents)	42.5%	100%

Note: 1) Integrated categories by weighted average

Reference: *Survey by Tokyo Metropolitan Government*

The atmospheric emission rate, as well as VOC content in the category were reset, so that they correspond to the categories in the *Yearbook of chemical industry*. Assuming that cosmetic products were used in a normal way, atmospheric emission rate of solid products and liquid products were set at either 0% or 100% (Table A 5-35). When integrating categories, the Table A5-36 principles were applied to the products most sold under the categories, and rates were reestablished.

Table A 5-36 Atmospheric emission rate by the way of usage, provided in the Survey by Tokyo Metropolitan Government

State of matter	Usage and process	Atmospheric emission rate
Solid	To use in water or wash away	0%
	To leave it and volatilize component	100%
Liquid	To use in water or wash away in a short time	0%
	To leave it for a long time and dry it	100%
	To volatilize component	100%
	To spray mist (only undiluted solution is used for estimation. Propellant solvent is separately estimated.)	100%

Reference: *Survey by Tokyo Metropolitan Government*

Table A 5-37 Atmospheric emission rate based on the Survey by Tokyo Metropolitan Government

Cosmetic products			Atmospheric emission rate
Skin care	Massage and Cold cream *1		100%
	Remover		0%
	Facial-wash	Facial-wash	0%
		Cleansing	0%
	Lotion	Lotion	100%
	Milk	Milk	100%
	Beauty essence	Beauty essence	100%
	Facial mask	Wash-off facial mask	0%
		Peel-off pack	100%
		Sheet pack	100%
	Face cream	(Classified into *1)	-
	Others	Spot care	100%
Makeup	Base	Makeup base	100%
	Foundation, concealer	Foundation, etc.	100%
	Face powder	Face powder	100%
	Eye color	Eye shadow	100%
	Eye liner	Eye liner	100%
	Eyelash liner	Eyelash liner	100%
	Eyebrow	Eyebrow	100%
	Cheek rouge	Cheek rouge	100%
	Lip color	Lip color	100%
	Nail color	Nail enamel	100%
		Nail care (including remover)	100%
Body care	Body cream, lotion	Body cream, lotion, etc.	100%
	Lip cream	Lip cream	100%
	Hand cream	Hand cream	100%
	UV care product	Suntan, sunscreen	100%
	Unwanted hair treatment agent	Hair removal, depilatory	100%
	Anhidrotic deodorant *2	Deodorant (for foot, for underarm)	100%
Fragrance	Perfume *3	Parfum, Eau de Parfum	0%
	Eau de toilette *3		100%
	Cologne *3		0%
Hair care in bath	Shampoo	Shampoo	0%
	Rinse, Hair conditioner	Rinse, Hair conditioner	0%
	Hair treatment, pack	Hair treatment	0%
Hair make	Blow styling agent, Hair spray, Hair gross	Hair styling agent	100%
	Hair tonic for female	(Classified into *6)	-
	Hair growing agent for female	(Classified into *7)	-
	Permanent wave lotion	Cold wave treating agent	100%
Hair color	Hair coloring agent for black hair, Hair coloring agent for white hair*4	Hair coloring agent for white hair	100%
		Hair coloring agent for black hair	100%
		Hair manicure for white hair	100%
		Hair manicure for black hair	100%
		Other types of hair color (including spray)	100%
		Bleach (decoloring)	100%
For men	Pre-shaving agent, shaving agent	Shaving agent	100%
	Face wash, pack	Skin care products	0%
	Skin lotion		100%
	Skin cream and milk		0%
	Make-up items		0%
	Hair tonic for men *6	Hair tonic	100%
	Hair growing agent *7	Hair growing agent, tonic	100%
	Blow styling agent	(Classified into *4)	-
	Hair spray, hair gloss		0%
	Hair coloring agent for black hair	(Classified into *5)	-
	Hair coloring agent for white hair	(Classified into *5)	-
	Anhidrotic deodorant	(Classified into *2)	-
	Fragrance	(Classified into *3)	-

Reference: *Survey by Tokyo Metropolitan Government*

- ***Activity data***

Sales amounts of cosmetic products by type provided in the *Yearbook of chemical industry* is used for

activity data. However, since imported goods are not included in the *Yearbook of chemical industry* there is assumed to be a wide gap between reported sales amounts and actual consumption amounts. Therefore, as for "perfume and cologne", since the percentage of import excess was especially high, correction measures were taken to account for exports/imports.

Table A 5-38 Cosmetic products provided in *Yearbook of chemical industry*

Skin care	Massage and cold cream
	Moisturizing cream
	Cleansing foam
	Cleansing cream
	Lotion
	Milk
	Beauty essence
	Facial mask
	Other skincare products
Makeup	Foundation
	Face powder
	Eye makeup
	Eyebrow and eyelash cosmetics
	Cheek rouge
	Lip rouge
	Nail cosmetics (including nail-polish remover)
Fragrance	Perfume and cologne
Body care	Lip balm
	Sunscreen and cosmetics for sun-burns
Hair care in bath	Shampoo
	Rinse
	Hair conditioner
Hair making	Pomade, hair oil, hair dress, perfume oil
	Hairdressing
	Setting lotion
	Hair spray
	Other items for hair (including permanent wave lotion)
Hair color	Hair color (including hair bleach)
For men	Products for shaving or bath
	Skin care products
	Hair tonic (including hair growing agents)

A5.1.2.2.m. Use of Products for Car Washing and Repair

a) Category Description

VOC components contained in various products for car washing and repairing including wax and cleaner are emitted into the air.

b) Methodological Issues

- ***Estimation Method***

Following the methodology of the Survey by Tokyo Metropolitan Government, the VOC amount used was estimated by multiplying the production amount of car repairing and washing products for each type of product, by the VOC content by type of product. The whole amount of VOCs contained in car repairing and washing products is assumed to be emitted into the atmosphere by the use of the products. The used amount of VOCs was applied for VOC emissions from this source category.

$$E = \sum_i (AD_i \times C_i)$$

E : NMVOC emissions from the use of car washing and repairing products [t-NMVOC]
AD_i : The production amount of i [t]
C_i : VOC content of car washing and repairing products i [%]

- ***Emission factors***

VOC content was newly established based on various statistical data and existing VOC content provided in the Survey by Tokyo Metropolitan Government; as for some whose minimum value and maximum value was indicated, the median value was calculated. (Table A 5-39)

Table A 5-39 VOC content for car washing and repairing products

Product		VOC	VOC content
Wax for cars, coating material		Hydrocarbon compounds including kerosene	50.0%
Products for car window	Window washer fluid	Methanol	25.0%
	Water repellent product	Ethanol	49.0%
		Isopropyl alcohol	42.0%
	Oil film remover	Ethanol	6.5%
		Isopropyl alcohol	12.5%
		Diethanolamine	5.0%
		Petroleum solvent	30.0%
	Frost remover	Ethylene glycol	25.0%
		Isopropyl alcohol	25.0%
Car cleaner		Ethylene glycol	10.0%
Paint for car, repairing agent	Paint		-
	Adhesive		-
Air fresher and air freshener for cars	Air fresher	Aroma chemical (liquid)	1.5%
		Ethanol	2.3%
		Methanol	3.5%
		Aroma chemical (gel)	3.5%
	Air freshener	Ethanol	50.0%

Reference: Established based on the *Survey by Tokyo Metropolitan Government*

- ***Activity data***

Production weight by type of chemical product for car indicated in *Research report on the current status of auto chemical manufacturing* (Japan Auto Chemical Industry Association) was used for activity data for FY1991-1996 and FY1999-2005. Activity data in FY2006 and thereafter was estimated by multiplying the consumption of car washing and repairing products per vehicle by the number of registered vehicles provided by the Automobile Inspection and Registration Information Association. Consumption of car washing and repairing products per vehicle was estimated by dividing the production weight for each type of chemical product for cars of FY2003 to FY2005 by the number of registered vehicles of each fiscal year, and multiplying the average weight of the three years[7] by the growth rate of travel distance per vehicle from FY2005. The travel distance per vehicle is calculated by dividing the travel distance in the *Statistical Yearbook of Motor Vehicle Fuel Consumption* (Ministry of Land, Infrastructure, Transport and Tourism) and other statistics by the number of registered vehicles mentioned above. The growth rate was used to reflect that the consumption of wax and coating material for cars has been showing a downward trend since FY1990 and according to Auto-parts & Accessories Retail Association, recently, consumption per vehicle has been decreasing due to a decline in the rate of utilization of cars, miniaturization of cars, and the prevalence of car washing machines. The consumption of other products for cars was also estimated based on the growth rate of travel distance per vehicle. For FY1990, the value for FY1991 was used. For FY1997 and FY1998, it was estimated

[7] Three-year average was used since the FY2005 value drastically increased from the previous year.

by interpolation, using activity data in FY1996 and FY1999.

A5.1.2.2.n. Chemicals Manufacture

a) Category Description

This source category provides the methods for estimating NMVOC emissions from highly volatile substances in manufacturing facilities to polymerize or synthesize chemical products, fugitive emissions by storage or shipping of chemical products, and emissions from solvent in chemical reaction by polymerizing or component extraction and use of raw materials.

b) Methodological Issues

- ***Estimation Method***

NMVOC emissions from chemicals manufacture were estimated by multiplying source-specific activity data (production amount of paint, production amount of print ink, shipping amount of solvent-type adhesive, amount of VOC of surface finishing equipment, shipping value of chemical industry-related products and production amount of film soft chemical products for wrapping) by each NMVOC emission factor defined by dividing source-specific VOC emissions in the *Study on the VOC Emission Inventory* by activity data.

$$E = AD \times EF$$

E : NMVOC emissions by chemical manufacture [t-NMVOC]
AD : Activity data by source
EF : Emission factor per activity data

The emissions estimated by the equation above include the emissions from chemical tankers estimated in A5.1.1.3.c Oil Transport (1.B.2.a.iii): Navigation. Therefore, the emissions from chemical tankers were subtracted from the total emissions in this category.

- ***Emission factors***

Emission factor was established by dividing emissions from emission activities indicated in the *Study on the VOC Emission Inventory* by each activity data shown in Table A 5-46. The emission factor for each fiscal year which was not subject to the voluntary action plan / the PRTR report was established as shown in Table A 5-40 - Table A 5-45.

Table A 5-40 Method of establishing NMVOC emission factors for chemical manufacture (paint manufacturing)

Fiscal Year (FY)	Method of establishing emission factor
1990-1999	Emission factor for FY2000 was used for all fiscal years.
2000, 2005-	Established by dividing VOC emissions (estimated figure based on voluntary action plan by Japan Paint Manufacturers Association) by the production amount of paint.
2001-2004	Average value of FY2000 and 2005 was used.

Table A 5-41 Method of establishing NMVOC emission factors for chemical manufacture (print ink manufacturing)

Fiscal Year (FY)	Method of establishing emission factor
1990-1999	Emission factor for FY2000 was used for all fiscal years.
2000, 2005-	Established by dividing VOC emissions (estimated figure based on voluntary action plan by Japan Printing Ink Makers Association) by the production amount of print ink.
2001-2004	Average value of FY2000 and 2005 was used.

Table A 5-42 Method of establishing NMVOC emission factors for chemical manufacture (solvent-type adhesive manufacturing)

Fiscal Year (FY)	Method of establishing emission factor
1990-1999	Emission factor for FY2000 was used for all fiscal years.
2000, 2005-	Established by dividing VOC emissions (estimated figure based on voluntary action plan by Japan Adhesive Industry Association) by the shipping amount of solvent-type adhesive.
2001-2004	Average value of FY2000 and 2005 was used.

Table A 5-43 Method of establishing NMVOC emission factors for chemical manufacture (manufacturing of surface finishing equipment)

Fiscal Year (FY)	Method of establishing emission factor
1990-1999	Emission factor for FY2000 was used for all fiscal years.
2000, 2005-	Established by dividing VOC emissions (estimated figure based on voluntary action plan by Japan Surface Finishing Suppliers Association) by the used amount of VOCs by manufacturing of surface finishing equipment.
2001-2004	Average value of FY2000 and 2005 was used.

Table A 5-44 Method of establishing NMVOC emission factors for chemical manufacture (manufacturing of various chemical products)

Fiscal Year (FY)	Method of establishing emission factor
1990-1994	Since no aggressive actions to reduce emissions have been taken, the emission factor for FY1995 was used for all fiscal years.
1995-1999	Since voluntary actions started in FY1995, it is considered that emissions have been on a downward trend since then. Therefore, emissions were estimated by extrapolation, using the trend for 2000-2010[1)].
2000, 2005-	Established by dividing VOC emissions from chemical industry (estimated figure based on voluntary action plan by Japan Chemical Industry Association) by shipping value of chemical industry-related products.
2001-2004	Estimated by interpolation, using emission factors in FY2000 and 2005.

Note: 1) In the case that emission factor for FY1990-1999 is established by extrapolation, it should be established based on the trend for and before FY2010, which is the target year of the voluntary action plans for VOC emission reduction.

Table A 5-45 Method of establishing emission factors for chemical manufacture (cellophane manufacturing)

Fiscal Year (FY)	Method of establishing emission factor
1990-1999	Emission factor for FY2000 was applied for all fiscal years.
2000, 2005-	Established by dividing VOC emissions from cellophane manufacturing (emissions reported to the PRTR) by the production amount of film soft chemical products for wrapping.
2001-2004	Average value of FY2000 and 2005 was used.

- ***Activity data***

The following data indicated in Table A 5-46 was used for activity data, since it is considered to be correlated to each emission activity. As for “Manufacturing of various chemical products”, the total shipping value for all various chemical products was used for activity data due to difficulty in selecting specific chemical products from many chemical products provided in voluntary action plan by Japan Chemical Industry Association. Since the total shipping value is available only for calendar year, the value was converted from calendar year to fiscal year using the following equation.

$$S_{FYi} = S_{CYi} \times 0.75 + S_{CY(i+1)} \times 0.25$$

S : Shipping value
FY_i : Fiscal year i
CY_i : Calendar year i

Table A 5-46 Activity data for chemical manufacture

Emission source	Activity data	Reference
Paint manufacturing	The production amount of paint	*Yearbook of chemical industry* (METI)
Print ink manufacturing	The production amount of print ink	*Yearbook of chemical industry* (METI)
Solvent-type adhesive manufacturing	The shipping amount of solvent-type adhesive	*Current Survey Report on Adhesive* (Japan Adhesive Industry Association)
Manufacturing of surface finishing equipment	Used amount of VOCs by manufacturing surface finishing equipment. Note: For FY1990-1999, the value for FY2000 was applied. For FY2001-2004, the average of the values for FY2000 and 2005 was used.	*VOC voluntary action plan and achievement report* (METI)
Manufacturing of various chemical products	Total shipping value of various chemical products reported in PRTR in voluntary action plan. (“Chemical industry” and “Manufacturing plastic products (not specified elsewhere)”)	*Census of manufactures* (METI)
Cellophane manufacturing	The production amount of film-soft chemical products for wrapping.	*Yearbook of Paper, Printing, Plastics Products and Rubber Products Statistics* (METI)

A5.1.2.2.o. Use of Removers

a) Category Description

Dichloroethane is used to remove paint before re-painting and is emitted during use.

b) Methodological issues

- ***Estimation Method***

It is difficult to take measures to reduce emissions such as through local venting during the use of removers. Therefore, the total amount of Dichloroethane used for removers was used for estimating emissions.

- ***Emission factors***

No emission factors were established since the activity data is directly the emissions.

- ***Activity Data***

The Dichloroethane used for removers was established based on the data provided by the JAHCS data as follows:

Table A 5-47 The method of establishing activity data for the use of removers

Fiscal Year (FY)	Method of establishing activity data
1990-1994	Since there is no data on the consumption by end-use between 1990 and 1994, it is estimated by multiplying the total consumption amount of each year by the ratio of remover-use to the total consumption of FY1995.
1995-	The Dichloroethane used for removers in *Consumption by End-Use* by the JAHCS.

A5.1.2.2.p. Use of Reagents

a) Category Description

NMVOCs are included in reagents that are used to induce chemical reactions during chemical experiments and component analyses, etc., and are emitted during use.

b) Methodological issues

- ***Estimation Method***

Following the estimation method in the *Study on the VOC Emission Inventory*, the amount of reagents used by substance is multiplied by the emission rate by substance, to estimate emissions.

$$E = AD \times EF$$

E : NMVOC emissions from the use of reagents [t-NMVOC]
AD : Amount of reagents used [t]
EF : Emission rate during reagent use [t-NMVOC/t]

- ***Emission factors***

Following the *Study on the VOC Emission Inventory*, the EF for reagent use as described in the *Report on the Promotion of Chemical Substance Safety Measures (The Survey on Methods for Emission Estimation for Below-threshold Entities and Methods for Emission Estimation for Ozone-depleting Substances and Low-content Substances)* is used for FY2000 and FY2005. Emission factor for FY2000 was used for the EFs up to FY1999, and the emission factors for FY2001- FY2004 are estimated by interpolating between FY2000 and FY2005 EFs.

- ***Activity Data***

The Dichloroethane/Trichloroethylene used for reagents was established based on the *Study on the VOC Emission Inventory* and the data provided by the JAHCS data as follows:

Table A 5-48 The method of establishing activity data for the use of reagents

Fiscal Year (FY)	Method of establishing activity data
1990-1994	Since there is no data on the consumption by end-use between 1990 and 1994, it is estimated by multiplying the total consumption amount of each year by the ratio of reagent-use to the total consumption of FY1995. (calculated from the *Consumption by End-Use* by the JAHCS).
1995-	The Dichloroethane/Trichloroethylene used for reagents in *Consumption by End-Use* (JAHCS).

For other reagents, Dichloroethane used for reagents in *Consumption by End-Use* by the JAHCS is multiplied by the ratio of reported substances in the *Study on the VOC Emission inventory* (from the environmental ordinance of Tokyo) that are used as reagents to the amount of Dichloroethane used as reagents, to estimate emissions.

A5.1.2.2.q. Use of Blowing Agents

a) Category Description

Dichloroethane is used as an auxiliary blowing agent for flexible polyurethane foams of polyurethane and is emitted during use.

b) Methodological issues

- ***Estimation Method***

The total amount of Dichloroethane used for blowing agents was used for estimating emissions.

- ***Emission factors***

No emission factors were established since the activity data is directly the emissions.

- ***Activity Data***

The Dichloroethane used for blowing agents production was established based on the data provided by JAHCS as follows:

Table A 5-49 The method of establishing activity data for the use of blowing agents production

Fiscal Year (FY)	Method of establishing activity data
1990-1994	Since there is no data on the consumption by end-use between 1990 and 1994, it is estimated by multiplying the total consumption amount of each year by the ratio of blow agent-use to the total consumption of FY1995.
1995-	The Dichloroethane used for blowing agents in *Consumption by End-Use* (JAHCS).

A5.1.2.2.r. Use of Fishing Net Antifouling Agents

a) Category Description

Solvents are used to dilute fishing net antifouling agents which are applied to nets used in fish farms or stationary nets. The nets are first immersed in the chemicals and then dried off before use. Solvents are emitted into the atmosphere at this stage.

b) Methodological issues

- ***Estimation Method***

Total amount of xylene used (sea aquaculture and stationary nets) from the 'Total amounts used for fishing net antifouling agents in sea aquaculture, etc.' (surveyed by the Fisheries Agency), in the ‘emissions from fishing net antifouling agents’, from the Emissions from Sources not Required to Report under PRTR, was used for emissions.

- ***Emission factors***

No emission factors were established since the activity data is directly the emissions.

- ***Activity Data***

Activity data is established as shown in the below Table, based on *Emissions from Sources not Required to Report under PRTR* and data provided by the Fisheries Agency.

Table A 5-50 The method of establishing activity data for the use of Fishing Net Antifouling Agents

Fiscal Year (FY)	Method of establishing activity data
1990-1997	Xylene used for fishing net antifouling agents for sea aquaculture and stationary nets in FY1998 is used, since no data exist for xylene used for fishing net antifouling agents.
1998-2001	Data provided by the Fisheries Agency is used.
2002-	Total amount of xylene used (sea aquaculture and stationary nets) from the 'Total amounts used for fishing net antifouling agents in sea aquaculture, etc.' (surveyed by the Fisheries Agency), in the ‘emissions from fishing net antifouling agents’, from the Emissions from So*urces not Required to Report under PRTR*, was used.

A5.1.2.2.s. Use of Converting Solvents

a) Category Description

The solvents used at the drying stage of the converting processing facilities, the drying and baking (wrinkle-resistant processing) stage during finishing, and the drying stage of printing, are emitted into the atmosphere.

b) Methodological issues

- ***Estimation Method***

Emissions were estimated by multiplying the product quantity in the dyeing and finishing processes, by the emission factor per product quantity.

- ***Emission factors***

Emission factors were established by dividing emissions based on the reported values in the Voluntary Action Plan of the Japan Textile Finishers' Association in the *Study on the VOC Emission Inventory*, by product quantity totals in the dyeing and finishing processes (excluding wool fabrics).

Table A 5-51 The method of establishing emission factors for the use of converting solvents

Fiscal Year (FY)	The method of establishing emission factor
1990-1999	Emission factor for FY2000 was applied.
2000, 2005-	Emission factors were established by dividing VOC emissions from the use of converting solvents (estimated values based on the reported values in the Voluntary Action Plan of the Japan Textile Finishers' Association), by product quantity in the dyeing and finishing processes (excluding wool fabrics).
2001-2004	Estimated by interpolating between FY2000 and FY2005 EFs.

- ***Activity Data***

Product quantity in the dyeing and finishing processes (excluding wool fabrics) in the *Yearbook of Current Production Statistics - Textiles and Consumer Goods Statistics* (METI) is used. As for wool fabrics, converting solvents are not used in the production process and is therefore excluded from the activity data.

A5.1.2.2.t. Use of Coating Solvents

a) Category Description

Emissions occur from solvents used when coating plastic films for special functions (antistatic agents, abrasion and scratch resistants, anti-fogging agents, electromagnetic shielding, conductivity imparting agents, UV absorbers, etc.).

b) Methodological issues

- ***Estimation Method***

Emissions were estimated by multiplying the film sales amount by the emission factor per sales amount.

- ***Emission factors***

Emission factors were established by dividing emissions based on the reported values in the Voluntary Action Plan of the Japan Polyethylene Products Industrial Federation in the *Study on the VOC Emission Inventory* by film sales amounts.

Table A 5-52 The method of establishing emission factors for the use of coating solvents

Fiscal Year (FY)	The method of establishing emission factor
1990-2004	The EF for FY2005 is applied.
2005-	Emission factors were established by dividing VOC emissions from the use of coating solvents (estimated values based on the reported values in the Voluntary Action Plan of Japan Polyethylene Products Industrial Federation) by film sales amounts.

- ***Activity Data***

The film sales amounts in the *Yearbook of Paper, Printing, Plastics Products and Rubber Products Statistics* are used.

A5.1.2.2.u. Use of Synthetic Leather Solvents

a) Category Description

N, N-dimethylformamide is used to dissolve polyurethane when manufacturing synthetic leather and is emitted in the process of use.

b) Methodological issues

- ***Estimation Method***

The sum of the atmospheric emissions of N, N-dimethylformamide from the plastic product manufacturing industry reported under the PRTR and the emissions similar as the above but from below-threshold entities given in the Estimation Results of Emissions from Sources That Are Not Required to Report Under the PRTR, are used as emissions.

- ***Emission factors***

No emission factors were established since the activity data is directly the emissions.

- ***Activity Data***

The sum of the atmospheric emissions of N, N-dimethylformamide from the plastic product manufacturing industry under the PRTR and the emissions similar as the above but from below-threshold entities given in the Estimation Results of Emissions from Sources That Are Not Required to Report Under the PRTR, are used as emissions.

Table A 5-53 The method of establishing activity data for the use of synthetic leather solvents

<table>
<tr><th rowspan="2">Fiscal Year (FY)</th><th colspan="2">Method of establishing activity data</th></tr>
<tr><th>Emissions under the PRTR</th><th>Emissions from sources not required to report under the PRTR</th></tr>
<tr><td>1990-2000</td><td colspan="2">Estimated by multiplying FY2001 atmospheric emissions by the ratio to the FY2001 data for consumption amounts of other resin for synthetic leather in the Yearbook of Paper, Printing, Plastics Products and Rubber Products Statistics.</td></tr>
<tr><td>2001-2012</td><td rowspan="2">The atmospheric emissions of N, N-dimethylformamide from the plastic product manufacturing industry, reported under the PRTR is used as emissions.</td><td>Estimated by multiplying FY2001 to FY2012 emissions reported under the PRTR, by the ratio of FY2017[8] emissions from sources not required to report under PRTR to the FY2017 emissions reported under the PRTR.</td></tr>
<tr><td>2013-</td><td>The atmospheric emissions of N, N-dimethylformamide from the plastic product manufacturing industry from below-threshold entities given in the Estimation Results of Emissions from Sources That Are Not Required to Report Under the PRTR is used.</td></tr>
</table>

[8] The value of the year with the highest ratio was used to avoid underestimation.

A5.1.2.2.v. Use of Fumigants

a) Category Description

Methyl bromide is emitted from the use of fumigants on croplands and in warehouses, etc.

b) Methodological issues

- ***Estimation Method***

Emissions were estimated by multiplying the amount of methyl bromide used for fumigants by the emission factor per use amount.

- ***Emission factors***

An emission factor (64%) based on the *Survey of Actual Use of Methyl Bromide* (National Institute for Environmental Studies, 1998) is applied to all years, following the *Study on the VOC Emission Inventory*.

- ***Activity Data***

The activity data was established as follows, based on the amount of methyl bromide used for fumigants provided in the domestic shipment amounts by use from the Methyl Bromide Association. As for the Soil and Quarantine categories, it is assumed that 100% is used as fumigants. As for the Other category, although it includes uses for industrial raw material, details are unknown and is therefore assumed that 50% is used as fumigants.

Table A 5-54 The method of establishing activity data for the use of fumigants

Fiscal Year (FY)	Method of establishing activity data
1990-1999	Amount of methyl bromide provided in the domestic shipment amounts by use (Surveyed by the Agricultural Safety Management Section, Food Safety and Consumer Affairs Bureau, MAFF) The Other category is estimated using this data.
2000, 2005-	Amount of methyl bromide used for fumigants provided in the domestic shipment amounts by use from the Methyl Bromide Association.
2001-2004	Amount of methyl bromide provided in the domestic shipment amounts by use (Surveyed by the Agricultural Safety Management Section, Food Safety and Consumer Affairs Bureau, MAFF) The Other category is estimated using this data.

A5.1.2.2.w. Use of Dampening Solutions

a) Category Description

Isopropyl alcohol, included in etch solutions that are added to dampening solutions used in offset printing, is emitted into the atmosphere as a VOC.

b) Methodological Issues

- ***Estimation Method***

Emissions were estimated by multiplying the sales amount of planographic printing ink by the NMVOC emissions per sales amount of planographic printing ink.

$$E = AD \times EF$$

E : NMVOC emissions from the use of dampening solutions [t-NMVOC]
AD : Sales amount of planographic printing ink [t]
EF : NMVOC emissions per sales amount of planographic printing ink [t-NMVOC/t]

- ***Emission factors***

The emission factors were established as follows, based on the reported values in the voluntary action plan of the Japan Federation of Printing Industries.

Table A 5-55 The method of establishing emission factors for the use of dampening solutions

Fiscal Year (FY)	Method of establishing emission factor
1990-1999	Emission factor for FY2000 was applied.
2000, 2004-	Emission factors were established by dividing VOC emissions from the use of dampening solutions (estimated values based on the reported values in the voluntary action plan of the Japan Federation of Printing Industries) by sales amounts of planographic printing ink.
2001-2003	Estimated by interpolating between FY2000 and FY2004 EFs.

- ***Activity data***

The sales amounts of planographic printing ink in the *Yearbook of Chemical Industry* are used.

A5.1.2.2.x. Use of Fabric Treatment Agents

a) Category Description

NMVOCs are emitted into the atmosphere from the use of fabric treatment agents (anti-static agents for fabrics, water repellents, fabric refreshers, and stain removers) through volatilizing or spraying the substances.

b) Methodological Issues

- ***Estimation Method***

NMVOC emissions are estimated by multiplying the sales amounts of each type of fabric treatment agent by the VOC content for each type of fabric treatment agent, and by the atmospheric emission rate for each type of fabric treatment agent.

$$E = \sum_i (AD_i \times R_i \times EF_i)$$

E : NMVOC emissions from the use of fabric treatment agents [t-NMVOC]

AD_i : Sales amount of fabric treatment agent i [t] (Estimated by multiplying the sales amount by specific gravity (0.8) when its unit is in volume)

R_i : VOC content in fabric treatment agent i [%]

EF_i : Atmospheric emission rate of fabric treatment agent i [%]

- ***Emission factors***

The VOC content and atmospheric emission rate were established as follows, based on how the value in the *Survey by the Tokyo Metropolitan Government* was established. The VOC content was established for each type, using the medium value of minimum and maximum VOC contents in the *Survey by the Tokyo Metropolitan Government.*

Table A 5-56 VOC content and atmospheric emission rate for the use of fabric treatment agents

Type of products	VOC content	Atmospheric emission rate
Anti-static agents for fabrics	50%	100%
Water repellents (for clothing, shoes, etc.)	35%	100%
Fabric refreshers	8%	100%
Stain removers (surfactants)	30%	100%
Stain removers (benzines)	50%	100%

- ***Activity data***

Established as follows, based on the method of the *[Expanded] National Emission Inventory for Volatile Organic Compounds* (MOE) (hereafter, *Expanded VOC Emission Inventory*)

Table A 5-57 Method of establishing activity data for the use of fabric treatment agents

Fiscal Year (FY)	Method of establishing activity data
2005-2007	Sales amounts of fabric treatment agents in the *Survey by the Tokyo Metropolitan Government*
Excluding the above	Estimated by multiplying the three-year average of FY2005 to FY2007 in the *Survey by the Tokyo Metropolitan Government* by each year's growth rate of annual expenditures of all households as compared to the average value of FY2005 to FY2007, where expenditures of all households are calculated by multiplying annual expenditures per household from "Other domestic non-durable goods – Others," etc. in the *Survey of Household Economy* (Ministry of Internal Affairs and Communications) by the number of all households in the *Population, vital statistics and number of households survey based on the Basic Resident Registration* (Ministry of Internal Affairs and Communications)

A5.1.2.2.y. Use of Air Fresheners

a) Category Description

NMVOCs contained in air fresheners are emitted into the atmosphere from the placing and use of air fresheners through volatilizing the substances.

b) Methodological Issues

- ***Estimation Method***

NMVOC emissions are estimated by multiplying the sales amounts of each type of air freshener by the VOC content for each type of air freshener, and by the atmospheric emission rate for each type of air freshener.

$$E = \sum_i (AD_i \times R_i \times EF_i)$$

E : NMVOC emissions from the use of air fresheners [t -NMVOC]

AD_i : Sales amounts of air freshener i [t] (Estimated by multiplying the sales amounts by specific gravity (0.8) when its unit is in volume)

R_i : VOC content in air freshener i [%]

EF_i : Atmospheric emission rate of air freshener i [%]

- ***Emission factors***

The VOC content and atmospheric emission rate were established as follows, based on how the value in the *Survey by the Tokyo Metropolitan Government* was established. The VOC content was established for each type, using the medium value of minimum and maximum VOC contents in the *Survey by the Tokyo Metropolitan Government.*

Table A 5-58 VOC content and atmospheric emission rate for the use of air fresheners

Type of air freshener		VOC content	Atmospheric emission rate
Air fresheners, etc. for rooms	Aerosol	30%	100%
	Plugin air freshener	30%	100%
	Others	30%	100%
Air fresheners, etc. for bathrooms	Aerosol	30%	100%
	Mists	30%	100%
	Others	30%	100%
Deodorizers	Refrigerator deodorizers	1%	100%

- ***Activity data***

Established as follows, based on the method of establishing activity data for the *Expanded VOC Emission Inventory* and the *Survey by the Tokyo Metropolitan Government.*

Table A 5-59 Method of establishing activity data for the use of air fresheners

Fiscal Year (FY)	Method of establishing activity data
2005-2007	Estimated sales amounts of air fresheners by dividing the sales total of air fresheners by the unit price in the *Survey by the Tokyo Metropolitan Government.*
Excluding the above	Same as the method of establishing activity data for fabric treatment agents excluding FY2005-2007.

A5.1.2.2.z. Use of Skin Disinfectants / Sanitizers

a) Category Description

Alcohols such as ethanol and isopropanol, etc. contained in skin disinfectants / sanitizers are emitted into the atmosphere during use.

b) Methodological Issues

- ***Estimation Method***

Emissions are estimated by multiplying the shipment amounts of each type of skin disinfectant / sanitizer by the VOC content for each type of skin disinfectant / sanitizer, and by the atmospheric emission rate for each type of skin disinfectant / sanitizer.

$$E = \sum_i (AD_i \times 0.8 \times R_i \times EF_i)$$

E : NMVOC emissions from the use of skin disinfectants / sanitizers [t-NMVOC]
AD_i : Shipment amounts of skin disinfectant / sanitizer i [t]
0.8 : Approximate value of specific gravity of alcohol [t/kL]
R_i : VOC content in skin disinfectant / sanitizer i [%]
EF_i : Atmospheric emission rate of skin disinfectant / sanitizer i [%]

- ***Emission factors***

The VOC content and atmospheric emission rate were established based on the value established in the *Survey by the Tokyo Metropolitan Government* and the *Expanded VOC Emission Inventory*, etc. The VOC content was established for each type as follows, and the atmospheric emission rate was set to 100%.

Table A 5-60 VOC content for the use of skin disinfectants / sanitizers

Type of skin disinfectant / sanitizer			VOC content
Disinfectant and sanitizer for external use (drugs, quasi-drugs)			45% (the medium value of the minimum/ maximum values (20%, 70%) in the *Survey by the Tokyo Metropolitan Government*)
Skin sanitizers	Alcohol formulations	Isopropanol	100% (Established conservatively, based on the specification tables of manufacturers)
		Isopropanol (liquid) 50%	50% (product specification)
		Isopropanol (liquid) 70%	70% (product specification)
		Ethanol	96% (the medium value of the minimum / maximum values (95.1, 96.9 vol%) of the specification of the *Japanese Pharmacopoeia* (Ministry of Health, Labour and Welfare))
		Ethanol for sanitization	79% (the medium value of the minimum / maximum value (76.9, 81.4 vol%) of the specification of the *Japanese Pharmacopoeia*)
		Absolute ethanol	100% (Established conservatively, based on the specification of the *Japanese Pharmacopoeia* (99.5% or more))
		Ethanol (liquid)	79% (Same as ethanol for sanitization)
	Others		1% (the value established in the *Expanded VOC Emission Inventory*)

- ***Activity data***

Established as follows, based on the value established in the *Survey by the Tokyo Metropolitan Government* and the shipment amounts, etc. for the "skin disinfectant and sanitizer" in the *Statistics of Production by Pharmaceutical Industry* (Ministry of Health, Labour and Welfare).

Table A 5-61 Method of establishing activity data for the use of skin disinfectants / sanitizers

Calendar Year (CY)	Disinfectant and sanitizer for external use (drugs, quasi-drugs)	Skin sanitizer
2005-2007	The value established in the *Survey by the Tokyo Metropolitan Government* was used.	Shipment amounts of "skin disinfectant and sanitizer" in the *Statistics of Production by Pharmaceutical Industry* (Ministry of Health, Labour and Welfare) was used with partial correction.
Excluding the above	Estimated by multiplying the three-year average of FY2005 to FY2007 in the *Survey by the Tokyo Metropolitan Government* by each year's growth rate of production value of "household medicines" given in the *Statistics of Production by Pharmaceutical Industry* as compared to the average value of FY2005 to FY2007.	

A5.1.2.2.aa. Use of Food Trays and Expanded Polystyrene

a) Category Description

Butanes or isobutanes remaining in food trays (polystyrene paper) or expanded polystyrene, are emitted into the atmosphere during use.

b) Methodological Issues

- ***Estimation Method***

Emissions are estimated by multiplying the shipment amounts of polystyrene paper and expanded polystyrene by the VOC content, and by the atmospheric emission rate.

$$E = AD \times R \times EF$$

E : NMVOC emissions from the use of food trays and expanded polystyrene [t-NMVOC]
AD : Shipment amounts of polystyrene paper and expanded polystyrene [t]
R : VOC content in polystyrene paper and expanded polystyrene [%]
EF : Atmospheric emission rate [%]

- ***Emission factors***

The VOC content was set to 1.0% and the atmospheric emission rate was set to 100%, based on the

value established in the *Expanded VOC Emission Inventory*.

- ***Activity data***

For food trays, shipment amounts of polystyrene paper provided by the Japan Polystyrene Foamed Sheet Industry Association were used. The value of 1991 was used for 1990 due to the lack of the data for 1990, since it was before the establishment of the industry association.

For expanded polystyrene, recovery amounts for recycling (equal to domestic distribution amounts) of expanded polystyrene by the Japan Expanded Polystyrene Association were used. The value of 1991 was used for 1990 due to lack of the data for 1990.

A5.1.2.2.bb. Use of writing utensils, etc.

a) Category Description

During the use of writing utensils, etc. (ballpoint pens, marking pens, whiteouts), the alcoholic content (benzyl alcohol) or organic solvents in the ink or whiteout are emitted into the atmosphere.

b) Methodological Issues

- ***Estimation Method***

Following the methodology for the *Expanded VOC Emission Inventory* and the *Survey by the Tokyo Metropolitan Government*, emissions are estimated by multiplying the number of ballpoint pens (water-based, oil-based), marking pens, and whiteout sold by solvent content, use rate of ink, VOC content, and by the atmospheric emission rate.

$$E = \sum_i AD_i \times SC_i \times UR_i \times SG \times 10^{-6} \times R_i \times EF_i$$

E : NMVOC emissions from the use of writing utensils, etc. [t-NMVOC]
AD_i : Number of writing utensils sold
SC_i : Solvent content in product i [mL/item]
UR_i : Use rate of ink in product i [%]
SG : Specific gravity of solvent [1.0 g/mL]
R_i : VOC content in product i [%]
EF_i : Atmospheric emission rate [%]
i : Type of writing utensil, etc.

- ***Emission factors***

The solvent content and VOC content were set as in the following table, based on the values established in the *Expanded VOC Emission Inventory*, etc. The atmospheric emission rate was set at 100%. Although emissions for the products still containing ink at disposal are possibly double-counted in the Waste sector, the use rate of ink is set at 100%, since information is not available to estimate the ratio.

Table A 5-62 Solvent content and VOC content of writing utensils, etc.

Type	Solvent content [mL/item]	VOC content
Ballpoint pens	0.2	Water-based ballpoint pens: 5% Oil-based ballpoint pens: 15%
Marking pens	3.0	FY1990 to 1997: Weighted averages were taken of the VOC content for water-based marking pens (15%) and oil-based marking pens (70%) using their respective numbers of pens sold. FY1998 onwards: Similar to FY1990 to 1997, weighted averages were taken of the VOC content, by borrowing the growth rate from FY1997, of the ratio of water-based ballpoint pens to the total number of ballpoint pens, and applying it to marking pens.
Whiteout	7.0	45%

- ***Activity data***

The number of ballpoint pens (water-based, oil-based), marking pens, and whiteout sold, provided in the *Yearbook of Current Production Statistics - Textiles and Consumer Goods Statistics* (METI) were used.

For whiteout, since data could not be obtained from the above statistics for 1990 to 1994, the following estimations were made. First, the total expenditures on writing utensils, etc. were estimated by multiplying household expenditures on writing utensils, etc. (*Survey of Household Economy* (two-or-more-person households)) by the number of households (*Household Survey*, Ministry of Internal Affairs and Communications) for 1995 to 2020. This was then used to divide the sales revenue of whiteout (*Yearbook of Current Production Statistics*) for 1995-2000 to yield the share of whiteout in total expenditures per year. Then by using linear approximation drawn from the share of whiteout for 1995-2020, the share of whiteout for 1990-1994 was estimated, and by multiplying this by the total expenditures in each year, the sales revenue for whiteout was estimated. Then by using the unit price (sales revenue/sales amount) of whiteout for 1995 and ratios to previous year prices of writing utensils, etc. (*Consumer Price Index (2020 standard)*, Ministry of Internal Affairs and Communications), prices for whiteout for 1990-1994 were estimated, and by dividing the sales revenue by this, the number of writing utensils, etc. sold were estimated for 1990-1994.

A5.1.2.2.cc. Use of wet wipes

a) Category Description

During the use of disinfecting/sanitizing wet wipes, the alcoholic content (ethyl alcohol) in the wet wipes is emitted into the atmosphere. Since wet wipes for nursing care, miscellaneous items, and makeup hardly use any alcohol, they are excluded from the scope for estimation.

b) Methodological Issues

- ***Estimation Method***

Following the methodology for the *Expanded VOC Emission Inventory*, emissions are estimated by multiplying the number of sheets of wet wipes produced, by the amount of liquid per sheet, the VOC content, and by the atmospheric emission rate.

$$E = AD \times L \times R \times 10^{-6} \times SG \times EF$$

E : NMVOC emissions from the use of wet wipes [t -NMVOC]

AD : Number of sheets of wet wipes produced

L : Amount of liquid per sheet [mL/sheet]

R : VOC content in wet wipes [%]

SG : Specific gravity of alcohol (0.8)

EF : Atmospheric emission rate [%]

- ***Emission factors***

Based on the values established in the *Expanded VOC Emission Inventory,* the amount of liquid per sheet was set at 3 [mL/sheet], the VOC content was set at 10%, and the atmospheric emission rate was set at 100%.

- ***Activity data***

Following the *Expanded VOC Emission Inventory,* the number of sheets of wet wipes produced was estimated by multiplying the number of disinfecting/sanitizing wet wipe packages produced provided by the Japan Hygiene Products Industry Association (JHPIA), by the number of sheets per package, and by the ratio of alcohol-containing products.

$$AD = \sum_i M_i \times S \times R_i$$

AD : Number of sheets of wet wipes produced

M_i : Number of disinfecting/sanitizing wet wipe packages produced

S : Number of sheets per package [sheet/package]

R_i : Ratio of alcohol-containing products [%]

i : Type of wet wipe (disinfecting, sanitizing)

The number of disinfecting/sanitizing wet wipe packages produced were set as in the following tables.

Table A 5-63 Method of establishing activity data for the use of disinfecting wet wipes

Fiscal Year (FY)	Method of establishing activity data
-2007	Number of disinfecting wet wipe packages produced was set at zero.
2008-2012	Based on interview results with JHPIA, it was assumed that wider sales began to the public in 2008, and therefore interpolation was done between packages produced in 2007 and 2013.
2013-	Following the *Expanded VOC Emission Inventory*, *Statistical Data of Wet Wipes* (JHPIA) was used.

Table A 5-64 Method of establishing activity data for the use of sanitizing wet wipes

Fiscal Year (FY)	Method of establishing activity data
-2000	Number of disinfecting wet wipe packages produced was set at zero.
2001-2004	Interpolation was done between packages produced in 2000 and 2005.
2005-2007	Following the *Expanded VOC Emission Inventory*, the *Survey by the Tokyo Metropolitan Government* data was used.
2008-2009	Following the *Expanded VOC Emission Inventory*, the 2007 value was used.
2010-	Following the *Expanded VOC Emission Inventory*, *Statistical Data of Wet Wipes* (JHPIA) was used.

Following the *Expanded VOC Emission Inventory*, the number of sheets per wet wipe package was wet at 50 [sheets/package]. The ratio of alcohol-containing products within disinfecting wet wipes was set at 100%, and 30% for sanitizing wet wipes.

A5.1.2.2.dd. Use of Oil Extraction Solvents

a) Category Description

Hexane is used as a solvent to extract oil from soybeans or rapeseeds to use for cooking oil and is emitted to the atmosphere in the process.

b) Methodological issues

- ***Estimation Method***

The atmospheric emissions of n-hexane from the food manufacturing industry reported under the PRTR are accounted as emissions.

- ***Emission factors***

No emission factors were established since the activity data is directly the emissions.

- ***Activity Data***

The atmospheric emissions of n-hexane from the food manufacturing industry reported under the PRTR are used as emissions.

Table A 5-65 The method of establishing activity data for the use of oil extraction solvents

Fiscal Year (FY)	Method of establishing activity data
1990-2009	Using the total amount of raw material processed for soybeans and rapeseed (domestic and imported) from the Ministry of Agriculture, Forestry and Fisheries' *Oilseed Production Survey* for fiscal years 2010 to 2023 as the explanatory variable, and the emissions of n-hexane as the dependent variable, a regression analysis was conducted. The emissions were then estimated using the obtained coefficient and the total processed raw material for each fiscal year. (The source of raw material processing amounts for fiscal years 1996–2004 is the Ministry of Agriculture, Forestry and Fisheries' *Japan's Oil and Fat Situation*.
2010-	The atmospheric emissions of n-hexane from the food manufacturing industry, reported under the PRTR is used as emissions.

A5.1.2.3 Others – Food and Beverage Industry (2.H.2.) (NMVOCs)

A5.1.2.3.a. Foods (Fermentation)

a) Category Description

NMVOCs are released as fugitive emissions of alcohol in the process of manufacturing foods or beverages. Alcohol which is generated by bread making and alcoholic brewing is included in the calculation; these are considered to be of biogenic-origin.

b) Methodological Issues

- ***Estimation Method***

NMVOC emissions from manufacturing foods or beverages were estimated by multiplying the production amount of bread and alcohol drinks, by the NMVOC emission factors per production amount of bread and alcoholic drinks.

➢ ***Calculation of NMVOC emissions from bread making***

$$E = AD \times EF$$

E : NMVOC emissions from bread making [t -NMVOC]
AD : Production amount of bread [1000 t]

EF : Emission factor per production amount of bread [kg-NMVOC/t]

➢ ***Calculation of NMVOC emissions from alcohol brewing***

$$E = AD \times ABV/100 \times EF$$

E : NMVOC emissions from alcohol brewing [t -NMVOC]
AD : Production volume of alcoholic drinks [1000 kL]
ABV: Ethyl alcohol content [%] (only for Shochu (Japanese distilled spirit), whiskey, spirits, and liqueur)
EF : Emission factor per production amount of alcoholic drinks [kg-NMVOC/kL]

● ***Emission factors***

Emission factor (4.5kg/t) for bread making, provided in the European Environment Agency's *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2009*, was used.

As for emission factors for brewing alcoholic drinks, those provided in the European Environment Agency's *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2009* were used (TableA5-66). The ethyl alcohol contents of the alcoholic drinks were only established for Shochu, whiskey, spirits and liqueurs. The ethyl alcohol contents of Shochu and whiskey were established based on the European Environment Agency's *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2009* (TableA5-67). The ethyl alcohol content provided in the *Study on the VOC Emission Inventory* was used for spirits and liqueurs. (TableA5-68).

Table A 5-66 Emission factors for brewing alcoholic drinks

Alcoholic drinks	Emission factor	Unit
Sake	0.08	kg/100L- volume of brewed alcoholic drinks
Sake compound	0.08	kg/100L- volume of brewed alcoholic drinks
Shochu (Japanese distilled spirit)	0.4	kg/100L- volume of brewed ethyl alcohol
Beer	0.035	kg/100L- volume of brewed alcoholic drinks
Fruit wine	0.08	kg/100L- volume of brewed alcoholic drinks
Whiskey	15	kg/100L- volume of brewed ethyl alcohol
Spirits	0.4	kg/100L- volume of brewed ethyl alcohol
Liqueurs	0.4	kg/100L- volume of brewed ethyl alcohol
Other liquors (including low-malt beer)	0.035	kg/100L-volume of brewed alcoholic drinks

Note: The *Study on the VOC Emission Inventory*, established based on the *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2009*

Table A 5-67 Ethyl alcohol content for alcoholic drinks (shochu, whiskey)

Alcoholic drinks	Ethyl alcohol content
Shochu (Japanese distilled spirit)	25%
Whiskey	40%

Note: Based on *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2009*

Table A 5-68 Methods of establishing ethyl alcohol content of spirits and liquor

Fiscal year (FY)	Methods of establishing ethyl alcohol content of spirits and liquor
1990-1999	The value of ethyl alcohol content for FY2000 provided in the *Study on the VOC Emission Inventory* was used.
2000	The value of ethyl alcohol content provided in the *Study on the VOC Emission Inventory* was used.
2001-2004	Estimated by interpolating between the ethyl alcohol contents for FY2000 and FY2005.
2005-	The value of ethyl alcohol content for each year provided in the *Study on the VOC Emission Inventory* was used.

● ***Activity data***

For bread, the production amount of various kinds of bread, provided in *Food Industry Trend Survey* (Ministry of Agriculture, Forestry and Fisheries of Japan), was used for activity data.

For alcoholic drinks, the volume of production of brewed alcoholic drinks, provided in Table of volume

of production of brewed alcoholic drinks and volume of stock (The National Tax Administration Agency) was used for activity data.

A5.1.3 Agriculture

A5.1.3.1 Field Burning of Agricultural Residues (3.F: CO, NOx)

a) Methodological Issues

- ***Estimation Method***

CO and NOx emissions were calculated by using the method indicated in the *2006 IPCC Guidelines*, which is the same method as that for CH_4 and N_2O estimation.

$$E = A \times M_B \times C_f \times G_{ef} \times 10^{-3}$$

E : CO and NOx emissions from field burning of agriculture residues [t-CO or t-NO_X]
A : Area burnt [ha]
M_B : Mass of fuel available for combustion [t/ha]
C_f : Combustion factor
G_{ef} : Emission factor [g-CO/kg or g-NO_X/kg]

- ***Emission factors***

CO : 92 g-CO/kg (dry matter) (default value in the *2006 IPCC Guidelines*)
NOx : 2.5 g-NO_X/kg (dry matter) (default value in the *2006 IPCC Guidelines*)

- ***Activity data***

Activity data are the same as those used for CH_4 and N_2O estimation described in "5.7. Field Burning of Agricultural Residues (3.F.)".

A5.1.4 Land Use, Land-Use Change and Forestry

A5.1.4.1 Biomass burning (4.(IV))

A5.1.4.1.a. Biomass Burning in Forest Land

a) Methodological Issues

- ***Estimation Method***

For CO and NO_X emissions due to biomass burning from forest fires, the Tier 1 method is used.

➢ ***CO***

$$bbGHG_f = L_{forest\ fires} \times ER$$

➢ ***NO_X***

$$bbGHG_f = L_{forest\ fires} \times ER \times NC_{ratio}$$

$bbGHG_f$: CO and NO_X emissions due to forest biomass burning
$L_{forest\ fires}$: Carbon released due to forest fires [t-C/yr]
ER : Emission ratio (CO: 0.06, NO_X: 0.121)
NC_{ratio} : Nitrogen-to-carbon ratio of the biomass

- ***Emission Factor***

➢ ***Emission ratio***

The following values are applied to emission ratios for CO and NO_X due to biomass burning.

CO: 0.06, NO_X: 0.121 (default value stated in the *GPG-LULUCF*, Table 3A.1.15)

➢ ***N/C ratio***

The following value is applied to the N/C ratio of the biomass.

N/C ratio: 0.01 (default value stated in the *GPG-LULUCF* p.3.50)

● ***Activity data***

For activity data in Forest land, carbon released by forest fire is used. For detailed information, see the description on the activity data in section 6.15 in Chapter 6.

A5.1.4.1.b. Burning of pruned branches from orchard trees

a) Methodological Issues

● ***Estimation Method***

For CO and NOx emissions due to biomass burning of pruned branches from orchard trees, the estimation method (Equation 2.27, p2.42, Vol.4) described in the *2006 IPCC Guidelines* is applied. The estimation equation is as follows:

$$L_{fire} = W_B \times C_f \times G_{ef} \times 10^{-6}$$

L_{fire} : CO and NOx emissions from fire [kt]
W_B : Amount burnt [t-d.m.]
C_f : Combustion factor
G_{ef} : Emission factor [t/kt-d.m.]

● ***Parameters***

For the combustion factor, a general value (0.9) which has been used generally in field burning of crop residues in agriculture in Japan is applied. The default emission factors (Agricultural residue value) described in the *2006 IPCC Guidelines* are used.

Table A 5-69 Emission factors [t/kt-d.m.]

Category	CO	NOx
Agricultural residue	92	2.5

Reference: *2006 IPCC Guidelines*, Vol.4, chp.2, Table 2.5

● ***Activity Data (Amount burned)***

For activity in orchard land, see the description on the activity data in section 6.15 in Chapter 6.

A5.1.4.1.c. Biomass Burning in Grassland

a) Methodological Issues

● ***Estimation Method***

For CO and NOx emissions due to biomass burning of grassland, the estimation method (Equation 2.27, p2.42, Vol.4) described in the *2006 IPCC Guidelines* for Tier 1 and 2 is applied. The estimation equation is as follows:

$$L_{fire} = A \times M_B \times C_f \times G_{ef} \times 10^{-6}$$

L_{fire} : CO and NOx Emissions from fire [kt]
M_B : Amount burnt [t-d.m./ha]
C_f : Combustion factor
G_{ef} : Emission factor [t/kt-d.m.]

- ***Parameters***

For the combustion factor, value of 0.9 is applied according to expert judgment that considering survey data on burning of grassland in Japan. The default emission factors (Savanna and grassland) described in the *2006 IPCC Guidelines* are used.

Table A 5-70 Emission factors [t/kt-d.m.]

Category	CO	NOx
Savanna and grassland	65	3.9

Note: *2006 IPCC Guidelines*, Vol.4, chp.2, Table 2.5

- ***Activity Data (Amount burned)***

For activity data in grassland, see the description on the activity data in section 6.15 in Chapter 6.

A5.1.5 Waste

A5.1.5.1 Incineration and Open Burning of Waste (5.C.)

A5.1.5.1.a. Municipal Solid Waste Incineration (5.C.1.–)

a) Methodological Issues

- ***Estimation Method***

The NO_X, CO, NMVOCs, and SO_X emissions from the specified sources were calculated by multiplying the incineration amount (wet basis) of Municipal Solid Waste (MSW) in each incinerator type (Continuous Incinerators, Semi-continuous Incinerators, Batch type Incinerators, Gasification melting furnaces) by Japan's country-specific emission factors. These emissions are categorized following the methods given in chapter 7 based on incinerations either with or without energy recovery. The former emissions are reported in the Energy sector, while the latter are reported in the Waste sector.

- ***Emission factors***

➢ ***NO_X, SO_X***

For incinerators, emission factors were established for each incinerator type by using the emission amount and amount of treated waste identified in the *General Survey of the Emissions of Air Pollutants*. (The categories of incinerator types included: [1301: Waste incinerator (MSW; continuous system)] and [1302: Waste incinerator (MSW; batch system)]). The incineration material was [53: MSW].) It is noted that while the *General Survey of the Emissions of Air Pollutants* classified the incinerators into two classes (Continuous and Batch), this report classifies incinerators into three classes ("Continuous", "Semi-continuous", and "Batch type") by dividing the Continuous system and assigning those which operated for less than 3,000 hours to the "Semi-continuous" class.

For gasification melting furnaces, the value for Continuous Incinerators with a similar incineration method was used.

Table A 5-71 NO_X and SO_X emission factors for MSW by type of incineration method

Item	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	From FY2000 onwards
NO_X EF [kg-NO_X/t (wet)]											
Continuous incinerator	1.238	1.260	1.192	1.223	1.205	1.213	1.179	1.179	1.179	1.127	1.127
Semi-continuous incinerator	1.055	0.969	1.056	1.021	1.048	1.226	1.283	1.283	1.284	1.226	1.226
Batch type incinerator	1.137	1.199	1.235	1.274	1.369	1.918	1.399	1.399	1.399	1.850	1.850
Gasification melting furnace	1.238	1.260	1.192	1.223	1.205	1.213	1.179	1.179	1.179	1.127	1.127
SO_X EF [kg-SO_X/t (wet)]											
Continuous incinerator	0.555	0.578	0.527	0.581	0.580	0.539	0.504	0.504	0.504	0.361	0.361
Semi-continuous incinerator	0.627	0.703	0.785	0.783	0.678	1.141	0.760	0.760	0.762	0.712	0.712
Batch type incinerator	1.073	0.996	1.036	1.200	1.071	1.625	1.012	1.012	1.013	1.714	1.714
Gasification melting furnace	0.555	0.578	0.527	0.581	0.580	0.539	0.504	0.504	0.504	0.361	0.361

Note: The data for 2000 were used for 2001 and subsequent years.
Reference: *General Survey of the Emissions of Air Pollutants* (MOE)

➢ ***CO***

For incinerators, the emission factors were established for each incinerator class based on the emission factors for individual facilities summarized in Japan Society for Atmospheric Environment (1996) as well as other reports. It is noted that while the Japan Society for Atmospheric Environment report subdivided the facilities by furnace type (e.g., stoker, fluidized bed, etc.), this report determined the emission factors for three classes of "Continuous", "Semi-continuous" and "Batch type" by taking the average weighted by incinerated amount for each furnace.

For gasification melting furnaces, the value for continuous stoker furnaces with a similar incineration method was used.

Table A 5-72 CO emission factors for MSW by type of incineration method [kg-CO/t (wet)]

Furnace type	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Continuous incinerator	557	557	555	554	554	553	553	554	555	555	555	556
Semi-continuous incinerator	548	548	567	591	611	609	607	611	615	603	589	604
Batch type incinerator	8,237	8,237	8,298	8,341	8,270	8,274	8,279	8,244	8,244	8,246	8,246	8,246
Gasification melting furnace	NA	NA	567	567	567	567	567	567	567	567	567	567

Reference: Japan Society for Atmospheric Environment (1996), and others.

➢ ***NMVOCs***

For both incinerators and gasification melting furnaces, NMVOC emission factors were established by multiplying the CH_4 emission factors for each furnace type of each fuel type by "NMVOC/CH_4", the emission ratio for fuel type. The ratio was determined by using the reference materials by Japan Environmental Sanitation Center (1989) and Institute of Behavioral Science (1984), which estimated CH_4 and NMVOC emissions per unit calorific value.

Table A 5-73 NMVOC emission factors for MSW by type of incineration method [kg-NMVOC/t (wet)]

Furnace type	1990	1995	2000	2005	2010	2013	2015	2020	2021	2022	2023	2024
Continuous incinerator	0.9	0.9	0.9	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Semi-continuous incinerator	7.8	7.8	8.5	2.2	2.4	2.3	2.3	2.4	2.4	2.3	2.2	2.3
Batch type incinerator	9.1	9.1	9.5	1.5	1.3	1.3	1.3	1.2	1.2	1.2	1.2	1.2
Gasification melting furnace	NA	NA	0.6	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8

Reference: Japan Environmental Sanitation Center (1989), Institute of Behavioral Science (1984)

● ***Activity data***

For incinerators, the activity data used was the incineration amount for each facility type as calculated by multiplying the incineration amount of MSW by the incineration rate for each facility type. The incineration amount data were extracted from the *Report of the Research on the State of Wide-range Movement and Cyclical Use of Wastes (the Volume on Cyclical Use)* (MOE). The incineration rate was calculated by the data in the *Waste Treatment in Japan* (MOE).

For gasification melting furnaces, the activity data used was the amount incinerated in gasification

melting furnaces, calculated from data in the *Waste Treatment in Japan* (MOE).

A5.1.5.1.b. Industrial Wastes Incineration (5.C.1.–)

a) Methodological Issues

- ***Estimation Method***

NO_X, CO, NMVOCs, and SO_X emissions from the specified sources were calculated by multiplying the incineration amount (wet basis) of industrial waste (IW) for each waste type by Japan's country-specific emission factors. These emissions are categorized following the methods given in chapter 7 based on incinerations either with or without energy recovery. The former emissions are reported in the Energy sector, while the latter are reported in the Waste sector.

- ***Emission factors***

➢ ***NO_X, SO_X***

An emission factor was established for each type of IW using the emission amount and amount of treated IW identified by the *General Survey of the Emissions of Air Pollutants*. The categories of incinerator types included: [1303: Waste incinerator (IW; continuous system)] and [1304: Waste incinerator (IW; batch system)]. The incinerator fuel covered the categories [23: Fuel wood] and [54: IW]). The six types of IW were "Paper/cardboard, wood", "Sludge", "Waste oil", "Plastics", "Textiles", and "Animal and vegetable residues/animal carcasses". Category [23: Fuel wood] was used for "Paper/cardboard, wood", "Waste textiles", and "Animal and vegetable residues/animal carcasses", while category [54: IW] was used for "Sludge", "Waste oil", and "Waste plastics". However, no emission factor was set for the mixed burning of multiple waste types.

Table A 5-74 NO_X and SO_X emission factors for IW by waste type

Item	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	From FY2000 onwards	Note
NO_X EF [kg-NO_X/t (wet)]												
Waste oil Plastics	0.999	1.034	1.222	1.278	1.092	1.158	1.297	1.296	1.294	1.415	1.415	54: IW
Paper/cardboard Wood Textile Animal and vegetable residues/ animal carcasses	1.545	3.674	2.891	1.885	1.869	1.312	1.147	1.172	1.180	5.818	5.818	23: Fuel wood
Sludge (incl. sewage sludge)	0.999	1.034	1.222	1.278	1.092	1.158	1.297	1.296	1.294	1.415	1.415	54: IW
SO_X EF [kg-SO_X/t (wet)]												
Waste oil Plastics	1.179	0.973	1.828	1.720	1.816	1.882	1.151	1.148	1.162	1.343	1.352	54: IW
Paper/cardboard Wood Textile Animal and vegetable residues/ animal carcasses	1.528	1.236	1.601	1.472	1.474	1.274	1.250	1.276	1.290	2.116	2.118	23: Fuel wood
Sludge (incl. sewage sludge)	1.179	0.973	1.828	1.720	1.816	1.882	1.151	1.148	1.162	1.343	1.352	54: IW

Note: The data for 2000 were used for 2001 and subsequent years.
Reference: *General Survey of the Emissions of Air Pollutants* (MOE)

➢ ***CO***

Based on the emission factors for individual facilities summarized in Japan Society for Atmospheric Environment (1996) as well as other reports, an emission factor was established for each type of IW. The six types of IW were "Paper/cardboard, wood", "Sludge", "Waste oil", "Plastics", "Textiles", and "Animal and vegetable residues/animal carcasses". The emission factor for "Wood" was used for "Waste textiles" and "Animal and vegetable residues/animal carcasses", for which there are no measurements. No emission factor was set for the mixed burning of multiple waste types.

Table A 5-75 CO emission factors for IW by waste type

Item	CO EF [g-CO/t (wet)]
Waste oil	127
Plastics	1,790
Paper/cardboard	1,344
Wood	
Textile	
Animal and vegetable residues/ animal carcasses	
Sludge (incl. sewage sludge)	2,285

Reference: Japan Society for Atmospheric Environment (1996) and others

➢ ***NMVOCs***

NMVOC emission factors were established by multiplying the CH_4 emission factors for each furnace type of each fuel type by "NMVOC/CH_4", the emission ratio for fuel type. The ratio was determined by using the reference materials by Japan Environmental Sanitation Center (1986) and Institute of Behavioral Science (1984), which estimated CH_4 and NMVOC emissions per unit calorific value.

Table A 5-76 NMVOC emission factors for IW by waste type

Item	NMVOC EF [g-NMVOC/t (wet)]	
	–FY2001	FY2002–
Waste oil	0.54	0.45
Plastics	3.40	0.90
Paper/cardboard	2.48	25.28
Wood		
Textile		
Animal and vegetable residues/ animal carcasses		
Sludge (incl. sewage sludge)	1.61	0.17

Reference: Japan Environmental Sanitation Center (1989), Institute of Behavioral Science (1984)

● ***Activity data***

The activity data used the incineration amount data for each type of waste extracted from the *Report of the Research on the State of Wide-range Movement and Cyclical Use of Wastes (the Volume on Cyclical Use)* (MOE).

A5.1.5.1.c. Open Burning of Industrial Waste (5.C.2.–)

a) Methodological Issues

● ***Estimation Method***

NO_X, CO, NMVOCs, and SO_X emissions from the specified sources were calculated by multiplying the amount of IW (wet basis) burned in the open air for each waste type by Japan's country-specific emission factors.

● ***Emission factors***

As no knowledge is obtained for making it possible to set emission factors specific to open burning of waste in Japan, the country-specific emission factors for IW incineration were substituted. For detail, the NO_X, CO, NMVOC and SO_X emission factors for plastics incineration as for plastics burned in the open air, and those for wood incineration as for other waste burned in the open air were adopted respectively. See also section "A5.1.5.1.b. Industrial Wastes Incineration (5.C.1.–)".

- ***Activity data***

The amount of IW burned in the open air obtained from the *Report on Survey of Organizations in Industrial Waste Administration* (MOE) was used as the activity data in and after FY1996. As for the past activity data from FY1990 to 1995 for which the survey data is not available, the data of FY1996 was uniformly used as a substitute since there are no other appropriate way to estimate.

A5.1.5.1.d. Incineration in Conjunction with Use of Waste as Fuel and Raw Material (1.A.-)

a) Methodological Issues

- ***Estimation Method***

CO and NMVOC emissions from this source were estimated by multiplying the utilization amount of fuel/raw material (wet basis) for each waste type by a Japan-specific emission factor. These emissions are reported in Energy sector (1.A.) following the methodologies given in chapter 7 (Waste).

- ***Emission Factors***

➢ ***CO***

The CO emission factors were established by converting the emission factors (energy unit basis) by furnace type, which are used for estimating emissions from 1.A Stationary Sources, to weight-based emission factors by multiplying the calorific values in the *General Energy Statistics*.

Table A 5-77 CO emission factors from incineration in conjunction with use of waste as fuel and raw material

Application	CO EF [kg-CO/t (wet)]								
	Waste oil	RDF	RPF	Waste tires		Plastics		Plastics (Liquefaction)	Wood
				–FY2004	FY2005–	–FY2022	FY2023–		
Simple incineration	0.13	1.79	1.79	1.79	1.79	–	–	–	–
Boilers	0.052	0.24	0.39	0.28	0.44	0.39	0.38	0.034	3.64
Cement kilns	–	19.8	32.2	23.0	36.5	32.2	31.6	–	–
Other furnaces	0.052	0.24	0.39	0.28	0.44	–	–	–	–
Pyrolysis furnaces	–	–	–	0.021	0.033	–	–	–	–
Gasification	–	–	–	0.015	0.024	–	–	–	–

➢ ***NMVOCs***

Just as for the incineration of MSW and IW, emission factors were determined from documents with estimates of emissions of CH_4 and NMVOCs per unit calorific values.

Table A 5-78 NMVOC emissions factors from incineration in conjunction with use of waste as fuel and raw material

Application	NMVOC EF [kg-NMVOC/t (wet)]								
	Waste oil	RDF	RPF	Waste tires		Plastics		Plastics (Liquefaction)	Wood
				–FY2004	FY2005–	–FY2022	FY2023–		
Boilers	0.015	0.00027	0.00043	0.00031	0.00049	0.00043	0.00042	0.010	0.12
Cement kilns	–	–	0.043	0.031	0.049	0.043	0.042	–	–
Pyrolysis furnaces	–	–	–	0.0051	0.0080	–	–	–	–
Gasification	–	–	–	0.0187	0.0297	–	–	–	–

- ***Activity data***

Same activity data that were used when estimating CH_4 emissions for the use of waste as fuel and raw material were used.

A5.1.6 Other Sectors

A5.1.6.1 Smoking (6.–: CO, NMVOCs)

a) Methodological Issues

1) CO

- ***Estimation Method***

CO emissions were calculated by multiplying the number of cigarettes sold by Japan's country-specific emission factor.

$$E_{CO} = AD \times EF$$

E_{CO} : CO emissions from smoking [g-CO]
AD : Number of cigarettes sold
EF : Emission factor [g-CO/cigarette]

- ***Emission factors***

The emission factor (0.055 [g-CO/cigarette]) was provided by Japan Tobacco Inc.

- ***Activity data***

The number of cigarettes sold published in the *Statistical Data of Cigarettes* on the Tobacco Institute of Japan website (https://www.tioj.or.jp) was used for activity data.

2) NMVOCs

- ***Estimation Method***

NMVOC emissions were calculated by multiplying the number of cigarettes sold by Japan's country-specific emission factor.

$$Enmvoc = \sum_{i,j} AD_{i,j} \times EF_{i,j} \times 10^{-12}$$

$Enmvoc$	: NMVOC emissions from smoking [t-NMVOC]
$AD_{i,j}$	: Number of cigarettes sold
$EF_{i,j}$	: Emission factor [μg-NMVOC/cigarette]
i	: Type of cigarette (cigarettes, heated cigarettes)
j	: Type of cigarette smoke (mainstream smoke, sidestream smoke)

- ***Emission factors***

For the emission factor for cigarettes, a total of the average amount of chemical substances designated in the *Expanded VOC Emission Inventory* occurring from seven cigarette brands, shown in *FY1999-2000 Component Analysis of Tobacco Smoke (Summary)* (MHLW), was used. (mainstream smoke: 1,287 [μg-NMVOC/cigarette], sidestream smoke: 8,294 [μg-NMVOC/cigarette]).

For the emission factor for heated cigarettes, a total of the average amount of chemical substances designated in the *Expanded VOC Emission Inventory* occurring from six major heated cigarette brands sold domestically was used. (mainstream smoke: 189 [μg-NMVOC/cigarette]).

- ***Activity data***

For cigarettes, the number of cigarettes sold published in the *Statistical Data of Cigarettes* on the Tobacco Institute of Japan website (https://www.tioj.or.jp) was used for activity data. For heated cigarettes, the activity data was established as follows.

Table A 5-79 Methods of establishing activity data for heated cigarettes

Fiscal Year (FY)	Methods of establishing activity data
1990-2013	Based on interview results with the Tobacco Institute of Japan, it was assumed that there were no sales of heated cigarettes, and therefore activity data was set at zero.
2014-2019	Estimated by interpolating between the number of cigarettes sold in FY2013 and FY2020 from the Statistical Data of Heated Cigarettes (the Tobacco Institute of Japan).
2020-	The number of cigarettes sold in the Statistical Data of Heated Cigarettes (the Tobacco Institute of Japan) was used.

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Annex 6. Assessment of Completeness, Definition of Notation Keys, and Sources and Sinks Reported as "NE"

A6.1. Assessment of Completeness

The current inventory is submitted in accordance with the common reporting tables (CRT), which requires entering emissions/removals data or a notation key such as "NO", "NE", or "NA" for all sources/sinks. Japan reviewed the definition of the notation keys, etc. and established decision trees for their application by the Committee for Greenhouse Gas Emissions Estimation Methods in FY2002, 2012, and 2014.

This chapter indicates the decision trees described above and classification of source/sink categories of Japan reported as "NE".

A6.2. Definition of Notation Keys

In Japan, the notation keys are used in accordance with the *MPGs* (Decision 18/CMA.1 Annex). The following table A6-1 indicates definitions of the notation keys provided in the *MPGs* (excluding the definitions regarding the flexibility provided to developing country Parties).

Table A 6-1 Definitions of notation keys indicated in the *MPGs*

Notation Key	Explanation
NO (Not Occurring)	"NO" (not occurring) for categories or processes, including recovery, under a particular source or sink category that do not occur within a Party.
NE (Not Estimated)	"NE" (not estimated) for activity data and/or emissions by sources and removals by sinks of GHGs that have not been estimated but for which a corresponding activity may occur within a Party. Each Party may use the notation key "NE" (not estimated) when the estimates would be insignificant in terms of level according to the following considerations: emissions from a category should only be considered insignificant if the likely level of emissions is below 0.05 per cent of the national total GHG emissions, excluding LULUCF, or 500 kilo-tonnes of carbon dioxide equivalent (kt CO_2 eq.), whichever is lower. The total national aggregate of estimated emissions for all gases from categories considered insignificant shall remain below 0.1 per cent of the national total GHG emissions, excluding LULUCF. Parties should use approximated activity data and default IPCC emission factors to derive a likely level of emissions for the respective category. Once emissions or removals have been estimated for a category and if they continue to occur, each Party shall report them in subsequent submissions.
NA (Not Applicable)	"NA" (not applicable) for activities under a given source/sink category that do occur within the Party but do not result in emissions or removals of a specific gas.
IE (Included Elsewhere)	"IE" (included elsewhere) for emissions by sources and removals by sinks of GHGs estimated but included elsewhere in the inventory instead of under the expected source/sink category.
C (Confidential)	"C" (confidential) for emissions by sources and removals by sinks of GHGs where the reporting would involve the disclosure of confidential information. Noting that a minimum level of aggregation is needed to protect confidential business and military information.

Reference : *MPGs* (Decision 18/CMA.1 Annex, paragraph 31, 32, 33, 47)

Applicability criteria for "NE" when the emissions are considered insignificant was stipulated by the Committee for the Greenhouse Gas Emissions Estimation Methods in FY2012 and FY2014.

If the *MPGs* are revised in the future, the definition of notation keys and their application will be reviewed.

A6.3. Decision Tree for Application of Notation Keys

A decision tree for the application of notation keys and that for applicability criteria for "NE" when the emissions are considered insignificant for Japan's inventory are shown in Figure A6-1 and Figure A6-2.

When emissions by sources and removals by sinks of GHGs could be confidential information, they are reported as "C".

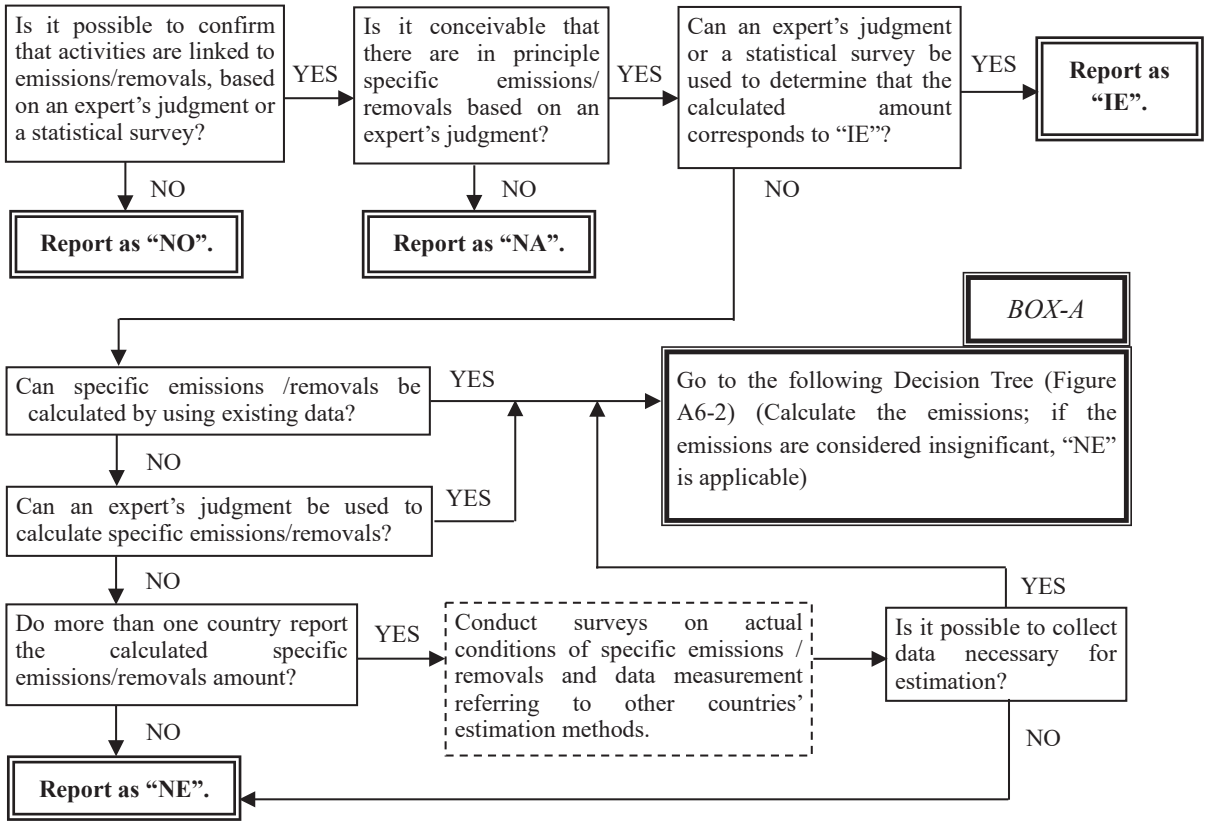

Figure A 6-1 Decision tree for application of notation keys

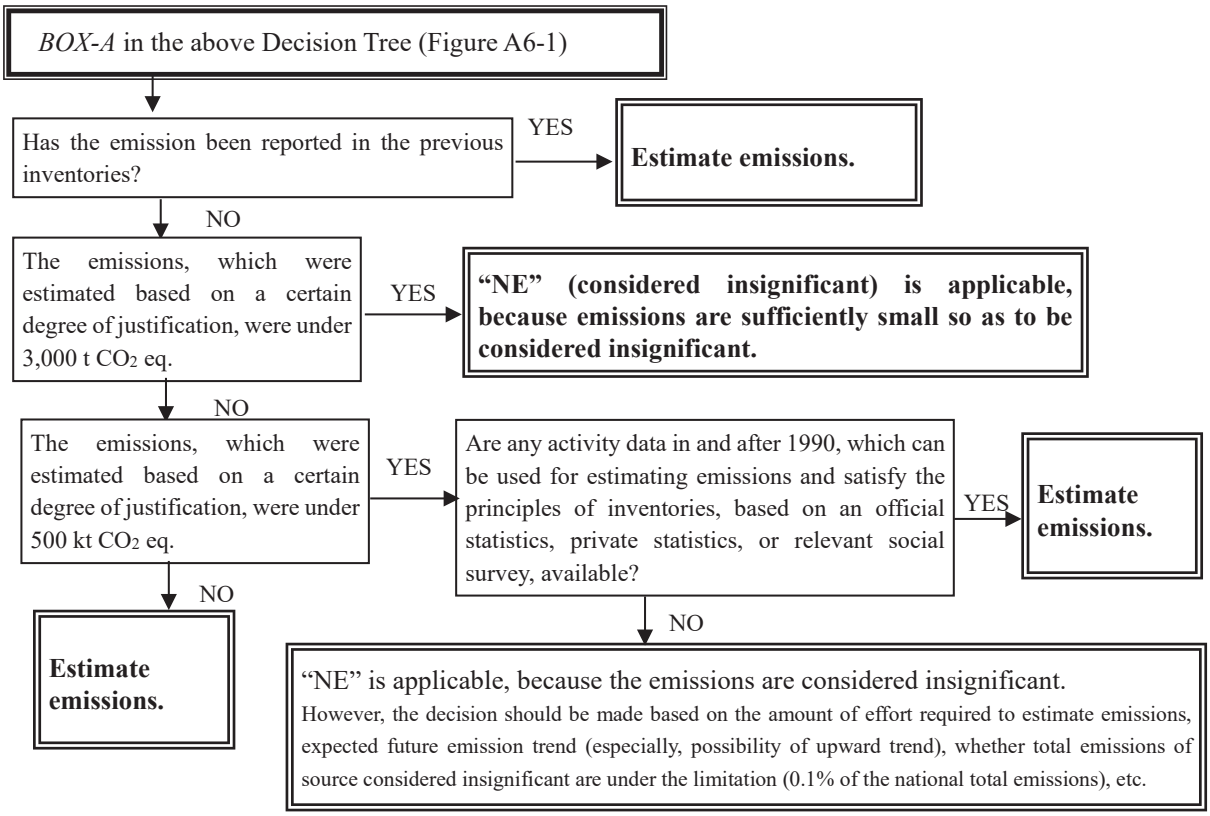

Figure A 6-2 Decision tree for determining applicability of "NE" when the emissions are considered insignificant

A6.4. Emission Sources Reported as "NE" (Considered Insignificant) in Japan

The notation key "NE" (considered insignificant) was used for the source categories indicated in the following Table A6-2, because the emissions are sufficiently small so as to be considered insignificant. Since the approximate total amount of emissions from these emission sources (excluding removals) is 122 kt (in CO_2 eq.) at maximum, it is not expected to exceed 0.1% of the national total emissions (approximately 1.05 Mt in CO_2 eq. for Japan), which is stipulated in paragraph 32 in the *MPGs* (Decision 18/CMA.1 Annex) as the upper limit of applicability of "NE" for being considered insignificant.

Table A 6-2 Emission sources reported as "NE" (considered insignificant)

	Code	Sector and Category			Gas	Likely Level of Emissions* [kt-CO_2 eq.]
#1	1.B.2.b.iv.	Energy	Fugitive emissions from fuels (Natural gas)	Transmission and storage	CO_2	<0.5
#2				Distribution	CO_2	
#3	1.B.2.c.ii.2		Fugitive emissions from fuels (Flaring)	Gas transmission and storage	CO_2	<0.05
#4	1.C.		CO_2 transport and storage		CO_2	<0.007
#5	2.C.7.	IPPU	Rare Earths Production		CO_2	<0.6
#6					PFCs	<0.4
#7	2.D.3.		NMVOC incineration		CH_4	<0.2
#8			NMVOC incineration		N_2O	<1
#9	2.F.1.		Refrigeration and Air Conditioning Equipment	Fugitive emissions from refrigerant containers	HFCs	<63
#10	2.G.2.		SF_6 and PFCs from other product use	Soundproof windows	SF_6	<0.3
#11	3.A.4.-	Agriculture	Enteric Fermentation	Deer	CH_4	<2.6
#12				Alpaca	CH_4	<0.08
#13	3.B.4.-		Manure Management	Deer	CH_4	<0.03
#14				Reindeer	CH_4	<0.01
#15				Fox	CH_4	<0.04
#16				Other poultries (duck, turkey, etc.)	CH_4	<0.9
#17				Deer	N_2O	<0.5
#18				Reindeer	N_2O	<0.02
#19				Fox	N_2O	<0.01
#20				Other poultries (duck, turkey, etc.)	N_2O	<0.3
#21	4.D.1.	LULUCF	Wetlands	Peat extraction	CO_2	<50
#22	4.D.			Biomass Burning	CH_4	<0.16
#23					N_2O	<0.14
#24	5.B.2.	Waste	Anaerobic digestion at biogas facilities		CH_4	<1.6
Total						**<122**

Note: Maximum possible amount of emissions between FY 1990 and the latest year, under certain assumptions and based on simple estimation methods such as Tier 1

A6.5. Other Source and Sink Categories not Estimated in Japan's Inventory

Based on consideration of availability of activity data and estimation methods provided in the *2006 IPCC Guidelines*, etc., the following table A6-3 indicates source and sink categories which were reported as "NE" for emissions/removals, excluding "NE" categories for being "considered insignificant" as described above.

Table A 6-3 Other Source and sink categories which were not estimated in Japan's inventory

	Code	Sector	Source and sink category				GHG
#1	1.A.3.	Energy	Fuel Combustion	Transport	Lubricants		CH_4
#2							N_2O
#3	1.B.1.a.		Fugitive Emissions from Fuels	Solid Fuels	Coal Mining and Handling		N_2O
#4					Coal Mining and Handling	Flaring of drained methane or conversion of methane to CO_2	CO_2
#5							CH_4
#6	1.B.1.c.				Other (Uncontrolled Combustion) (FY1999 only)		CO_2
#7	1.B.2.a.iv.			Oil and Natural Gas	Oil	Refining/Storage	CO_2
#8						Other (Accidents)	CO_2
#9							CH_4
#10	2.B.1.	IPPU	Chemical Industry	Ammonia Production			CH_4
#11	2.D.1.		Non-energy Products from Fuels and Solvent Use	Lubricant Use			CH_4
#12							N_2O
#13	2.D.2.			Paraffin Wax Use			CH_4
#14							N_2O
#15	2.E.5.		Electronics Industry	Microelectromechanical systems			HFCs
#16							PFCs
#17	4.D.2.	LULUCF	Wetlands	Land converted to Wetlands	Cropland converted to Wetlands	Soil	Carbon Stock Change
#18					Grassland converted to Wetlands		
#19					Settlements converted to Wetlands		
#20					Other Land converted to Wetlands		

Note: This table does not include sources with recovery reported as "NE", because recovery not estimated does not lead to underestimation of emissions. See related sections of each sector for more details of each item listed in this table.

Annex 7. Hierarchical Structure of Japan's National GHG Inventory File System

Multiple MS Excel files have been used when estimating the Japanese inventory. The explanation of each MS Excel file and the hierarchical structure of the Japanese National GHGs Inventory (JNGI) file system are shown below.

Table A 7-1 Explanation of each MS Excel file

Sector	Excel file name	Contents
	JPN_20xx_1990 - JPN_20xx_20yy	Common reporting tables (CRT) generated by ETF Reporting Tool
1. Energy	1A-L3-CO2-1990-20xx - 1A-L3-CO2-20yy-20xx	CO_2 emissions from fuel combustion
	1A-L3-CRT-20xx	CRT format data of GHG emissions from fuel combustion (including emissions by energy use of waste)
	1A-L3-timeseries-20xx	Time-series data of GHG emissions from fuel combustion
	1A-L2-MAP_EB-1990-20xx - 1A-L2-MAP_EB-20yy-20xx	Activity data for furnaces
	1A-L3-Biomass-20xx	GHG emissions from biomass combustion
	1A-L3-CO-20xx	CO emissions from furnaces and off-road vehicles
	1A-L3-HC-20xx	CH_4, NMVOC emissions from furnaces and off-road vehicles
	1A-L3-N2O-20xx	N_2O emissions from furnaces and off-road vehicles
	1A-L3-NOxSO2-20xx	NOx, SO_2 emissions from fuel combustion (except transport category)
	1A-L2-nonCO2-ADEF-20xx	Activity data and emission factors of non-CO_2 from fuel combustion (except transport category)
	1A-L2-NOxSO2-ADEF-20xx	Activity data and emission factors of NOx, SO_2 from fuel combustion (except transport category)
	1A-L3-Lub-20xx	CO_2 emissions from lubricant
	1A-L2-EBEF-20xx	Emission factors for CO_2 from fuel combustion
	1A-L1-EB-20xx	Data of the *General Energy Statistics* using in categories other than stationary combustion
	1A3-L3-CH4N2O-20xx	GHG emissions from mobile combustion (transport category) (except CO_2)
	1A3-L2-ADEF-20xx	Activity data and emission factors for mobile combustion (transport category)
	1A3-L2-2wADEF-20xx	Activity data and emission factors for motorcycles
	1B-L3-20xx	Fugitive GHG emissions from fuels
	1B-L2-ADEF-20xx	Activity data and emission factors for fugitive emissions from fuels
2. Industrial processes and product use (IPPU)	2-L2-ADEF-20xx	Activity data and emission factors of IPPU sector (except F-gases)
	2-L3-20xx	GHG emissions from IPPU sector (except F-gases)
	2-L3-CCU-20xx	CO_2 emissions and fixations of IPPU sector
	2-L3-Fgas-20xx	F-gas (HFCs, PFCs, SF_6, NF_3) emissions
	2-L3-NMVOC-20xx	NMVOC emissions from the IPPU sector
	2-L2-NMVOC-20xx	Activity data and emission factors for NMVOC emissions from the IPPU sector
3. Agriculture	3A-L3-CH4-20xx	CH_4 emissions from enteric fermentation
	3B-L3-CH4N2O-20xx	GHG emissions from manure management
	3C-L3-CH4-20xx	CH_4 emissions from rice cultivation
	3D-L3-N2O-20xx	N_2O emissions from agricultural soils
	3F-L3-CH4N2OCO-20xx	GHG emissions from field burning of agricultural residues
	3GH-L3-CO2-20xx	CO_2 emissions from lime application and urine application to agricultural soil
	3AB-L2-ADEF-20xx	Activity data and emission factors of livestock
	3CDFGH-L2-ADEF-20xx	Activity data and emission factors of rice cultivation and agricultural soils, etc
4. LULUCF	4-L3-nonCSC-20xx	GHG emissions excluding carbon stock change
	4-L3-4A-CO2-20xx	CO_2 emissions and removals from forest land
	4-L3-4B-CO2-20xx	CO_2 emissions and removals from cropland
	4-L3-4C-CO2-20xx	CO_2 emissions and removals from grassland
	4-L3-4D-CO2-20xx	CO_2 emissions and removals from wetlands
	4-L3-4E-CO2-20xx	CO_2 emissions and removals from settlements
	4-L3-4F-CO2-20xx	CO_2 emissions and removals from other land
	4-L3-4G-CO2-20xx	CO_2 emissions and removals from HWP
	4-L3-4H-CO2-20xx	CO_2 emissions and removals from other
	4-L2-Area(Pref.)-20xx	Area of mineral and organic soils
	4-L2-LandArea-20xx	Land area for each land use category
	4-L2-BlueCarbon-20xx	Carbon stock changes in coastal wetlands
	4-L2-Orchard-20xx	Carbon stock changes in orchard
	4-L2-Parameter-20xx	Parameters for each land use category
	4-L2-Soil-20xx	Land area and carbon stock changes in cropland and grassland
	4-L2-Biochar-20xx	Organic carbon stocks from biochar amendments in mineral soil in cropland
5. Waste	5A3-L2-AD-20xx	Activity data of solid waste disposal (uncategorized waste disposal sites)
	5A-L3-20xx	GHG emissions from solid waste disposal
	5A-L2-AD-20xx	Activity data of solid waste disposal (managed waste disposal sites)
	5B-L3-20xx	GHG emissions from biological treatment of solid waste
	5B-L2-AD-20xx	Activity data of biological treatment of solid waste
	5C-L2-AD-20xx	Activity data of incineration and open burning of waste
	5C-L3-20xx	GHG emissions from incineration and open burning of waste
	5C-L3-Energy-20xx	GHG emissions from waste incineration and energy use (reported in the energy sector)
	5D-L3-20xx	GHG emissions from wastewater treatment and discharge
	5D-L2-AD-20xx	Activity data of wastewater treatment and discharge
	5E-L3-20xx	GHG emissions from other
	5E-L2-AD-20xx	Activity data of other
	5-L2-EF-20xx	Emission factors of waste sector
6. Other	6-L3-20xx	CO, NMVOC emissions from smoking
7. Indirect CO_2	7-L3-Indirect CO2-20xx	Indirect CO_2 emissions
	7-L3-Indirect N2O-20xx	Indirect N_2O emissions
Memo item	1D-L3-bunker-20xx	GHG emissions from international bunker fuels
NDC-LULUCF	4NDC-2-AR-20xx	GHG emissions and removals from afforestation/reforestation
	4NDC-2-BC_Other-20xx	GHG emissions and removals from coastal wetland activities
	4NDC-2-CM-20xx	GHG emissions and removals from cropland management
	4NDC-2-D-20xx	GHG emissions and removals from deforestation
	4NDC-2-FM-20xx	GHG emissions and removals from forest management
	4NDC-2-HWP-20xx	CO_2 emissions and removals from HWP in forest management
	4NDC-2-GM-20xx	GHG emissions and removals from grazing land management
	4NDC-2-UG-20xx	GHG emissions and removals from urban greening
	4NDC-3-summary-20xx	GHG emissions and removals, and the accounting quantities from NDC LULUCF activities

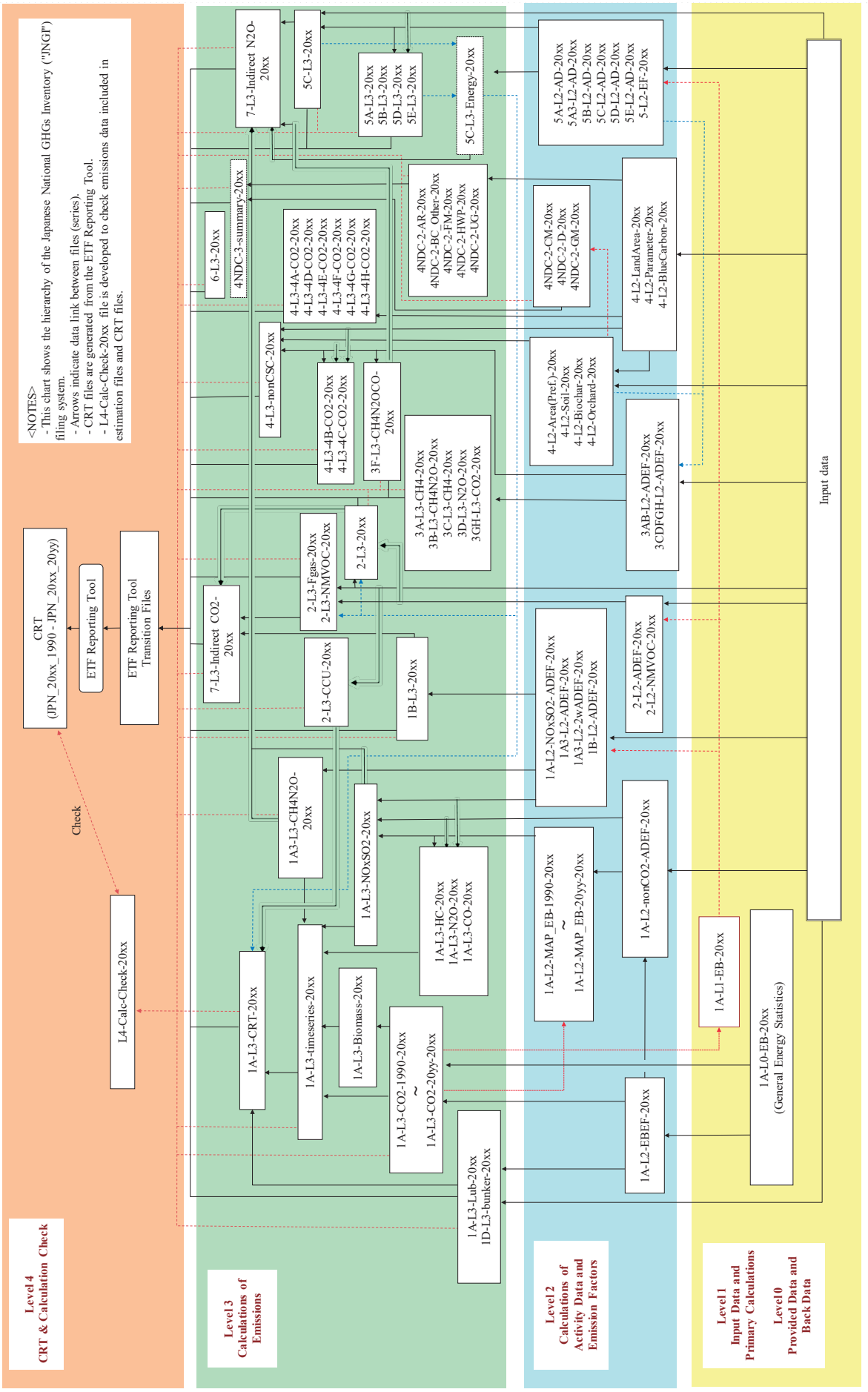

Figure A 7-1 Hierarchical structure of Japan's National GHG Inventory File System

Annex 8. Common Reporting Tables

The "Summary2 Table" of the Common Reporting Tables (CRTs) indicated below shows Japan's emissions and removals for FY2024. Other tables are available on the following GIO website.

https://www.nies.go.jp/gio/en/archive/crf/index.html

Table A 8-1 Japan's GHG emissions and removals for FY2024

SUMMARY 2 SUMMARY REPORT FOR CO_2 EQUIVALENT EMISSIONS
(Sheet 1 of 1)

2024
JPN-CRT-2026-V0.1
Japan

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO_2 [1]	CH_4	N_2O	HFCs	PFCs	Unspecified mix of HFCs and PFCs	SF_6	NF_3	Total
	CO_2 equivalents (kt) [2]								
Total (net emissions) [1]	**919,505.64**	**28,163.83**	**15,211.02**	**27,576.99**	**2,481.32**	**NA,NO**	**2,006.55**	**179.65**	**995,125.00**
1. Energy	**922,935.09**	**1,914.09**	**4,217.75**						**929,066.93**
1.A. Fuel combustion	922,614.49	1,032.82	4,217.31						927,864.62
1.A.1. Energy industries	404,752.87	195.56	1,409.40						406,357.82
1.A.2. Manufacturing industries and construction	218,205.68	524.34	1,052.52						219,782.55
1.A.3. Transport	180,630.42	95.19	1,331.42						182,057.03
1.A.4. Other sectors	119,025.52	217.73	423.97						119,667.21
1.A.5. Other	NO	NO	NO						NO
1.B. Fugitive emissions from fuels	320.60	881.28	0.44						1,202.31
1.B.1. Solid fuels	0.39	486.37	0.35						487.11
1.B.2. Oil and natural gas and other emissions from energy production	320.20	394.91	0.09						715.21
1.C. CO_2 transport and storage	NE,NO								NE,NO
2. Industrial processes and product use	**37,304.74**	**27.73**	**314.15**	**27,576.99**	**2,481.32**	**NA,NO**	**2,006.55**	**179.65**	**69,891.13**
2.A. Mineral industry	26,167.20	NA	NA						26,167.20
2.B. Chemical industry	2,856.24	12.80	164.37	63.65	32.14	NA,NO	41.45	12.17	3,182.82
2.C. Metal industry	4,770.85	14.93	NA	0.98	NA,NE,NO	NA,NO	150.85	NO	4,937.60
2.D. Non-energy products from fuels and solvent use	2,589.23	NE,NO	NE,NO						2,589.23
2.E. Electronic Industry			56.10	64.64	1,322.04	NA,NO	376.51	167.48	1,986.77
2.F. Product uses as ODS substitutes				27,442.39	1,072.32	NO	NO	NO	28,514.71
2.G. Other product manufacture and use	NA	NA	93.69	5.34	54.82	NO	1,437.74	NO	1,591.58
2.H. Other	921.22	NA,NO	NA,NO	NO	NO	NO	NO	NO	921.22
3. Agriculture	**353.30**	**22,802.60**	**7,122.16**						**30,278.06**
3.A. Enteric fermentation		8,458.65							8,458.65
3.B. Manure management		2,476.74	3,066.04						5,542.78
3.C. Rice cultivation		11,841.15							11,841.15
3.D. Agricultural soils		NO	4,048.96						4,048.96
3.E. Prescribed burning of savannahs		NO	NO						NO
3.F. Field burning of agricultural residues		26.06	7.16						33.22
3.G. Liming	205.00								205.00
3.H. Urea application	148.30								148.30
3.I. Other carbon-containing fertilizers									
3.J. Other									
4. Land use, land-use change and forestry [1]	**-50,115.83**	**252.05**	**442.94**						**-49,420.84**
4.A. Forest land	-57,025.05	177.02	134.32						-56,713.70
4.B. Cropland	4,240.96	42.01	18.00						4,300.98
4.C. Grassland	577.40	16.55	12.31						606.26
4.D. Wetlands	-317.07	NA,NE	NA,NE						-317.07
4.E. Settlements	3,308.02	16.46	249.70						3,574.18
4.F. Other land	646.39	NA,NO	28.60						674.99
4.G. Harvested wood products	-1,546.37								-1,546.37
4.H. Other	-0.10	NO	NO						-0.10
5. Waste	**9,028.35**	**3,167.36**	**3,114.02**						**15,309.73**
5.A. Solid waste disposal		1,447.14							1,447.14
5.B. Biological treatment of solid waste		71.98	189.81						261.80
5.C. Incineration and open burning of waste	8,467.90	9.36	1,195.61						9,672.87
5.D. Waste water treatment and discharge		1,638.87	1,728.60						3,367.47
5.E. Other	560.45	NA	NA						560.45
6. Other *(as specified in summary 1)*	**NA**	**NA**	**NA**	**NA**	**NA**	**NO**	**NO**	**NO**	**NA,NO**

Memo items: [3]									
1.D.1. International bunkers	38,399.51	37.19	267.71						38,704.42
1.D.1.a. Aviation	24,715.14	4.75	180.00						24,899.89
1.D.1.b. Navigation	13,684.37	32.44	87.72						13,804.53
1.D.2. Multilateral operations	NO	NO	NO						NO
1.D.3. CO_2 emissions from biomass	72,597.79								72,597.79
1.D.4. CO_2 captured	NO								NO
5.F.1. Long-term storage of C in waste disposal sites	NE								NE
Indirect N_2O			1,841.15						

Indirect CO_2 [4]	1,860.53								

Total CO_2 equivalent emissions without LULUCF	**1,044,545.84**
Total CO_2 equivalent emissions with LULUCF	**995,125.00**
Total CO_2 equivalent emissions, including indirect CO_2, without LULUCF	**1,046,406.37**
Total CO_2 equivalent emissions, including indirect CO_2, with LULUCF	**996,985.53**

(1) For CO_2 from LULUCF, the net emissions/removals are to be reported. For reporting purposes, the signs are always negative (-) for removals and positive (+) for emissions.
(2) As per decision 18/CMA.1, annex, para. 37, each Party shall use the 100-year time-horizon GWP values from the IPCC Fifth Assessment Report, or 100-year time-horizon GWP values from a subsequent IPCC assessment report as agreed upon by the CMA, to report aggregate emissions and removals of GHGs, expressed in CO_2 eq. Each Party may in addition also use other metrics (e.g. global temperature potential) to report supplemental information on aggregate emissions and removals of GHGs, expressed in CO_2 eq. In such cases, the Party shall provide in the national inventory document information on the values of the metrics used and the IPCC assessment report they were sourced from.
(3) Parties are asked to report emissions from international aviation and international navigation and multilateral operations, as well as CO_2 emissions from biomass and CO_2 captured, under memo items. These emissions should not be included in the national total emissions from the energy sector. Amounts of biomass used as fuel are included in the national energy consumption but the corresponding CO_2 emissions are not included in the national total as it is assumed that the biomass is produced in a sustainable manner. If the biomass is harvested at an unsustainable rate, net CO_2 emissions are accounted for as a loss of biomass stocks in the Land Use, Land-use Change and Forestry sector.
(4) In accordance with the modalities, procedures and guidelines (chapter II), for Parties that decide to report indirect CO_2, the national totals shall be provided with and without indirect CO_2.

Note: Minimum level of aggregation is needed to protect confidential business and military information, where it would identify particular entity's/entities' confidential data.

Annex 9. Methodological Details of the Contribution from the LULUCF Sector in the NDC

A9.1. Summary of the Contribution from the LULUCF Sector in the NDC

A9.1.1. Activities Subject to Estimation, Their Scope, and Estimation Methodology Tiers of the Contribution from the LULUCF Sector in the NDC

This annex chapter, based on Decision 4/CMA.1, describes the activities subject to estimation of the contribution from the LULUCF sector in Japan's NDC, their scope, and the methodologies for accounting and estimation. This Annex is intended to be a supplemental explanation of the contribution from the LULUCF sector in the NDC to be reported in "4. Structured summary" of Common Tabular Formats (CTF).

The contribution from the LULUCF sector in Japan's NDC are calculated based on removals by measures for forest and other carbon sinks by adopting activity-based accounting. Most of the scope is the same as the LULUCF activities under the second commitment period of the Kyoto Protocol: afforestation and reforestation (AR), deforestation (D), forest management (FM), cropland management (CM) and grazing management (GM), excluding urban greening (UG) in which the scope has been expanded from revegetation (RV). In addition to this, coastal wetlands (BC[1]) was added as a new activity. The removals by sink activities other than LULUCF activities is reported as "others" here. Table A 9-1 shows the status of estimations of carbon pools and gases reported for each activity. The tiers of the methodology used for the estimations are shown in Table A 9-2.

Table A 9-1 Reporting status of each carbon pool and gas for LULUCF activities

LULUCF Activity	Change in carbon pool reported						Greenhouse gas sources reported						
	Living biomass	Litter	Dead wood	Soil		HWP	Fertili-zation	Drainage of organic soils		N mineralization in mineral soils	Biomass burning		
				Mineral	Organic		N_2O	CH_4	N_2O	N_2O	CO_2	CH_4	N_2O
Afforestation and reforestation	R	R	R	R	NO	IE	IE	NO	NO	NA	IE	IE	IE
Deforestation	R	R	R	R	NO	IO	NO	NO	NO	R	NO	NO	NO
Forest management	R	R	R	R	NO	R	R	NO	NO	R	IE	R	R
Cropland management	R	NA	NA	R	R			R		R	R	R	R
Grazing land management	R	NA	NA	R	R			R		R	NO	NO	NO
Urban greening	R	R	IE	R	NO		IE	NO	NO	NA	NO	NO	NO
Coastal wetlands	R	R	R	R	NO		NO	NO	NO	NO	NO	NO	NO

R: Reported, NA: Not Applicable, NO: Not Occurring, IE: Included Elsewhere, IO: Instantaneous Oxidation

Table A 9-2 Methodological tiers used to calculate each LULUCF activity /others

LULUCF Activity/Others	CO_2		CH_4		N_2O	
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
Afforestation and reforestation	T2,T3	CS				
Deforestation	T2	CS			T2	CS,D
Forest management	T2,T3	CS,D	T1	D	T1,T2	CS,D
Cropland management	T2,T3	CS,D	T1	D	T2	CS,D
Grazing land management	T2,T3	CS,D	T1	D	T2	CS,D
Urban greening	T2	CS,D				
Coastal wetlands	T1,T3	CS,D				
Others	CS	CS				

T1: IPCC Tier 1, T2: IPCC Tier 2, T3: IPCC Tier 3, D: IPCC default, CS: country-specific method or emissions factor

[1] BC stands for blue carbon in this annex.

A9.1.2. Accounting Approach and Accounting Quantity for each LULUCF Activity

The accounting approach used for each LULUCF activity is established in accordance with Article 4.14 of the Paris Agreement, taking into account the existing methodology and guidance based on the *2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol* (hereinafter referred to as *KP Supplement*), which was applied to each LULUCF activity in the second commitment period of the Kyoto Protocol. The gross-net approach was applied to afforestation and reforestation (AR) and deforestation (D) activities, which covered only lands with activities which have been implemented since 1990, as in the second commitment period of the Kyoto Protocol. The reference level approach was applied for forest management (FM). The reference level was set as zero for the forest carbon pools under FM, as in the second commitment period of the Kyoto Protocol, by only accounting for lands where additional anthropogenic activities (e.g., thinning) have been reliably conducted since 1990, while future projections were applied to the reference level for the Harvested Wood Products (HWP) pool. Then, the sum of the reference levels for the forest carbon pools and HWP pool was used as the reference level for the entire FM. For CM and GM activities, the reference level approach was applied for mineral soil carbon pools, with the reference values assuming no application of compost, green manure and biochar in each reporting year to ensure the same weather conditions, and the net-net approach was applied for other carbon pools using 1990 as the base year, as in the second commitment period of the Kyoto Protocol. UG activities cover the area of urban green space that have been established, serviced, or conserved. In such net sink activities, it is important to maintain and enhance the amount of removals in each year, so the net removals for the relevant fiscal year from the UG activity were determined as the accounting quantity. The BC activities cover removals from newly created and conserved coastal wetlands including seagrass meadows and macroalgal beds. In such cases, similar to UG activities, it is important to maintain and enhance the amount of removals in each year. Therefore, the net removals from all coastal wetlands for the relevant years were determined as the accounting quantity. These are equivalent to the gross-net accounting approach. The accounted quantity of the contribution from the LULUCF sector in the NDC which was from LULUCF activities and others in FY2024 was 52,341 kt-CO_2eq. The annual accounted values before the target year provided in this Annex chapter are presented only as a reference to track progress of where Japan currently stands. Since our NDC targets were set as a single year net GHG emissions and removals target, the contribution will be accounted for only in the target years. (Table A 9-3).

Table A 9-3 The contribution from the LULUCF sector in the NDC [kt-CO_2 eq.]

LULUCF activity/Others	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Afforestation/reforestation	-1,858	-1,843	-1,551	-1,491	-1,359	-1,638	-1,565	-1,499	-1,442	-1,373	-1,325
Deforestation	3,125	3,294	3,259	2,949	2,914	3,832	3,847	3,599	3,624	3,003	3,022
Forest management	-62,479	-58,990	-57,548	-57,122	-55,929	-52,122	-49,773	-50,448	-47,961	-46,871	-45,377
Cropland management	-5,116	-5,397	-5,656	-5,385	-5,347	-5,699	-5,754	-5,618	-5,368	-5,676	-5,795
Grazing land management	-802	-906	-975	-1,060	-1,047	-1,125	-1,200	-1,215	-1,161	-1,189	-1,143
Urban greening	-1,818	-1,788	-1,771	-1,751	-1,713	-1,694	-1,649	-1,608	-1,529	-1,469	-1,400
Coastal wetlands	-356	-352	-350	-347	-345	-360	-347	-309	-318	-303	-323
Other	NO	NO	NO	NO	NO	NO	NO	NO	-0.006	-0.099	-0.098
Total accounting quantity	-69,304	-65,982	-64,593	-64,208	-62,826	-58,806	-56,441	-57,098	-54,155	-53,878	-52,341

(CO_2) +: Emissions, -: Removals

Note: The NDC implantation period in Japan is FY2021-FY2030. The figures for FY2014-2020 are provided for the information purpose of showing the historical trend.

A9.2. Scope of Estimations for each LULUCF Activity

A9.2.1. Afforestation/Reforestation (AR)

For AR activity, annual GHG emissions and removals associated with growth and forest management practices were estimated for land that was not forested at the end of 1989, but was converted to forest through afforestation or other human activities after 1990. This activity is similar to “land converted to forest land (4.A.2.)” in the inventory, but the starting point for counting the area covered is different (1990 for AR activity). The loss of carbon stocks of living biomass from lands prior to conversion to forest land is to be accounted for under the activities before the conversions. The carbon stock changes in HWP originating from AR land are difficult to distinguish from HWP originating from FM activity, and therefore all the amount is collectively estimated under FM activity.

A9.2.2. Deforestation (D)

For D activity, annual GHG emissions from deforestation and site preparation were estimated for the land that was anthropogenically converted from forest to non-forest land use after 1990. The increase in carbon stocks due to growth on the converted land is to be accounted for under the post-conversion activities.

A9.2.3. Forest Management (FM)

For FM activity, GHG emissions and removals from the following activities (excluding AR activities) of forests with standing trees in “forest land remaining forest land (4.A.1.)” in the inventory were estimated.

- Ikusei-rin forests: forestry practices conducted since 1990 to maintain forests in appropriate conditions, including regeneration (land preparation, soil scarification, planting, etc.), tending (weeding, pre-commercial cutting, etc.), thinning and harvesting.
- Tennensei-rin forests: protection or conservation of forests, including regulating logging activities and restrictions on land-use changes, which have been carried out by law Carbon stock changes in HWP from the above-mentioned forests are also included in the estimation of this activity.

A9.2.4. Cropland Management (CM)

For CM activity, GHG emissions and removals resulting from the practices of cultivating and other activities in rice fields, upland fields, and orchards in cropland (4.B.) in the inventory were estimated. Dilapidated farmland which is included in the inventory is not included in CM because the land is not being properly managed.

A9.2.5. Grazing land Management (GM)

For GM activity, GHG emissions and removals resulting from grazing in pasture land under grassland (4.C.) in the inventory were estimated.

"Grazed Meadow land" which has no change in nominal management practices and "wild land" which is not land dedicated for grazing, are not included in GM, although they are reported under grassland in the inventory.

A9.2.6. Urban Greening (UG)

For UG activity, GHG emissions and removals from urban green areas under settlements (4.E.) of the

inventory were included. The scope of activities includes urban green areas with an area of less than 0.05 ha as well as those that were established or serviced before 1990, and green spaces conserved by zoning, which were not subject to reporting and estimation under Revegetation (RV) activity of the Kyoto Protocol.

A9.2.7. Coastal Wetlands (BC)

For BC activity, GHG emissions and removals from the blue carbon habitats in coastal wetlands in wetlands (4.D.) of the inventory were included. Of coastal wetlands, mangroves and seagrass meadows and macroalgal beds are included in the scope of activities. The scope may be expanded in the future as estimation methods are established.

A9.3. Methods for Estimating and Accounting for GHG Emissions and Removals for Each LULUCF Activity

A9.3.1. Afforestation and Reforestation Activities

A9.3.1.1. Method of Identifying Areas of Activity

As described in section 6.2.2. a), the change from non-forest to forest detected by interpretation of satellite images was considered as an AR activity, and the AR cumulative occurrence area for the fiscal year *i* was calculated by multiplying the AR cumulative occurrence rate from 1990 to the end of the most recent year (year *i*) by the national land area. When interpreting satellite images, the area subject to AR activities and the forest restoration area due to natural succession are distinguished by judging whether each forest cover change is human-induced or not. This judgement is based on whether any signs of human activities, such as uniform tree species and uniform tree height, artificial forestation blocks, or work roads for forestation, are observed or not.

Table A 9-4 Area subject to AR activity [kha]

	1990 - 2014	1990 - 2015	1990 - 2016	1990 - 2017	1990 - 2018	1990 - 2019	1990 - 2020	1990 - 2021	1990 - 2022	1990 - 2023	1990 - 2024
AR accumulated occurrence area	96.8	97.8	98.7	98.8	98.9	98.7	98.5	98.5	98.5	98.4	98.3

A9.3.1.2. Methods for Estimating Carbon Stock Changes and GHG Emissions

a) Living Biomass

- ***Methodology***

The annual carbon stock accumulation of living biomass that occurred after conversion from other land uses to forests are to be included in this estimation. The calculation was based on the Tier 2 stock-difference method which is the same method used for "forest land remaining forest land (4.A.1.)". Since it is difficult to directly obtain the area where AR activities occur by tree species and by forest age, the carbon stock of living biomass ($C_{AR\_LB,\ i}$) of the area subject to AR activities in fiscal year *i* was calculated, by multiplying the cumulative area of AR occurrence since 1990 in fiscal year *i* ($A_{AR,\ i}$) with the carbon stock per unit area, which is calculated by dividing the total carbon stock ($C_{IM,\ i}$) by the total area ($A_{IM,\ i}$) of intensively managed forests at the end of fiscal year *i*, using the data extracted from the National Forest Resources Database (Forestry Agency), assuming that the composition of tree species and age class in intensively managed forests is the same as that of AR area.

$$\Delta C_{AR\_LB,i} = \left(C_{AR\_LB,i} - C_{AR\_LB,i-1}\right)/(t_i - t_{i-1})$$

$$C_{AR\_LB,i} = A_{AR,i} \times \frac{C_{IM\_LB,i}}{A_{IM,i}}$$

$\Delta C_{AR\_LB,i}$: Carbon stock changes in living biomass in the area subject to AR activity in fiscal year *i* [t-C/yr]
t_i, t_{i-1} : At the time of the carbon stock survey: year *i* and year *i-1* (both at the end of fiscal year)
$C_{AR\_LB,i}$: Carbon stocks in living biomass in the area subject to AR activity at the end of fiscal year *i* [t-C]
$C_{IM\_LB,i}$: Carbon stock in living biomass in intensively managed forests at the end of fiscal year *i* [t-C]
$A_{AR,i}$: Cumulative area of AR occurrence since 1990 in fiscal year *i* [ha]
$A_{IM,i}$: Area of intensively managed forests at the end of fiscal year *i* [ha]

- ***Activity Data***

The cumulative area of AR occurrence since 1990 was used.

b) Dead wood, Litter and Soils

- ***Methodology***

The carbon stock changes in dead wood, litter and mineral soils in areas subject to AR activities were calculated by using the same method used for "land converted to forest land (4.A.2.)" in section 6.4.2. b) 2) for forests less than 20 years old, and the same method as "forest land remaining forest land (4.A.1.)" in section 6.4.1. b) 2) for forests of 21 years old and older.

As mentioned in section 6.4.1.b) 2), the emissions from organic soils were reported as "NO".

- ***Activity Data***

The cumulative area of AR occurrence since 1990 was used for dead wood and mineral soils estimation, and the cumulative area of AR occurrence within 20 years was used for litter estimation.

c) Harvested Wood Products (HWP)

As the amount of HWP originated from AR land cannot be distinguished from that originated from FM land, it was reported collectively in FM activities and reported as "IE" in this category.

d) Other gases

1) N_2O emissions from N fertilization

As the amount of nitrogen-based fertilizer applied in Forest land cannot be separated between those in AR activities and in FM activities, N_2O emissions from N fertilization are reported collectively in FM activities, and reported as "IE" in this category.

2) N_2O and CH_4 emissions from drainage of organic soils

As described in section 6.13, drainage activities in forest land with organic soils are not implemented in Japan. Therefore, N_2O and CH_4 emissions were reported as "NO" in this category.

3) N_2O Emissions from N mineralization due to carbon loss associated with land-use conversions and management change in mineral soils

According to the Tier 1 or Tier 2 methods described in *the 2006 IPCC Guidelines*, N_2O emissions from N immobilization associated with gain of soil organic matter are not subject to estimation. Therefore, N_2O emissions were reported as "NA", since soil carbon stock changes in AR are reported to be on the increase.

4) Emissions from Biomass Burning

As the area of forest fire occurrence cannot be distinguished by whether it is from AR activities or FM activities, associated emissions were reported collectively in FM activities and reported as “IE” in this category.

A9.3.1.3. Method of Accounting and Calculation Results

The accounting quantity was calculated by gross-net approach with 1990 as the base year. The net removals of area subject to AR activities in Table A 9-5 were used as the accounting quantity as is. The calculation results are as follows.

Table A 9-5 Emissions and removals, and the accounting quantity from AR activity [kt-CO_2 eq.]

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
AR net removals (accounting quantity)	-1,857.71	-1,842.58	-1,551.29	-1,490.85	-1,358.86	-1,638.00	-1,565.15	-1,498.91	-1,441.86	-1,373.36	-1,324.78
Living biomass	-1,464.60	-1,450.07	-1,159.08	-1,106.36	-977.99	-1,262.62	-1,194.23	-1,131.08	-1,077.42	-1,013.58	-968.38
Dead wood	-58.25	-58.81	-59.39	-58.90	-58.94	-58.70	-58.60	-58.70	-58.70	-58.59	-58.54
Litter	-99.01	-95.95	-92.73	-87.81	-84.00	-80.06	-76.10	-72.40	-69.01	-65.83	-62.72
Mineral soils	-235.85	-237.75	-240.09	-237.78	-237.94	-236.63	-236.22	-236.73	-236.73	-235.35	-235.13
Organic soils	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Harvested wood products (HWP)	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Other gases	IE, NO, NA	IE, NO, NA	IE, NO, NA	IE, NO, NA	IE, NO, NA	IE, NO, NA	IE, NO, NA	IE, NO, NA	IE, NO, NA	IE, NO, NA	IE, NO, NA
Fertilization (N_2O)	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Organic soil drainage (CH_4, N_2O)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N mineralization in mineral soil (N_2O)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Biomass burning (CH_4, N_2O)	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE

(CO_2) +: Emissions, -: Removals

A9.3.2. Deforestation Activity

A9.3.2.1. Method of Identifying Area of Activity

As described in section 6.2.2.a), the change from forest to non-forest detected by the interpretation of satellite images was identified as a D activity, and the national land area was multiplied by the D occurrence rate for a single year to calculate the D occurrence area for a single fiscal year, and the cumulative D occurrence area was calculated by multiplying the national land area by the total D occurrence rate from 1990 to the most recent fiscal year. In Japan, land conversion from forest land to other land uses means an exclusion of the land from forest plans. Therefore, as far as the area of harvested forest would remain included in forest plans, the area would not be regarded as D activity but as temporary loss of biomass stock, and would be distinguished from area subject to D activity which means conversion to other land uses, in the Forest Registers.

Japan identifies forest change as D activity only in the cases when lands undergo transformation or artificial construction are observed, or obvious conversion to non-forest land such as cropland are detected. By this methodology, D activity is distinguished from temporary loss of biomass stock in forest land such as clear-cut under ongoing forestry activities.

Sample field surveys are conducted at plots which are interpreted as D areas every year, and the accuracy of D interpretation is approximately 90% on average.

Under the system based on the Forest Law, regeneration is expected to be done within around two years after a harvest event. If natural regeneration is selected as a means of regeneration, trees are expected to be established within five years after a harvest event.

Table A 9-6 Area subject to D activity [kha]

	1990 - 2014	1990 - 2015	1990 - 2016	1990 - 2017	1990 - 2018	1990 - 2019	1990 - 2020	1990 - 2021	1990 - 2022	1990 - 2023	1990 - 2024
D Accumulated occurrence area	286.7	295.5	304.3	311.8	319.2	327.1	335.0	342.1	349.3	354.5	359.7
Area of occurrence in a single year	7.8	8.8	8.8	7.5	7.5	7.9	7.9	7.1	7.1	5.2	5.2

A9.3.2.2. Methods for Estimating Carbon Stock Changes and GHG Emissions

a) Living Biomass

- ***Methodology***

It is difficult to directly obtain the area subject to D activities by species and by forest age as with the area subject to AR activities. Therefore, the forest biomass stock lost due to D activities was calculated assuming that the average forest biomass stock in the forests with standing trees at the beginning of the fiscal year subject to calculation is lost due to D activities. Specifically, the average carbon stock per unit area of the forests with standing trees at the beginning of the fiscal year extracted from the National Forest Resources Database was multiplied by the D area occurred in the single fiscal year subject to calculation. All emissions resulting from deforestation were accounted for in the year in which deforestation occurred.

- ***Activity Data***

The area of D occurrence in a single fiscal year was used.

b) Dead Wood, Litter and Soils

- ***Methodology***

The carbon stock changes in dead wood, litter and mineral soils associated with D activities were calculated in the same way as for the conversion from forest to other land uses, as described in section 6.6.2.b). Since there is no drainage treatment during D activities in organic soil areas, the relevant emissions in this category were reported as “NO”.

- ***Activity Data***

For the estimation of dead wood and litter, the area of D activities that occurred in a single fiscal year was used. For the estimation of mineral soils, the cumulative area of D activities occurred since 1990 was used in the case of conversions to upland fields and to orchards, whereas that of D activities occurred within 20 years was used in the case of conversion to land uses other than upland fields or orchards.

c) Harvested Wood Products (HWP)

The carbon stock changes in the HWP pool were reported as “IO” because HWP from the area subject to D activity was accounted for by instantaneous oxidization when the wood was harvested in accordance with the methodology described in section 2.8.2 of the *KP supplement*.

d) Other Gases

1) N_2O Emissions from N Fertilization

As no fertilization was conducted during the D activities, the emissions in this category were reported as “NO”.

2) N_2O and CH_4 Emissions from Drainage of Organic Soils

As there is no drainage treatment during D activities, the emissions in this category were reported as "NO".

3) N_2O Emissions from N Mineralization due to Carbon Loss Associated with Land-Use Conversions and Management Changes in Mineral Soils

N_2O emissions from nitrogen mineralization associated with land-use changes and management were calculated using Tier 2 estimation method described in the *2006 IPCC Guidelines*. The estimation equation and parameters used are the same as those used in section 6.14, "land Converted to Other Land (4.F.2.)" calculation. Soil carbon loss data from D activities were used for the amount of soil carbon mineralized by land conversion on the area subject to D activities.

4) Emissions from Biomass burning

In Japan, controlled burning activities are not carried out in deforestation activities because of severe restrictions imposed by the "Waste Management and Public Cleansing Law" and the "Fire Defense Law". Therefore, CH_4, N_2O emissions from biomass burning in D land are reported as "NO".

A9.3.2.3. Method of Accounting and Calculation Results

The accounting quantity was calculated using the gross-net approach with 1990 as the base year. The net emissions in the D activities of Table A 9-7 are directly used as the accounting quantity. The calculation results are as follows.

Table A 9-7 Emissions and removals, and the accounting quantity from D activity [kt-CO_2 eq.]

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
D Emissions (accounting quantity)	3,125.42	3,294.37	3,259.04	2,949.09	2,914.24	3,831.85	3,846.99	3,598.70	3,623.52	3,003.17	3,022.44
Living biomass	1,324.58	1,497.03	1,495.62	1,275.47	1,268.65	2,186.03	2,201.41	2,006.90	2,018.48	1,476.66	1,485.43
Dead wood	213.40	241.19	241.19	205.57	205.57	216.97	216.97	196.30	196.30	142.86	142.86
Litter	139.42	157.58	157.58	134.30	134.30	141.75	141.75	128.25	128.25	93.34	93.34
Mineral soils	1,359.10	1,312.70	1,280.86	1,251.85	1,225.55	1,208.08	1,207.85	1,189.44	1,201.87	1,211.08	1,220.94
Organic soils	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Harvested wood products (HWP)	IO	IO	IO	IO	IO	IO	IO	IO	IO	IO	IO
Other gases	88.91	85.87	83.79	81.89	80.17	79.03	79.01	77.81	78.62	79.23	79.87
Fertilization (N_2O)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Organic soil drainage (CH_4, N_2O)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N mineralization in mineral soil (N_2O)	88.91	85.87	83.79	81.89	80.17	79.03	79.01	77.81	78.62	79.23	79.87
Biomass burning (CH_4, N_2O)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

(CO_2) +: Emissions, -: Removals

A9.3.3. Forest Management

A9.3.3.1. Method of Identifying Area of Activity

Japan estimates the area subject to FM activity for Ikusei-rin forests and Tennensei-rin forests according to the following procedures.

a) Ikusei-rin Forests

The area of forests subject to FM activities is estimated by considering FM rates which is calculated as a ratio of "forests where forestry practices including thinning have been carried out since 1990" in "total Ikusei-rin forests excluding AR area".

[Setting of survey plots]

Approximately 20,000 survey plots of Ikusei-rin forests were randomly selected from the National

Forest Resources Database. For setting plots of intensively managed forests, forests under the certain age where AR activities possibly happened were excluded from the survey plots and the area distribution of private or national, tree species, and regions was considered.

[Survey items and methods]

Survey items are status of the forest (tree species, forest age, number of standing trees, etc.), if there is a trace of forestry practices since 1990 and which practice was conducted, if any. Survey methods include field surveys, interviews with forestry cooperatives, etc. and literature review of administrative documents and other documents related to subsidized afforestation projects.

[Calculation of FM rate]

The FM rate for FY2023 was calculated subtracting duplicate from the cumulative number of plots surveyed from the first year of the survey, 2007, to the end of FY2023. Since the current survey result applied for same plot, the FM activities implemented from 1990 to the end of the FY2023 are subject to the calculation.

[Calculation of FM area]

The area of forests subject to FM activities was calculated by considering FM rates by private forests or national forests and by each tree species, region, and age class after subtracting the AR area from the area of Ikusei-rin forests at the end of FY2023. Since the total forest area in FY2023 from the Forest Registers and the satellite images was used, the area of D activities that occurred in 2023 was already subtracted from the area.

Table A 9-8 FM ratio of Ikusei-rin forests by private and national forests
(applicable to the calculation for FY2024)

Sub-category / Tree species		Region	Private forest	National forest
Intensively managed forest	Japanese cedar	Tohoku, Kita-kanto, Hokuriku, Tosan	0.90	0.93
		Minami-kanto, Tokai	0.77	0.90
		Kinki, Chugoku, Shikoku, Kyusyu	0.82	0.92
	Hinoki cypress	Tohoku, Kanto, Chubu	0.86	0.93
		Kinki, Chugoku, Shikoku, Kyusyu	0.89	0.94
	Japanese larch	All	0.92	0.87
	Other	All	0.76	0.85
Semi-natural forest / All		All	0.49	0.67

Note:
1) Surveyed points are approximately 22,400 nationwide
2) Region is a division of several prefectures commonly used in Japan.
3) The values listed here are area-weighted averages of FM rates by age class.
4) The uncertainty estimated for the FM rate listed here is 3% for Japan as a whole.

b) Tennensei-rin Forests

For Tennensei-rin forests, forest lands subject to legal measures of protection or conservation such as regulating logging activities and land-use change using data extracted from the NFRDB are regarded as subject to FM activities. Tennensei-rin forests consist of Protection Forests, Special Zones and Special Protection Zones of National Parks and other protected forests/zones as shown in Table A 9-9 below. The Protection Forests are designated under Article 25 of the Forest Law (legislation No. 249, 1951) for the purpose of fulfilling multiple functions of forests (such as headwater conservation and sediment erosion prevention). In the Protection Forests, cutting stands, changing land characteristics and related

activities without prior approval are prohibited. In addition, placing signs which show the Protection Forest area, conducting field inspection and monitoring by utilizing satellite images are implemented. With respect to the National Parks, the parks are protected by restricting development and changing the characteristics of land, prohibiting hunting animals and harvesting plants, limiting people's and vehicles' accesses, based on the Natural Parks Law (legislation No.161, 1957). These measures have been applied to the Tennensei-rin forests continuously since 1990.

Table A 9-9 Area of protected/conserved Tennensei-rin forests (FY2024) [kha]

Protected / Conserved forest type	Private forest	National forest	Total
Protection forest	2,874	4,582	7,455
Area for conservation facility installation project	1	0	1
Protected forest	0	634	634
Special protected zones in national parks	48	168	215
Class I special zones in national parks	45	196	241
Class II special zones in national parks	140	233	373
Special protected zones in quasi-national parks	7	30	37
Class I special zones in quasi-national parks	27	62	88
Class II special zones in quasi-national parks	91	73	164
Special zone in national environment conservation area	2	9	11
Special seed forest	9	1	10
Total （excluding duplicate designations）	3,243 (2,790)	5,986 (4,337)	9,229 (7,127)

Reference: NFRDB (1st April 2024)
Note: This table includes forests with less standing trees.

Table A 9-10 Area subject to FM activity [kha]

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Area subject to FM	15,545.7	15,597.5	15,690.1	15,835.0	15,953.2	16,032.2	16,099.8	16,163.1	16,211.9	16,248.7	16,294.9
Ikusei-rin forest	8,520.1	8,620.9	8,694.8	8,822.7	8,905.6	8,929.9	8,995.0	9,051.7	9,119.5	9,145.2	9,165.9
Tennensei-rin forest	7,025.6	6,976.7	6,995.3	7,012.3	7,047.6	7,102.3	7,104.8	7,111.4	7,092.4	7,103.5	7,129.0

A9.3.3.2. Methods for Estimating Carbon Stock Changes and GHG Emissions

a) Living Biomass

1) Ikusei-rin Forest

Carbon stock changes were estimated from the forest carbon stocks of total Ikusei-rin forests in each year using the stock-difference method. Since the carbon stock changes of total Ikusei-rin forests include the changes from AR and D activities, the amount of changes caused by AR activities was excluded from the total changes and the impact by D activities was eliminated by adding the amount of changes caused by the D activity. Carbon stock changes in forests subject to FM activities were calculated by applying the FM rates for each tree species, region, and age class, after eliminating the effects of AR and D activities from the total stock change in Ikusei-rin forests.

2) Tennensei-rin Forest

Carbon stock changes were calculated from the forest carbon stocks for the forest area shown in section A9.3.3.1.

b) Dead wood, Litter and Soils

Carbon stock changes in dead wood, litter and mineral soil carbon pools were estimated by using the same Tier 3 method as "forest land remaining forest land (4.A.1.)". It was estimated by multiplying carbon emissions/removals per unit area in each carbon pool, which were calculated by the CENTURY-

jfos model for each forest management type, tree species, region and age class, by the FM area by forest management type, tree species, region and age class. See section 6.4.1.b) 2) for estimation equations, key assumptions and parameters applied for the calculation by CENTURY-jfos model.

As described in section 6.4.1.b) 2), no drainage of organic soils in forest land is practiced in Japan. Under the Tier 1 and Tier 2 estimation methods provided in the *2006 IPCC Guidelines*, emissions from drainage of organic soils are estimated only if the soil is drained. Therefore, it is considered that emissions do not occur in undrained organic soils, and the emissions were reported as "NO".

c) Harvested Wood Products (HWP)

Carbon stock changes in HWP under FM activities, including those originating from AR land, are calculated using the same equations, parameters and activity data in the categories of buildings, wood for other uses than buildings, and paper and paperboards as for HWP (4.G.) under the inventory 4.G, described in section 6.10.

For reporting under FM activities, HWP derived from D activities were excluded from the figures reported in the inventory. The inflow of logs derived from D activities is estimated by multiplying the total national log production ($Harvest_{RW,i}$) by the percentage of harvested standing trees derived from D activities among the total harvested volume $\left((Stock_{i,D,ST} \cdot D_i)/Harvest_{ST,i}\right)$, according to the following equation.

$$Inflow_{i,D,RW} = Harvest_{RW,i} \times \left\{(Stock_{i,D,ST} \times D_i)/Harvest_{ST,i}\right\}$$

$Inflow_{i,D,RW}$: D-derived inflow (logs) in year *i* [m^3]

$Harvest_{RW,i}$: Material (logs) production in year *i* [m^3]

$Stock_{i,D,ST}$: Average volume per ha of the entire standing trees (trunk volume) [m^3/ha]

D_i : Area of D occurrence in year *i* [ha]

$Harvest_{ST,i}$: Harvested standing trees (trunk volume) in year *i* [m^3]

d) Other Gases

1) Direct and Indirect N_2O Emissions from N Fertilization

As the amount of nitrogen-based fertilizer applied in Forest land cannot be separated between those in AR activities and in FM activities, N_2O emissions from N fertilization are reported collectively in FM activities. With respect to the methodology and parameters applied to this category, see section 6.12.

2) N_2O and CH_4 Emissions from Drainage of Soils

As soil drainage activity for organic soils in forest land does not occur in Japan, N_2O and CH_4 emissions were reported as "NO".

3) N_2O Emissions from N Mineralization due to Carbon Loss associated with Land-Use Conversions and Management Change in Mineral Soils

N_2O emissions from N mineralization associated with loss of soil organic matter is estimated by using the Tier 2 method described in the *2006 IPCC Guidelines*. The estimation method and parameters are the same as section 6.14. The activity data is gross loss of soil carbon in FM which was extracted from land where soil carbon has decreased, by each forest age, tree species, and prefecture.

4) Emissions from Biomass Burning

As forest fire area cannot be separated between those in AR activities and in FM activities, GHG emissions associated with forest fires (wildfires) are reported collectively in FM activities. Calculations are performed only for non-CO_2 emissions since CO_2 emissions are already included in the calculation of carbon stock changes and reported as "IE". Emissions due to biomass burning are estimated by multiplying GHG emissions due to fire for all forests calculated in section 6.15 by the ratio of total area subject to FM and AR activities to all forest land area. Moreover, controlled burning activities in forests are not implemented in Japan because of severe restrictions imposed by the "Waste Management and Public Cleansing Law" and the "Fire Defense Law".

A9.3.3.3. Method of Accounting and Calculation Results

As in the second commitment period of the Kyoto Protocol, the reference level approach was used to calculate the accounting quantities. The details of the reference level and the accounting quantity are as follows.

a) Forest Management Reference Level for forest carbon pools

In accounting for forest management, a reference level of zero was set for the five forest carbon pools. Since a narrow approach is used in Japan to identify forests subject to forest management, the reference level is set to zero in order to calculate removals using the gross-net method and the only lands where activities have been reliably conducted since 1990 are subject to removals calculation.

b) Forest Management Reference Level for HWP pool

For the HWP pool, the reference level is set as follows, using future projections based on historical trends until 2012, in accordance with the methodology of the *KP supplement*.

The prediction of activity data after 2013 were estimated: for the floor area of buildings by exponentially extrapolating the trend over 20 years from 1993 to 2012; for the production of plywood and wooden board, by linearly extrapolating the trend over 20 years from 1993 to 2012; and for the production of paper and paperboards, by linearly extrapolating the trend over 10 years from 2003 to 2012, respectively. As for the calculation parameter of the ratio of domestic wood, the average values of 10 years from 2003 to 2012 were applied. The periods referenced for the past trend for prediction vary among the activity data and parameters, because the trend which showed a high correlation was applied for each activity data and parameter. The average values for 10 years were also applied where the past trend was not clear (e.g., underground buried logs). For the projection of the HWP inflow resulting from D activities, the average value of area of D occurrence in a single fiscal year from 2008 to 2012 was used. In order to ensure consistency with the methodology used for estimating FM activity related GHG emissions and removals in HWP, the reference level is recalculated when updating the statistics or revising the estimation method used in line with the provisions set out in decision 4/CMA.1.

c) Calculation Results

The total of the value after applying the reference level to net removals in FM is the accounting quantity from FM activity.

Table A 9-11 Emissions and removals, and the accounting quantity from FM activity [kt-CO_2 eq.]

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
FM accounting quantity	-62,479.28	-58,989.56	-57,548.03	-57,122.36	-55,929.19	-52,122.33	-49,773.07	-50,447.99	-47,960.58	-46,870.61	-45,376.82
FMRL	1,305.94	1,344.14	1,379.92	1,412.62	1,451.69	1,496.40	1,541.67	1,592.86	1,638.35	1,682.36	1,724.22
(Forest)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(HWP)	1,305.94	1,344.14	1,379.92	1,412.62	1,451.69	1,496.40	1,541.67	1,592.86	1,638.35	1,682.36	1,724.22
FM net removals	-61,173.34	-57,645.42	-56,168.11	-55,709.73	-54,477.50	-50,625.93	-48,231.40	-48,855.13	-46,322.23	-45,188.25	-43,652.61
Living biomass	-55,385.88	-51,804.29	-50,040.51	-49,221.86	-47,806.48	-44,117.24	-42,505.19	-42,173.50	-40,117.42	-39,606.36	-38,532.13
Dead wood	-2,287.03	-2,386.66	-2,510.79	-2,651.46	-2,782.42	-2,885.84	-2,997.89	-3,069.82	-3,156.74	-3,211.21	-3,287.78
Litter	-83.36	-1.88	60.67	93.53	129.33	175.68	216.26	258.42	305.19	337.56	349.96
Mineral soils	-2,419.65	-2,291.76	-2,147.69	-2,013.20	-1,862.77	-1,695.33	-1,536.98	-1,379.64	-1,221.18	-1,060.35	-890.73
Organic soils	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Harvested wood products (HWP)	-1,081.81	-1,232.81	-1,599.37	-2,005.00	-2,227.18	-2,179.26	-1,482.86	-2,573.93	-2,212.51	-1,735.25	-1,503.74
Other gases	84.39	71.99	69.58	88.27	72.03	76.07	75.27	83.33	80.43	87.36	211.82
Fertilization (N_2O)	0.80	0.76	0.76	0.89	0.73	0.70	0.72	0.85	0.77	0.57	0.57
Organic soil drainage (CH_4, N_2O)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N mineralization in mineral soil (N_2O)	65.57	66.38	67.73	68.56	69.32	71.21	72.42	74.74	76.56	78.19	79.90
Biomass burning (CH_4, N_2O)	18.02	4.85	1.09	18.83	1.98	4.16	2.14	7.75	3.10	8.61	131.35

(CO_2) +: Emissions, -: Removals

A9.3.4. Cropland Management

A9.3.4.1. Method of Identifying Area of Activity

As with the Cropland in the inventory, the CM area is based on the area of rice fields, upland fields, and orchards in *The Statistics of Cultivated and Planted Area* of the Ministry of Agriculture, Forestry and Fisheries, shown in Table 6-2. In the calculation of N_2O emissions from mineral soil carbon pools and mineralized nitrogen associated with land use change and management, cropland converted from forest land is included in D activities, and therefore, the land area converted from forest to cropland since 1990 was ascertained from the D survey and subtracted from the current area of rice fields, upland fields and orchards.

Table A 9-12 Area subject to CM activity [kha]

	1990	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Area subject to CM	4,596.5	3,909.7	3,889.3	3,867.1	3,842.7	3,820.9	3,800.7	3,778.0	3,755.2	3,734.0	3,708.3	3,685.6
Area of mineral soils (excluding area subject to D)	4,444.6	3,749.7	3,728.8	3,706.3	3,681.6	3,659.5	3,638.8	3,615.6	3,591.7	3,569.5	3,543.6	3,520.5

A9.3.4.2. Methods for Estimating Carbon Stock Changes and GHG Emissions

a) Living Biomass

The carbon stock changes in living biomass under CM (ΔC_{CM_LB}) was calculated from the annual carbon stock increase accumulated by growth ($\Delta C_{orchard\_LB\_SC}$ and $\Delta C_{annualcrop\_LB\_SC}$) as well as the loss of carbon stock due to conversion from cropland ($\Delta C_{LB\_conversion\_to\_others}$). Carbon stock changes in living biomass in orchards ($\Delta C_{orchard\_LB\_SC}$) were estimated including the loss due to conversion, by using the same method of Tier 2 stock-difference method as “cropland remaining cropland (4.B.1.)” described in section 6.5.1.b)1). The carbon stock changes in annual crops are calculated as the increase to the average carbon stock associated with the growth obtained in the current year at the time of land conversion to cropland, as described in section 6.5.2.b)1), " land converted to cropland (4.B.2.)". The estimation equations were described below and see Table 6-9, Table 6-11 and section 6.5.1.b)1) of the report for the parameters and activity data used.

$$\Delta C_{CM\_LB} = \Delta C_{orchard\_LB\_SC} + \Delta C_{annualcrop\_LB\_SC} - \Delta C_{LB\_conversion\_to\_others}$$

$$\Delta C_{annualcrop\_LB\_SC} = \Delta A_{others-annualcrop} \times C_{annualcrop\_LB}$$

$$\Delta C_{LB\_conversion\_to\_others} = \Delta A_{annualcrop-others} \times C_{annualcrop\_LB}$$

ΔC_{CM-LB} : Carbon stock changes in living biomass subject to CM activities [t-C/yr]
$\Delta C_{orchard\_LB\_SC}$: Carbon stock changes in living biomass in orchards [t-C/yr]
$\Delta C_{annualcrop\_LB\_SC}$: Carbon stock changes (gains) in living biomass of annual crops in rice fields and upland fields [t-C/yr]
$\Delta C_{LB\_conversion\_to\_others}$: Carbon stock changes (losses) due to land conversion from cropland [t-C/yr]
$\Delta A_{others-annualcrop}$: Annual area converted from other land-use category to cropland (rice fields or upland fields) [ha/yr]
$\Delta A_{annualcrop-others}$: Annual area converted from rice fields and upland fields to other non-forest land-use Categories [ha/yr]
$C_{annualcrop\_LB}$: Carbon stocks in living biomass of annual crops per unit area in rice fields and upland fields [t-C/ha]

b) Dead Wood, Litter

Since no carbon stock changes occurred as described in section 6.5.1.b) 2), the carbon stock changes for this category were reported as "NA".

c) Soils

1) Mineral Soils

Carbon stock changes in mineral soils in CM were estimated by applying the Tier 3 (Roth C model) estimation method, as described in section 6.5.1.b) 3). The activity area used for the estimation excluded the area of land subject to D activities.

For mineral soils, in addition to the above, soil carbon sequestration due to biochar application were calculated separately. As described in section 6.5.1.b) 3), the methodology of the calculations, parameters and activities are the same as those reported in the inventory.

2) Organic Soils

The relevant emissions reported in cropland (4.B.) in the inventory were reported. The methodology of the calculations, parameters and activities used are as described in section 6.5.1.b) 3).

d) Other Gases

1) CH_4 Emissions from Drainage of Organic Soils

CH_4 emissions from drainage of organic soils (4.(II)) reported in cropland in the Inventory were reported. The methodology of the calculations, parameters and activities used are described as section 6.13.

2) N_2O Emissions from N Mineralization due to Carbon Loss associated with Land-Use Conversions and Management Change in Mineral Soils

N_2O emissions generated from land converted to cropland were calculated using the same methodology, estimation equation and parameters as in section 6.14. The activity area used for the calculation excludes the area subject to D activities.

3) Emissions from Biomass Burning

The relevant emissions reported in cropland under Biomas Burning (4.(IV)) in the Inventory were reported, since the emissions are from activities on Cropland. The estimation method and parameters are as described in section 6.15.

A9.3.4.3. Method of Accounting and Calculation Results

The reference level approach was applied for mineral soil carbon pools, and net-net approach with 1990 as the base year, as in the second commitment period of the Kyoto Protocol, was applied for other carbon pools and other gasses. The details of the reference level and the accounting quantity are as follows.

a) Reference Level for Mineral soil carbon pool

Application of organic materials into soils increases soil carbon storage in mineral soils. The reference level of mineral soils was set as net CO_2 emissions calculated based on the condition without application of organic materials into soils in each reporting year to ensure the same weather conditions used for the real emissions and removals estimation. Specifically, the Roth C model described above, which also used to estimate real emissions and removals, was used to calculate these reference values (described in Table A 9-13).

b) Calculation Results

The calculation results are as follows.

Table A 9-13 Emissions and removals, and the accounting quantity from CM activity [kt-CO_2 eq.]

	1990 (base year)	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
CM accounting quantity	-	-5,116.46	-5,397.20	-5,656.41	-5,385.31	-5,347.02	-5,698.56	-5,753.61	-5,617.69	-5,367.98	-5,676.10	-5,795.11
Base year values	1,755.63	1,755.63	1,755.63	1,755.63	1,755.63	1,755.63	1,755.63	1,755.63	1,755.63	1,755.63	1,755.63	1,755.63
RL(Mineral soils)	-	9,494.44	8,977.54	9,613.38	8,660.92	7,908.86	8,457.67	7,877.17	7,830.42	8,426.23	8,480.59	8,318.88
CM net emissions	-	6,133.60	5,335.97	5,712.60	5,031.23	4,317.46	4,514.74	3,879.20	3,968.35	4,813.87	4,560.11	4,279.40
Living biomass	416.11	168.19	221.81	231.96	202.08	263.48	234.66	289.25	263.43	258.32	261.58	256.64
Dead wood	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Litter	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mineral soils	-	4,734.41	3,884.91	4,252.82	3,602.11	2,826.60	3,052.19	2,362.21	2,478.93	3,331.33	3,075.32	2,799.74
Organic soils	1,244.46	1,175.09	1,173.74	1,172.45	1,171.54	1,171.49	1,171.78	1,171.57	1,169.70	1,167.96	1,166.59	1,166.11
Other gases	95.06	55.91	55.52	55.38	55.51	55.89	56.12	56.18	56.29	56.27	56.62	56.92
Organic soil drainage (CH_4)	26.75	26.98	26.88	26.84	26.73	26.71	26.71	26.70	26.58	26.49	26.40	26.37
N mineralization in mineral soil (N_2O)	34.08	5.45	5.55	5.82	6.44	7.29	7.90	8.41	9.04	9.52	10.33	11.07
Biomass burning (CH_4, N_2O)	34.23	23.48	23.09	22.71	22.34	21.89	21.51	21.07	20.66	20.27	19.89	19.48

(CO_2) +: Emissions, -: Removals

A9.3.5. Grazing Land Management

A9.3.5.1. Method of Identifying Area of Activity

The area subject to GM activity is the area of pasture land under Grassland (4.C.) in the inventory, obtained by *The Statistics of Cultivated and Planted Area*, MAFF, shown in Table 6-2. As with CM activity, in the calculation of N_2O from the carbon pool of mineral soils and mineralized nitrogen from land-use change and management, pastureland established through forest conversion is included in the D activity, and therefore the land area converted from forest to pasture land after 1990 was ascertained from the D survey and subtracted from the current area of pastureland.

Table A 9-14 Area subject to GM activity [kha]

	1990	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Area subject to GM	646.6	607.8	606.5	603.4	601.0	598.6	596.8	595.1	593.4	591.3	589.0	585.9
Area of mineral soils (excluding area subject to D)	604.7	548.9	547.1	543.5	540.8	538.1	536.0	534.2	532.0	529.3	526.8	523.3

A9.3.5.2. Methods for Estimating Carbon Stock Changes and GHG Emissions

a) Living Biomass

The carbon stock changes in living biomass in the area subject to GM activities was calculated from the

carbon stock changes that occurred after conversion and the loss of carbon stock in living biomass due to conversion from pastureland to other land uses. Carbon stock changes were assumed to be zero in Grazing land remaining Grazing land. The estimation equation, parameters and activity data used were the same as Table 6-9, Table 6-11 and section 6.6.2.b) 1).

b) Dead Wood, Litter

As carbon stock changes in dead wood and litter in grassland do not occur as described in section 6.6.1. a), the carbon stock changes for this category was reported as "NA".

c) Soils

1) Mineral Soils

Carbon stock changes in mineral soils in GM were estimated by applying the Tier 3 (Roth C model) estimation method as described in section 6.5.1.b) 3). The activity area used for the estimation excludes the D area.

2) Organic Soils

The relevant emissions reported in grassland (4.C.) in the Inventory were reported. The methodology of the calculations, parameters and activities used are as described in section 6.5.1.b) 3).

d) Other Gases

1) CH_4 Emissions from Drainage of Organic Soils

CH_4 emissions from drainage of organic soils (4.(II)) reported in pastureland in the Inventory were reported. The estimation equation, parameters and the activity data used are as described in section 6.13.

2) N_2O Emissions from Mineralized N Associated with Land Use Change and Management

N_2O emissions generated from land converted to pasture land were calculated using the same methodology, estimation equation and parameters as in section 6.14. The activity area used for the calculation excludes the area subject to D activities.

3) Emissions from Biomass Burning

As open burning in pastureland does not occur in Japan, emissions from biomass burning in GM were reported as "NO".

A9.3.5.3. Method of Accounting and Calculation Results

The reference level approach was applied for mineral soil carbon pools, and net-net approach with 1990 as the base year, as in the second commitment period of the Kyoto Protocol, was applied for other carbon pools and other gasses. The details of the reference level and the accounting quantity are as follows.

a) Reference Level for Mineral soil carbon pool

Application of organic materials into soils increases soil carbon storage in mineral soils. The reference level of mineral soils was set as net CO_2 emissions calculated based on the condition without application of manure, green manure and biochar into soils in each reporting year to ensure the same weather conditions used for the real emissions and removals estimation. Specifically, the Roth C model described above, which also used to estimate real emissions and removals, was used to calculate these reference values (described in Table A 9-15).

b) Calculation Results

The calculation results are as follows.

Table A 9-15 Emissions and removals, and the accounting quantity from GM Activity [kt-CO_2 eq.]

	1990 (base year)	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
GM accounting quantity	-	-802.21	-906.48	-975.42	-1,060.26	-1,046.57	-1,125.03	-1,199.63	-1,214.80	-1,161.43	-1,189.00	-1,143.37
Base year values	-223.67	-223.67	-223.67	-223.67	-223.67	-223.67	-223.67	-223.67	-223.67	-223.67	-223.67	-223.67
RL(Mineral soils)	-	2,732.28	2,581.28	2,474.72	2,463.04	2,077.29	2,069.77	1,603.92	1,429.62	1,909.02	1,998.28	1,896.79
GM net emissions/removals	-	1,706.40	1,451.13	1,275.63	1,179.10	807.04	721.07	180.62	-8.85	523.91	585.61	529.75
Living biomass	-255.00	15.96	18.49	14.63	19.46	32.11	25.06	14.98	15.01	8.73	25.23	26.95
Dead wood	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Litter	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mineral soils	-	1,648.24	1,388.63	1,229.01	1,127.70	743.02	664.13	133.78	-55.67	483.42	528.66	471.11
Organic soils	27.02	36.32	38.04	27.76	27.73	27.70	27.68	27.67	27.62	27.59	27.55	27.53
Other gases	4.31	5.88	5.97	4.22	4.21	4.20	4.20	4.19	4.18	4.17	4.17	4.15
Organic soil drainage (CH_4)	2.37	3.18	3.33	2.43	2.43	2.43	2.43	2.42	2.42	2.42	2.41	2.41
N mineralization in mineral soil (N_2O)	1.94	2.70	2.63	1.79	1.78	1.78	1.77	1.77	1.76	1.76	1.75	1.74
Biomass burning (CH_4, N_2O)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

(CO_2) +: Emissions, -: Removals

A9.3.6. Urban Greening Activity

A9.3.6.1. Method of Identifying Area of Activity

The area subject to urban greening activities is the same as the area of urban green spaces under Settlements (4.E.) in the inventory. Specifically, the total area of green spaces conserved by zoning and urban green facilities under Settlements remaining settlements (4.E.1) is subject to the calculation of this activity. See section 6.8.1 for details of the methods of identifying the area subject to this activity.

Table A 9-16 Area subject to UG activity [kha]

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Area subject to UG	135.2	131.5	129.4	127.6	124.8	122.2	118.9	116.0	110.1	105.8	101.0
Green spaces conserved by zoning	4.5	4.6	4.6	4.6	4.6	4.7	4.7	4.7	3.2	3.1	3.0
Facility green space	130.7	126.9	124.8	123.0	120.1	117.5	114.2	111.3	106.9	102.7	97.9

A9.3.6.2. Methods for Estimating Carbon Stock Changes and GHG Emissions

a) Carbon stock changes

The carbon stock changes in the living biomass, dead wood, litter, and soil carbon pools were the same as the values for urban green space reported as Settlements remaining settlements (4.E.) in the inventory. The methodology for the calculation, parameters and activities are as described in section 6.8.1.

b) Other Gases

1) N_2O Emissions from N Fertilization

Although fertilizer is applied in urban parks in Japan, it is assumed that the amount of nitrogen-based fertilizer applied to urban parks is included in the demand of nitrogen-based fertilizers calculated for in the Agriculture sector. Therefore, it was reported as “IE”.

2) N_2O and CH_4 Emissions from Drainage of Organic Soils

As soil drainage activity for organic soils in settlements subject to UG activity is not conducted in Japan, this category is reported as “NO”.

3) N_2O Emissions due to nitrogen mineralization from land use conversion and management changes

As soil carbon stock changes in settlements subject to UG activity are reported to be on the increases, according to Tier 1 or Tier 2 methods described in *the 2006 IPCC Guidelines*, it is not necessary to estimate N_2O emissions from N immobilization associated with gain of soil organic matter were not estimated. Therefore, N_2O emissions in this subcategory is reported as "NA".

4) Emissions from Biomass Burning

In settlements subject to these activities, burning of residues is strictly restricted by the "Waste Management and Public Cleansing Law" and the "Fire Defense Law". In addition, wildfires do not usually occur in lands subject to UG activity because these lands are managed as a part of urban area. Therefore, biomass burning activities which lead to carbon emissions do not occur and Japan reports this category as "NO".

A9.3.6.3. Method of Accounting and Calculation Results

The accounting quantity was calculated using the gross-net approach. The calculation results are as follows.

Table A 9-17 Emissions and removals, and the accounting quantity from UG Activity [kt-CO_2]

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
UG net removals (accounting quantity)	-1,818.27	-1,788.44	-1,770.88	-1,751.27	-1,713.29	-1,693.81	-1,648.99	-1,608.14	-1,528.68	-1,469.37	-1,399.88
Living biomass	-1,444.31	-1,418.49	-1,405.99	-1,392.09	-1,361.07	-1,350.34	-1,314.42	-1,282.00	-1,213.84	-1,164.53	-1,108.34
Dead wood	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Litter	-18.78	-18.63	-18.47	-18.27	-18.03	-17.69	-17.36	-17.11	-16.69	-16.28	-15.76
Mineral soils	-355.19	-351.31	-346.41	-340.91	-334.18	-325.77	-317.21	-309.03	-298.15	-288.57	-275.77
Organic soils	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other gases	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO
Fertilization (N_2O)	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Organic soil drainage (CH_4, N_2O)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N mineralization in mineral soil (N_2O)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Biomass burning (CH_4, N_2O)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

(CO_2) +: Emissions, -: Removals

A9.3.7. Coastal Wetland Activity

A9.3.7.1. Method of Identifying Area of Activity

The area subject to Coastal Wetlands (BC: blue carbon) activities is the same as the area of coastal wetlands under Wetlands (4.D.) in the inventory. Specifically, the total area of mangroves and seagrass meadow and macroalgal beds under wetlands remaining wetlands (4.D.1) is regarded as subject to this activity. See section 6.8.1 for details of the methods of identifying the area subject to this activity.

Table A 9-18 Area subject to BC activity [kha]

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Area subject to BC	168.3	163.6	158.9	154.2	149.5	157.1	153.6	142.8	142.8	142.9	146.5
Mangrove forests	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
Seagrass meadow and macroalgal beds	167.9	163.3	158.6	153.9	149.2	156.8	153.2	142.4	142.4	142.6	146.2

A9.3.7.2. Methods for Estimation for Carbon Stock Changes and GHG Emissions

a) Carbon stock changes and Sequestrated Carbon

The carbon stock changes in the living biomass, dead wood, litter, and soil carbon pools in mangroves and sequestrated carbon from seagrass meadows and macroalgal beds were the same values as those for coastal wetlands reported as wetlands remaining wetlands (4.D.1) in the inventory. The methodology for the estimation, parameters and activities are as described in section 6.7.1.b).

b) Other Gases

BC activities do not include sources of non-CO_2 gases emissions, and therefore this category is reported as "NO".

A9.3.7.3. Method of Accounting and Calculation Results

The accounting quantity was calculated using the gross-net approach. The calculation results are as follows.

Table A 9-19 Emissions and removals, and the accounting quantity from BC Activity [kt-CO_2]

			2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
BC net removals (accounting quantity)			-355.64	-352.28	-349.89	-347.15	-344.91	-359.81	-347.16	-308.99	-317.62	-302.80	-323.07
	Living biomass		-0.59	-0.05	-0.33	-0.32	-0.72	-0.65	-0.69	-0.68	-0.67	-0.66	-0.65
	Dead wood		-0.09	-0.01	-0.05	-0.05	-0.12	-0.10	-0.11	-0.11	-0.11	-0.11	-0.10
	Litter		-0.01	0.00	0.00	0.00	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01	-0.01
	Mineral soils		-354.95	-352.22	-349.50	-346.77	-344.06	-359.05	-346.35	-308.19	-316.84	-302.02	-322.31
	Organic soils		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Other gases		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		Fertilization (N_2O)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		Organic soil drainage (CH_4, N_2O)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		N mineralization in mineral soil (N_2O)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		Biomass burning (CH_4, N_2O)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

(CO_2) +: Emissions, -: Removals

A9.4. Others

A9.4.1. Scope of Estimation

There are some sink activities in addition to the LULUCF activities in the *Plan for Global Warming Countermeasures* of Japan, one of which is the sink measure by CO_2-removing concrete (hereafter referred to as "environmentally friendly concrete"). Of the various types of environmentally friendly concrete, only the concrete using biochar, whose fixation amount is not subtracted from the emissions by sources, is included under "Others". The details of classification of environmentally friendly concrete are described in Section 4.9.5.1.

A9.4.1.1. Concrete using Biochar

A9.4.1.1.a. Method of Identifying Activity data

The activity data are described in Section 4.9.5.1.

A9.4.1.1.b. Methods for Estimation for CO_2 Fixation

The estimation method for CO_2 fixation is described in Section 4.9.5.1.

A9.4.1.1.c. Method of Accounting and Calculation Results

The fixed amount for each year was used as the accounting quantity. The results of the estimation are shown below.

Table A 9-20 Emissions and removals, and accounting quantity from others [kt-CO_2]

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
Others net removals (accounting quantity)	NO	NO	NO	NO	NO	NO	NO	NO	-0.006	-0.099	-0.098
Concrete using biochar	NO	NO	NO	NO	NO	NO	NO	NO	-0.006	-0.099	-0.098

References

1. IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2006.
2. IPCC, *2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol*, 2014.
3. Ministry of Agriculture, Forestry and Fisheries, *Statistics of Cultivated and Planted Area* (Survey of Cropland area)
4. Forestry Agency, *National Forest Resources Database*.
5. Forestry Agency, *"FY2024 Report on Forest GHG Inventory Information Development Project (FM Forests Survey)" (in Japanese)*, 2025
6. Coleman, K. & Jenkinson D. S., *Roth C-26.3 - A model for the turnover of carbon in soil. In Evaluation of Soil Organic Matter Models: Using Existing Long-Term Datasets*, Ed. D. S. Powlson, P. Smith & J. U. Smith, p. 237-246, Springer, Berlin, 1996

Abbreviations

1. Greenhouse Gases

Table AB-1 Greenhouse Gases

Term	Gas
CO_2	Carbon dioxide
CH_4	Methane
N_2O	Nitrous oxide
HFCs	Hydrofluorocarbons
PFCs	Perfluorocarbons
SF_6	Sulfur hexafluoride
NF_3	Nitrogen trifluoride

Table AB-2 Precursors and SO_x

Term	Gas
NO_x	Nitrogen oxides
CO	Carbon monoxide
NMVOC	Non-methane volatile organic compounds
SO_x	Sulfur oxide

2. Prefixes and Units

Table AB-3 Prefixes

Term	Prefix	Definition
P	peta	10^{15}
T	tera	10^{12}
G	giga	10^{9}
M	mega	10^{6}
k	kilo	10^{3}
h	hecto	10^{2}
da	deca	10^{1}
d	deci	10^{-1}
c	centi	10^{-2}
m	milli	10^{-3}
μ	micro	10^{-6}

Table AB-4 Units

Term	Definition
m^3	cubic metre (=kL)
L	liter
a	are
ha	hectare
g	gram
t	tonne (=1,000 kg)
J	joule
°C	degree Celsius
yr	year
cap	capita
d.m.	dry matter

3. Notation Keys

Table AB-5 Notation keys (See Annex 6 for details)

Notation Key	Definition
NO	Not Occurring
NE	Not Estimated
NA	Not Applicable
IE	Included Elsewhere
C	Confidential
IO	Instantaneous Oxidation

4. Other Abbreviations

Table AB-6 Abbreviations

	Terms	Definition
A	AD	Activity Data
	ARD	Afforestation, Reforestation and Deforestation

	Terms	Definition
B	BFG	Blast Furnace Gas
	BOD	Biochemical Oxygen Demand
C	CFG	Converter Furnace Gas
	CGER	Center for Global Environmental Research
	CM	Cropland Management
	CO_2 eq.	Gas Emission in CO_2 equivalent
	COD	Chemical Oxygen Demand
	COG	Coke Oven Gas
	CRT	Common Reporting Tables
	CS	Country-Specific
	CY	Calendar Year
E	EEA	European Environment Agency
	EF	Emission Factor
	EMEP	European Monitoring and Evaluation Programme
D	DWW	Domestic Wastewater
F	FM	Forest Management
	FY	Fiscal Year
G	GCV	Gross Calorific Value
	GHG	Greenhouse Gas
	GIO	Greenhouse Gas Inventory Office
	GM	Grazing Land Management
	GPG-LULUCF	Good Practice Guidance for Land Use, Land-Use Change and Forestry
	GWP	Global Warming Potential
I	IEA	International Energy Agency
	IEF	Implied Emission Factor
	IPCC	Intergovernmental Panel on Climate Change
	IW	Industrial Waste
	IWW	Industrial Wastewater
J	JNGI	Japanese National GHG Inventory
K	KP	Kyoto Protocol
L	LNG	Liquefied Natural Gas
	LPG	Liquefied Petroleum Gas
	LTO	Landing and Take-off
	LULUCF	Land Use, Land-Use Change and Forestry
M	MAFF	Ministry of Agriculture, Forestry and Fisheries
	MDI	Metered Dose Inhalers
	METI	Ministry of Economy, Trade and Industry
	MOE	Ministry of the Environment
	MLIT	Ministry of Land, Infrastructure and Transport and Tourism
	MSW	Municipal Solid Waste
	MW	Municipal Waste
N	NCV	Net Calorific Value
	NDC	Nationally Determined Contribution
	NFRDB	National Forest Resource Data Base
	NGL	Natural Gas Liquids
	NID	National Inventory Document
	NIES	National Institute for Environmental Studies
Q	QA/QC	Quality Assurance / Quality Control
	QAWG	Quality Assurance Working Group
R	RDF	Refuse Derived Fuel
	RPF	Refuse Paper and Plastic Fuel
	RV	Revegetation
S	SCIW	Specially-Controlled Industrial Waste
T	THC	Total Hydrocarbon
U	UG	Urban Greening
	UNFCCC	United Nations Framework Convention on Climate Change