National Greenhouse Gas Inventory Document of JAPAN

2024

Ministry of the Environment, Japan

Greenhouse Gas Inventory Office of Japan (GIO), CGER, NIES

Center for Global Environmental Research

National Institute for Environmental Studies, Japan

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Foreword

On the basis of Article 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 described in the *2006 IPCC Guidelines*. Chapter 8 comprises current status of reporting of the emissions from sources not covered by these guidelines. 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, 2024
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 over 60 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. Wakana Taki, together with Ms. Akiko Higuchi, Ms. Takako Takagi, and Ms. Sachiyo Harigae, our assistants, who supported us with the smooth operation of GIO.

April, 2024

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Table of Contents

Foreword i
Preface iii
Contents v

EXECUTIVE SUMMARY OF THE NATIONAL GHG INVENTORY DOCUMENT OF JAPAN 1
E.S.1. Background Information on the GHG Inventory 1
E.S.2. Summary of National Emission and Removal Related Trends 2
E.S.3. Overview of Source and Sink Category Emission Estimates and Trends 4
E.S.4. Brief Description of Key Categories 6
E.S.5. Improvements Introduced 6

CHAPTER 1. NATIONAL INSTITUTIONAL ARRANGEMENTS AND CROSS-CUTTING INFORMATION 1-1
1.1. Background Information on Japan's Greenhouse Gas Inventory and Climate Change 1-1
1.2. Description of Japan's National Circumstances and Inventory Arrangements 1-1
1.2.1. Japan's National Entity for Inventory Preparation and Other Institutional, Legal and Procedural Arrangements 1-1
1.2.1.1. Institutional and Legal Arrangements for the Inventory Preparation 1-1
1.2.1.2. Roles and Responsibilities of Each Entity Involved in the Inventory Preparation Process 1-3
1.2.1.3. Response for Inventory Review 1-5
1.2.2. Inventory Preparation Process 1-6
1.2.2.1. Annual Cycle of Inventory Preparation 1-6
1.2.2.2. Process of the Inventory Preparation 1-7
1.2.3. Documentation and Archiving of Inventory Information 1-8
1.2.3.1. Documentation of Information 1-9
1.2.3.2. Archiving of Electronic Information 1-9
1.2.3.3. Archiving in Printed Form 1-9
1.2.4. Process for Official Consideration and Approval of the Inventory 1-10
1.3. Brief General Description of Methodologies (Including Tiers Used) and Data Sources Used 1-10
1.3.1. Collection of Activity Data 1-10
1.3.2. Selection of Emission Factors and Estimation Methods 1-11
1.3.3. Improvement Process of Estimations for Emissions and Removal 1-11
1.4. Brief Description of Key Categories 1-12
1.5. Brief General Description of the QA/QC Plan and Implementation 1-16
1.6. General Uncertainty Assessment, Including Data Pertaining to the Overall Uncertainty of the Inventory Total 1-16
1.7. General Assessment of the Completeness 1-17
1.7.1. Information on Completeness 1-17
1.7.2. Description of Insignificant Categories 1-17
1.7.3. Total Aggregate Emissions Considered Insignificant 1-17
1.8. Metrics Used 1-17

CHAPTER 2. TRENDS IN GHG EMISSIONS AND REMOVALS 2-1
2.1. Description and Interpretation of Emission and Removal Trends for Aggregate GHGs 2-1
2.1.1. Overview of GHGs Emissions and Removals 2-1
2.1.2. CO_2 2-4
2.1.3. CH_4 2-7
2.1.4. N_2O 2-8
2.1.5. HFCs 2-9
2.1.6. PFCs 2-10
2.1.7. SF_6 2-11
2.1.8. NF_3 2-12
2.1.9. Indirect CO_2 2-13
2.2. Description and Interpretation of Emission and Removal Trends by Categories 2-14
2.2.1. Energy 2-16
2.2.2. Industrial Processes and Product Use 2-16
2.2.3. Agriculture 2-18
2.2.4. Land Use, Land Use Change and Forestry (LULUCF) 2-19
2.2.5. Waste 2-20
2.2.6. Indirect CO_2 2-20
2.3. Description and Interpretation of Emission Trends for Indirect GHGs and SO_X 2-21

CHAPTER 3. ENERGY (CRT SECTOR 1) 3-1
3.1. Overview of Sector 3-1
3.2. Fuel Combustion (1.A) 3-1
3.2.1. Comparison of the Sectoral Approach with the Reference Approach 3-4
3.2.1.1. Detailed Description of the Reference Approach (CRT Table 1.A(b)) 3-4
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)) 3-5
3.2.2. International Bunker Fuels (CRT Table 1.D) 3-10
3.2.3. Feedstocks and Non-Energy Use of Fuels (CRT Table 1.A(d)) 3-13
3.2.4. CO_2 Emissions from Energy Industries (1.A.1: CO_2) 3-15
3.2.5. CH_4 and N_2O Emissions from Energy Industries (1.A.1: CH_4, N_2O) 3-33
3.2.6. CO_2 Emissions from Manufacturing Industries and Construction (1.A.2: CO_2) 3-45
3.2.7. CH_4 and N_2O Emissions from Manufacturing Industries and Construction (1.A.2: CH_4, N_2O) 3-48
3.2.8. CO_2 Emissions from Transport (1.A.3: CO_2) 3-52
3.2.9. CH_4 and N_2O Emissions from Transport (1.A.3: CH_4, N_2O) 3-55
3.2.9.1. Domestic Aviation (1.A.3.a) 3-56
3.2.9.2. Road Transportation (1.A.3.b) 3-58
3.2.9.3. Railways (1.A.3.c) 3-69
3.2.9.4. Domestic Navigation (1.A.3.d) 3-71
3.2.9.5. Other Transportation (1.A.3.e) 3-73
3.2.10. CO_2 Emissions from Other Sectors and Other (1.A.4, 1.A.5: CO_2) 3-73
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) 3-76

3.2.12. Emissions from waste incineration with energy recovery 3-78
3.3. Fugitive Emissions from Fuels (1.B) 3-83
3.3.1. Solid Fuels (1.B.1) 3-83
3.3.1.1. Coal Mining and Handling (1.B.1.a) 3-83
3.3.1.2. Fuel Transformation (1.B.1.b) 3-91
3.3.1.3. Others (Uncontrolled combustion and burning coal dumps) (1.B.1.c) 3-95
3.3.2. Oil, Natural Gas and Other Emissions from Energy Production (1.B.2) 3-95
3.3.2.1. Oil (1.B.2.a) 3-95
3.3.2.2. Natural Gas (1.B.2.b) 3-104
3.3.2.3. Venting and Flaring (1.B.2.c) 3-116
3.3.2.4. Other (Fugitive Emissions Associated with the Geothermal Power Generation) (1.B.2.d) 3-119
3.4. CO_2 transport and storage (1.C) 3-122
3.4.1. Transport of CO_2 (1.C.1) 3-122
3.4.1.1. Pipelines (1.C.1.a) 3-122
3.4.1.2. Ships (1.C.1.b) 3-122
3.4.1.3. Other (1.C.1.c) 3-123
3.4.2. Injection and Storage (1.C.2) 3-123
3.4.2.1. Injection (1.C.2.a) 3-123
3.4.2.2. Storage (1.C.2.b) 3-123
3.4.3. Other (1.C.3) 3-124
3.4.4. Information item 3-124

CHAPTER 4. INDUSTRIAL PROCESSES AND PRODUCT USE (CRT SECTOR 2) 4-1
4.1. Overview of Sector 4-1
4.2. Mineral Industry (2.A.) 4-3
4.2.1. Cement Production (2.A.1.) 4-4
4.2.2. Lime Production (2.A.2.) 4-7
4.2.3. Glass Production (2.A.3.) 4-9
4.2.4. Other Process Uses of Carbonates (2.A.4.) 4-12
4.2.4.1. Ceramics (2.A.4.a.) 4-12
4.2.4.2. Other uses of soda ash (2.A.4.b.) 4-14
4.2.4.3. Non-metallurgical Magnesium Production (2.A.4.c.) 4-15
4.2.4.4. Other – Desulfurization of Exhaust Gas and Chemical Products (2.A.4.d.-) 4-15
4.3. Chemical Industry (2.B.) 4-17
4.3.1. Ammonia Production (2.B.1.) 4-18
4.3.2. Nitric Acid Production (2.B.2.) 4-20
4.3.3. Adipic Acid Production (2.B.3.) 4-21
4.3.4. Caprolactam, Glyoxal and Glyoxylic Acid Production (2.B.4.) 4-23
4.3.4.1. Caprolactam (2.B.4.a.) 4-23
4.3.4.2. Glyoxal (2.B.4.b.) 4-24
4.3.4.3. Glyoxylic acid (2.B.4.c.) 4-25
4.3.5. Carbide Production (2.B.5.) 4-26
4.3.5.1. Silicon Carbide (2.B.5.a.) 4-26
4.3.5.2. Calcium Carbide (2.B.5.b.) 4-27

4.3.6. Titanium Dioxide Production (2.B.6.) 4-29
4.3.7. Soda Ash Production (2.B.7.) 4-31
4.3.8. Petrochemical and Carbon Black Production (2.B.8.) 4-31
4.3.8.1. Methanol (2.B.8.a.) 4-31
4.3.8.2. Ethylene (2.B.8.b.) 4-32
4.3.8.3. 1,2-Dichloroethane and Chloroethylene (2.B.8.c.) 4-34
4.3.8.4. Ethylene Oxide (2.B.8.d.) 4-36
4.3.8.5. Acrylonitrile (2.B.8.e.) 4-38
4.3.8.6. Carbon Black (2.B.8.f.) 4-40
4.3.8.7. Other (2.b.8.g.) 4-42
4.3.9. Fluorochemical Production (2.B.9.) 4-46
4.3.9.1. By-product Emissions - Production of HCFC-22 (2.B.9.a.i.) 4-46
4.3.9.2. Fugitive Emissions (2.B.9.b.) 4-47
4.3.10. Other (2.B.10.) 4-49
4.3.10.1. Hydrogen Production(2.B.10.a.) 4-49
4.3.10.2. Other – Utilization of Carbonated Gas (2.B.10.b.-) 4-50
4.4. Metal Industry (2.C.) 4-50
4.4.1. Iron and Steel Production (2.C.1.) 4-51
4.4.1.1. Steel (2.C.1.a.) 4-52
4.4.1.2. Use of Electric Arc Furnaces in Steel Production (2.C.1.a.) 4-52
4.4.1.3. Pig Iron (2.C.1.b.) 4-54
4.4.1.4. Limestone and Dolomite Use in Iron and Steel Production (2.C.1.b.) 4-54
4.4.1.5. By-product Gas Flaring in Iron and Steel Production (2.C.1.b.) 4-55
4.4.1.6. Direct Reduced Iron (2.C.1.c.) 4-57
4.4.1.7. Sinter (2.C.1.d.) 4-57
4.4.1.8. Pellet (2.C.1.e.) 4-57
4.4.1.9. Other – Utilization of Carbonated Gas (2.C.1.f.-) 4-57
4.4.2. Ferroalloys Production (2.C.2.) 4-58
4.4.3. Aluminum Production (2.C.3.) 4-59
4.4.3.1. By-product emissions (2.C.3.a.) 4-59
4.4.3.2. F-gases used in foundries (2.C.3.b.) 4-61
4.4.4. Magnesium Production (2.C.4.) 4-61
4.4.5. Lead Production (2.C.5.) 4-62
4.4.6. Zinc Production (2.C.6.) 4-62
4.4.7. Other – Rare Earths Production (2.C.7.a.) 4-63
4.5. Non-energy Products from Fuels and Solvent Use (2.D.) 4-63
4.5.1. Lubricant Use (2.D.1.) 4-63
4.5.2. Paraffin Wax Use (2.D.2.) 4-65
4.5.3. Other (2.D.3.) 4-66
4.5.3.1. Road Paving with Asphalt (2.D.3.b.) 4-66
4.5.3.2. Asphalt Roofing (2.D.3.c.) 4-66
4.5.3.3. Urea used as a catalyst (2.D.3.d.-) 4-66
4.5.3.4. NMVOC Incineration (2.D.3.d.-) 4-68
4.6. Electronics Industry (2.E.) 4-70
4.6.1. Semiconductor (2.E.1.) 4-70

4.6.2. Liquid Crystals (2.E.2.) 4-73
4.6.3. Photovoltaics (2.E.3.) 4-75
4.6.4. Heat Transfer Fluid (2.E.4.) 4-76
4.6.5. Other – Microelectromechanical systems (2.E.5.a.) 4-76
4.7. Product Uses as Substitutes for ODS (2.F.) 4-76
4.7.1. Refrigeration and Air Conditioning Equipment (2.F.1.) 4-77
4.7.1.1. Commercial Refrigeration (2.F.1.a.) 4-77
4.7.1.2. Domestic Refrigeration (2.F.1.b.) 4-82
4.7.1.3. Industrial Refrigeration (2.F.1.c.) 4-84
4.7.1.4. Transport Refrigeration (2.F.1.d.) 4-84
4.7.1.5. Mobile Air-Conditioning (2.F.1.e.) 4-86
4.7.1.6. Stationary Air-Conditioning (Household) (2.F.1.f.) 4-88
4.7.2. Foam Blowing Agents (2.F.2.) 4-90
4.7.2.1. Closed Cells (2.F.2.a.) 4-90
4.7.2.2. Open Cells (2.F.2.b.) 4-93
4.7.3. Fire Protection (2.F.3.) 4-94
4.7.4. Aerosols (2.F.4.) 4-97
4.7.4.1. Metered Dose Inhalers (2.F.4.a.) 4-97
4.7.4.2. Other – Aerosols (2.F.4.b.-) 4-99
4.7.5. Solvents (2.F.5.) 4-101
4.7.6. Other Applications (2.F.6.) 4-103
4.8. Other Product Manufacture and Use (2.G.) 4-103
4.8.1. Electrical Equipment (2.G.1.) 4-104
4.8.2. SF_6 and PFCs from Other Product Use (2.G.2.) 4-106
4.8.2.1. Military Applications (2.G.2.a.) 4-106
4.8.2.2. Accelerators (2.G.2.b.) 4-107
4.8.2.3. Soundproof windows (2.G.2.c.) 4-108
4.8.2.4. Adiabatic properties: shoes and tyres (2.G.2.d.) 4-108
4.8.2.5. Other – Railway Silicon Rectifiers (2.G.2.e.ii.-) 4-108
4.8.3. N_2O from Product Uses - Medical Applications (2.G.3.a.) 4-109
4.8.4. Other – PFCs and HFCs from Waterproofing electronic circuits (2.G.4.-) 4-110
4.9. Other (2.H.) 4-111
4.9.1. Reporting Related to Direct Utilization of CO_2 4-112
4.9.2. Food and Beverages Industry (2.H.2.) 4-113
4.9.3. Emissions from Imported Carbonated Gas (2.H.3.-) 4-114
4.9.4. Utilization of Carbonated Gas (2.H.3.-) 4-114
4.9.5. Environmentally Friendly Concrete 4-115
4.9.5.1. CO_2 Fixing Concrete During Manufacturing (2.H.3.-) 4-115
4.9.5.2. Concrete Using CO_2-origin Material (1.A.2.c., 1.A.2.d., 1.A.2.f.) 4-116
4.9.5.3. Concrete Using Biochar (4.H.) 4-118

CHAPTER 5. AGRICULTURE (CRT SECTOR 3) 5-1
5.1. Overview of Sector 5-1
5.2. Enteric Fermentation (3.A.) 5-2
5.2.1. Cattle (3.A.1.) 5-2

5.2.2. Sheep, Swine, Buffalo, Goats & Horses (3.A.2., 3.A.3., 3.A.4.-) 5-9
5.2.3. Other Livestock (3.A.4.-) 5-11
5.3. Manure Management (3.B.) 5-11
5.3.1. Cattle, Swine and Poultry (Hen and Broiler) (3.B.1., 3.B.3., 3.B.4.-) 5-12
5.3.2. Sheep, Buffalo, Goats, Horses, Rabbit and Mink (3.B.2., 3.B.4.-) 5-33
5.3.3. Other Livestock (3.B.4.-) 5-35
5.3.4. Indirect N_2O emissions (3.B.5.) 5-35
5.3.4.1. Atmospheric Deposition (3.B.5.-) 5-35
5.3.4.2. Nitrogen Leaching and Run-off (3.B.5.-) 5-38
5.4. Rice Cultivation (3.C.) 5-38
5.4.1. Irrigated (Continuously Flooded and Intermittently Flooded (Single Aeration)) (3.C.1.) 5-38
5.4.2. Rain-fed, Deep Water and Other (3.C.2., 3.C.3., 3.C.4.) 5-46
5.5. Agricultural Soils (3.D.) 5-47
5.5.1. Direct N_2O Emissions from Managed Soils (3.D.1.) 5-47
5.5.1.1. Inorganic N Fertilizers (3.D.1.a.) 5-47
5.5.1.2. Organic N Fertilizers (3.D.1.b.) 5-51
5.5.1.3. Urine and Dung Deposited by Grazing Animals (3.D.1.c.) 5-56
5.5.1.4. Crop Residues (3.D.1.d.) 5-56
5.5.1.5. Mineralization/Immobilization Associated with Loss/Gain of Soil Organic Matter (3.D.1.e.) 5-60
5.5.1.6. Cultivation of Organic Soils (3.D.1.f.) 5-62
5.5.2. Indirect N_2O Emissions from Managed Soils (3.D.2.) 5-65
5.5.2.1. Atmospheric Deposition (3.D.2.a.) 5-65
5.5.2.2. Nitrogen Leaching and Run-off (3.D.2.b.) 5-67
5.6. Prescribed Burning of Savannahs (3.E.) 5-69
5.7. Field Burning of Agricultural Residues (3.F.) 5-69
5.8. Liming (3.G.) 5-72
5.9. Urea application (3.H.) 5-73
5.10. Other Carbon-containing Fertilizers (3.I.) 5-74
5.11. Other (3.J.) 5-74

CHAPTER 6. LAND USE, LAND-USE CHANGE AND FORESTRY (CRT SECTOR 4) 6-1
6.1. Overview of Sector 6-1
6.2. Land-use definitions and the land representation approaches used and their correspondence to the LULUCF categories 6-2
6.2.1. Method of determining the area of each land-use category 6-2
6.2.2. Method of estimating the area converted from other land uses 6-4
6.2.3. Land-use transition matrix 6-7
6.3. Country-specific approaches 6-8
6.3.1. Parameters for estimating carbon stock changes due to land-use conversions 6-8
6.3.2. Information on approaches used for natural disturbances 6-13
6.3.3. Information on approaches used for reporting harvested wood products 6-13
6.4. Forest land (4.A.) 6-13
6.4.1. Forest land remaining Forest land (4.A.1.) 6-15

6.4.2. Land converted to Forest land (4.A.2.) 6-27
6.5. Cropland (4.B.) 6-32
6.5.1. Cropland remaining Cropland (4.B.1.) 6-33
6.5.2. Land converted to Cropland (4.B.2.) 6-42
6.6. Grassland (4.C.) 6-47
6.6.1. Grassland remaining Grassland (4.C.1.) 6-48
6.6.2. Land converted to Grassland (4.C.2.) 6-51
6.7. Wetlands (4.D.) 6-55
6.7.1. Wetlands remaining Wetlands (4.D.1.) 6-55
6.7.2. Land converted to Wetlands (4.D.2.) 6-66
6.8. Settlements (4.E.) 6-69
6.8.1. Settlements remaining Settlements (4.E.1.) 6-71
6.8.2. Land converted to Settlements (4.E.2.) 6-82
6.9. Other land (4.F.) 6-86
6.9.1. Other land remaining Other land (4.F.1.) 6-87
6.9.2. Land converted to Other land (4.F.2.) 6-87
6.10. Harvested Wood Products (4.G.) 6-91
6.10.1. Buildings 6-91
6.10.2. Wood for other uses than buildings 6-96
6.10.3. Paper and paperboard 6-100
6.11. Other (4.H.) 6-103
6.11.1. Concrete using Biochar 6-103
6.12. Direct /Indirect N_2O emissions from N inputs to managed soils (4.(I)) 6-103
6.13. CH_4 and N_2O Emissions from Drainage and Other Management of Organic soils (4.(II)) 6-106
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)) 6-109
6.15. Biomass burning (4.(IV)) 6-113

CHAPTER 7. WASTE (CRT SECTOR 5) 7-1
7.1. Overview of Sector 7-1
7.1.1. Overview of Waste Management and Estimation Category 7-1
7.1.2. Overview of Greenhouse Gas Emissions on Waste Sector 7-2
7.1.3. General Description for Methodological Issues on the Waste Sector 7-3
7.1.4. General Assessment Procedure for the Uncertainty on the Waste Sector 7-4
7.1.5. General Recalculations for Emissions from Waste Sector 7-5
7.2. Solid Waste Disposal (5.A.) 7-6
7.2.1. Managed Disposal Sites (5.A.1.) 7-7
7.2.2. Unmanaged Waste Disposal Sites (5.A.2.) 7-19
7.2.3. Uncategorized Waste Disposal Sites (5.A.3.) 7-19
7.2.3.1. Inappropriate Disposal (5.A.3.-) 7-19
7.3. Biological Treatment of Solid Waste (5.B.) 7-22
7.3.1. Composting (5.B.1) 7-22
7.3.2. Anaerobic Digestion at Biogas Facilities (5.B.2.) 7-25
7.4. Incineration and Open Burning of Waste (5.C.) 7-26

7.4.1. Waste Incineration (without Energy Recovery) (5.C.1.) 7-31
7.4.1.1. Municipal Solid Waste (5.C.1.-) 7-31
7.4.1.2. Industrial Waste (5.C.1.-) 7-41
7.4.1.3. Specially-controlled Industrial Waste (5.C.1.-) 7-49
7.4.2. Open Burning of Waste (5.C.2.) 7-53
7.4.2.1. Municipal Solid Waste (5.C.2.-) 7-53
7.4.2.2. Industrial Waste (5.C.2.-) 7-53
7.4.3. Waste Incineration and Energy Use (Reported on Energy Sector) (1.A.) 7-56
7.4.3.1. Waste Incineration with Energy Recovery (1.A.) 7-56
7.4.3.2. Direct Use of Waste as Alternative Fuel (1.A.) 7-58
7.4.3.3. Incineration of Waste Processed as Fuel (1.A.) 7-68
7.5. Wastewater Treatment and Discharge (5.D.) 7-74
7.5.1. Domestic Wastewater (5.D.1.) 7-75
7.5.1.1. Sewage Treatment Plant (5.D.1.-) 7-76
7.5.1.2. Domestic Sewage Treatment Plant (Mainly *Johkasou*) (5.D.1.-) 7-78
7.5.1.3. Human Waste Treatment Plant (5.D.1.-) 7-81
7.5.1.4. Natural Decomposition of Domestic Wastewater (5.D.1.-) 7-85
7.5.2. Industrial Wastewater (5.D.2.) 7-90
7.5.2.1. Industrial Wastewater Treatment (5.D.2.-) 7-90
7.5.2.2. Natural Decomposition of Industrial Wastewater (5.D.2.-) 7-94
7.5.2.3. Landfill Leachate Treatment (5.D.2.-) 7-97
7.6. Other (5.E.) 7-101
7.6.1. Decomposition of Fossil-fuel Derived Surfactants (5.E.-) 7-101

CHAPTER 8. OTHER (CRT SECTOR 6) 8-1
8.1. Overview of Sector 8-1
8.2. CO_2, CH_4, N_2O, HFCs, PFCs, SF_6, and NF_3 8-1
8.3. NO_X, CO, NMVOC, and SO_X 8-1

CHAPTER 9. INDIRECT CARBON DIOXIDE AND NITROUS OXIDE EMISSIONS 9-1
9.1. Overview of Sector 9-1

CHAPTER 10. RECALCULATION AND IMPROVEMENTS 10-1
10.1. Explanations and Justifications for Recalculations 10-1
10.2. Implications for Emission and Removal Levels 10-1
10.3. Implication for Emission and Removal Trends, including Time-series Consistency 10-8
10.4. Areas of improvement and planned improvements 10-8
10.4.1. Improvements after submission of the inventory 10-8
10.4.2. Planned Improvements 10-10

ANNEX 1. KEY CATEGORIES ANNEX1-1
A1.1. Outline of Key Category Analysis Annex1-1
A1.2. Results of Key Category Analysis Annex1-1

ANNEX 2. ASSESSMENT OF UNCERTAINTY ANNEX2-1

A2.1. Methodology of Uncertainty Assessment Annex2-1
A2.2. Results of Uncertainty Assessment Annex2-1

ANNEX 3. NATIONAL ENERGY BALANCE ANNEX3-1
A3.1. Discrepancies between the figures reported in the CRF tables and the IEA statistics Annex3-1
A3.2. General Energy Statistics Annex3-11
A3.3. Quality Standard for Diesel Oil Annex3-21
A3.4. Conversion factors of calorific values Annex3-21

ANNEX 4. QUALITY ASSURANCE/QUALITY CONTROL (QA/QC) PLAN ANNEX4-1
A4.1. QA/QC Procedures Applied Annex4-1
A4.2. Verification Activities Annex4-4
A4.3. Treatment of Confidential Information Annex4-4

ANNEX 5. DETAILED METHODOLOGICAL DESCRIPTIONS FOR INDIVIDUAL SOURCE OR SINK CATEGORIES ANNEX5-1
A5.1. Methodology for Estimating Emissions of Precursors Annex5-1
A5.1.1 Energy Sector Annex5-1
A5.1.2 Industrial Processes and Product Use (IPPU) Annex5-26
A5.1.3 Agriculture Annex5-65
A5.1.4 Land Use, Land-Use Change and Forestry Annex5-65
A5.1.5 Waste Annex5-67
A5.1.6 Other sectors Annex5-71

ANNEX 6. ASSESSMENT OF COMPLETENESS, DEFINITION OF NOTATION KEYS, AND SOURCES AND SINKS REPORTED AS “NE” ANNEX6-1
A6.1. Assessment of Completeness Annex6-1
A6.2. Definition of Notation Keys Annex6-1
A6.3. Decision Tree for Application of Notation Keys Annex6-2
A6.4. Emission sources reported as “NE” (considered insignificant) in Japan Annex6-3
A6.5. Other Source and sink categories not estimated in Japan’s inventory Annex6-4

ANNEX 7. HIERARCHICAL STRUCTURE OF JAPAN’S NATIONAL GHG INVENTORY FILE SYSTEM ANNEX7-1

ANNEX 8. COMMON REPORTING TABLES ANNEX8-1

ANNEX 9. METHODOLOGICAL DETAILS OF THE LULUCF SECTOR ACCOUNTING IN THE NDC ANNEX9-1
A9.1. Summary of Greenhouse Gas (GHG) Emissions by Sources and Removals by Sinks in the LULUCF Sector in the NDC Annex9-1
A9.1.1 Activities Subject to GHG Emissions and Removals Estimation, Their Scope, and Estimation Methodology Tiers in the LULUCF Sector in the

NDC ____ Annex9-1
A9.1.2 Accounting Approach and Accounting Quantity for each NDC-LULUCF Activity ____ Annex9-2
A9.2. Scope of Estimations for each NDC-LULUCF Activity ____ Annex9-2
A9.2.1 Afforestation/Reforestation (AR) ____ Annex9-2
A9.2.2 Deforestation (D) ____ Annex9-3
A9.2.3 Forest Management (FM) ____ Annex9-3
A9.2.4 Cropland Management (CM) ____ Annex9-3
A9.2.5 Grazing land Management (GM) ____ Annex9-3
A9.2.6 Urban Greening (UG) ____ Annex9-3
A9.3. Methods for Estimating and Accounting for GHG Emissions and Removals for each NDC-LULUCF Activity ____ Annex9-4
A9.3.1 Afforestation and Reforestation Activities ____ Annex9-4
A9.3.2 Deforestation Activity ____ Annex9-6
A9.3.3 Forest Management ____ Annex9-8
A9.3.4 Cropland Management ____ Annex9-13
A9.3.5 Grazing Land Management ____ Annex9-15
A9.3.6 Urban Greening Activity ____ Annex9-16

Abbreviations

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 FY2022[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 emissions and estimated on a fiscal year basis. "CY" stands for "calendar year".

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

Total GHGs emissions[2] in FY2022 (excluding LULUCF[3], including indirect CO_2[4], hereafter, definition omitted) were 1,135 million tonnes (in CO_2 eq.). They decreased by 10.9% compared to the emissions in FY1990.

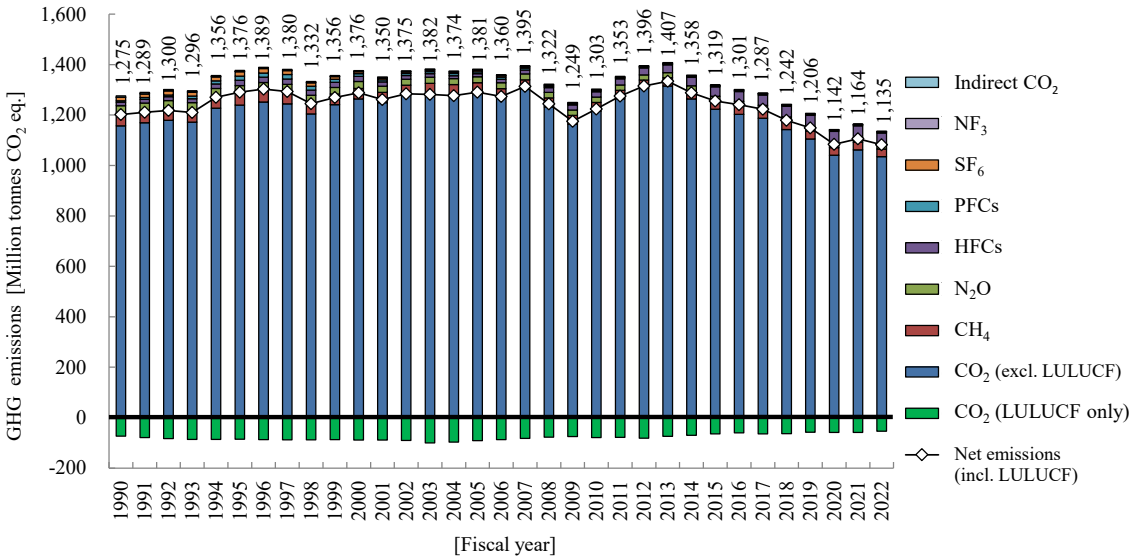

Figure 1 Trends in GHG emissions and removals in Japan

[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

[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	1,157.4	1,169.1	1,178.9	1,171.9	1,226.9	1,239.2	1,251.7	1,244.4	1,204.6	1,241.2	1,264.0	1,249.4	1,279.0	1,287.5	1,282.9	1,290.3	1,267.3	1,303.0	1,232.2	1,163.4
CO_2 (incl. LULUCF) *1	1	1,083.7	1,089.8	1,095.8	1,085.6	1,140.7	1,153.4	1,164.7	1,156.6	1,116.6	1,153.8	1,175.5	1,160.2	1,188.2	1,186.9	1,185.7	1,198.7	1,180.3	1,220.7	1,154.5	1,088.3
CO_2 (LULUCF only)	1	-73.7	-79.2	-83.0	-86.3	-86.2	-85.9	-87.0	-87.9	-88.0	-87.4	-88.5	-89.2	-90.8	-100.6	-97.2	-91.6	-87.0	-82.3	-77.7	-75.0
CH_4 (excl. LULUCF)	28	49.8	49.1	49.0	48.0	48.1	46.7	45.3	44.8	42.9	42.5	41.7	40.4	39.5	38.5	38.2	38.2	37.5	36.8	35.9	35.3
CH_4 (incl. LULUCF)	28	49.9	49.2	49.1	48.1	48.2	46.8	45.4	44.9	43.0	42.6	41.8	40.5	39.6	38.6	38.3	38.2	37.6	36.9	36.1	35.4
N_2O (excl. LULUCF)	265	28.9	28.6	28.7	28.6	29.6	29.9	30.7	31.4	30.1	24.6	26.9	23.7	23.0	23.2	23.0	22.7	22.7	22.3	21.5	20.9
N_2O (incl. LULUCF)	265	29.7	29.4	29.5	29.4	30.4	30.7	31.5	32.2	30.9	25.4	27.6	24.4	23.7	23.8	23.6	23.3	23.3	22.9	22.0	21.4
HFCs	HFC-134a: 1,300 etc.	13.4	14.6	15.0	15.4	18.0	21.6	21.1	21.1	20.5	21.1	19.8	17.0	14.4	14.5	11.4	11.8	13.6	15.6	18.0	19.7
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	2.8
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	5.5	5.3	5.0	4.8	4.8	4.7	4.7	4.6	4.2	4.2	4.2	3.8	3.6	3.4	3.3	3.3	3.2	3.0	2.7	2.5
Gross Total (excluding LULUCF, excluding indirect CO_2)		1,269.4	1,283.6	1,295.4	1,290.9	1,351.1	1,371.4	1,384.1	1,375.9	1,327.8	1,351.8	1,371.3	1,346.4	1,371.0	1,378.2	1,370.4	1,378.0	1,356.5	1,391.8	1,318.9	1,246.9
Net Total (including LULUCF, excluding indirect CO_2)		1,196.7	1,205.3	1,213.3	1,205.6	1,265.8	1,286.4	1,297.9	1,288.9	1,240.7	1,265.2	1,283.7	1,258.0	1,281.0	1,278.4	1,273.9	1,287.2	1,270.2	1,310.2	1,241.9	1,172.5
Gross Total (excluding LULUCF, including indirect CO_2)		1,274.9	1,288.9	1,300.4	1,295.7	1,355.9	1,376.1	1,388.8	1,380.5	1,332.0	1,355.9	1,375.6	1,350.2	1,374.6	1,381.6	1,373.7	1,381.3	1,359.6	1,394.8	1,321.6	1,249.5
Net Total (including LULUCF, including indirect CO_2)		1,202.2	1,210.7	1,218.4	1,210.4	1,270.6	1,291.1	1,302.6	1,293.5	1,244.9	1,269.4	1,287.9	1,261.8	1,284.5	1,281.8	1,277.3	1,290.4	1,273.3	1,313.2	1,244.6	1,175.1

[Million tonnes CO_2 eq.]	GWP	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Changes in emissions/removals (2022)	
															1990	Previous year
CO_2 (excl. LULUCF) *1	1	1,214.8	1,264.8	1,306.0	1,315.3	1,263.8	1,223.2	1,203.2	1,187.5	1,142.5	1,105.5	1,040.5	1,061.9	1,034.9	-10.6%	-2.5%
CO_2 (incl. LULUCF) *1	1	1,135.5	1,186.5	1,224.8	1,241.4	1,193.5	1,158.8	1,142.7	1,123.5	1,079.2	1,047.7	981.7	1,003.1	981.2	-9.5%	-2.2%
CO_2 (LULUCF only)	1	-79.3	-78.3	-81.2	-73.9	-70.3	-64.4	-60.5	-64.0	-63.3	-57.7	-58.8	-58.8	-53.7	-27.2%	-8.7%
CH_4 (excl. LULUCF)	28	34.8	33.5	32.7	32.7	32.1	31.7	31.6	31.4	30.9	30.6	30.4	30.4	29.9	-40.0%	-1.7%
CH_4 (incl. LULUCF)	28	34.9	33.6	32.8	32.7	32.2	31.8	31.7	31.5	31.0	30.7	30.5	30.5	29.9	-40.0%	-1.7%
N_2O (excl. LULUCF)	265	20.6	20.2	19.9	19.9	19.5	19.2	18.7	19.0	18.5	18.0	17.7	17.6	17.3	-40.3%	-1.9%
N_2O (incl. LULUCF)	265	21.1	20.7	20.4	20.3	19.9	19.6	19.1	19.4	18.9	18.4	18.1	18.0	17.7	-40.6%	-1.9%
HFCs	HFC-134a: 1,300 etc.	22.0	24.6	27.7	30.3	33.8	37.1	39.5	41.0	42.3	44.5	46.1	46.9	46.1	244.0%	-1.6%
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	-50.5%	4.9%
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	-84.5%	-4.6%
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	1102.4%	1.4%
Indirect CO_2	1	2.4	2.4	2.3	2.3	2.2	2.2	2.2	2.1	2.1	2.0	1.9	1.8	1.8	-66.8%	-1.3%
Gross Total (excluding LULUCF, excluding indirect CO_2)		1,300.2	1,350.7	1,393.3	1,405.0	1,355.6	1,317.1	1,299.1	1,284.8	1,240.0	1,204.2	1,140.5	1,162.2	1,133.6	-10.7%	-2.5%
Net Total (including LULUCF, excluding indirect CO_2)		1,221.5	1,273.0	1,312.7	1,331.7	1,285.8	1,253.2	1,239.1	1,221.3	1,177.2	1,147.0	1,082.2	1,103.9	1,080.5	-9.7%	-2.1%
Gross Total (excluding LULUCF, including indirect CO_2)		1,302.6	1,353.1	1,395.6	1,407.3	1,357.8	1,319.3	1,301.2	1,286.9	1,242.1	1,206.2	1,142.3	1,164.0	1,135.5	-10.9%	-2.5%
Net Total (including LULUCF, including indirect CO_2)		1,223.9	1,275.4	1,315.0	1,334.0	1,288.1	1,255.4	1,241.2	1,223.4	1,179.2	1,149.0	1,084.0	1,105.8	1,082.3	-10.0%	-2.1%

*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 FY2022 by sector[5] shows that the energy (excluding indirect CO_2) accounts for 87.1% of total GHGs emissions. It is followed by the industrial processes and product use sector (excluding indirect CO_2) (8.2%), the agriculture sector (3.0%), the waste sector (1.5%), and indirect CO_2 emissions (0.2%).

Removals by the LULUCF in FY2022 were equivalent to 4.7% of total GHGs emissions.

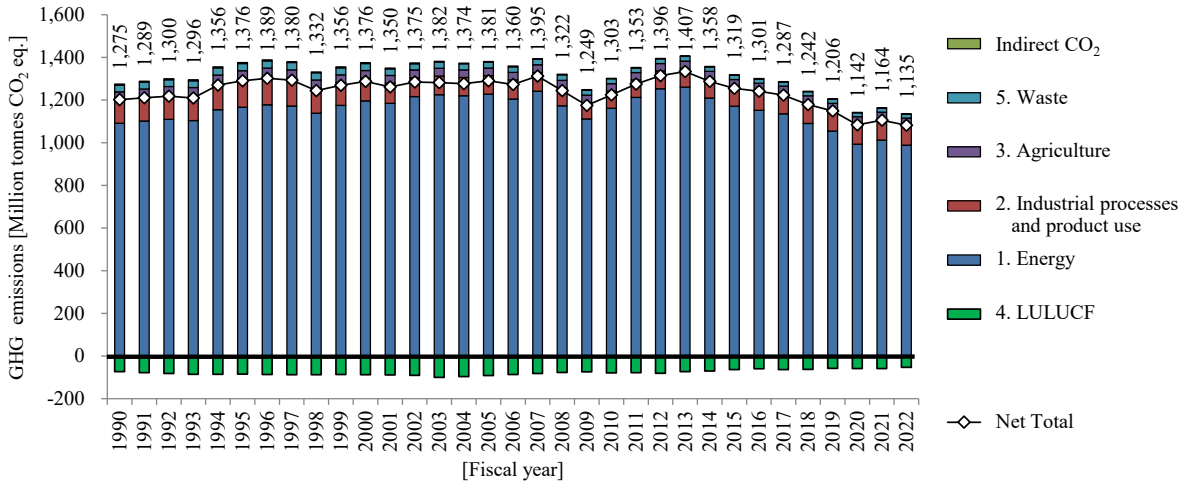

Figure 2 Trends in GHGs emissions and removals in each sector

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

Table 2 Trends in GHGs emissions and removals in each sector

[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]	1,091.6	1,101.9	1,109.9	1,103.9	1,154.8	1,166.7	1,178.1	1,172.6	1,138.4	1,175.0	1,196.9	1,184.6	1,216.2	1,225.1	1,220.9	1,227.8	1,205.1	1,241.3	1,173.5	1,112.3
2. Industrial processes and product use[*1]	107.4	111.8	113.8	115.8	122.6	131.8	134.0	131.1	118.8	106.9	105.0	94.8	89.0	87.9	85.4	86.5	89.1	88.2	83.7	76.4
3. Agriculture	39.3	38.9	39.8	39.8	40.0	39.0	38.2	38.3	37.0	37.1	37.0	36.3	36.4	35.9	35.8	36.3	36.1	36.5	35.4	35.2
4. LULUCF[*2]	-72.7	-78.3	-82.1	-85.3	-85.3	-85.0	-86.2	-87.0	-87.1	-86.6	-87.7	-88.4	-90.0	-99.8	-96.5	-90.9	-86.3	-81.6	-77.0	-74.4
5. Waste	31.1	30.9	32.0	31.5	33.8	33.8	33.8	34.0	33.6	32.8	32.4	30.7	29.4	29.2	28.3	27.4	26.1	25.8	26.3	23.1
Indirect CO_2	5.5	5.3	5.0	4.8	4.8	4.7	4.7	4.6	4.2	4.2	4.2	3.8	3.6	3.4	3.3	3.3	3.2	3.0	2.7	2.5
Gross Total (excluding LULUCF, excluding indirect CO_2)	1,269.4	1,283.6	1,295.4	1,290.9	1,351.1	1,371.4	1,384.1	1,375.9	1,327.8	1,351.8	1,371.3	1,346.4	1,371.0	1,378.2	1,370.4	1,378.0	1,356.5	1,391.8	1,318.9	1,246.9
Net Total (including LULUCF, excluding indirect CO_2)	1,196.7	1,205.3	1,213.3	1,205.6	1,265.8	1,286.4	1,297.9	1,288.9	1,240.7	1,265.2	1,283.7	1,258.0	1,281.0	1,278.4	1,273.9	1,287.2	1,270.2	1,310.2	1,241.9	1,172.5
Gross Total (excluding LULUCF, including indirect CO_2)	1,274.9	1,288.9	1,300.4	1,295.7	1,355.9	1,376.1	1,388.8	1,380.5	1,332.0	1,355.9	1,375.6	1,350.2	1,374.6	1,381.6	1,373.7	1,381.3	1,359.6	1,394.8	1,321.6	1,249.5
Net Total (including LULUCF, including indirect CO_2)	1,202.2	1,210.7	1,218.4	1,210.4	1,270.6	1,291.1	1,302.6	1,293.5	1,244.9	1,269.4	1,287.9	1,261.8	1,284.5	1,281.8	1,277.3	1,290.4	1,273.3	1,313.2	1,244.6	1,175.1

[Million tonnes CO_2 eq.]	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
1. Energy[*1]	1,162.2	1,213.0	1,253.3	1,260.8	1,210.2	1,171.3	1,152.2	1,136.3	1,090.7	1,055.1	993.4	1,012.9	989.2
2. Industrial processes and product use[*1]	79.6	81.3	83.7	87.9	90.4	91.3	93.4	95.4	95.7	96.2	95.2	97.0	93.4
3. Agriculture	35.4	34.6	34.2	34.5	34.1	33.9	33.9	34.0	33.8	33.7	33.8	33.9	33.5
4. LULUCF[*2]	-78.7	-77.7	-80.6	-73.4	-69.7	-63.9	-60.0	-63.5	-62.8	-57.3	-58.3	-58.3	-53.2
5. Waste	23.0	21.9	22.1	21.9	20.9	20.6	19.6	19.1	19.8	19.3	18.0	18.3	17.5
Indirect CO_2	2.4	2.4	2.3	2.3	2.2	2.2	2.2	2.1	2.1	2.0	1.9	1.8	1.8
Gross Total (excluding LULUCF, excluding indirect CO_2)	1,300.2	1,350.7	1,393.3	1,405.0	1,355.6	1,317.1	1,299.1	1,284.8	1,240.0	1,204.2	1,140.5	1,162.2	1,133.6
Net Total (including LULUCF, excluding indirect CO_2)	1,221.5	1,273.0	1,312.7	1,331.7	1,285.8	1,253.2	1,239.1	1,221.3	1,177.2	1,147.0	1,082.2	1,103.9	1,080.5
Gross Total (excluding LULUCF, including indirect CO_2)	1,302.6	1,353.1	1,395.6	1,407.3	1,357.8	1,319.3	1,301.2	1,286.9	1,242.1	1,206.2	1,142.3	1,164.0	1,135.5
Net Total (including LULUCF, including indirect CO_2)	1,223.9	1,275.4	1,315.0	1,334.0	1,288.1	1,255.4	1,241.2	1,223.4	1,179.2	1,149.0	1,084.0	1,105.8	1,082.3

*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, 48 and 41 sources and sinks were identified as Japan's key categories for FY2022 and FY1990, respectively. On the other hand, in the case of excluding the LULUCF sector, 38 and 36 sources and sinks were identified as the key categories for FY2022 and FY1990, respectively. More detailed information is described in Annex 1.

E.S.5. Improvements Introduced

Application of the *NID Outline* and improvements in descriptions of the NID and calculation methodologies were carried out 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 FY2022[1], on the basis of Article 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 inventories 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 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 estimation of emissions and removals and the preparation of the Common Reporting Tables (CRT) and

[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 April 1, 2023.

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 inventories, 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 inventories are determined as Japan's official GHG emission/removal values. The inventories are 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.

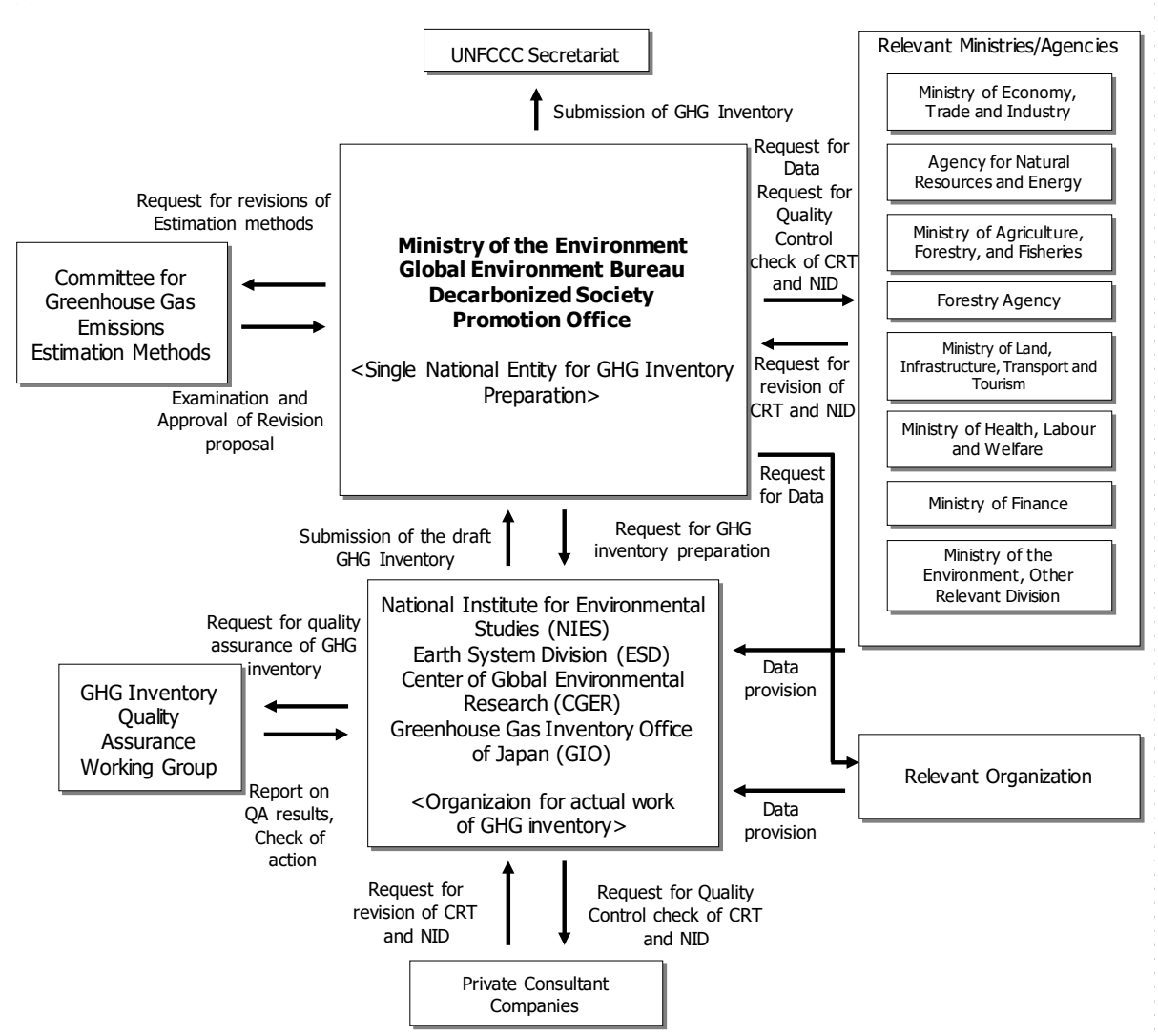

Figure 1-1 Japan's institutional arrangement for the national inventory preparation

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 reviews.
- (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, and Breakout group on NMVOC), as well as the Sub-breakout group on Carbon Capture and Utilization (CCU) are set up. The inventory WG and the breakout groups/sub-breakout group comprise experts in various fields and consider suggestions for inventory improvements.

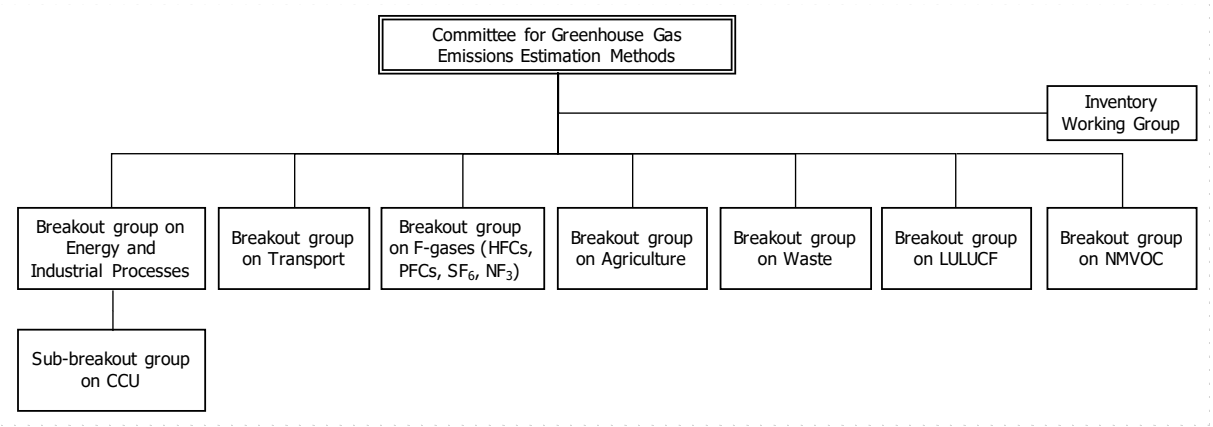

Figure 1-2 Structure of the Committee for the Greenhouse Gas Emissions Estimation Methods

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 reviews.
- (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 by TERTs pursuant to *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.

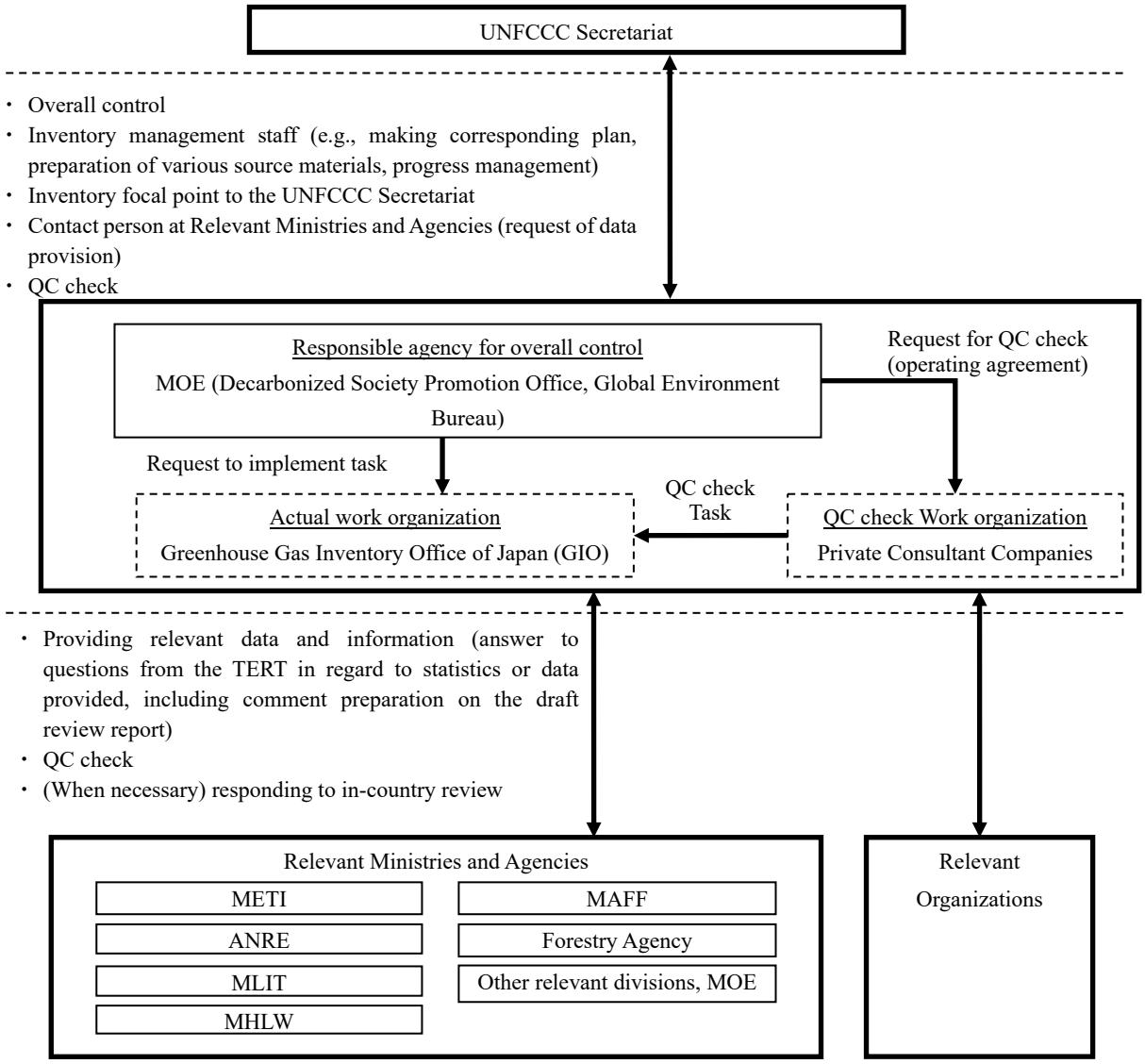

Figure 1-3 Basic structure of Japan's national system to respond to inventory review

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 inventory preparation

*Inventory preparation in fiscal yaer "n"

	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 Improvement (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, the selected 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 in the files but also check the estimations by calculating the amount of 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 drafts of inventories.

Subsequently, the GIO sends out the primary drafts of the inventories and press releases as electronic computer files to the MOE and the relevant ministries and agencies and asks them to check the contents of the primary drafts. 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 inventories and official announcements 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 for finalized data
- 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 server, hosted by the National Institute for Environmental Studies (in which GIO is included), and where inventory-related information is stored, is automatically backed up every day. Access to the server is restricted to specific ID holders only.
- 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 step 7 and 8 in section 1.2.2.2.):

The primary drafts of the inventories and press releases 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 inventories 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 inventories are determined as Japan's official GHG emission/removal values. The inventories are 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.ii fugitive emissions from fuel (oil and natural gas (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 data or statistics
Relevant Ministries/ Agencies	MOE	Research of Air Pollutant Emissions from Stationary Sources/ Waste Treatment in Japan/ Report of the research on the state of wide-range movement and cyclical use of wastes (the volume on cyclical use)/ Survey of Industrial Waste Treatment Facilities
	METI	General Energy Statistics / Current Production Statistics / Amount of nitric acid production/ Documents of Fluorocarbons etc Measures Working Group, Group for Chemical Substance Policy, Manufacturing Industries Sub-Group, Industrial Structure Council
	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	Amount of Fuel Used by Pressurized Fluidized Bed Boilers
	Japan Coal Frontier Organization	Coal Production/ History of Coal Policy
	Japan Cement Association	Amount of clinker production / Cement Handbook
	Japan Iron and Steel Federation	Emissions from Coke Oven Covers, Desulfurization Towers, and Desulfurization Recycling Towers
	Japan Paper Association	Amount of final disposal of industrial waste / Amount of RPF incineration

1.3.2. Selection of Emission Factors and Estimation Methods

Calculation methods for Japan's emission and removal amounts 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 emission and removal amounts, based on the *2006 IPCC Guidelines*.

1.3.3. Improvement Process of Estimations for Emissions and Removal

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, a 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.

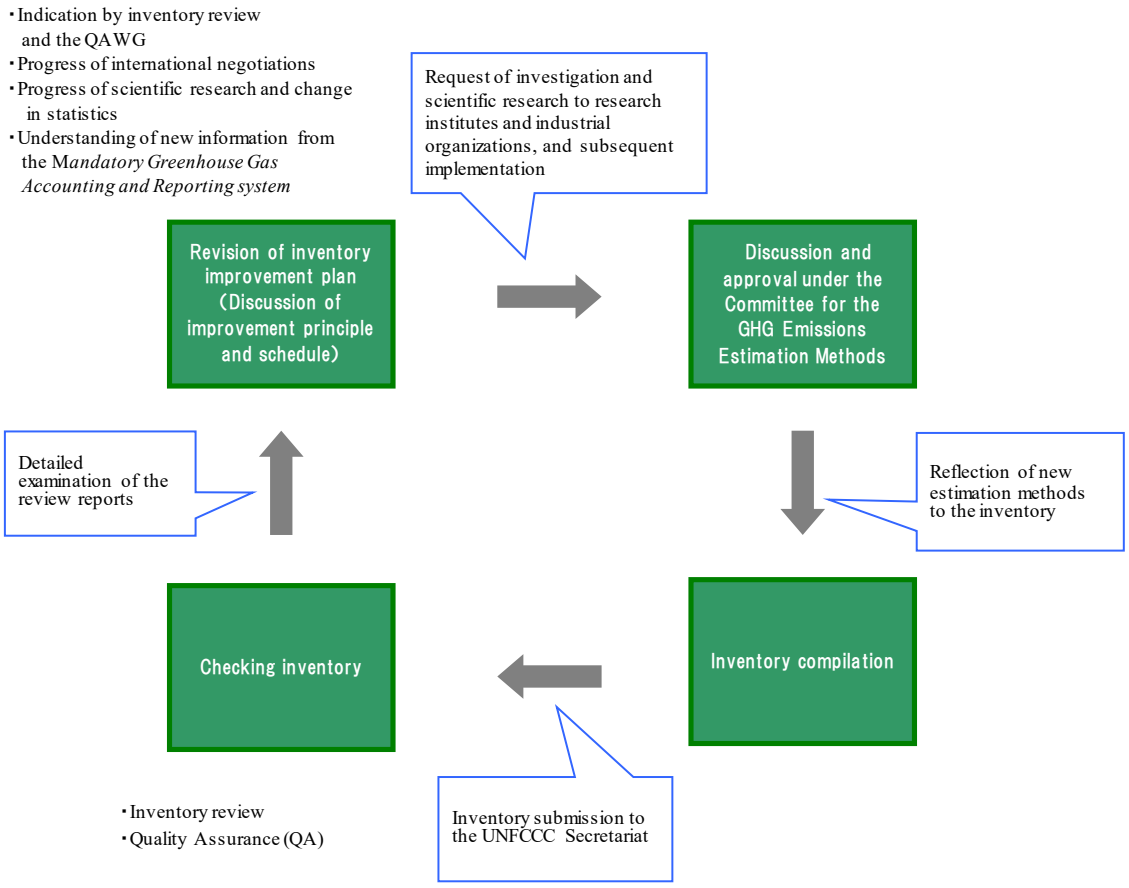

Figure 1-4 Diagram of the inventory improvement process

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, 48 and 41 sources and sinks were identified as Japan's key categories for FY2022 and FY1990, respectively (Table 1-3 and Table 1-4). On the other hand, in the case of excluding the LULUCF sector, 38 and 36 sources and sinks were identified as the key categories for FY2022 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 (FY2022, 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		#11	
#3	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	#3	#7	#2	#7
#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	#5	#25	#22
#6	4.A.	Forest Land	1. Forest Land Remaining Forest Land	CO_2	#6	#8	#3	#4
#7	1.A.1.	Energy Industries	Liquid Fuels	CO_2	#7	#2	#31	#15
#8	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	#8	#3	#32	#19
#9	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	#9	#9	#29	
#10	2.F.	Product Uses as Substitutes for ODS	1. Refrigeration and Air Conditioning Equipment	HFCs	#10	#6	#6	#6
#11	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	#11	#10		
#12	2.A.	Mineral Industry	1. Cement Production	CO_2	#12	#11	#24	#25
#13	3.C.	Rice Cultivation		CH_4	#13		#27	
#14	1.A.3.	Transport	d. Domestic Navigation	CO_2	#14			
#15	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	#15	#16	#10	#16
#16	5.C.	Incineration and Open Burning of Waste		CO_2	#16		#15	
#17	1.A.3.	Transport	a. Domestic Aviation	CO_2	#17	#21		
#18	3.A.	Enteric Fermentation		CH_4	#18		#7	
#19	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	#19		#14	#26
#20	1.A.4.	Other Sectors	Solid Fuels	CO_2	#20	#18		
#21	2.C.	Metal Industry	1. Iron and Steel Production	CO_2	#21			
#22	2.A.	Mineral Industry	2. Lime Production	CO_2	#22			
#23	4.B.	Cropland	1. Cropland Remaining Cropland	CO_2			#22	#24
#24	4.E.	Settlements	2. Land Converted to Settlements	CO_2		#17	#12	#5
#25	3.B.	Manure Management		N_2O			#5	
#26	3.D.	Agricultural Soils	1. Direct Emissions	N_2O			#13	
#27	2.F.	Product Uses as Substitutes for ODS	2. Foam Blowing Agents	HFCs		#24	#17	#14
#28	2.B.	Chemical Industry	Other Products Except Anmonia	CO_2			#16	#28
#29	2.D.	Non-energy Products from Fuels and Solvent Use		CO_2			#20	
#30	3.D.	Agricultural Soils		N_2O			#4	#20
#31	4.G.	Harvested Wood Products		CO_2			#33	#29
#32	5.D.	Wastewater Treatment and Discharge		N_2O			#28	
#33	5.A.	Solid Waste Disposal		CH_4		#14		#9
#34	2.E.	Electronics Industry		PFCs			#19	
#35	2.G.	Other Product Manufacture and Use		SF_6		#15	#9	#2
#36		Indirect CO_2	from IPPU Sector	Ind CO_2		#23	#26	#11
#37	5.C.	Incineration and Open Burning of Waste		N_2O			#23	
#38	1.A.3.	Transport	b. Road Transportation	N_2O			#21	#10
#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		#20		#3
#41	2.E.	Electronics Industry		SF_6			#18	#13
#42	4.F.	Other Land	2. Land Converted to Other Land	CO_2				#12
#43	4.(III)	N_2O Emissions from N Mineralization/Immobilization		N_2O			#30	#21
#44	2.B.	Chemical Industry	2. Nitric Acid Production	N_2O				#27
#45	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O				#8
#46	2.B.	Chemical Industry	9. Fluorochemical Production	HFCs		#12		
#47	2.B.	Chemical Industry	9. Fluorochemical Production	SF_6		#22		
#48	2.B.	Chemical Industry	3. Adipic Acid Production	N_2O		#19		#23

Note1: Ap1-L: Approach 1-Level Assessment, Ap1-T: Approach 1-Trend Assessment,
Ap2-L: Approach 2-Level Assessment, Ap2-T: Approach 2-Trend Assessment
Note2: 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	#16
#3	1.A.1.	Energy Industries	Liquid Fuels	CO_2	#3	#17
#4	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	#4	#23
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	#5	#24
#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	#26
#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	5.C.	Incineration and Open Burning of Waste		CO_2	#14	#20
#15	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	#15	
#16	4.E.	Settlements	2. Land Converted to Settlements	CO_2	#16	#7
#17	5.A.	Solid Waste Disposal		CH_4	#17	#13
#18	3.A.	Enteric Fermentation		CH_4	#18	#10
#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	4.B.	Cropland	1. Cropland Remaining Cropland	CO_2	#21	#21
#22	2.C.	Metal Industry	1. Iron and Steel Production	CO_2	#22	
#23	1.A.3.	Transport	a. Domestic Aviation	CO_2	#23	
#24	2.A.	Mineral Industry	2. Lime Production	CO_2	#24	
#25	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	#25	#27
#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	#12
#29	3.D.	Agricultural Soils	1. Direct Emissions	N_2O		#15
#30	3.B.	Manure Management		N_2O		#6
#31	2.B.	Chemical Industry	Other Products Except Anmonia	CO_2		#18
#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		#19
#35	2.D.	Non-energy Products from Fuels and Solvent Use		CO_2		#28
#36	5.D.	Wastewater Treatment and Discharge		N_2O		#31
#37	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O		#14
#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		#11
#41	4.(III)	N_2O Emissions from N Mineralization/Immobilization		N_2O		#25

Note1: Ap1-L: Approach 1-Level Assessment, Ap2-L: Approach 2-Level Assessment
Note2: Figures recorded in the Level columns indicate the ranking of individual level assessments.

Table 1-5 Japan's key categories (FY2022, 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	#18	#10	
#3	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	#3	#7	#2	#5
#4	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	#4	#4	#7	#14
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	#5	#5	#22	#17
#6	1.A.1.	Energy Industries	Liquid Fuels	CO_2	#6	#2	#27	#12
#7	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	#7	#3	#28	#15
#8	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	#8	#8	#26	
#9	2.F.	Product Uses as Substitutes for ODS	1. Refrigeration and Air Conditioning Equipment	HFCs	#9	#6	#5	#4
#10	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	#10	#9		
#11	2.A.	Mineral Industry	1. Cement Production	CO_2	#11	#10	#21	#20
#12	3.C.	Rice Cultivation		CH_4	#12		#24	
#13	1.A.3.	Transport	d. Domestic Navigation	CO_2	#13			
#14	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	#14	#14	#9	#13
#15	5.C.	Incineration and Open Burning of Waste		CO_2	#15		#13	
#16	1.A.3.	Transport	a. Domestic Aviation	CO_2	#16	#19		
#17	3.A.	Enteric Fermentation		CH_4	#17		#6	
#18	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	#18		#12	#19
#19	1.A.4.	Other Sectors	Solid Fuels	CO_2		#15		#23
#20	3.B.	Manure Management		N_2O			#4	
#21	3.D.	Agricultural Soils	1. Direct Emissions	N_2O			#11	
#22	2.F.	Product Uses as Substitutes for ODS	2. Foam Blowing Agents	HFCs			#15	#10
#23	2.B.	Chemical Industry	Other Products Except Anmonia	CO_2			#14	#22
#24	2.D.	Non-energy Products from Fuels and Solvent Use		CO_2			#18	
#25	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O			#3	#16
#26	5.D.	Wastewater Treatment and Discharge		N_2O			#25	
#27	5.A.	Solid Waste Disposal		CH_4		#12		#7
#28	2.E.	Electronics Industry		PFCs			#17	
#29	2.G.	Other Product Manufacture and Use		SF_6		#13	#8	#2
#30		Indirect CO_2	from IPPU Sector	Ind CO_2			#23	#9
#31	5.C.	Incineration and Open Burning of Waste		N_2O			#20	
#32	1.A.3.	Transport	b. Road Transportation	N_2O			#19	#8
#33	1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	CH_4		#17		#3
#34	2.E.	Electronics Industry		SF_6			#16	#11
#35	2.B.	Chemical Industry	2. Nitric Acid Production	N_2O				#21
#36	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O				#6
#37	2.B.	Chemical Industry	9. Fluorochemical Production	HFCs		#11		
#38	2.B.	Chemical Industry	3. Adipic Acid Production	N_2O		#16		#18

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	#16
#3	1.A.1.	Energy Industries	Liquid Fuels	CO_2	#3	#17
#4	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	#4	#19
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	#5	#20
#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	#18
#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	5.C.	Incineration and Open Burning of Waste		CO_2	#13	#15
#14	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	#14	
#15	5.A.	Solid Waste Disposal		CH_4	#15	#9
#16	3.A.	Enteric Fermentation		CH_4	#16	#8
#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	#22
#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		#13
#25	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2		#28
#26	3.D.	Agricultural Soils	1. Direct Emissions	N_2O		#14
#27	3.B.	Manure Management		N_2O		#5
#28	2.B.	Chemical Industry	Other Products Except Anmonia	CO_2		#12
#29	1.A.3.	Transport	b. Road Transportation	N_2O		#11
#30	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O		#4
#31	2.D.	Non-energy Products from Fuels and Solvent Use		CO_2		#23
#32	5.D.	Wastewater Treatment and Discharge		N_2O		#27
#33	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O		#10
#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		#7

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 FY2022 were approximately 1,082 million tonnes (CO_2 equivalents). 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-2022		I	J	
Category	GHGs	FY1990 emissions / removals	FY2022 emissions / removals	Combined uncertainty in FY1990		Combined uncertainty in FY2022		Inventory trend in national emissions for FY2022 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	1,078,221	982,337	-2%	+1%	-3%	+2%	-8.9%	-3.1%	+2.1%
1A. Fuel Combustion (Stationary:CH_4,N_2O)	CH_4, N_2O	3,709	4,206	-22%	+29%	-24%	+27%	13.4%	0.0%	+0.0%
1A. Fuel Combustion (Transport:CH_4,N_2O)	CH_4, N_2O	3,719	1,470	-30%	+89%	-28%	+83%	-60.5%	0.0%	+0.0%
1B. Fugitive Emissions from Fuels	CO_2, CH_4, N_2O	5,988	1,166	-37%	+77%	-18%	+38%	-80.5%	0.0%	+0.0%
2. IPPU (CO_2,CH_4,N_2O)	CO_2, CH_4, N_2O	74,077	41,768	-5%	+5%	-5%	+5%	-43.6%	-0.1%	+0.1%
2. IPPU (HFCs,PFCs,SF_6,NF_3)	HFCs, PFCs, SF_6, NF_3	33,364	51,657	-11%	+40%	-7%	+8%	54.8%	-0.5%	+0.5%
3. Agriculture	CO_2, CH_4, N_2O	39,281	33,510	-11%	+25%	-10%	+23%	-14.7%	-0.1%	+0.1%
4. LULUCF	CO_2, CH_4, N_2O	-72,708	-53,175	-13%	13%	-11%	+11%	-26.9%	-0.4%	+0.4%
5. Waste	CO_2, CH_4, N_2O	31,071	17,524	-11%	+11%	-11%	+12%	-43.6%	-0.2%	+0.2%
Indirect CO_2	Ind CO_2	5,490	1,821	-26%	+48%	-24%	+45%	-66.8%	0.0%	+0.0%
Total Net Emissions		1,202,213	1,082,284	-2.0%	+2.1%	-2.5%	+2.0%	-10.0%	-3.1%	+2.2%

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 1.14 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 FY2022[1,2] (excluding LULUCF[3], including indirect CO_2[4], hereafter, definition omitted) were 1,135 million tonnes (in CO_2 eq.). They decreased by 10.9% compared to the emissions in FY1990.

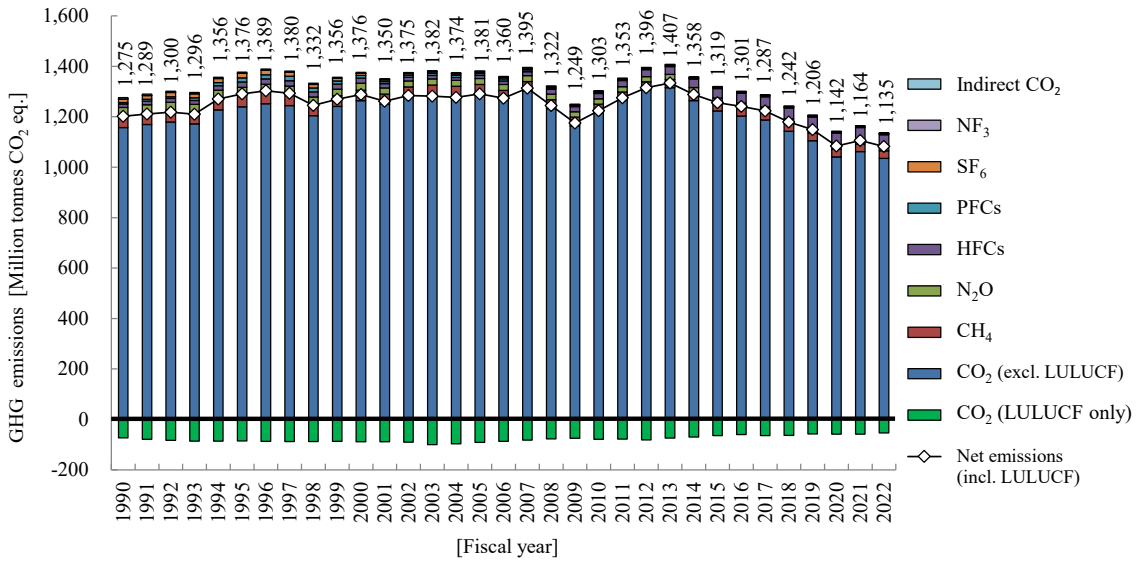

Figure 2-1 Trends in GHG emissions and removals in Japan

CO_2 emissions in FY2022 were 1,035 million tonnes (excluding LULUCF, excluding indirect CO_2, hereafter, definition omitted), accounting for 91.1% of total GHG emissions. They decreased by 10.6% since FY1990 and decreased by 2.5% compared to the previous year. CO_2 removals[5] in FY2022 were 53.7 million tonnes, which were equivalent to 4.7% of total GHG emissions. They decreased by 27.2% since FY1990 and decreased by 8.7% 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.

5 Since the inventory reports all GHG emissions and removals from the LULUCF sector, these values do not correspond to emissions and removals in the NDC.

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

[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	1,157.4	1,169.1	1,178.9	1,171.9	1,226.9	1,239.2	1,251.7	1,244.4	1,204.6	1,241.2	1,264.0	1,249.4	1,279.0	1,287.5	1,282.9	1,290.3	1,267.3	1,303.0	1,232.2	1,163.4
CO_2 (incl. LULUCF) *1	1	1,083.7	1,089.8	1,095.8	1,085.6	1,140.7	1,153.4	1,164.7	1,156.6	1,116.6	1,153.8	1,175.5	1,160.2	1,188.2	1,186.9	1,185.7	1,198.7	1,180.3	1,220.7	1,154.5	1,088.3
CO_2 (LULUCF only)	1	-73.7	-79.2	-83.0	-86.3	-86.2	-85.9	-87.0	-87.9	-88.0	-87.4	-88.5	-89.2	-90.8	-100.6	-97.2	-91.6	-87.0	-82.3	-77.7	-75.0
CH_4 (excl. LULUCF)	28	49.8	49.1	49.0	48.0	48.1	46.7	45.3	44.8	42.9	42.5	41.7	40.4	39.5	38.5	38.2	38.2	37.5	36.8	35.9	35.3
CH_4 (incl. LULUCF)	28	49.9	49.2	49.1	48.1	48.2	46.8	45.4	44.9	43.0	42.6	41.8	40.5	39.6	38.6	38.3	38.2	37.6	36.9	36.1	35.4
N_2O (excl. LULUCF)	265	28.9	28.6	28.7	28.6	29.6	29.9	30.7	31.4	30.1	24.6	26.9	23.7	23.0	23.2	23.0	22.7	22.7	22.3	21.5	20.9
N_2O (incl. LULUCF)	265	29.7	29.4	29.5	29.4	30.4	30.7	31.5	32.2	30.9	25.4	27.6	24.4	23.7	23.8	23.6	23.3	23.3	22.9	22.0	21.4
HFCs	HFC-134a: 1,300 etc.	13.4	14.6	15.0	15.4	18.0	21.6	21.1	21.1	20.5	21.1	19.8	17.0	14.4	14.5	11.4	11.8	13.6	15.6	18.0	19.7
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	2.8
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	5.5	5.3	5.0	4.8	4.8	4.7	4.7	4.6	4.2	4.2	4.2	3.8	3.6	3.4	3.3	3.3	3.2	3.0	2.7	2.5
Gross Total (excluding LULUCF, excluding indirect CO_2)		1,269.4	1,283.6	1,295.4	1,290.9	1,351.1	1,371.4	1,384.1	1,375.9	1,327.8	1,351.8	1,371.3	1,346.4	1,371.0	1,378.2	1,370.4	1,378.0	1,356.5	1,391.8	1,318.9	1,246.9
Net Total (including LULUCF, excluding indirect CO_2)		1,196.7	1,205.3	1,213.3	1,205.6	1,265.8	1,286.4	1,297.9	1,288.9	1,240.7	1,265.2	1,283.7	1,258.0	1,281.0	1,278.4	1,273.9	1,287.2	1,270.2	1,310.2	1,241.9	1,172.5
Gross Total (excluding LULUCF, including indirect CO_2)		1,274.9	1,288.9	1,300.4	1,295.7	1,355.9	1,376.1	1,388.8	1,380.5	1,332.0	1,355.9	1,375.6	1,350.2	1,374.6	1,381.6	1,373.7	1,381.3	1,359.6	1,394.8	1,321.6	1,249.5
Net Total (including LULUCF, including indirect CO_2)		1,202.2	1,210.7	1,218.4	1,210.4	1,270.6	1,291.1	1,302.6	1,293.5	1,244.9	1,269.4	1,287.9	1,261.8	1,284.5	1,281.8	1,277.3	1,290.4	1,273.3	1,313.2	1,244.6	1,175.1

[Million tonnes CO_2 eq.]	GWP	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Changes in emissions/removals (2022)	
															1990	Previous year
CO_2 (excl. LULUCF) *1	1	1,214.8	1,264.8	1,306.0	1,315.3	1,263.8	1,223.2	1,203.2	1,187.5	1,142.5	1,105.5	1,040.5	1,061.9	1,034.9	-10.6%	-2.5%
CO_2 (incl. LULUCF) *1	1	1,135.5	1,186.5	1,224.8	1,241.4	1,193.5	1,158.8	1,142.7	1,123.5	1,079.2	1,047.7	981.7	1,003.1	981.2	-9.5%	-2.2%
CO_2 (LULUCF only)	1	-79.3	-78.3	-81.2	-73.9	-70.3	-64.4	-60.5	-64.0	-63.3	-57.7	-58.8	-58.8	-53.7	-27.2%	-8.7%
CH_4 (excl. LULUCF)	28	34.8	33.5	32.7	32.7	32.1	31.7	31.6	31.4	30.9	30.6	30.4	30.4	29.9	-40.0%	-1.7%
CH_4 (incl. LULUCF)	28	34.9	33.6	32.8	32.7	32.2	31.8	31.7	31.5	31.0	30.7	30.5	30.5	29.9	-40.0%	-1.7%
N_2O (excl. LULUCF)	265	20.6	20.2	19.9	19.9	19.5	19.2	18.7	19.0	18.5	18.0	17.7	17.6	17.3	-40.3%	-1.9%
N_2O (incl. LULUCF)	265	21.1	20.7	20.4	20.3	19.9	19.6	19.1	19.4	18.9	18.4	18.1	18.0	17.7	-40.6%	-1.9%
HFCs	HFC-134a: 1,300 etc.	22.0	24.6	27.7	30.3	33.8	37.1	39.5	41.0	42.3	44.5	46.1	46.9	46.1	244.0%	-1.6%
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	-50.5%	4.9%
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	-84.5%	-4.6%
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	1102.4%	1.4%
Indirect CO_2	1	2.4	2.4	2.3	2.3	2.2	2.2	2.2	2.1	2.1	2.0	1.9	1.8	1.8	-66.8%	-1.3%
Gross Total (excluding LULUCF, excluding indirect CO_2)		1,300.2	1,350.7	1,393.3	1,405.0	1,355.6	1,317.1	1,299.1	1,284.8	1,240.0	1,204.2	1,140.5	1,162.2	1,133.6	-10.7%	-2.5%
Net Total (including LULUCF, excluding indirect CO_2)		1,221.5	1,273.0	1,312.7	1,331.7	1,285.8	1,253.2	1,239.1	1,221.3	1,177.2	1,147.0	1,082.2	1,103.9	1,080.5	-9.7%	-2.1%
Gross Total (excluding LULUCF, including indirect CO_2)		1,302.6	1,353.1	1,395.6	1,407.3	1,357.8	1,319.3	1,301.2	1,286.9	1,242.1	1,206.2	1,142.3	1,164.0	1,135.5	-10.9%	-2.5%
Net Total (including LULUCF, including indirect CO_2)		1,223.9	1,275.4	1,315.0	1,334.0	1,288.1	1,255.4	1,241.2	1,223.4	1,179.2	1,149.0	1,084.0	1,105.8	1,082.3	-10.0%	-2.1%

*1 Excluding indirect CO_2

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

CH_4 emissions in FY2022 (excluding LULUCF) were 29.9 million tonnes (in CO_2 eq.), accounting for 2.6% of total GHG emissions. They decreased by 40.0% since FY1990 and decreased by 1.7% compared to the previous year.

N_2O emissions in FY2022 (excluding LULUCF) were 17.3 million tonnes (in CO_2 eq.), accounting for 1.5% of total GHG emissions. They decreased by 40.3% since FY1990 and decreased by 1.9% compared to the previous year.

HFC emissions in CY2022 were 46.1 million tonnes (in CO_2 eq.), accounting for 4.1% of total GHG emissions. They increased by 244% since CY1990 and decreased by 1.6% compared to the previous year.

PFC emissions in CY2022 were 3.0 million tonnes (in CO_2 eq.), accounting for 0.3% of total GHG emissions. They decreased by 50.5% since CY1990 and increased by 4.9% compared to the previous year.

SF_6 emissions in CY2022 were 2.1 million tonnes (in CO_2 eq.), accounting for 0.2% of total GHG emissions. They decreased by 84.5% since CY1990 and decreased by 4.6% compared to the previous year.

NF_3 emissions in CY2022 were 0.3 million tonnes (in CO_2 eq.), accounting for 0.03% of total GHG emissions. They increased 1,100% since CY1990 and increased by 1.4% compared to the previous year.

Indirect CO_2 emissions in FY2022 were 1.8 million tonnes (in CO_2 eq.), accounting for 0.2% of total GHG emissions. They decreased by 66.8% since FY1990 and decreased by 1.3% compared to the previous year.

2.1.2. CO_2

CO_2 emissions in FY2022 were 1,035 million tonnes, accounting for 91.1% of total GHG emissions. They decreased by 10.6% since FY1990 and decreased by 2.5% compared to the previous year.

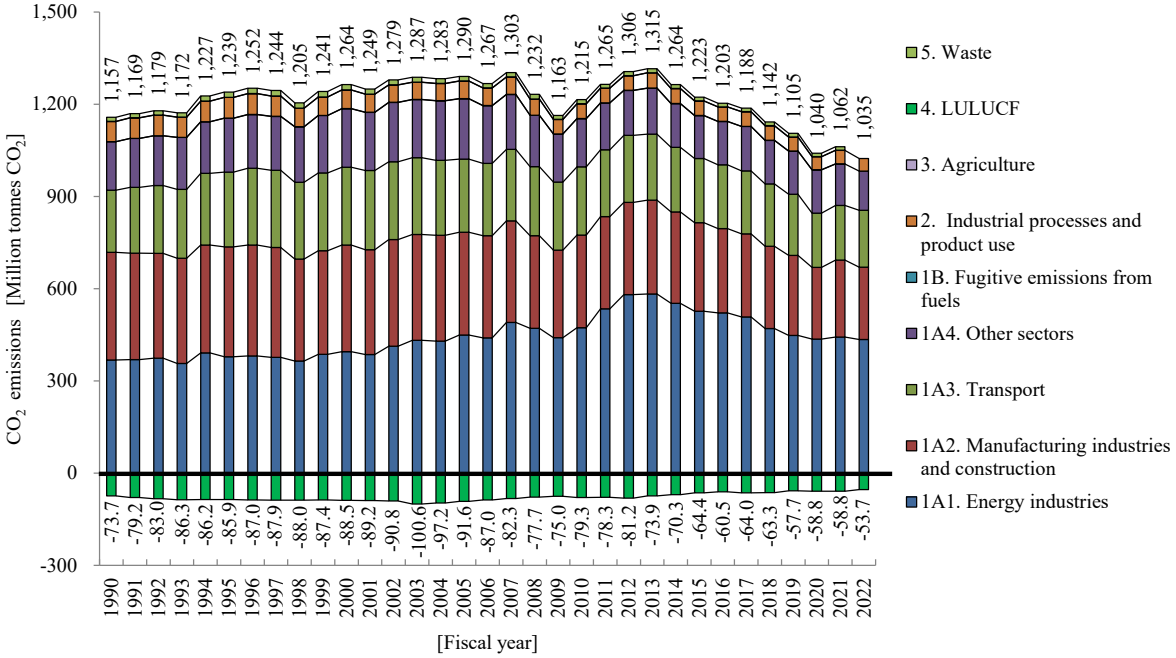

Figure 2-2 Trends in CO_2 emissions

The breakdown of CO_2 emissions in FY2022 shows that fuel combustion accounts for 94.9% and is followed by industrial processes and product use (4.0%) and waste sectors (1.1%). As for the breakdown of CO_2 emissions within the fuel combustion category, energy industries accounts for 42.0% and is followed by manufacturing industries and construction at 22.7%, transport at 17.9%, and other sectors[6] 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 18.2% since FY1990 and decreased by 1.7% 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 decreased emissions from liquid fuel consumption. Emissions from manufacturing industries and construction decreased by 32.9% since FY1990 and decreased by 6.3% 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 8.5% compared to FY1990 and increased by 4.0% 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 19.3% since FY1990 and decreased by 5.3% 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.

6 It covers emissions from commercial/institutional, residential and agriculture/forestry/fishing.

CO_2 removals in FY2022 were 53.7 million tonnes, which were equivalent to 4.7% of total GHG emissions. They decreased by 27.2% since FY1990 and decreased by 8.7% compared to the previous year.

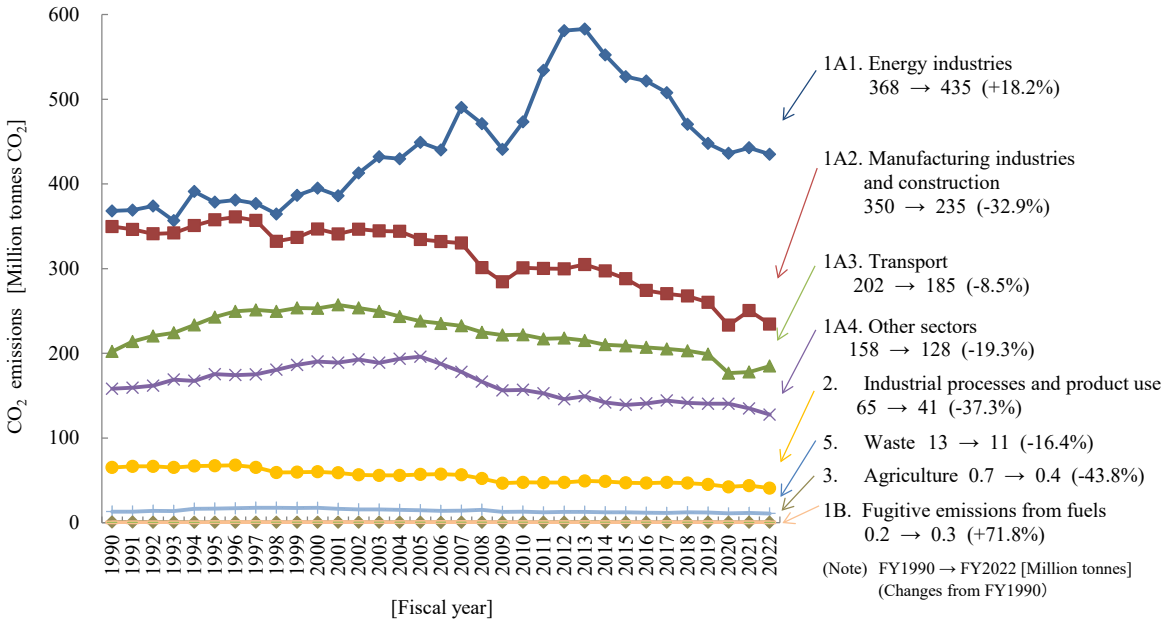

Figure 2-3 Trends in CO_2 emissions in each sector

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	2014	2015	2016	2017	2018	2019	2020	2021	2022
1A. Fuel combustion	1,078,221	1,154,331	1,185,228	1,217,687	1,153,152	1,252,193	1,201,715	1,162,787	1,143,734	1,127,567	1,082,476	1,047,476	986,343	1,005,829	982,337
1A1. Energy industries	368,156	378,496	395,022	449,110	473,294	582,933	552,340	526,751	521,531	507,753	470,283	447,733	436,129	442,679	435,051
a. Public electricity and heat production	303,055	317,587	330,118	378,044	404,239	521,862	493,350	468,472	466,659	454,708	415,366	396,011	392,288	395,616	387,888
b. Petroleum refining	36,023	40,676	46,506	50,334	47,165	42,401	40,578	41,124	37,057	36,244	37,035	35,330	28,958	30,683	31,149
c. Manufacture of solid fuels and other energy industries	29,078	20,232	18,398	20,732	21,891	18,670	18,412	17,154	17,816	16,801	17,881	16,391	14,883	16,380	16,013
1A2. Manufacturing industries and construction	349,747	357,627	346,858	334,482	301,024	304,833	297,271	287,997	274,234	270,282	267,605	260,257	233,175	250,407	234,600
a. Iron and steel	150,622	142,999	152,022	154,093	153,145	157,541	155,085	148,849	142,731	139,734	136,157	134,124	111,963	124,783	114,875
b. Non-ferrous metals	8,429	7,381	6,311	5,686	3,961	3,742	3,637	3,239	3,499	3,130	3,286	2,878	2,760	3,041	2,987
c. Chemicals	58,039	64,339	59,518	54,952	50,117	48,265	46,580	45,563	42,362	42,926	42,234	42,158	39,541	42,727	41,261
d. Pulp, paper and print	27,106	31,428	31,672	29,732	22,644	23,832	22,900	23,305	20,847	20,508	20,439	18,999	17,848	17,759	15,932
e. Food processing, beverages and tobacco	7,649	10,133	11,468	12,169	9,821	9,809	9,526	8,459	8,416	7,895	8,809	7,801	8,005	8,301	8,218
f. Non-metallic minerals	43,634	46,461	40,100	35,443	28,711	29,803	28,991	28,054	27,097	26,921	27,018	25,873	25,104	24,972	22,818
g. Other	54,267	54,888	45,766	42,407	32,625	31,842	30,553	30,530	29,282	29,167	29,662	28,425	27,954	28,825	28,509
1A3. Transport	202,140	242,797	253,091	238,065	221,969	215,115	210,149	208,875	207,066	205,253	203,016	199,023	176,576	177,896	185,040
a. Domestic aviation	7,162	10,278	10,677	10,799	9,193	10,149	10,173	10,067	10,187	10,399	10,537	10,488	5,238	6,819	9,705
b. Road transportation	180,367	217,028	226,690	213,605	201,457	193,437	188,540	187,641	185,722	183,803	181,451	177,628	160,907	160,349	164,513
c. Railways	935	822	711	647	574	540	524	523	499	520	492	490	468	449	449
d. Domestic navigation	13,675	14,669	15,012	13,014	10,745	10,989	10,912	10,645	10,659	10,530	10,537	10,417	9,963	10,280	10,373
1A4. Other sectors	158,178	175,411	190,258	196,030	156,866	149,312	141,955	139,164	140,902	144,279	141,572	140,463	140,463	134,847	127,646
a. Commercial/institutional	79,069	88,210	98,179	105,958	74,849	74,216	69,211	67,052	67,286	67,805	74,651	71,092	67,760	69,081	65,233
b. Residential	58,167	67,477	72,226	70,395	64,217	60,319	58,014	55,392	55,712	59,260	52,156	53,361	55,807	51,574	49,646
c. Agriculture/forestry/fishing	20,942	19,723	19,853	19,676	17,800	14,777	14,730	16,720	17,905	17,213	14,764	16,011	16,896	14,192	12,768
1A5. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
1B. Fugitive emissions from fuels	203	526	527	532	500	462	470	446	479	459	447	404	408	374	348
1C. CO_2 transport and storage	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO,NA	NE,NO,NA	NE,NO,NA	NE,NO,NA	NE,NO	NE,NO	NE,NO
2. Industrial processes and product use	65,196	67,217	60,155	56,971	47,673	49,267	48,677	47,198	46,790	47,533	46,824	45,188	42,256	43,711	40,884
3. Agriculture	732	473	501	428	427	594	567	474	461	502	450	450	441	434	411
4. LULUCF	-73,696	-85,875	-88,469	-91,593	-79,325	-73,895	-70,256	-64,364	-60,501	-64,020	-63,314	-57,743	-58,785	-58,762	-53,660
5. Waste	13,022	16,678	17,540	14,715	13,033	12,805	12,336	12,291	11,713	11,463	12,302	11,943	11,028	11,509	10,880
Total (including LULUCF)	1,083,678	1,153,351	1,175,482	1,198,741	1,135,461	1,241,425	1,193,510	1,158,831	1,142,677	1,123,504	1,079,185	1,047,719	981,690	1,003,094	981,201
Total (excluding LULUCF)	1,157,374	1,239,226	1,263,951	1,290,333	1,214,785	1,315,320	1,263,766	1,223,195	1,203,178	1,187,524	1,142,499	1,105,462	1,040,476	1,061,855	1,034,861

*1 Excluding indirect CO_2

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

CO_2 emissions per capita in FY2022 were 8.28 tonnes. They decreased by 11.5% since FY1990 and decreased by 2.1% compared to the previous year.

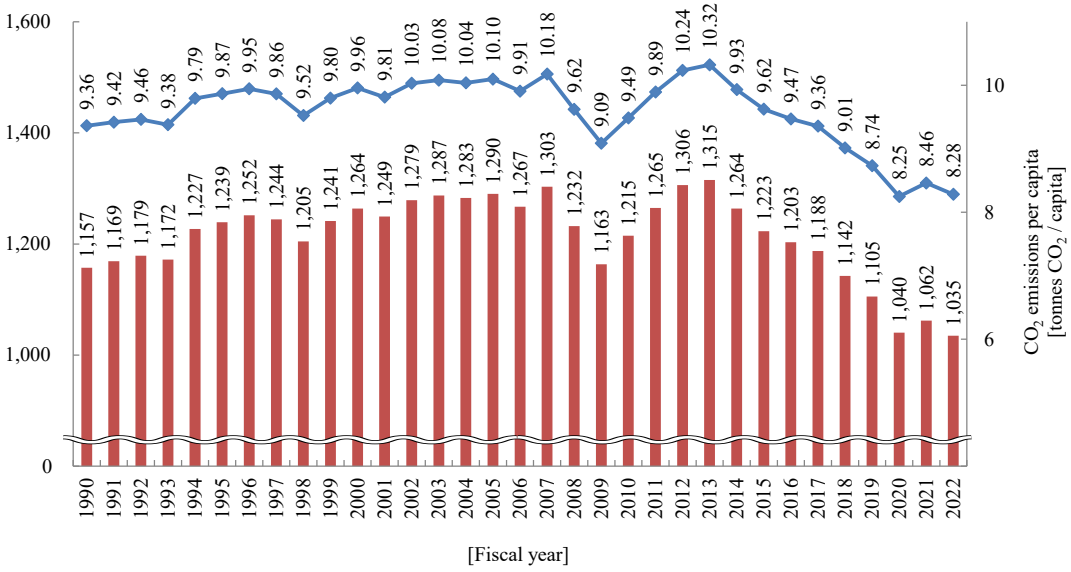

Figure 2-4 Trends in total CO_2 emissions and CO_2 emissions per capita
Reference of population data: *Population Census* and *Annual Report of Population Estimates* (Ministry of Internal Affairs and Communications, Statistics Bureau)

CO_2 emissions per unit of Real GDP (million yen) in FY2022 were 1.88 tonnes. They decreased by 30.2% since FY1990 and decreased by 4.0% compared to the previous year.

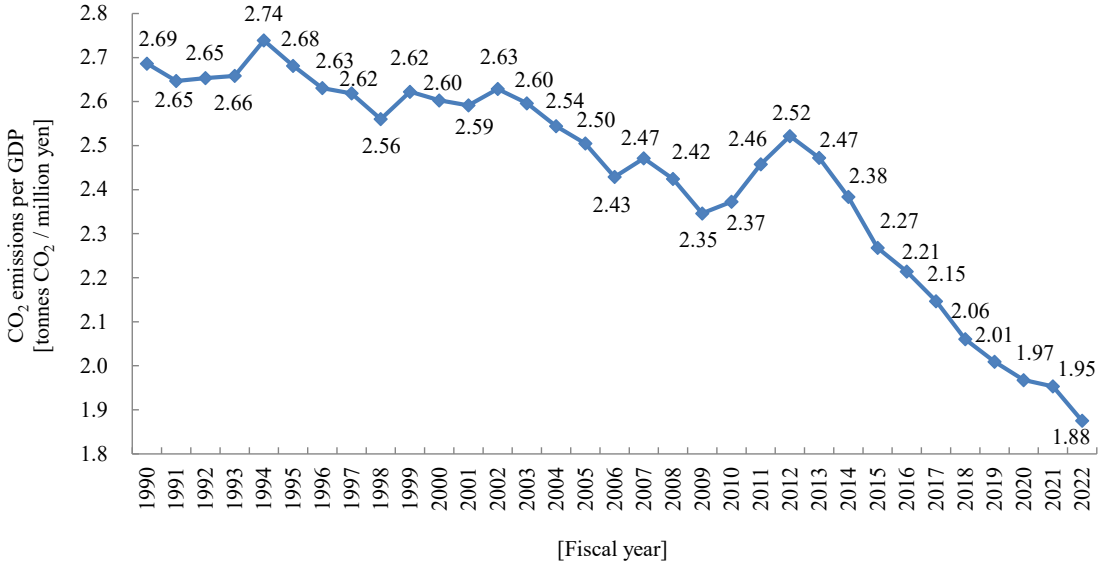

Figure 2-5 Trends in CO_2 emissions per unit of Real GDP
Reference of Real GDP data: *Annual Report on National Accounts* (Cabinet Office, Government of Japan) (Expenditure Approach, chained 2015 yen)

2.1.3. CH_4

CH_4 emissions in FY2022 were 29.9 million tonnes (in CO_2 eq., including LULUCF), accounting for 2.6% of total GHG emissions. They decreased by 40.0% since FY1990 and decreased by 1.7% compared to the previous year. Their decrease since FY1990 is mainly a result of a 76.1% decrease in emissions from the waste sector (e.g. solid waste disposal).

The breakdown of the FY2022 emissions showed that the largest source was rice cultivation accounting for 43.6%. It is followed by enteric fermentation (28.9%) and manure management (9.0%).

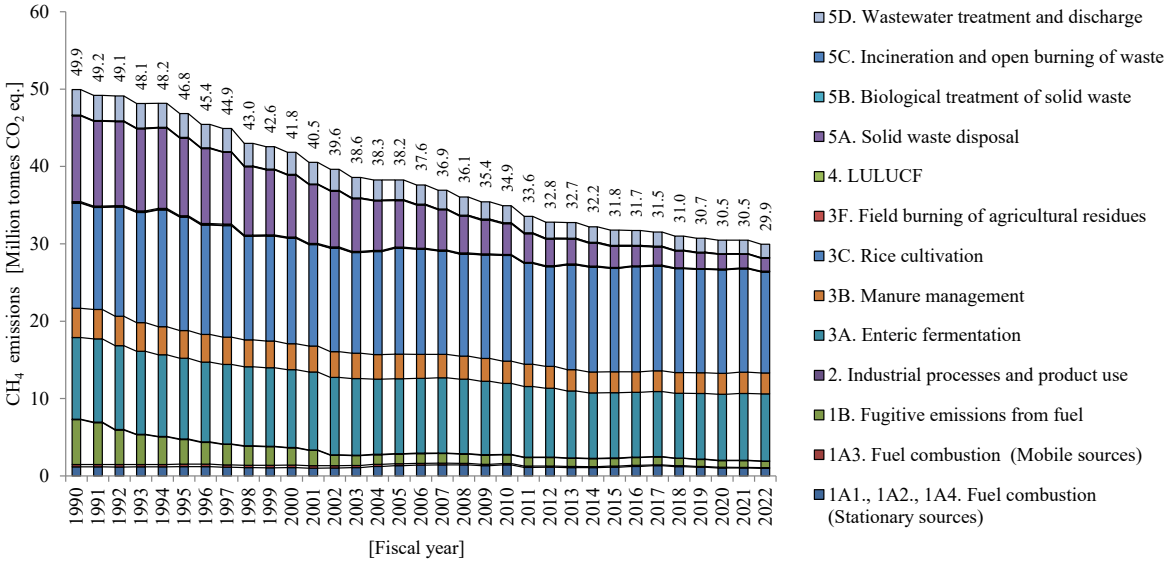

Figure 2-6 Trends in CH_4 emissions

Table 2-3 Trends in CH_4 emissions

[Thousand tonnes CO_2 eq.]

Category	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
1A. Fuel combustion	1,483	1,516	1,395	1,578	1,587	1,222	1,208	1,261	1,360	1,434	1,325	1,234	1,115	1,108	1,074
1A1. Energy industries	514	448	295	278	302	268	252	310	396	437	364	290	230	230	218
1A2. Manufacturing industries and construction	403	424	415	495	602	555	581	589	605	632	611	583	526	547	526
1A3. Transport	298	315	318	250	173	147	138	132	126	121	117	112	98	95	100
1A4. Other sectors	267	329	367	555	509	253	237	230	233	245	233	250	261	236	231
1B. Fugitive emissions from fuels	5,784	3,183	2,229	1,240	1,133	1,040	1,023	997	1,009	1,025	938	893	854	855	817
1B1. Solid fuels	5,482	2,822	1,847	788	672	633	638	615	605	621	559	535	525	526	510
1B2. Oil and natural gas and other emissions	301	361	381	452	461	407	385	382	404	404	380	358	329	330	307
2. Industrial processes and product use	68	65	61	60	60	52	48	54	48	48	45	46	43	49	43
3. Agriculture	28,002	28,764	27,100	26,600	25,750	24,988	24,748	24,552	24,657	24,625	24,509	24,545	24,661	24,780	24,468
3A. Enteric fermentation	10,554	10,437	10,042	9,689	9,186	8,665	8,449	8,438	8,378	8,393	8,361	8,471	8,547	8,642	8,661
3B. Manure management	3,786	3,595	3,365	3,180	2,881	2,759	2,711	2,707	2,664	2,679	2,680	2,701	2,711	2,750	2,709
3C. Rice cultivation	13,585	14,663	13,636	13,682	13,649	13,527	13,554	13,374	13,584	13,523	13,440	13,343	13,373	13,356	13,068
3F. Field burning of agricultural residues	78	69	56	49	34	36	35	32	30	29	28	31	30	32	30
4. LULUCF	117	107	99	98	88	84	105	85	79	103	79	82	79	87	80
5. Waste	14,479	13,197	10,954	8,671	6,301	5,359	5,072	4,819	4,564	4,302	4,108	3,921	3,731	3,586	3,465
5A. Solid waste disposal	11,092	10,024	8,007	5,992	3,996	3,205	2,956	2,734	2,519	2,344	2,173	2,025	1,885	1,757	1,637
5B. Biological treatment of solid waste	60	60	61	107	104	112	112	114	115	100	100	92	83	86	86
5C. Incineration and open burning of waste	31	33	23	20	13	13	12	11	10	11	12	11	10	9	9
5D. Wastewater treatment and discharge	3,295	3,080	2,863	2,553	2,188	2,029	1,993	1,959	1,920	1,846	1,824	1,793	1,753	1,733	1,733
Total (including LULUCF)	49,932	46,833	41,838	38,249	34,918	32,744	32,202	31,768	31,718	31,537	31,006	30,721	30,483	30,465	29,947
Total (excluding LULUCF)	49,815	46,726	41,739	38,151	34,831	32,661	32,098	31,683	31,639	31,434	30,926	30,639	30,404	30,378	29,867

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

2.1.4. N_2O

N_2O emissions in FY2022 were 17.7 million tonnes (in CO_2 eq., including LULUCF), accounting for 1.6% of total GHG emissions. They decreased by 40.6% since FY1990 and decreased by 1.9% compared to the previous year. Their decrease since FY1990 is mainly a result of an 90.5% 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 FY2022 emissions showed that the largest source was agricultural soils accounting for 29.5%. It is followed by manure management (19.4%) and fuel combustion (stationary sources) (18.3%).

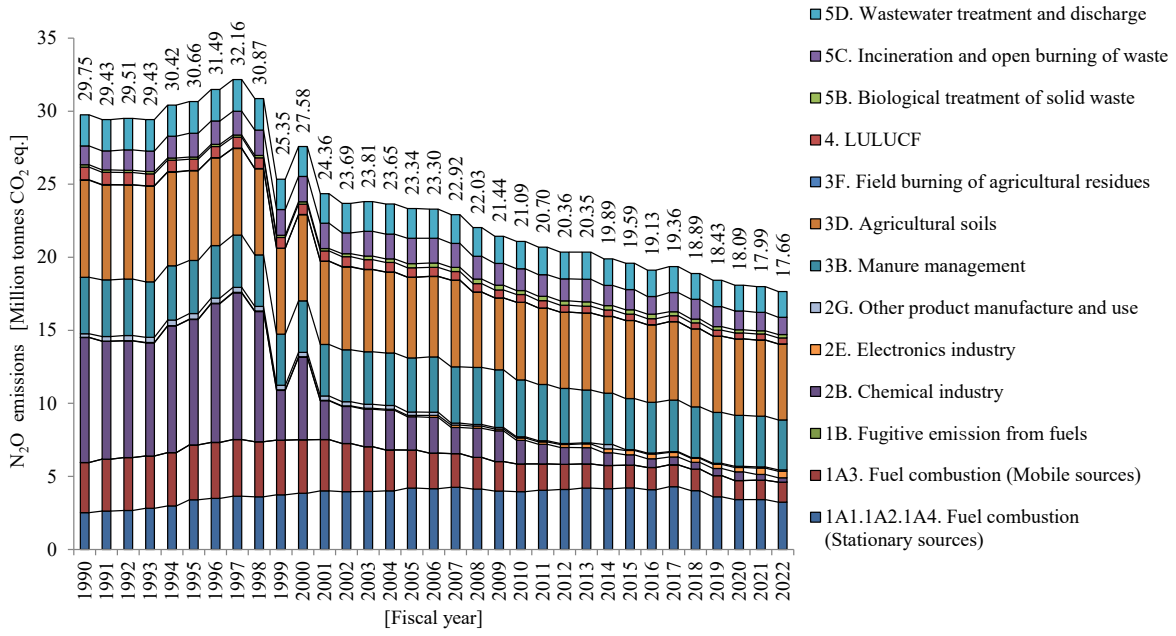

Figure 2-7 Trends in N_2O emissions

Table 2-4 Trends in N_2O emissions

[Thousand tonnes CO_2 eq.]

Category	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
1A. Fuel combustion	5,946	7,151	7,511	6,800	5,853	5,852	5,749	5,766	5,613	5,794	5,509	5,059	4,721	4,737	4,602
1A1. Energy industries	791	1,203	1,435	1,883	1,843	2,097	2,086	2,124	2,006	2,173	2,004	1,653	1,629	1,660	1,638
1A2. Manufacturing industries and construction	1,120	1,517	1,671	1,661	1,533	1,566	1,531	1,543	1,487	1,487	1,458	1,417	1,306	1,300	1,152
1A3. Transport	3,421	3,753	3,660	2,597	1,902	1,653	1,593	1,554	1,521	1,501	1,480	1,455	1,301	1,319	1,370
1A4. Other sectors	613	677	746	660	575	536	539	546	599	632	567	535	485	457	441
1B. Fugitive emissions from fuels	2	2	2	1	1	1	1	1	1	1	1	1	1	0	0
2. Industrial processes and product use	8,813	8,994	5,976	2,602	1,857	1,439	1,428	1,067	982	907	779	836	966	915	840
2B. Chemical industry	8,555	8,595	5,645	2,275	1,612	1,120	870	709	601	533	450	490	589	397	301
2E. Electronics industry	13	25	39	99	160	252	263	299	323	312	273	276	302	431	448
2G. Other product manufacture and use	245	374	291	228	85	67	294	58	58	62	56	70	75	87	92
3. Agriculture	10,546	9,797	9,447	9,243	9,217	8,904	8,776	8,847	8,790	8,897	8,822	8,709	8,729	8,693	8,631
3B. Manure management	3,865	3,638	3,529	3,702	3,890	3,617	3,525	3,494	3,472	3,516	3,474	3,486	3,497	3,472	3,419
3D. Agricultural soils	6,658	6,138	5,903	5,527	5,317	5,277	5,241	5,343	5,310	5,373	5,339	5,214	5,224	5,212	5,203
3F. Field burning of agricultural residues	23	21	16	14	10	10	10	9	9	8	8	8	8	9	8
4. LULUCF	871	767	707	631	521	452	438	424	413	404	399	399	400	403	405
5. Waste	3,571	3,949	3,940	4,060	3,645	3,702	3,500	3,491	3,327	3,357	3,380	3,427	3,276	3,247	3,179
5B. Biological treatment of solid waste	161	159	161	284	275	298	296	302	305	265	263	244	220	226	226
5C. Incineration and open burning of waste	1,287	1,621	1,733	1,749	1,489	1,553	1,384	1,386	1,219	1,320	1,348	1,376	1,296	1,255	1,187
5D. Wastewater treatment and discharge	2,123	2,169	2,046	2,028	1,881	1,851	1,819	1,803	1,803	1,772	1,769	1,807	1,760	1,766	1,766
Total (including LULUCF)	29,749	30,659	27,583	23,338	21,093	20,349	19,892	19,595	19,125	19,359	18,890	18,432	18,092	17,995	17,658
Total (excluding LULUCF)	28,878	29,892	26,875	22,706	20,573	19,897	19,454	19,171	18,713	18,955	18,490	18,032	17,692	17,592	17,252

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

2.1.5. HFCs

HFC emissions in CY2022[7] were 46.1 million tonnes (in CO_2 eq.), accounting for 4.1% of total GHG emissions. They increased by 244% since CY1990, and decreased by 1.6% compared to the previous year. Their increase since CY1990 is mainly a result of an increase in emissions from refrigeration and air conditioning (+42.8 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 decrease in leaks during operation from commercial refrigeration and air conditioning.

The breakdown of the CY2022 emissions showed that the largest source was refrigerants of refrigeration and air conditioning equipment accounting for 92.8%. It is followed by foam blowing agents (5.6%).

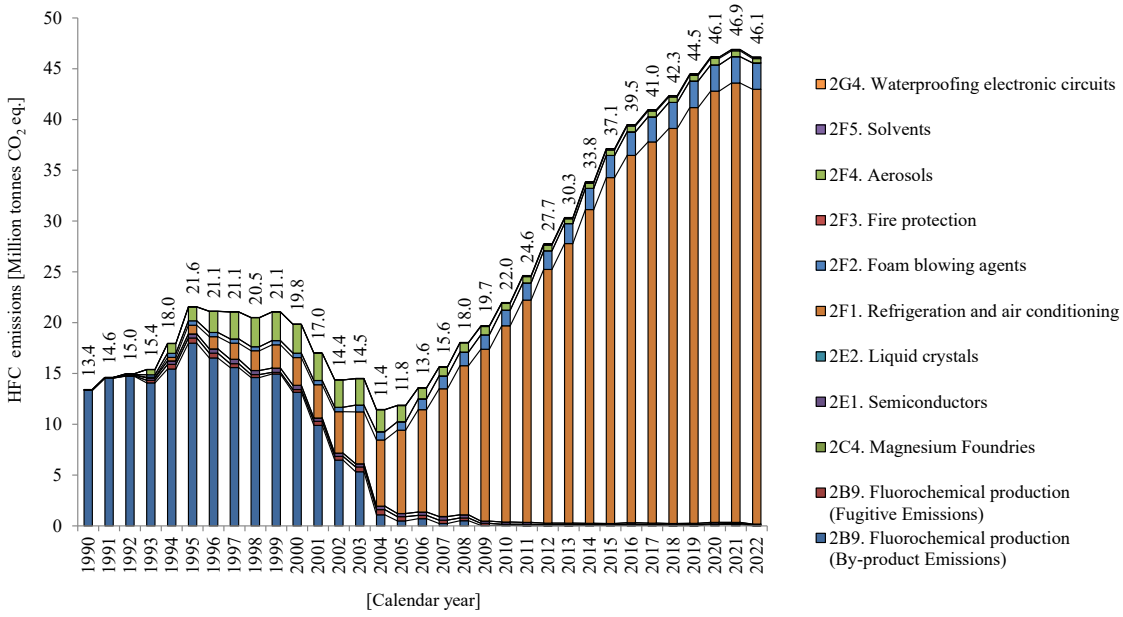

Figure 2-8 Trends in HFC emissions

Table 2-5 Trends in HFC emissions

[Thousand tonnes CO_2 eq.]

Category	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
2B9. Fluorochemical production	13,347	18,483	13,408	898	160	132	111	100	156	118	90	119	187	220	66
a. By-product emissions	13,346	17,980	13,144	491	45	14	20	25	20	32	10	11	118	110	4
b. Fugitive emissions	1	503	264	407	115	119	91	75	136	86	81	108	69	109	63
2C4. Magnesium production	NO	NO	NO	NO	NO	1	1	1	1	1	2	1	1	2	1
2E. Electronics industry	55	416	434	315	220	131	131	126	143	153	144	133	151	111	97
2E1. Semiconductors	55	415	432	312	217	129	129	124	141	152	142	132	150	110	96
2E2. Liquid crystals	0.001	0.2	2	2	3	2	2	2	2	2	2	1	1	1	1
2F. Product uses as substitutes for ODS	1	2,657	5,993	10,631	21,581	30,070	33,599	36,893	39,183	40,678	42,098	44,208	45,799	46,559	45,966
2F1. Refrigeration and air conditioning	NO	841	2,713	8,198	19,322	27,521	30,898	34,059	36,159	37,524	38,890	40,918	42,464	43,266	42,810
2F2. Foam blowing agents	1	452	440	829	1,538	1,957	2,082	2,179	2,323	2,454	2,558	2,610	2,571	2,586	2,591
2F3. Fire protection	NO	NO	4	7	8	8	9	9	8	9	9	9	9	9	9
2F4. Aerosols	NO	1,365	2,835	1,592	653	473	485	519	561	574	522	548	626	568	426
2F5. Solvents	NO	NO	NO	6	61	110	124	127	131	117	119	124	128	129	129
2G4. Waterproofing electronic circuits	6.5	5.4	6.5	4.4	3.3	2.3	2.4	2.4	2.5	2.3	2.5	4.9	5.3	5.5	5.7
Total	13,410	21,561	19,841	11,848	21,964	30,337	33,844	37,122	39,485	40,953	42,336	44,467	46,144	46,896	46,137

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

2.1.6. PFCs

PFC emissions in CY2022 were 3.0 million tonnes (in CO_2 eq.), accounting for 0.3% of total GHG emissions. They decreased by 50.5% since CY1990 and increased by 4.9% compared to the previous year. Their decrease since CY1990 is mainly the result of a decrease in emissions from the solvents. (-66.7%)

The breakdown of the CY2022 emissions showed that the largest source was semiconductor manufacturing accounting for 47.6%. It is followed by solvents such as those for washing metals (46.1%).

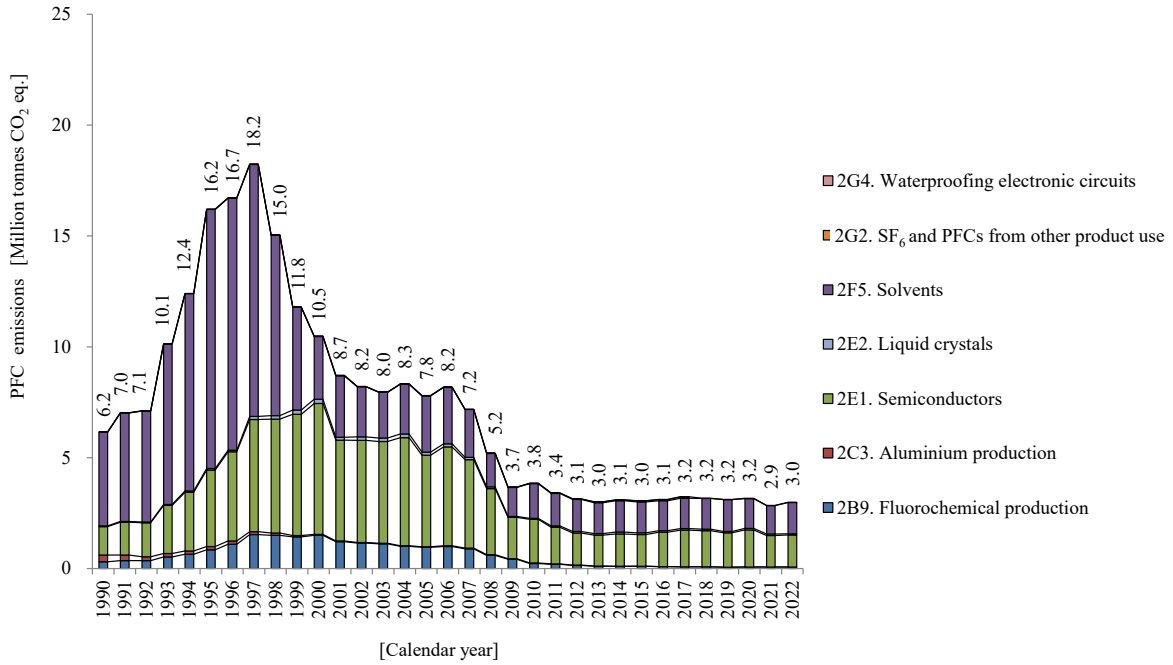

Figure 2-9 Trends in PFC emissions

Table 2-6 Trends in PFC emissions

[Thousand tonnes CO_2 eq.]

Category	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
2B9. Fluorochemical production	304	840	1,499	955	227	100	97	104	88	73	79	58	67	72	67
2C3. Aluminium production	301	153	39	32	23	14	3	NO	NO	NO	NO	NO	NO	NO	NO
2E. Electronics industry	1,314	3,521	6,097	4,263	2,015	1,461	1,542	1,507	1,615	1,731	1,698	1,617	1,744	1,483	1,503
2E1. Semiconductors	1,286	3,443	5,905	4,126	1,973	1,393	1,461	1,429	1,551	1,655	1,627	1,549	1,675	1,413	1,452
2E2. Liquid crystals	28	78	192	137	42	68	81	78	64	76	71	67	69	70	52
2F5. Solvents	4,228	11,684	2,834	2,542	1,567	1,395	1,411	1,394	1,350	1,366	1,384	1,429	1,343	1,279	1,406
2G. Other product manufacture and use	15	12	15	10	11	14	13	12	23	22	39	52	60	71	72
2G2. SF_6 and PFCs from other product use	NO	NO	NO	0.2	4	9	8	7	18	17	33	41	48	58	60
2G4. Waterproofing electronic circuits	15	12	15	10	7	5	6	5	6	5	6	11	12	12	13
Total	6,163	16,210	10,483	7,802	3,843	2,985	3,066	3,017	3,076	3,192	3,200	3,156	3,214	2,905	3,049

2.1.7. SF_6

SF_6 emissions in CY2022 were 2.1 million tonnes (in CO_2 eq.), accounting for 0.2% of total GHG emissions. They decreased by 84.5% since CY1990 and decreased by 4.6% 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. (-93.1%)

The breakdown of the CY2022 emissions showed that the largest source was other product use (e.g. accelerator, etc.) accounting for 38.2%. It is followed by electrical equipment (27.2%) and semiconductor (14.0%).

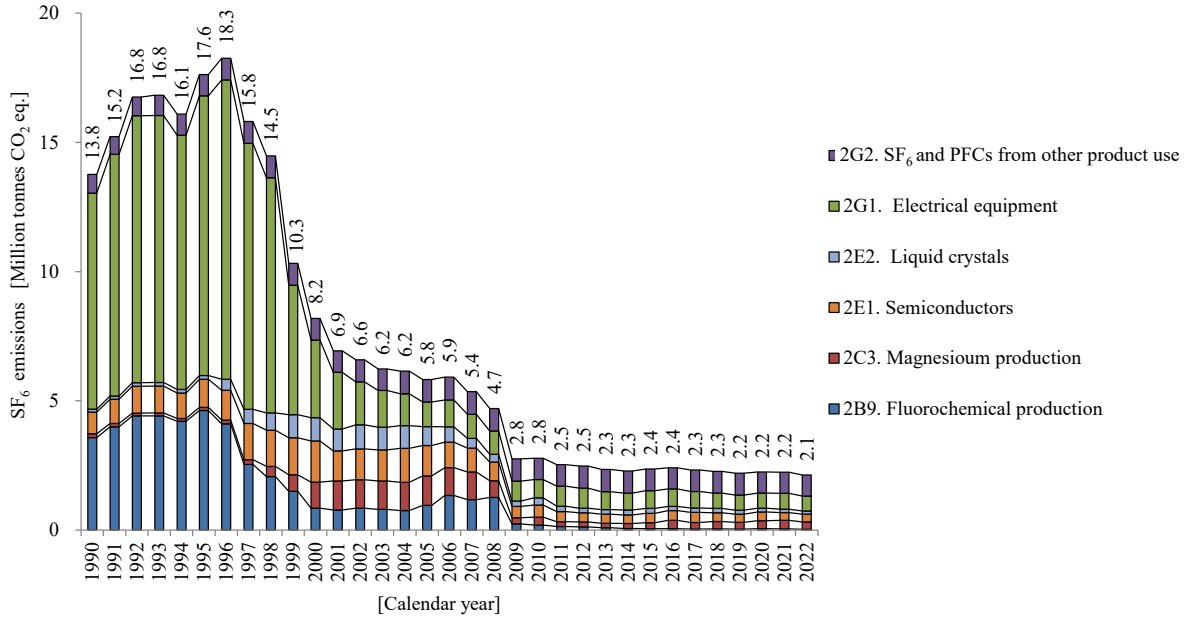

Figure 2-10 Trends in SF_6 emissions

Table 2-7 Trends in SF_6 emissions

[Thousand tonnes CO_2 eq.]

Category	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
2B9. Fluorochemical production	3,577	4,630	846	959	195	96	63	54	52	42	47	41	54	47	34
2C3. Magnesium production	151	118	1,011	1,138	303	165	188	235	324	254	282	259	306	329	282
2E. Electronics industry	951	1,230	2,496	1,907	750	531	528	554	539	560	511	467	486	433	423
2E1. Semiconductors	838	1,084	1,592	1,174	473	356	331	357	378	393	339	316	343	300	299
2E2. Liquid crystals	113	146	904	734	277	175	197	197	161	168	172	152	143	133	124
2G. Other product manufacture and use	9,085	11,647	3,839	1,824	1,531	1,555	1,508	1,523	1,492	1,468	1,432	1,435	1,401	1,429	1,397
2G1. Electrical equipment	8,362	10,821	2,999	956	706	699	654	686	675	639	590	590	589	616	581
2G2. SF_6 and PFCs from other product use	723	826	840	868	825	856	854	837	817	829	843	844	812	813	816
Total	13,764	17,624	8,191	5,828	2,779	2,346	2,288	2,366	2,407	2,324	2,272	2,202	2,246	2,238	2,136

2.1.8. NF_3

NF_3 emissions in CY2022 were 0.3 million tonnes (in CO_2 eq.), accounting for 0.03% of total GHG emissions. They increased by 1,100% since CY1990 and increased by 1.4% 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 1,220%)

The breakdown of the CY2022 emissions showed that the largest source was semiconductor manufacture accounting for 90.1%. It is followed by fluorochemical production (5.7%) and liquid crystal manufacture (4.2%).

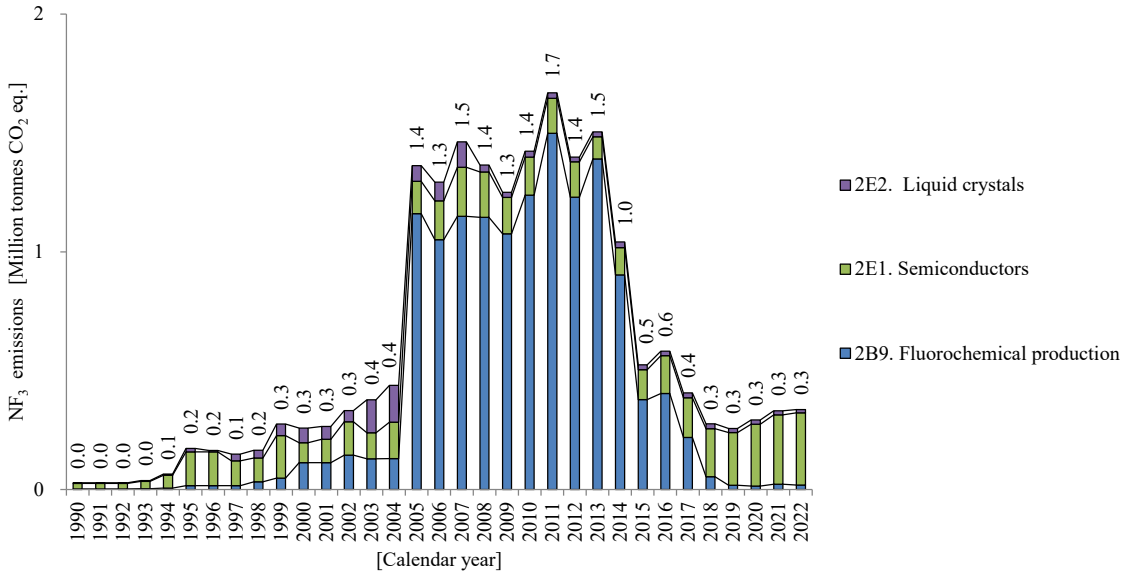

Figure 2-11 Trends in NF_3 emissions

Table 2-8 Trends in NF_3 emissions

[Thousand tonnes CO_2 eq.]

Category	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
2B9. Fluorochemical production	3	16	113	1,161	1,238	1,391	903	378	404	219	54	18	14	22	19
2E. Electronics industry	25	156	145	202	185	113	139	146	177	188	222	239	279	309	317
2E1. Semiconductors	23	142	84	136	161	93	114	125	159	167	202	221	261	291	303
2E2. Liquid crystals	2	15	62	66	25	20	25	21	18	21	20	17	18	18	14
Total	28	172	258	1,363	1,423	1,504	1,042	524	582	407	276	257	293	332	336

2.1.9. Indirect CO_2

Indirect CO_2 emissions[8] in FY2022 were 1.8 million tonnes (in CO_2 eq.), accounting for 0.2% of total GHG emissions. They decreased by 66.8% since FY1990 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.

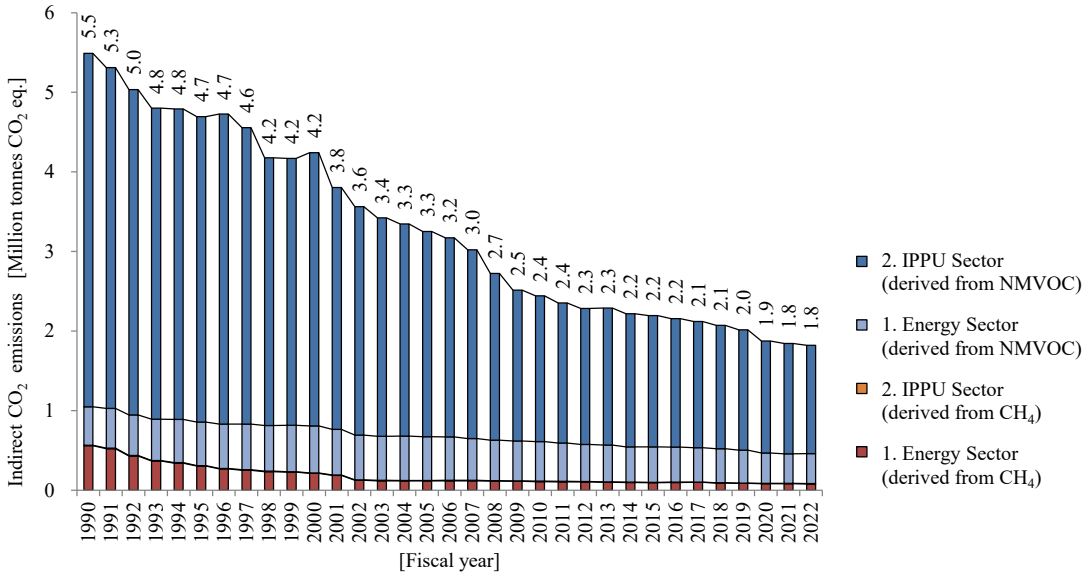

Figure 2-12 Trends in Indirect CO_2 emissions

Table 2-9 Trends in Indirect CO_2 emissions

[Thousand tonnes CO_2 eq.]

Emission Source	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Derived from CH_4	565	310	217	123	113	104	102	100	101	103	94	90	86	87	83
1. Energy Sector	559	304	211	117	107	99	97	95	96	98	90	85	82	82	78
2. IPPU Sector	7	6	6	6	6	5	5	5	5	5	4	5	4	5	4
Derived from NMVOC	4,924	4,383	4,025	3,128	2,328	2,185	2,115	2,094	2,056	2,019	1,978	1,925	1,789	1,757	1,738
1. Energy Sector	482	547	591	549	498	464	442	445	440	432	427	414	381	371	378
2. IPPU Sector	4,442	3,836	3,433	2,579	1,830	1,721	1,673	1,650	1,616	1,586	1,551	1,511	1,408	1,385	1,360
Total	5,490	4,693	4,242	3,251	2,442	2,289	2,218	2,194	2,157	2,121	2,073	2,015	1,875	1,844	1,821

[8] Emissions derived from fuel combustion-origin, waste incineration-origin, and biomass-origin CO, CH_4, and NMVOC are excluded to avoid double counting and/or by concept of carbon neutrality.

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

The breakdown of GHG emissions and removals in FY2022 by sector[9] showed that energy (excluding indirect CO_2, hereafter, definition omitted) accounted for 87.1% of total GHG emissions. It is followed by industrial processes and product use (excluding indirect CO_2, hereafter, definition omitted) (8.2%), agriculture (3.0%), waste (1.5%), and indirect CO_2 emissions (0.2%).

Removals by LULUCF in FY2022 were equivalent to 4.7% of total GHG emissions.

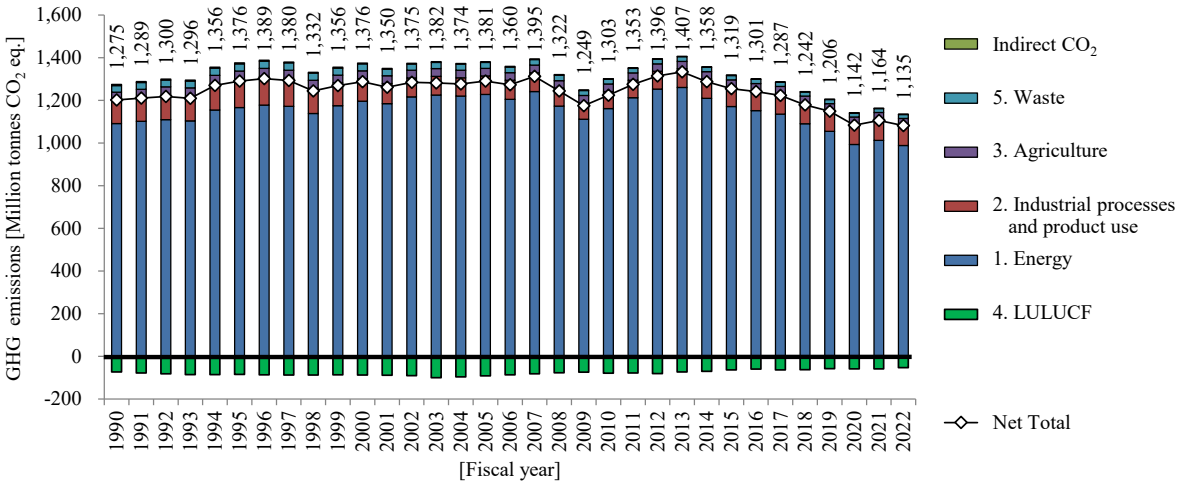

Figure 2-13 Trends in GHG emissions and removals in each sector

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

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

[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	1,091.6	1,101.9	1,109.9	1,103.9	1,154.8	1,166.7	1,178.1	1,172.6	1,138.4	1,175.0	1,196.9	1,184.6	1,216.2	1,225.1	1,220.9	1,227.8	1,205.1	1,241.3	1,173.5	1,112.3
2. Industrial processes and product use*1	107.4	111.8	113.8	115.8	122.6	131.8	134.0	131.1	118.8	106.9	105.0	94.8	89.0	87.9	85.4	86.5	89.1	88.2	83.7	76.4
3. Agriculture	39.3	38.9	39.8	39.8	40.0	39.0	38.2	38.3	37.0	37.1	37.0	36.3	36.4	35.9	35.8	36.3	36.1	36.5	35.4	35.2
4. LULUCF*2	-72.7	-78.3	-82.1	-85.3	-85.3	-85.0	-86.2	-87.0	-87.1	-86.6	-87.7	-88.4	-90.0	-99.8	-96.5	-90.9	-86.3	-81.6	-77.0	-74.4
5. Waste	31.1	30.9	32.0	31.5	33.8	33.8	33.8	34.0	33.6	32.8	32.4	30.7	29.4	29.2	28.3	27.4	26.1	25.8	26.3	23.1
Indirect CO_2	5.5	5.3	5.0	4.8	4.8	4.7	4.7	4.6	4.2	4.2	4.2	3.8	3.6	3.4	3.3	3.3	3.2	3.0	2.7	2.5
Gross Total (excluding LULUCF, excluding indirect CO_2)	1,269.4	1,283.6	1,295.4	1,290.9	1,351.1	1,371.4	1,384.1	1,375.9	1,327.8	1,351.8	1,371.3	1,346.4	1,371.0	1,378.2	1,370.4	1,378.0	1,356.5	1,391.8	1,318.9	1,246.9
Net Total (including LULUCF, excluding indirect CO_2)	1,196.7	1,205.3	1,213.3	1,205.6	1,265.8	1,286.4	1,297.9	1,288.9	1,240.7	1,265.2	1,283.7	1,258.0	1,281.0	1,278.4	1,273.9	1,287.2	1,270.2	1,310.2	1,241.9	1,172.5
Gross Total (excluding LULUCF, including indirect CO_2)	1,274.9	1,288.9	1,300.4	1,295.7	1,355.9	1,376.1	1,388.8	1,380.5	1,332.0	1,355.9	1,375.6	1,350.2	1,374.6	1,381.6	1,373.7	1,381.3	1,359.6	1,394.8	1,321.6	1,249.5
Net Total (including LULUCF, including indirect CO_2)	1,202.2	1,210.7	1,218.4	1,210.4	1,270.6	1,291.1	1,302.6	1,293.5	1,244.9	1,269.4	1,287.9	1,261.8	1,284.5	1,281.8	1,277.3	1,290.4	1,273.3	1,313.2	1,244.6	1,175.1

[Million tonnes CO_2 eq.]	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
1. Energy*1	1,162.2	1,213.0	1,253.3	1,260.8	1,210.2	1,171.3	1,152.2	1,136.3	1,090.7	1,055.1	993.4	1,012.9	989.2
2. Industrial processes and product use*1	79.6	81.3	83.7	87.9	90.4	91.3	93.4	95.4	95.7	96.2	95.2	97.0	93.4
3. Agriculture	35.4	34.6	34.2	34.5	34.1	33.9	33.9	34.0	33.8	33.7	33.8	33.9	33.5
4. LULUCF*2	-78.7	-77.7	-80.6	-73.4	-69.7	-63.9	-60.0	-63.5	-62.8	-57.3	-58.3	-58.3	-53.2
5. Waste	23.0	21.9	22.1	21.9	20.9	20.6	19.6	19.1	19.8	19.3	18.0	18.3	17.5
Indirect CO_2	2.4	2.4	2.3	2.3	2.2	2.2	2.2	2.1	2.1	2.0	1.9	1.8	1.8
Gross Total (excluding LULUCF, excluding indirect CO_2)	1,300.2	1,350.7	1,393.3	1,405.0	1,355.6	1,317.1	1,299.1	1,284.8	1,240.0	1,204.2	1,140.5	1,162.2	1,133.6
Net Total (including LULUCF, excluding indirect CO_2)	1,221.5	1,273.0	1,312.7	1,331.7	1,285.8	1,253.2	1,239.1	1,221.3	1,177.2	1,147.0	1,082.2	1,103.9	1,080.5
Gross Total (excluding LULUCF, including indirect CO_2)	1,302.6	1,353.1	1,395.6	1,407.3	1,357.8	1,319.3	1,301.2	1,286.9	1,242.1	1,206.2	1,142.3	1,164.0	1,135.5
Net Total (including LULUCF, including indirect CO_2)	1,223.9	1,275.4	1,315.0	1,334.0	1,288.1	1,255.4	1,241.2	1,223.4	1,179.2	1,149.0	1,084.0	1,105.8	1,082.3

*1 Excluding indirect CO_2

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

2.2.1. Energy

Emissions from the energy sector in FY2022 were 989 million tonnes (in CO_2 equivalents). They decreased by 9.4% since FY1990 and decreased by 2.3% compared to the previous year.

The breakdown of the FY2022 emissions showed that CO_2 from fuel combustion accounted for 99.3%. The largest source within fuel combustion[10] was solid fuel CO_2, which accounted for 40.8%, and is then followed by liquid fuel CO_2 (36.2%) and gaseous fuel CO_2 (20.3%).

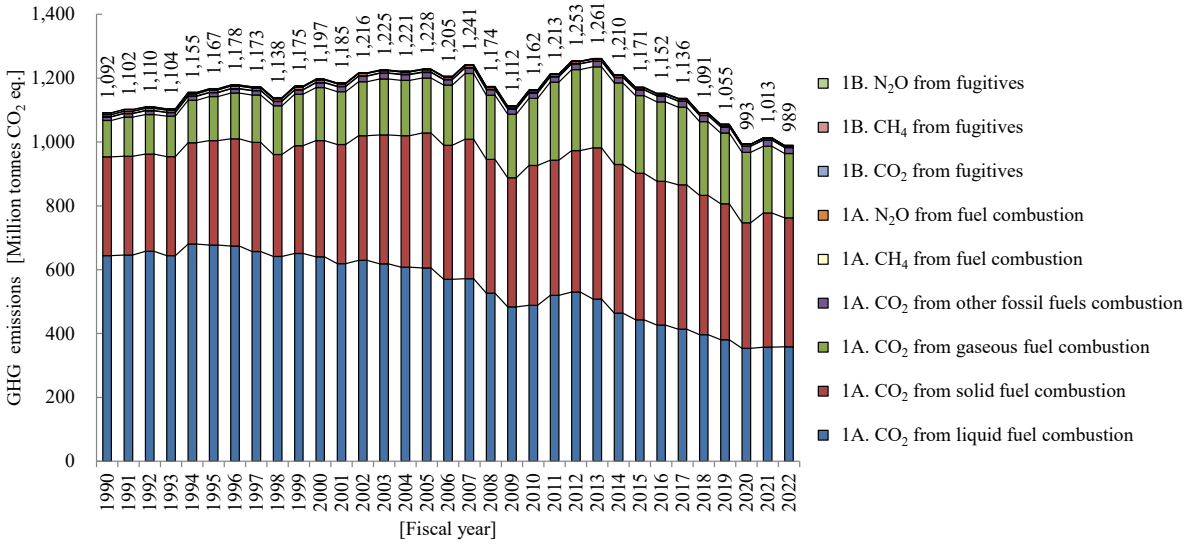

Figure 2-14 Trends in GHG emissions from the energy sector

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

[Thousand tonnes CO_2 eq.]

Source category	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
1A. Fuel combustion	1,085,649	1,162,998	1,194,134	1,226,066	1,160,591	1,259,267	1,208,672	1,169,814	1,150,707	1,134,795	1,089,310	1,053,770	992,179	1,011,674	988,013
Liquid fuel CO_2	643,929	677,008	640,194	605,559	488,289	507,904	464,256	443,360	426,682	413,933	396,830	380,372	353,480	357,248	358,505
Solid fuel CO_2	309,413	327,103	363,995	422,372	438,505	473,808	465,126	458,748	450,157	452,166	435,798	426,297	393,791	420,161	403,873
Gaseous fuel CO_2	114,167	137,927	166,073	172,415	209,932	253,378	255,508	243,368	248,829	242,817	231,347	221,419	220,274	209,302	201,244
Other fossil fuels (Waste) CO_2	10,712	12,294	14,966	17,341	16,427	17,104	16,826	17,312	18,066	18,651	18,502	19,387	18,797	19,117	18,714
CH_4	1,483	1,516	1,395	1,578	1,587	1,222	1,208	1,261	1,360	1,434	1,325	1,234	1,115	1,108	1,074
N_2O	5,946	7,151	7,511	6,800	5,853	5,852	5,749	5,766	5,613	5,794	5,509	5,059	4,721	4,737	4,602
1B. Fugitive emissions from fuels	5,988	3,712	2,758	1,774	1,634	1,502	1,494	1,443	1,489	1,485	1,386	1,298	1,263	1,230	1,166
CO_2	203	526	527	532	500	462	470	446	479	459	447	404	408	374	348
CH_4	5,784	3,183	2,229	1,240	1,133	1,040	1,023	997	1,009	1,025	938	893	854	855	817
N_2O	1.9	1.9	1.6	1.1	0.9	0.8	0.7	0.7	0.6	0.6	0.6	0.6	0.5	0.5	0.5
1C. CO_2 transport and storage	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO,NA	NE,NO,NA	NE,NO,NA	NE,NO,NA	NE,NO	NE,NO	NE,NO
Total	1,091,637	1,166,710	1,196,892	1,227,840	1,162,225	1,260,769	1,210,166	1,171,258	1,152,196	1,136,280	1,090,696	1,055,067	993,442	1,012,904	989,179

2.2.2. Industrial Processes and Product Use

Emissions from the industrial processes and product use sector in FY2022 were 93.4 million tonnes (in CO_2 eq.). They decreased by 13.0% since FY1990 and decreased by 3.7% compared to the previous year.

The breakdown of GHG emissions from this sector in FY2022 showed that the largest source was HFC emissions from product uses as ODS substitutes, accounting for 49.2%. It was followed by the mineral industry emissions such as CO_2 emissions from cement production (31.0%) and CO_2 emissions from the metal industry (5.6%).

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

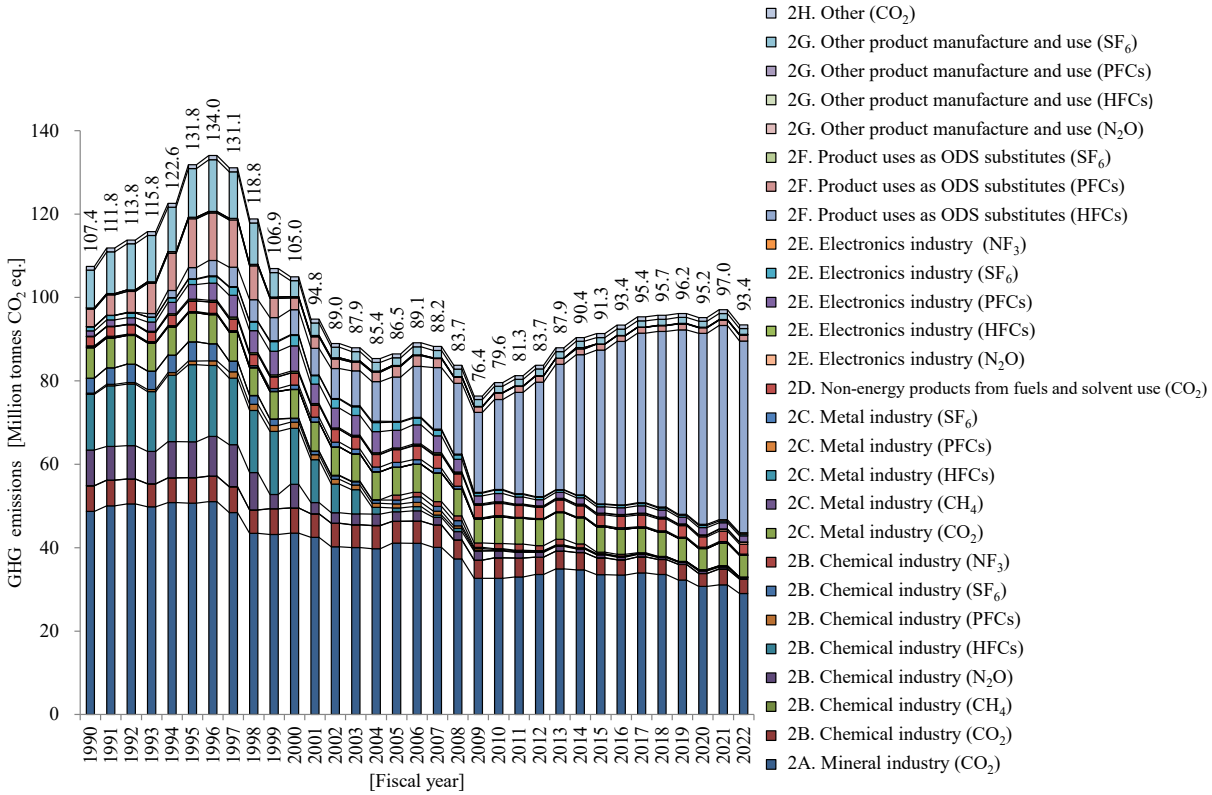

Figure 2-15 Trends in GHG emissions from the industrial processes and product use sector

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	2014	2015	2016	2017	2018	2019	2020	2021	2022
2A. Mineral industry (CO_2)	48,714	50,689	43,487	41,112	32,676	34,930	34,678	33,526	33,421	33,940	33,565	32,232	30,703	31,085	29,005
2B. Chemical industry	31,937	38,694	27,575	11,490	8,329	7,094	6,212	5,393	4,996	4,873	4,356	4,506	4,031	4,597	3,972
CO_2	6,110	6,090	6,026	5,205	4,856	4,224	4,139	4,012	3,665	3,859	3,610	3,752	3,093	3,809	3,458
CH_4	42	42	38	38	41	32	28	36	30	28	25	28	27	30	26
N_2O	8,555	8,595	5,645	2,275	1,612	1,120	870	709	601	533	450	490	589	397	301
HFCs	13,347	18,483	13,408	898	160	132	111	100	156	118	90	119	187	220	66
PFCs	304	840	1,499	955	227	100	97	104	88	73	79	58	67	72	67
SF_6	3,577	4,630	846	959	195	96	63	54	52	42	47	41	54	47	34
NF_3	3	16	113	1,161	1,238	1,391	903	378	404	219	54	18	14	22	19
2C. Metal industry	7,770	7,229	7,941	7,872	6,708	6,591	6,516	6,353	6,375	6,218	6,119	5,771	5,379	5,776	5,509
CO_2	7,292	6,935	6,868	6,679	6,363	6,391	6,305	6,098	6,032	5,943	5,815	5,493	5,056	5,427	5,208
CH_4	26	24	22	23	20	20	20	19	18	20	20	18	16	19	17
HFCs	NO	NO	NO	NO	NO	1	1	1	1	1	2	1	1	2	1
PFCs	301	153	39	32	23	14	3	NO	NO	NO	NO	NO	NO	NO	NO
SF_6	151	118	1,011	1,138	303	165	188	235	324	254	282	259	306	329	282
2D. Non-energy products from fuels and solvent use (CO_2)	2,207	2,551	2,841	3,031	2,898	2,817	2,657	2,608	2,700	2,809	2,875	2,766	2,521	2,495	2,328
2E. Electronics industry	2,359	5,349	9,211	6,786	3,330	2,489	2,603	2,632	2,797	2,944	2,847	2,732	2,962	2,767	2,788
N_2O	13	25	39	99	160	252	263	299	323	312	273	276	302	431	448
HFCs	55	416	434	315	220	131	131	126	143	153	144	133	151	111	97
PFCs	1,314	3,521	6,097	4,263	2,015	1,461	1,542	1,507	1,615	1,731	1,698	1,617	1,744	1,483	1,503
SF_6	951	1,230	2,496	1,907	750	531	528	554	539	560	511	467	486	433	423
NF_3	25	156	145	202	185	113	139	146	177	188	222	239	279	309	317
2F. Product uses as substitutes for ODS	4,230	14,341	8,826	13,173	23,148	31,465	35,009	38,287	40,533	42,043	43,482	45,637	47,142	47,838	47,372
HFCs	1	2,657	5,993	10,631	21,581	30,070	33,599	36,893	39,183	40,678	42,098	44,208	45,799	46,559	45,966
PFCs	4,228	11,684	2,834	2,542	1,567	1,395	1,411	1,394	1,350	1,366	1,384	1,429	1,343	1,279	1,406
SF_6	NO	NO	NO	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	1,819	1,595	1,576	1,554	1,530	1,562	1,541	1,593	1,567
N_2O	245	374	291	228	85	67	294	58	58	62	56	70	75	87	92
HFCs	6	5	6	4	3	2	2	2	3	2	2	5	5	6	6
PFCs	15	12	15	10.2	11	14	13	12	23	22	39	52	60	71	72
SF_6	9,085	11,647	3,839	1,824	1,531	1,555	1,508	1,523	1,492	1,468	1,432	1,435	1,401	1,429	1,397
2H. Other (CO_2)	874	954	933	944	880	904	898	954	972	982	959	945	884	894	885
Total	107,442	131,845	104,965	86,474	79,599	87,929	90,393	91,348	93,370	95,363	95,732	96,152	95,162	97,045	93,426

Despite the increase in HFC emissions from product uses as substitutes for ODS compared to 1990, emissions from the industrial processes and product use sector decreased in the same period. The main driving factors for the decrease in emissions since FY1990 were the decrease in CO_2 emissions from

cement production (mineral industry) as the clinker production declined, the decrease in emissions of HFC-23 produced as a by-product of HCFC-22 production (chemical industry) due to regulation under the Act on the Protection of the Ozone Layer Through the Control of Specified Substances and Other Measures, and the decrease in N_2O emissions from adipic acid production (chemical industry) as the N_2O abatement equipment came on stream.

2.2.3. Agriculture

Emissions from the agriculture sector in FY2022 were 33.5 million tonnes (in CO_2 eq.). They decreased by 14.7% since FY1990 and decreased by 1.2% compared to the previous year.

The breakdown of the FY2022 emissions from this sector showed that the largest source was the rice cultivation (CH_4) accounting for 39.0%. It was followed by enteric fermentation (CH_4) (25.8%), and agricultural soils (N_2O) (15.5%) as a result of the nitrogen-based fertilizer applications.

The main driving factor for the decrease in emissions since FY1990 was the decrease in CH_4 emissions from enteric fermentation due to the decrease in the number of cattle, and 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.

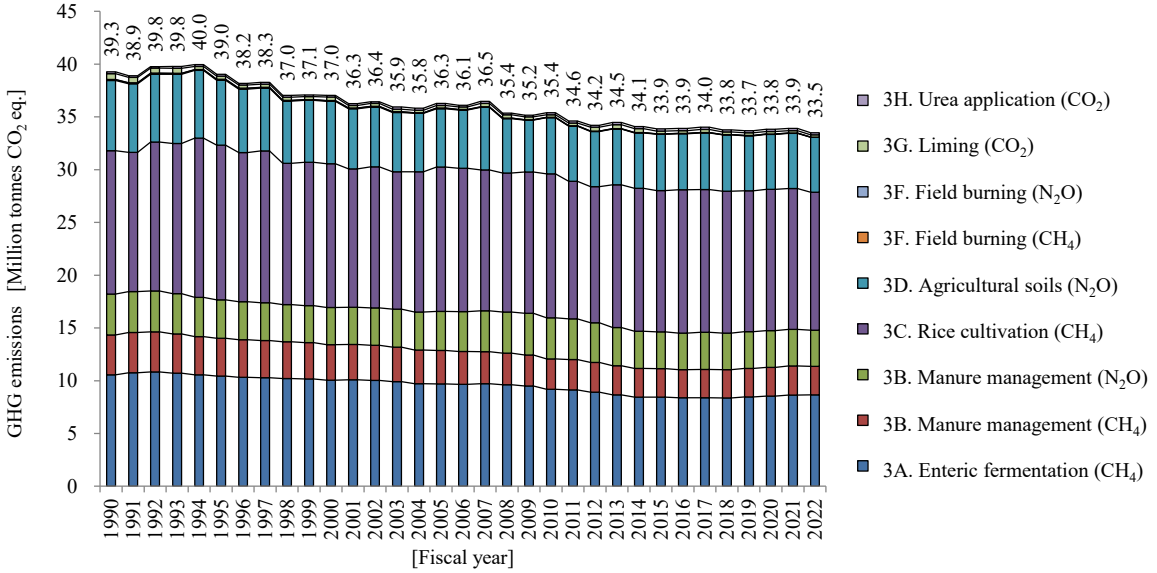

Figure 2-16 Trends in GHG emissions from the agriculture sector

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

[Thousand tonnes CO_2 eq.]

Category	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
3A. Enteric fermentation (CH_4)	10,554	10,437	10,042	9,689	9,186	8,665	8,449	8,438	8,378	8,393	8,361	8,471	8,547	8,642	8,661
3B. Manure management	7,651	7,234	6,894	6,882	6,771	6,376	6,236	6,201	6,136	6,194	6,154	6,187	6,208	6,222	6,128
CH_4	3,786	3,595	3,365	3,180	2,881	2,759	2,711	2,707	2,664	2,679	2,680	2,701	2,711	2,750	2,709
N_2O	3,865	3,638	3,529	3,702	3,890	3,617	3,525	3,494	3,472	3,516	3,474	3,486	3,497	3,472	3,419
3C. Rice cultivation (CH_4)	13,585	14,663	13,636	13,682	13,649	13,527	13,554	13,374	13,584	13,523	13,440	13,343	13,373	13,356	13,068
3D. Agricultural soils (N_2O)	6,658	6,138	5,903	5,527	5,317	5,277	5,241	5,343	5,310	5,373	5,339	5,214	5,224	5,212	5,203
3F. Field burning of agricultural residues	101	90	73	63	44	46	44	41	39	37	36	39	38	41	39
CH_4	78	69	56	49	34	36	35	32	30	29	28	31	30	32	30
N_2O	23	21	16	14	10	10	10	9	9	8	8	8	8	9	8
3G. Liming (CO_2)	550	304	333	231	243	380	363	259	253	294	242	242	233	225	203
3H. Urea application (CO_2)	182	170	168	197	184	214	204	215	208	208	208	208	208	208	208
Total	39,281	39,034	37,048	36,271	35,395	34,486	34,091	33,872	33,908	34,024	33,781	33,704	33,831	33,906	33,510

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 FY2022 was 53.2 million tonnes (in CO_2 eq.). They decreased by 26.9% since FY1990 and decreased by 8.7% compared to the previous year. The long-term declining trend in removals from 2004 is largely due to the maturity of Japanese forests.

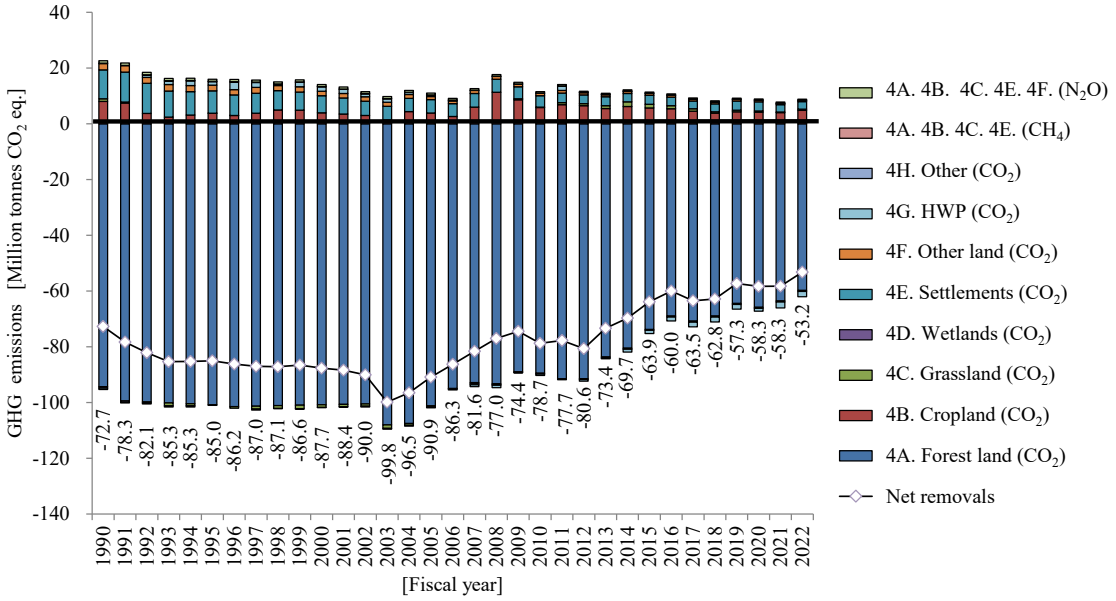

Figure 2-17 Trends in GHG emissions and removals from the LULUCF sector

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	2014	2015	2016	2017	2018	2019	2020	2021	2022
4A. Forest land	-94,175	-100,677	-100,671	-101,066	-89,386	-83,492	-80,374	-73,679	-68,890	-70,657	-68,871	-64,345	-65,735	-63,467	-59,640
CO_2	-94,291	-100,794	-100,787	-101,185	-89,497	-83,604	-80,507	-73,793	-68,999	-70,793	-68,983	-64,462	-65,851	-63,595	-59,763
CH_4	11	12	10	12	5	4	26	7	2	26	3	6	3	11	4
N_2O	105	106	106	107	106	107	108	107	108	110	109	112	113	117	119
4B. Cropland	8,116	3,854	4,050	3,971	5,905	5,522	6,239	5,755	5,499	4,621	3,858	4,369	4,258	4,083	4,878
CO_2	8,021	3,773	3,982	3,908	5,846	5,464	6,181	5,698	5,442	4,564	3,801	4,311	4,200	4,025	4,819
CH_4	54	52	51	49	47	46	46	45	45	45	44	44	44	43	43
N_2O	41	29	18	14	11	12	12	12	12	13	13	14	15	15	16
4C. Grassland	994	81	-896	-312	159	1,098	1,710	1,376	1,081	842	562	640	449	243	443
CO_2	964	51	-925	-341	130	1,069	1,680	1,346	1,052	813	533	611	420	214	415
CH_4	17	17	17	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	12	12	12
4D. Wetlands	-528	-216	-57	-358	-291	-362	-361	-312	-311	-351	-350	-348	-324	-338	-339
CO_2	-528	-216	-57	-358	-291	-362	-361	-312	-311	-351	-350	-348	-324	-338	-339
CH_4	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	NA,NE,NO	NA,NE,NO	NA,NE,NO
N_2O	IE,NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO	IE,NA,NE,NO
4E. Settlements	11,018	8,589	6,581	5,246	4,444	3,470	3,335	3,446	3,320	3,029	3,057	3,483	3,543	2,879	2,973
CO_2	10,374	8,037	6,071	4,797	4,085	3,175	3,055	3,177	3,062	2,780	2,811	3,239	3,300	2,634	2,726
CH_4	35	26	22	20	19	16	16	16	15	15	16	16	16	17	16
N_2O	609	526	489	429	340	278	265	253	243	233	230	228	227	228	230
4F. Other land	2,381	2,098	1,730	1,152	932	759	742	731	718	661	651	608	576	461	429
CO_2	2,279	2,005	1,648	1,083	881	716	701	692	680	625	616	574	544	431	401
CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N_2O	102	93	82	69	51	43	41	40	38	36	35	34	32	30	28
4G. HWP (CO_2)	-515	1,269	1,599	503	-479	-353	-1,005	-1,171	-1,427	-1,659	-1,742	-1,669	-1,072	-2,133	-1,918
4H. Other (CO_2)	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	-0.01
Total	-72,708	-85,001	-87,662	-90,864	-78,716	-73,359	-69,713	-63,854	-60,010	-63,513	-62,835	-57,261	-58,306	-58,272	-53,175

The breakdown of the FY2022 emissions and removals from this sector showed that the largest was CO_2 removals from forest land of 59.8 million tonnes, accounting for 112.4% of this sector's net total emissions / removals.

2.2.5. Waste

Emissions from the waste sector in FY2022 were 17.5 million tonnes (in CO_2 eq.). They decreased by 43.6% since FY1990 and by 4.5% compared to the previous year.

The breakdown of the FY2022 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 58.4%. It was followed by wastewater treatment and discharge (N_2O) (10.1%), wastewater treatment and discharge (CH_4) (9.9%).

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.

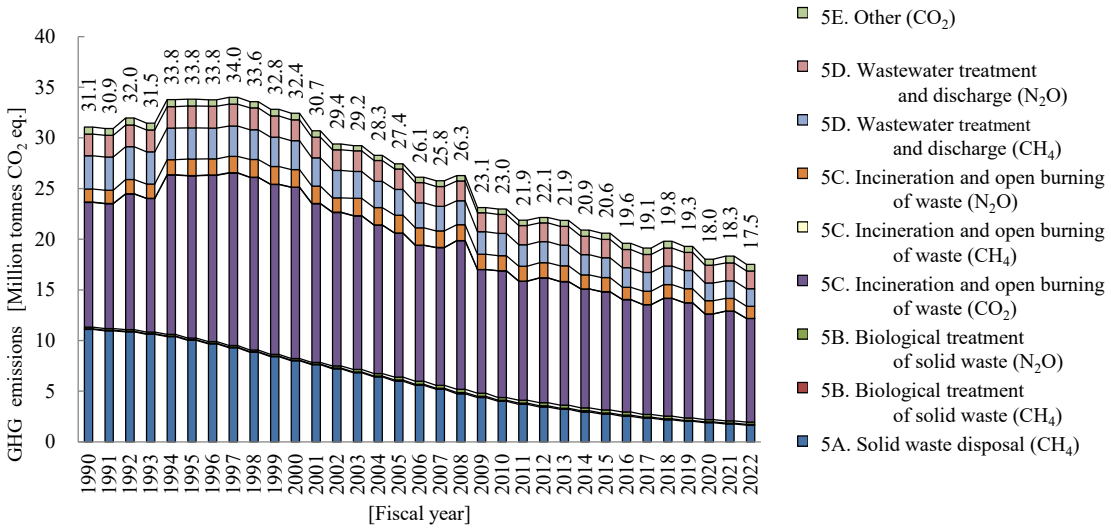

Figure 2-18 Trends in GHG emissions from the waste sector

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

[Thousand tonnes CO_2 eq.]

Category	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
5A. Solid waste disposal (CH_4)	11,092	10,024	8,007	5,992	3,996	3,205	2,956	2,734	2,519	2,344	2,173	2,025	1,885	1,757	1,637
5B. Biological treatment of solid waste	221	219	222	391	379	410	408	416	421	366	362	336	303	312	312
CH_4	60	60	61	107	104	112	112	114	115	100	100	92	83	86	86
N_2O	161	159	161	284	275	298	296	302	305	265	263	244	220	226	226
5C. Incineration and open burning of waste	13,637	17,664	18,640	15,977	14,008	13,766	13,115	13,063	12,324	12,158	12,989	12,748	11,737	12,094	11,422
CO_2	12,319	16,010	16,884	14,209	12,506	12,200	11,719	11,666	11,095	10,827	11,629	11,361	10,431	10,829	10,226
CH_4	31	33	23	20	13	13	12	11	10	11	12	11	10	9	9
N_2O	1,287	1,621	1,733	1,749	1,489	1,553	1,384	1,386	1,219	1,320	1,348	1,376	1,296	1,255	1,187
5D. Wastewater treatment and discharge	5,417	5,249	4,909	4,581	4,069	3,880	3,812	3,762	3,723	3,618	3,593	3,601	3,512	3,499	3,499
CH_4	3,295	3,080	2,863	2,553	2,188	2,029	1,993	1,959	1,920	1,846	1,824	1,793	1,753	1,733	1,733
N_2O	2,123	2,169	2,046	2,028	1,881	1,851	1,819	1,803	1,803	1,772	1,769	1,807	1,760	1,766	1,766
5E. Other (CO_2)	703	668	656	507	527	605	617	625	619	637	673	582	597	679	654
Total	31,071	33,823	32,433	27,447	22,979	21,865	20,908	20,600	19,605	19,122	19,791	19,291	18,034	18,341	17,524

2.2.6. Indirect CO_2

See Section 2.1.9. above.

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

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 FY2022 were 1.0 million tonnes. They decreased by 46.8% since FY1990 and decreased by 0.3% compared to the previous year.

Carbon monoxide (CO) emissions in FY2022 were 2.2 million tonnes. They decreased by 48.6% since FY1990 and 5.7% compared to the previous year[11].

Non-methane volatile organic compounds (NMVOC) emissions in FY2022 were 0.8 million tonnes. They decreased by 63.4% since FY1990 and increased by 0.02% compared to the previous year.

Sulfur oxide (SO_X)[12] emissions in FY2022 were 0.3 million tonnes. They decreased by 73.6% since FY1990 and decreased by 0.5% compared to the previous year.

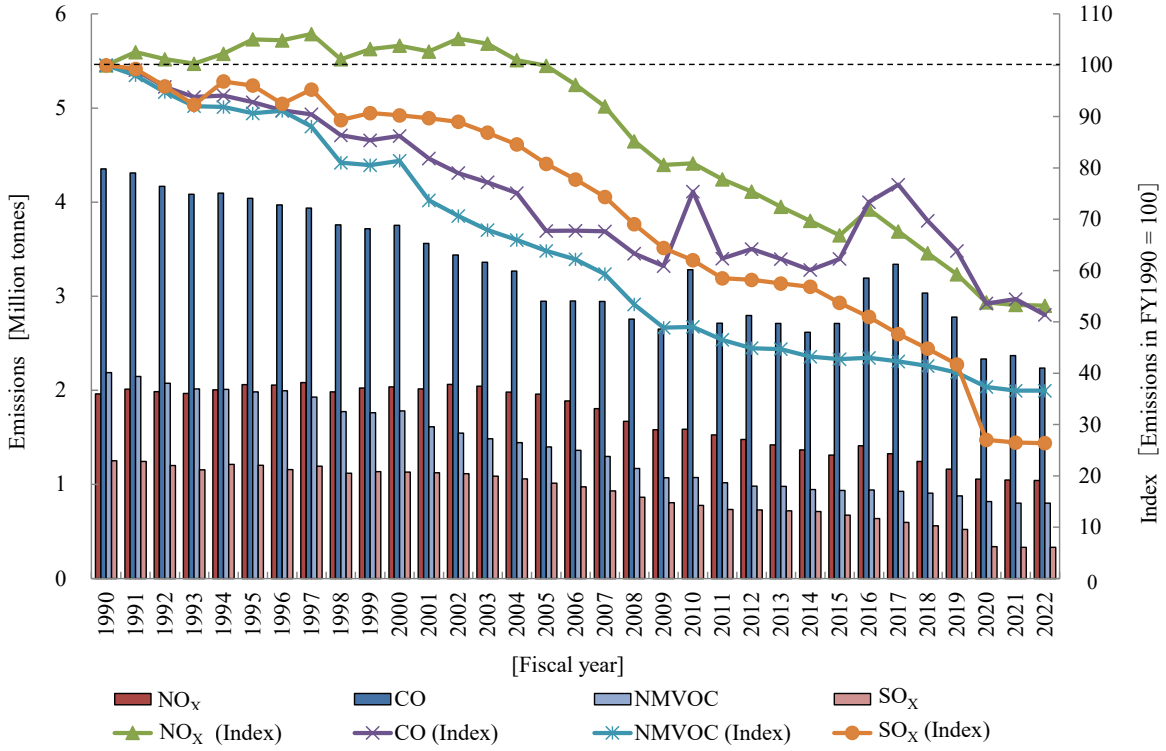

Figure 2-19 Trends in emissions of indirect GHGs and SO_X

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

[11] 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.

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

References

1. Cabinet Office, Government of Japan, *Annual Report on National Accounts.*
2. IPCC, *Fifth Assessment Report,* 2013.
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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 FY2022, GHG emissions (CO_2, CH_4 and N_2O) from the energy sector accounted for 989,179 kt-CO_2 eq., and represented 87.1% of Japan's total GHG emissions (excluding LULUCF). The emissions from the energy sector had decreased by 9.4% compared to FY1990.

The methodologies are shown in the below table.

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 in the 2008 submission, regardless of their use as energy or energy recovery. However, to comply with ERT recommendations and the requirements of the IPCC Guidelines, the emissions 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
CO_2	1.A.1. Energy industries	kt-CO_2	368,156	378,496	395,022	449,110	473,294	582,933	552,340	526,751	521,531	507,753	470,283	447,733	436,129	442,679	435,051
	a. Public electricity and heat production	kt-CO_2	303,055	317,587	330,118	378,044	404,239	521,862	493,350	468,472	466,659	454,708	415,366	396,011	392,288	395,616	387,888
	b. Petroleum refining	kt-CO_2	36,023	40,676	46,506	50,334	47,165	42,401	40,578	41,124	37,057	36,244	37,035	35,330	28,958	30,683	31,149
	c. Manufacture of solid fuels and other energy industries	kt-CO_2	29,078	20,232	18,398	20,732	21,891	18,670	18,412	17,154	17,816	16,801	17,881	16,391	14,883	16,380	16,013
	1.A.2. Manufacturing industries and construction	kt-CO_2	349,747	357,627	346,858	334,482	301,024	304,833	297,271	287,997	274,234	270,282	267,605	260,257	233,175	250,407	234,600
	a. Iron and steel	kt-CO_2	150,622	142,999	152,022	154,093	153,145	157,541	155,085	148,849	142,731	139,734	136,157	134,124	111,963	124,783	114,875
	b. Non-ferrous metals	kt-CO_2	8,429	7,381	6,311	5,686	3,961	3,742	3,637	3,239	3,499	3,130	3,286	2,878	2,760	3,041	2,987
	c. Chemicals	kt-CO_2	58,039	64,339	59,518	54,952	50,117	48,265	46,580	45,563	42,362	42,926	42,234	42,158	39,541	42,727	41,261
	d. Pulp, paper and print	kt-CO_2	27,106	31,428	31,672	29,732	22,644	23,832	22,900	23,305	20,847	20,508	20,439	18,999	17,848	17,759	15,932
	e. Food processing, beverages and tobacco	kt-CO_2	7,649	10,133	11,468	12,169	9,821	9,809	9,526	8,459	8,416	7,895	8,809	7,801	8,005	8,301	8,218
	f. Non-metallic minerals	kt-CO_2	43,634	46,461	40,100	35,443	28,711	29,803	28,991	28,054	27,097	26,921	27,018	25,873	25,104	24,972	22,818
	g. Other	kt-CO_2	54,267	54,888	45,766	42,407	32,625	31,842	30,553	30,530	29,282	29,167	29,662	28,425	27,954	28,825	28,509
	1.A.3. Transport	kt-CO_2	202,140	242,797	253,091	238,065	221,969	215,115	210,149	208,875	207,066	205,253	203,016	199,023	176,576	177,896	185,040
	a. Domestic aviation	kt-CO_2	7,162	10,278	10,677	10,799	9,193	10,149	10,173	10,067	10,187	10,399	10,537	10,488	5,238	6,819	9,705
	b. Road transportation	kt-CO_2	180,367	217,028	226,690	213,605	201,457	193,437	188,540	187,641	185,722	183,803	181,451	177,628	160,907	160,349	164,513
	c. Railways	kt-CO_2	935	822	711	647	574	540	524	523	499	520	492	490	468	449	449
	d. Domestic navigation	kt-CO_2	13,675	14,669	15,012	13,014	10,745	10,989	10,912	10,645	10,659	10,530	10,537	10,417	9,963	10,280	10,373
	e. Other transportation	kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	1.A.4. Other sectors	kt-CO_2	158,178	175,411	190,258	196,030	156,866	149,312	141,955	139,164	140,902	144,279	141,572	140,463	140,463	134,847	127,646
	a. Commercial/institutional	kt-CO_2	79,069	88,210	98,179	105,958	74,849	74,216	69,211	67,052	67,286	67,805	74,651	71,092	67,760	69,081	65,233
	b. Residential	kt-CO_2	58,167	67,477	72,226	70,395	64,217	60,319	58,014	55,392	55,712	59,260	52,156	53,361	55,807	51,574	49,646
	c. Agriculture/forestry/fishing	kt-CO_2	20,942	19,723	19,853	19,676	17,800	14,777	14,730	16,720	17,905	17,213	14,764	16,011	16,896	14,192	12,768
	1.A.5 Other	kt-CO_2	NO	NO	NO	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	NO	NO	NO
	b. Mobile	kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Total	kt-CO_2	1,078,221	1,154,331	1,185,228	1,217,687	1,153,152	1,252,193	1,201,715	1,162,787	1,143,734	1,127,567	1,082,476	1,047,476	986,343	1,005,829	982,337
CH_4	1.A.1. Energy industries	kt-CH_4	18.37	16.01	10.53	9.94	10.79	9.57	9.00	11.07	14.15	15.61	13.01	10.36	8.20	8.22	7.80
	a. Public electricity and heat production	kt-CH_4	0.82	1.02	1.31	1.21	1.19	3.61	3.36	5.63	8.45	10.34	7.72	5.18	3.27	3.14	3.06
	b. Petroleum refining	kt-CH_4	0.09	0.11	0.22	1.51	2.50	0.12	0.11	0.21	0.26	0.32	0.26	0.18	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	5.52	5.24	5.45	4.95	5.03	5.00	4.84	4.99	4.65
	1.A.2. Manufacturing industries and construction	kt-CH_4	14.39	15.14	14.82	17.68	21.52	19.81	20.74	21.04	21.59	22.56	21.83	20.81	18.80	19.54	18.78
	a. Iron and steel	kt-CH_4	4.66	4.28	5.03	7.03	9.19	6.84	7.08	7.82	8.57	9.13	7.80	6.43	4.36	4.96	4.61
	b. Non-ferrous metals	kt-CH_4	0.39	0.36	0.29	0.23	0.18	0.24	0.25	0.24	0.27	0.27	0.30	0.25	0.24	0.29	0.26
	c. Chemicals	kt-CH_4	0.31	0.32	0.49	1.27	2.38	0.87	0.78	0.72	0.67	0.64	0.89	1.04	1.22	1.30	1.30
	d. Pulp, paper and print	kt-CH_4	1.06	1.06	1.13	1.34	1.60	1.43	1.50	1.51	1.43	1.48	1.60	1.55	1.43	1.51	1.41
	e. Food processing, beverages and tobacco	kt-CH_4	0.09	0.13	0.15	0.16	0.14	0.50	0.60	0.75	0.93	1.04	0.95	0.70	0.53	0.54	0.53
	f. Non-metallic minerals	kt-CH_4	4.16	4.96	3.94	3.63	3.08	3.18	3.18	2.98	2.81	2.72	3.12	3.22	3.44	3.41	3.16
	g. Other	kt-CH_4	3.72	4.02	3.79	4.03	4.95	6.75	7.36	7.02	6.92	7.29	7.19	7.61	7.57	7.54	7.50
	1.A.3. Transport	kt-CH_4	10.64	11.27	11.37	8.92	6.16	5.24	4.92	4.70	4.51	4.32	4.18	4.00	3.50	3.39	3.55
	a. Domestic aviation	kt-CH_4	0.23	0.26	0.29	0.22	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.05	0.04	0.06	0.08
	b. Road transportation	kt-CH_4	10.10	10.68	10.76	8.43	5.87	4.95	4.63	4.41	4.23	4.05	3.90	3.73	3.26	3.13	3.27
	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	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	0.19	0.19	0.19	0.19	0.19	0.18	0.18	0.19
	e. Other transportation	kt-CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	1.A.4. Other sectors	kt-CH_4	9.55	11.73	13.10	19.83	18.20	9.02	8.47	8.23	8.32	8.74	8.32	8.91	9.33	8.43	8.23
	a. Commercial/institutional	kt-CH_4	1.30	3.01	4.23	10.27	8.96	2.09	1.77	1.75	1.73	1.81	2.14	2.46	2.42	2.20	2.29
	b. Residential	kt-CH_4	7.04	7.71	7.88	7.69	6.89	6.38	6.12	5.82	5.88	6.27	5.46	5.54	5.81	5.30	5.12
	c. Agriculture/forestry/fishing	kt-CH_4	1.21	1.02	0.99	1.86	2.35	0.55	0.58	0.66	0.71	0.66	0.72	0.91	1.10	0.93	0.82
	1.A.5 Other	kt-CH_4	NO	NO	NO	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	NO	NO	NO
	b. Mobile	kt-CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Total	kt-CH_4	52.95	54.15	49.82	56.37	56.66	43.65	43.13	45.04	48.58	51.23	47.33	44.09	39.83	39.58	38.36
		kt-CO_2 eq.	1,483	1,516	1,395	1,578	1,587	1,222	1,208	1,261	1,360	1,434	1,325	1,234	1,115	1,108	1,074
N_2O	1.A.1. Energy industries	kt-N_2O	2.98	4.54	5.41	7.10	6.95	7.91	7.87	8.01	7.57	8.20	7.56	6.24	6.15	6.27	6.18
	a. Public electricity and heat production	kt-N_2O	1.72	3.09	3.72	5.32	5.13	6.61	6.64	6.69	6.28	6.92	6.43	5.30	5.24	5.26	5.21
	b. Petroleum refining	kt-N_2O	1.05	1.31	1.58	1.61	1.61	1.21	1.17	1.26	1.22	1.21	1.06	0.88	0.85	0.95	0.92
	c. Manufacture of solid fuels and other energy industries	kt-N_2O	0.22	0.14	0.12	0.17	0.21	0.09	0.07	0.06	0.07	0.07	0.06	0.06	0.06	0.06	0.06
	1.A.2. Manufacturing industries and construction	kt-N_2O	4.23	5.73	6.30	6.27	5.79	5.91	5.78	5.82	5.61	5.61	5.50	5.35	4.93	4.91	4.35
	a. Iron and steel	kt-N_2O	1.12	1.34	1.40	1.47	1.50	1.32	1.32	1.34	1.33	1.33	1.26	1.30	1.16	1.12	0.99
	b. Non-ferrous metals	kt-N_2O	0.25	0.23	0.21	0.08	0.05	0.06	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.05	0.05
	c. Chemicals	kt-N_2O	0.74	1.19	1.20	1.04	0.96	1.07	1.00	1.00	0.91	1.01	0.94	0.95	0.88	0.96	0.80
	d. Pulp, paper and print	kt-N_2O	0.48	0.91	0.95	0.98	1.14	1.23	1.26	1.26	1.22	1.19	1.19	1.06	0.84	0.87	0.78
	e. Food processing, beverages and tobacco	kt-N_2O	0.04	0.05	0.07	0.08	0.08	0.07	0.07	0.06	0.06	0.05	0.05	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	1.62	1.66	1.59	1.53	1.54	1.51	1.50	1.38	1.21
	g. Other	kt-N_2O	0.80	0.94	0.76	0.64	0.50	0.52	0.45	0.45	0.45	0.45	0.46	0.44	0.46	0.48	0.46
	1.A.3. Transport	kt-N_2O	12.91	14.16	13.81	9.80	7.18	6.24	6.01	5.86	5.74	5.66	5.58	5.49	4.91	4.98	5.17
	a. Domestic aviation	kt-N_2O	0.21	0.29	0.32	0.32	0.28	0.30	0.30	0.30	0.30	0.30	0.31	0.30	0.15	0.20	0.29
	b. Road transportation	kt-N_2O	11.60	12.77	12.41	8.53	6.10	5.17	4.95	4.82	4.70	4.62	4.55	4.47	4.06	4.08	4.18
	c. Railways	kt-N_2O	0.37	0.32	0.28	0.25	0.23	0.21	0.20	0.20	0.19	0.20	0.19	0.19	0.18	0.17	0.17
	d. Domestic navigation	kt-N_2O	0.73	0.78	0.79	0.69	0.57	0.56	0.55	0.54	0.54	0.54	0.54	0.53	0.51	0.53	0.53
	e. Other transportation	kt-N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	1.A.4. Other sectors	kt-N_2O	2.31	2.55	2.82	2.49	2.17	2.02	2.03	2.06	2.26	2.39	2.14	2.02	1.83	1.72	1.67
	a. Commercial/institutional	kt-N_2O	1.51	1.78	2.08	1.79	1.56	1.49	1.52	1.53	1.70	1.82	1.64	1.50	1.28	1.25	1.22
	b. Residential	kt-N_2O	0.28	0.32	0.35	0.34	0.29	0.27	0.25	0.24	0.24	0.26	0.22	0.22	0.23	0.21	0.20
	c. Agriculture/forestry/fishing	kt-N_2O	0.53	0.45	0.38	0.36	0.32	0.26	0.26	0.29	0.32	0.31	0.28	0.30	0.32	0.27	0.25
	1.A.5 Other	kt-N_2O	NO	NO	NO	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	NO	NO	NO
	b. Mobile	kt-N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Total	kt-N_2O	22.44	26.98	28.34	25.66	22.09	22.08	21.70	21.76	21.18	21.86	20.79	19.09	17.81	17.87	17.37
		kt-CO_2 eq.	5,946	7,151	7,511	6,800	5,853	5,852	5,749	5,766	5,613	5,794	5,509	5,059	4,721	4,737	4,602
Total of all gases		kt-CO_2 eq.	1,085,649	1,162,998	1,194,134	1,226,066	1,160,591	1,259,267	1,208,672	1,169,814	1,150,707	1,134,795	1,089,310	1,053,770	992,179	1,011,674	988,013

In FY2022, emissions from fuel combustion were 988,013 kt-CO_2 eq., which accounted for 87.0% 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 FY2022 decreased by 2.3% compared to the previous year. The main driving factor for the decrease is the CO_2 emissions from 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 18.2% since FY1990 and decreased by 1.7% 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 32.9% since FY1990 and decreased by 6.3% 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 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 8.5% compared to FY1990 and increased by 4.0% 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 due to the influence of COVID-19 pandemic, however, it is in an increasing trend after FY2021.

The CO_2 emissions from other sectors (1.A.4) decreased by 19.3% since FY1990 and decreased by 5.3% 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.

On the annual review in 2012 (FCCC/ARR/2012/JPN, paragraph 33), the Expert Review Team (ERT) recommended that Japan improve the transparency of the information on the drivers of emission trends in the energy sector. In response to the recommendation, the table below provides some indicators that might have relations to the emission trends. 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
1	1.A. Fuel combustion	Final electricity consumption	TWh	765	872	973	1,025	1,035	990	974	949	951	965	946	927	913	924	903
2	1.A.2. Manufacturing industries and construction	Indices of Industrial Production	CY2015=100	109.1	103.3	107.7	109.3	101.2	101.1	100.5	99.8	100.6	103.5	103.8	99.9	90.3	95.5	95.3
3	1.A.3.b. Road transportation	Vehicle kilometers traveled (VKT)	billion VKT	585	673	728	727	708	724	718	721	730	740	748	745	666	650	692
4	1.A.4.a.Commercial/ institutional	Indices of Tertiary Industry Activity	CY2015=100	83.8	90.8	95.2	100.7	97.6	100.8	99.2	100.3	100.5	101.9	103.0	102.3	95.3	97.5	99.6

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).

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 Table) • (Waste only) Consumption of sectoral approach[3]
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.)

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.

[2] Numbers with # indicate the corresponding sector (row) numbers in the *General Energy Statistics* (Japan's Energy Balance Table).
[3] In response to the recommendation on the annual review in 2018 (FCCC/ARR/2018/JPN, E.11).

➢ *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[4] of energy consumption between the reference approach and the sectoral approach during FY1990-2022 range between -1.77% (FY2012) and +1.86% (FY2022).

Energy consumption from wastes used for energy and from the incineration of wastes with energy recovery is calculated in the sectoral approach in accordance with the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*.

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[5]]) 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 '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 FY1990-2022 range between -0.70% (FY1990) and +3.88% (FY2004).

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 differences between both approaches for solid fuels were large values in FY2004 and FY2008 (+9.96%, +6.25%), and small values in FY2005 and FY2009 (+2.06%, -1.92%). It is because of the same reason as the difference of energy consumption which is described in the previous section.

[4] Difference = (RA-SA)/SA
RA: Reference Approach, SA: Sectoral Approach

[5] Numbers with $ indicate the corresponding energy source (column) numbers in the *General Energy Statistics* (Japan's Energy Balance Table).

Table 3-5 Comparison of energy consumption[6]

[PJ]

	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Reference Approach	**15,135**	**16,518**	**17,046**	**17,415**	**16,589**	**18,024**	**17,308**	**16,752**	**16,507**	**16,390**	**15,746**	**15,162**	**14,314**	**14,634**	**14,469**
Liquid fuels	9,526	10,132	9,443	8,920	7,179	7,395	6,811	6,501	6,271	6,180	5,823	5,552	5,162	5,365	5,363
Solid fuels	3,285	3,603	4,180	4,763	4,979	5,284	5,080	5,137	5,022	5,024	4,927	4,830	4,401	4,791	4,698
Gaseous fuels	2,042	2,465	3,050	3,275	3,979	4,882	4,949	4,650	4,719	4,680	4,502	4,271	4,261	3,990	3,928
Other fossil fuels	281	318	373	457	452	462	468	464	496	507	494	510	489	487	480
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Sectoral Approach	**15,318**	**16,556**	**17,035**	**17,399**	**16,624**	**18,087**	**17,407**	**16,800**	**16,603**	**16,348**	**15,745**	**15,218**	**14,433**	**14,552**	**14,204**
Liquid fuels	9,459	9,973	9,451	8,949	7,260	7,463	6,839	6,542	6,294	6,122	5,884	5,637	5,241	5,300	5,305
Solid fuels	3,368	3,598	3,986	4,638	4,819	5,223	5,119	5,049	4,962	4,987	4,833	4,730	4,382	4,663	4,482
Gaseous fuels	2,209	2,667	3,226	3,355	4,093	4,939	4,981	4,744	4,850	4,731	4,535	4,341	4,320	4,102	3,938
Other fossil fuels	281	318	373	457	452	462	468	464	496	507	494	510	489	487	480
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Difference (%)	**-1.19%**	**-0.23%**	**0.06%**	**0.09%**	**-0.21%**	**-0.35%**	**-0.57%**	**-0.29%**	**-0.57%**	**0.26%**	**0.00%**	**-0.37%**	**-0.83%**	**0.56%**	**1.86%**
Liquid fuels	0.71%	1.60%	-0.09%	-0.33%	-1.11%	-0.90%	-0.41%	-0.63%	-0.38%	0.94%	-1.04%	-1.51%	-1.50%	1.23%	1.10%
Solid fuels	-2.46%	0.15%	4.87%	2.70%	3.32%	1.17%	-0.77%	1.73%	1.20%	0.73%	1.96%	2.10%	0.43%	2.76%	4.83%
Gaseous fuels	-7.56%	-7.58%	-5.43%	-2.38%	-2.80%	-1.16%	-0.65%	-1.99%	-2.71%	-1.08%	-0.72%	-1.62%	-1.37%	-2.73%	-0.25%
Other fossil fuels	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE

Table 3-6 Comparison of CO_2 emissions

[Mt-CO_2]

	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Reference Approach	**1,071**	**1,164**	**1,205**	**1,237**	**1,173**	**1,254**	**1,199**	**1,168**	**1,144**	**1,137**	**1,091**	**1,052**	**983**	**1,021**	**1,008**
Liquid fuels	659.9	701.9	656.2	621.1	501.9	512.2	472.1	450.1	433.6	427.7	402.4	383.4	355.3	370.2	369.5
Solid fuels	295.7	323.8	377.9	431.1	450.8	474.5	457.3	462.1	451.1	450.8	440.8	431.6	392.3	428.6	419.9
Gaseous fuels	104.4	126.1	155.9	167.4	203.5	249.9	253.2	238.0	241.6	239.6	229.0	217.2	216.6	202.8	199.8
Other fossil fuels	10.7	12.3	15.0	17.3	16.4	17.1	16.8	17.3	18.1	18.7	18.5	19.4	18.8	19.1	18.7
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Sectoral Approach	**1,078**	**1,154**	**1,185**	**1,218**	**1,153**	**1,252**	**1,202**	**1,163**	**1,144**	**1,128**	**1,082**	**1,047**	**986**	**1,006**	**982**
Liquid fuels	643.9	677.0	640.2	605.6	488.3	507.9	464.3	443.4	426.7	413.9	396.8	380.4	353.5	357.2	358.5
Solid fuels	309.4	327.1	364.0	422.4	438.5	473.8	465.1	458.7	450.2	452.2	435.8	426.3	393.8	420.2	403.9
Gaseous fuels	114.2	137.9	166.1	172.4	209.9	253.4	255.5	243.4	248.8	242.8	231.3	221.4	220.3	209.3	201.2
Other fossil fuels	10.7	12.3	15.0	17.3	16.4	17.1	16.8	17.3	18.1	18.7	18.5	19.4	18.8	19.1	18.7
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Difference (%)	**-0.70%**	**0.84%**	**1.67%**	**1.59%**	**1.68%**	**0.12%**	**-0.19%**	**0.41%**	**0.06%**	**0.82%**	**0.76%**	**0.38%**	**-0.34%**	**1.48%**	**2.60%**
Liquid fuels	2.48%	3.68%	2.51%	2.57%	2.78%	0.85%	1.69%	1.53%	1.62%	3.33%	1.40%	0.79%	0.52%	3.64%	3.05%
Solid fuels	-4.45%	-1.02%	3.82%	2.06%	2.79%	0.15%	-1.69%	0.73%	0.22%	-0.30%	1.14%	1.23%	-0.38%	2.00%	3.98%
Gaseous fuels	-8.56%	-8.61%	-6.11%	-2.89%	-3.07%	-1.39%	-0.89%	-2.21%	-2.92%	-1.32%	-1.00%	-1.91%	-1.68%	-3.10%	-0.73%
Other fossil fuels	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Peat	IE	IE	IE	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 tendency for their trends.

[6] In this chapter, soild 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.

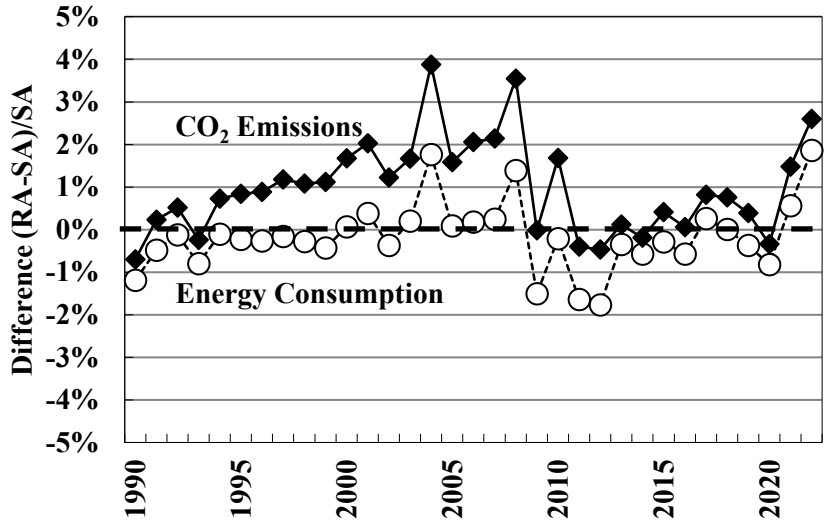

Figure 3-1 Trends in difference of energy consumption and CO_2 emissions

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 Energy Balance Table (*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.

The CO_2 amount captured for geological storage is not subtracted in the reference approach emission calculation, although it is subtracted in the sectoral 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)

[Mt-CO_2]

	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
RA	**1,071**	**1,164**	**1,205**	**1,237**	**1,173**	**1,254**	**1,199**	**1,168**	**1,144**	**1,137**	**1,091**	**1,052**	**983**	**1,021**	**1,008**
Liquid fuels	659.9	701.9	656.2	621.1	501.9	512.2	472.1	450.1	433.6	427.7	402.4	383.4	355.3	370.2	369.5
Solid fuels	295.7	323.8	377.9	431.1	450.8	474.5	457.3	462.1	451.1	450.8	440.8	431.6	392.3	428.6	419.9
Gaseous fuels	104.4	126.1	155.9	167.4	203.5	249.9	253.2	238.0	241.6	239.6	229.0	217.2	216.6	202.8	199.8
Other fossil fuels	10.7	12.3	15.0	17.3	16.4	17.1	16.8	17.3	18.1	18.7	18.5	19.4	18.8	19.1	18.7
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
SA	**1,078**	**1,154**	**1,185**	**1,218**	**1,153**	**1,252**	**1,202**	**1,163**	**1,144**	**1,128**	**1,082**	**1,047**	**986**	**1,006**	**982**
Liquid fuels	643.9	677.0	640.2	605.6	488.3	507.9	464.3	443.4	426.7	413.9	396.8	380.4	353.5	357.2	358.5
Solid fuels	309.4	327.1	364.0	422.4	438.5	473.8	465.1	458.7	450.2	452.2	435.8	426.3	393.8	420.2	403.9
Gaseous fuels	114.2	137.9	166.1	172.4	209.9	253.4	255.5	243.4	248.8	242.8	231.3	221.4	220.3	209.3	201.2
Other fossil fuels	10.7	12.3	15.0	17.3	16.4	17.1	16.8	17.3	18.1	18.7	18.5	19.4	18.8	19.1	18.7
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
RA-SA	**-7.5**	**9.7**	**19.8**	**19.3**	**19.4**	**1.5**	**-2.3**	**4.8**	**0.7**	**9.2**	**8.2**	**4.0**	**-3.4**	**14.9**	**25.5**
Liquid fuels	16.0	24.9	16.0	15.6	13.6	4.3	7.9	6.8	6.9	13.8	5.6	3.0	1.8	13.0	11.0
Solid fuels	-13.8	-3.3	13.9	8.7	12.3	0.7	-7.9	3.3	1.0	-1.4	5.0	5.3	-1.5	8.4	16.1
Gaseous fuels	-9.8	-11.9	-10.1	-5.0	-6.4	-3.5	-2.3	-5.4	-7.3	-3.2	-2.3	-4.2	-3.7	-6.5	-1.5
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	0.0	0.0	0.0
Peat	NA	NA	NA	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**	**-2.6**	**0.9**	**1.0**	**4.0**	**4.8**	**10.2**	**5.3**	**17.9**	**10.6**
Liquid fuels	1.4	7.2	0.8	0.5	-0.5	-2.4	-2.3	-0.1	-1.0	1.6	-1.3	0.3	0.3	4.2	0.5
Solid fuels	-14.3	-2.7	13.0	11.1	11.0	-0.7	-0.8	1.2	2.0	3.2	6.3	9.3	2.9	12.6	10.1
Gaseous fuels	0.9	0.0	-0.7	0.0	-1.5	1.5	0.5	-0.2	0.0	-0.7	-0.1	0.6	2.1	1.1	0.0
Coal Blending	**0.3**	**0.4**	**0.5**	**0.7**	**0.7**	**-0.2**	**-0.2**	**0.0**	**-0.1**	**-0.1**	**-0.1**	**-0.1**	**0.1**	**-0.1**	**-0.2**
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	0.0	0.0	0.0
Solid fuels	0.3	0.4	0.5	0.7	0.7	-0.2	-0.2	0.0	-0.1	-0.1	-0.1	-0.1	0.1	-0.1	-0.2
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	0.0	0.0	0.0
Oil Product Blending	**-1.8**	**-0.5**	**0.2**	**0.4**	**0.1**	**-1.4**	**-1.3**	**-1.4**	**-1.5**	**-1.5**	**-1.6**	**-1.4**	**-1.3**	**-1.3**	**-1.4**
Liquid fuels	-1.8	-0.5	0.2	0.4	0.1	-1.4	-1.3	-1.4	-1.5	-1.5	-1.6	-1.4	-1.3	-1.3	-1.4
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	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	0.0	0.0	0.0
Other Energy Transformation[1)]	**0.6**	**-0.2**	**2.6**	**3.6**	**4.2**	**0.0**	**-3.2**	**0.4**	**-0.9**	**1.1**	**-4.5**	**-5.2**	**-8.0**	**-1.5**	**-0.7**
Liquid fuels	0.6	-0.2	2.5	3.6	4.1	0.0	-3.2	0.3	-0.9	1.0	-4.3	-4.9	-7.7	-1.3	-0.7
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	0.0	0.0	0.0
Gaseous fuels	0.1	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.1	-0.2	-0.3	-0.3	-0.3	-0.1
Transformation and Consumption Stockpile Change	**2.6**	**1.7**	**2.4**	**-0.3**	**2.6**	**0.7**	**-2.7**	**1.8**	**-4.3**	**-1.6**	**3.4**	**-3.2**	**-5.9**	**-5.0**	**13.7**
Liquid fuels	0.7	1.5	-0.9	-0.1	0.5	-2.9	-0.4	-1.5	-2.7	-1.4	-0.2	-1.3	-2.1	-0.6	1.0
Solid fuels	1.9	0.6	3.0	-1.6	2.4	3.7	-4.6	4.3	1.4	-2.4	0.9	-2.1	-2.9	-2.5	8.0
Gaseous fuels	0.0	-0.3	0.3	1.4	-0.3	-0.1	2.3	-0.9	-3.0	2.2	2.7	0.2	-0.9	-2.0	4.8
Oil Refining[2)]	**0.4**	**0.7**	**-2.5**	**-0.8**	**-0.9**	**-0.3**	**3.4**	**-1.2**	**3.1**	**3.7**	**2.8**	**0.3**	**3.3**	**1.4**	**0.0**
Liquid fuels	0.4	0.7	-2.5	-0.8	-0.9	-0.3	3.4	-1.2	3.1	3.7	2.8	0.3	3.3	1.4	0.0
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	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	0.0	0.0	0.0
Petrochemical	**2.3**	**2.9**	**3.6**	**3.9**	**3.6**	**4.6**	**4.5**	**4.4**	**3.5**	**3.5**	**3.4**	**3.4**	**3.1**	**3.7**	**3.5**
Liquid fuels	2.6	3.2	4.0	4.3	4.0	4.9	4.8	4.7	3.7	3.7	3.6	3.5	3.3	3.8	3.6
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	0.0	0.0	0.0
Gaseous fuels	-0.3	-0.3	-0.4	-0.4	-0.4	-0.3	-0.3	-0.3	-0.2	-0.2	-0.2	-0.2	-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**	**0.0**	**0.0**	**0.0**
Liquid fuels	9.7	10.9	9.0	5.9	4.4	4.7	4.9	4.1	4.2	4.6	4.6	4.6	4.6	5.2	6.1
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	0.0	0.0	0.0
Gaseous fuels	-10.5	-11.4	-9.4	-6.0	-4.4	-4.7	-4.9	-4.1	-4.2	-4.6	-4.6	-4.6	-4.6	-5.2	-6.1
Total	**-7.6**	**9.6**	**19.8**	**19.1**	**19.2**	**1.7**	**-2.1**	**4.9**	**0.7**	**9.1**	**8.2**	**4.0**	**-3.3**	**15.0**	**25.6**
Liquid fuels	13.6	22.7	13.0	13.8	11.6	2.6	5.8	4.8	4.8	11.7	3.6	1.2	0.4	11.4	9.2
Solid fuels	-11.4	-1.2	16.9	10.3	14.1	2.7	-5.6	5.5	3.2	0.7	7.0	7.1	0.1	10.1	17.9
Gaseous fuels	-9.8	-11.9	-10.1	-5.0	-6.5	-3.6	-2.3	-5.4	-7.3	-3.3	-2.4	-4.3	-3.8	-6.5	-1.5
(RA-SA)-(Total)	**0.1**	**0.1**	**0.0**	**0.2**	**0.2**	**-0.2**	**-0.2**	**-0.1**	**0.0**	**0.1**	**0.0**	**0.0**	**-0.1**	**-0.1**	**0.0**
Liquid fuels	2.4	2.2	3.0	1.8	2.0	1.8	2.0	2.0	2.2	2.0	2.0	1.8	1.4	1.6	1.8
Solid fuels	-2.4	-2.1	-3.0	-1.6	-1.8	-2.0	-2.2	-2.1	-2.2	-2.0	-2.0	-1.8	-1.6	-1.7	-1.8
Gaseous fuels	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.1	0.0	0.0

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)).

On the annual review in 2012 (FCCC/ARR/2012/JPN) and 2013 (FCCC/ARR/2013/JPN), the ERT noted that the Japanese carbon emission factor (EF) for jet kerosene (18.3 t-C/TJ based on the gross calorific value) is lower than the EF for jet kerosene included in the *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories* (18.5 t-C/TJ based on the gross calorific value[7]). The ERT recommended that Japan provide additional information.

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

➢ *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*

[7] This value is also the default value in the *2006 IPCC Guidelines*.

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.

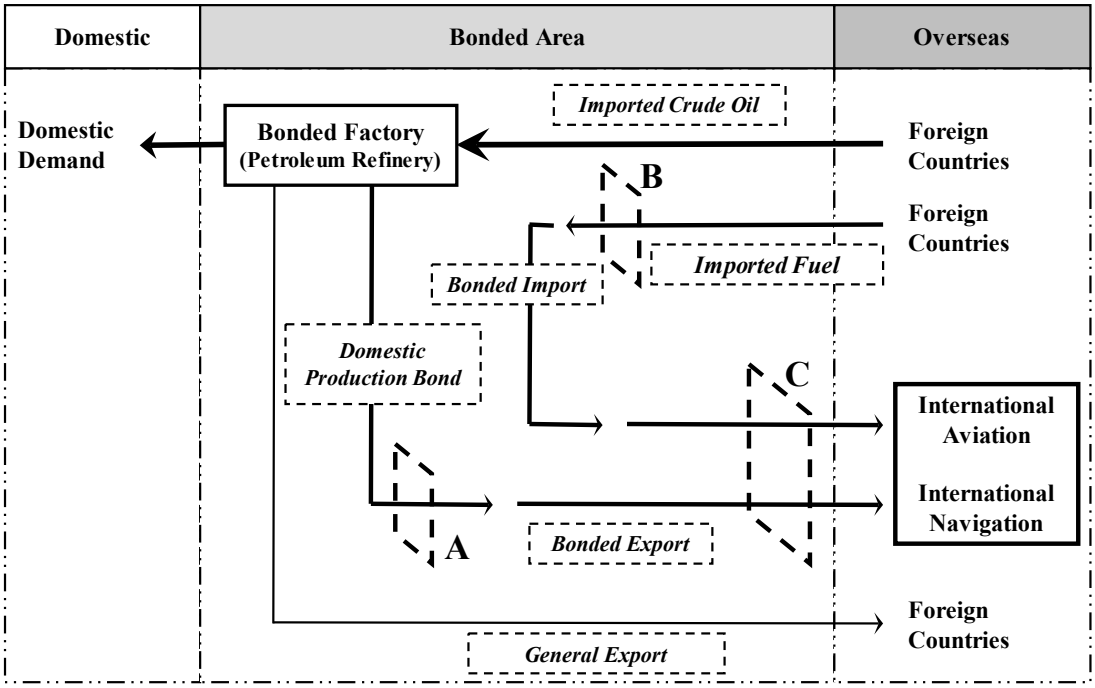

Figure 3-2 Activity data for international bunkers

- 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. (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 factor	
				Calorific value
Ammonia production	2.B.1	Naphtha	See Table 3-11	See Table 3-19
		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.8.g	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	See Table 3-11	
Paraffin wax use	2.D.2	Bitumen	See Table 3-11	

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 1.A (other fossil fuels), 2.D.3, 2.B.8, 2.H.2, 5.C or 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 FY2022, CO_2 emissions from this category accounted for 435,051 kt-CO_2, and represented 38.3% of Japan's total GHG emissions (excluding LULUCF). Public electricity and heat production (1.A.1.a) accounts for 89.2% 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)[8] 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

[8] 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

The energy consumption and emissions from waste incineration with energy recovery are reported in fuel combustion (1.A.) as "other fossil fuels" and "biomass" in accordance with the *2006 IPCC Guidelines*.

The estimation method, emission factors and activity data for emissions from waste incineration with energy recovery are the same as those used in the waste incineration (5.C.1.) in accordance with the *2006 IPCC Guidelines*. Please refer to Chapter 7 for further details on the estimation methods.

The CO_2 emissions from biomass are not included in the national totals[9] 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.

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 stored from fiscal year 2004 to 2007 and 2016 through 2019. Those captured CO_2 are reported under "CO_2 amount captured" in liquid fuels of 1.A.1.b Petroleum refining of the CRT table 1.A(a)s1, and the amount is subtracted from the emissions. 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.

[9] 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.)

- ***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.

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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Solid fuels (coal based fuels)																
Coal	$0100															
Steel making coal	$0110	24.5	24.5	24.5	24.5	24.5	24.6	24.6	24.6	24.6	24.6	24.6	24.6	24.6	24.6	24.6
Coking coal	$0111	24.5	24.5	24.5	24.5	24.5	24.4	24.4	24.4	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	25.1	25.1	25.1	25.1	25.1
Imported steam coal	$0121	24.7	24.7	24.7	24.7	24.7	24.4	24.4	24.4	24.4	24.4	24.3	24.3	24.3	24.3	24.3
Imported steam coal for general use	$0122	24.7	24.7	24.7	24.7	24.7	24.4	24.4	24.4	24.4	24.4	24.3	24.3	24.3	24.3	24.3
Imported steam coal for power generation use	$0123	24.7	24.7	24.7	24.7	24.7	24.4	24.4	24.4	24.4	24.4	24.3	24.3	24.3	24.3	24.3
Indigenous produced steam coal	$0124	24.9	24.9	24.9	24.9	24.9	23.7	23.7	23.7	23.7	23.7	24.2	24.2	24.2	24.2	24.2
Hard coal, anthracite & lignite	$0130	25.5	25.5	25.5	25.5	25.5	25.9	25.9	25.9	25.9	25.9	25.9	25.9	25.9	25.9	25.9
Coal products	$0200															
Coke	$0211	29.4	29.4	29.4	29.4	29.4	30.2	30.2	30.2	30.2	30.2	29.9	29.9	29.9	29.9	29.9
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	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	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	10.9	10.9	10.9	10.9	10.9
Blast furnace gas	$0222	27.2	26.9	26.7	26.5	26.4	26.5	26.6	26.5	26.5	26.5	26.3	26.3	26.4	26.3	26.3
Converter furnace gas	$0225	38.4	38.4	38.4	38.4	38.4	41.7	41.7	41.7	41.7	41.7	42.0	42.0	42.0	42.0	42.0
Liquid fuels (oil based fuels)																
Crude oil	$0300															
Crude oil for refinery use	$0310	19.1	19.0	19.0	19.1	19.1	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0	19.0
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	19.0	19.0	19.0	19.0	19.0
Residual and straight run fuel oil for refinery use	$0312	21.3	21.4	21.4	21.4	21.4	19.7	19.6	19.5	19.6	19.4	19.4	19.4	19.3	19.3	19.1
Crude oil for power generation use	$0320	19.1	19.1	19.2	19.6	19.2	19.2	19.2	19.3	19.3	19.3	19.3	19.2	19.5	19.1	19.1
Bituminous mixture fuel	$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	20.0	20.0	20.0
Natural gas liquid (NGL) / condensate	$0330	16.1	16.7	17.5	18.2	18.4	18.3	18.3	18.3	18.3	18.3	18.2	18.3	18.3	18.2	18.5
NGL/condensate for refinery use	$0331	17.4	18.1	18.0	18.3	18.4	18.3	18.3	18.3	18.3	18.3	18.2	18.3	18.3	18.3	18.5
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	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	18.3	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	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	19.3	19.3	19.3	19.3	19.3
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	18.7	18.7	18.7
Gasoline (biofuel blended)[3]		18.3	18.3	18.3	18.3	18.2	18.6	18.6	18.6	18.5	18.5	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	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	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	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	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	19.3	19.3	19.3	19.3	19.3
Fuel oil C	$0437	19.5	19.5	19.5	19.5	19.5	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2	20.2
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	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	20.2	20.2	20.2	20.2	20.2
Fuel oil C for power generation use	$0440	19.5	19.5	19.5	19.5	19.5	19.8	19.8	19.8	19.8	19.8	20.1	20.1	20.1	20.0	20.0
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	19.9	19.9	19.9
Other heavy oil products	$0452	20.8	20.8	20.8	20.8	20.8	20.4	20.4	20.4	20.4	20.4	20.4	20.4	20.4	20.4	20.4
Oil coke	$0455	25.4	25.4	25.4	25.4	25.4	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.8	24.8
Galvanic furnace gas	$0456	38.4	38.4	38.4	38.4	38.4	41.7	41.7	41.7	41.7	41.7	42.0	42.0	42.0	42.0	42.0
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	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	16.4	16.4	16.4	16.4	16.4	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	14.0	14.0	14.0	13.9	13.9	13.9	13.9	13.9
Indigenous natural gas	$0520	13.9	13.9	13.9	13.9	13.9	14.0	14.0	14.0	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	14.0	14.0	14.0	13.9	13.9	13.9	13.9	13.9
Coal mining gas	$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	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	14.0	14.0	14.0	13.9	13.9	13.9	13.9	13.9
City gas	$0600															
City 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	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	16.4	16.4	16.4	16.4	16.4	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	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	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	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	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	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	13.5	13.5	13.5

1) Code number for fuels of the *General Energy Statistics* (Energy Balance Table)
2) Used in the reference approach.
3) Used in the sectoral approach.

Table 3-12 References and methodologies of carbon emission factors for fuel combustion (FY1990-2012)

Fuel				Code	FY1990-2012
Solid fuels	Coal		Steel making coal	$0110	Same as coking coal
			Coking coal	$0111	Kainou (2005)
			Pulverized coal injection (PCI) coal	$0112	Same as coking coal
			Imported steam coal	$0121	Same as imported steam coal for general use
			Imported steam coal for general use	$0122	Environmental Agency (1992)
			Imported steam coal for power generation use	$0123	Same as imported steam coal for general use
			Indigenous produced steam coal	$0124	Environmental Agency (1992)
			Hard coal, anthracite & lignite	$0130	Kainou (2005)
	Coal Products		Coke	$0211	Environmental Agency (1992)
			Coal tar	$0212	Kainou (2005)
			Coal briquette	$0213	Environmental Agency (1992)
			Coke oven gas	$0221	Kainou (2005)
			Blast furnace gas	$0222	Values based on the carbon balance in blast furnace and converter furnace in the *General Energy Statistics*
			Converter furnace gas	$0225	Kainou (2005)
Liquid fuels	Oil		Crude oil for refinery use	$0310	Same as crude oil for refinery use
			Crude oil for refinery use	$0311	Weighted average of brand-specific CEFs based on the share of imports
			Residual and straight run fuel oil for refinery use	$0312	
			Crude oil for power generation use	$0320	Estimated by interpolating by approximate equation of crude oil for refinery use
			Bituminous mixture fuel	$0321	Kainou (2005)
			Natural gas liquid (NGL) / condensate	$0330	Weighted average of brand-specific CEFs based on the share of imports
			NGL/condensate for refinery use	$0331	
			NGL/condensate for power generation use	$0332	
			NGL/condensate for petrochemical use	$0333	
	Oil Products		Pure naphtha	$0420	Environmental Agency (1992)
			Reformate	$0421	Values of gasoline
		Fuel oil	Gasoline (crude oil origin)	$0431	Environmental Agency (1992)
			Gasoline (biofuel blended)		Weighted average of CEFs of crude oil origin and biomass origin based on the share of domestic consumption
			Jet fuel oil	$0432	Environmental Agency (1992)
			Kerosene	$0433	Environmental Agency (1992)
			Gas oil or diesel oil (crude oil origin)	$0434	Environmental Agency (1992)
			Gas oil or diesel oil (biofuel blended)		Weighted average of CEFs of crude oil origin and biomass origin based on the share of domestic consumption
			Fuel oil A	$0436	Environmental Agency (1992)
			Fuel oil C	$0437	Same as fuel oil C for general use
			Fuel oil B	$0438	Environmental Agency (1992)
			Fuel oil C for general use	$0439	Environmental Agency (1992)
			Fuel oil C for power generation use	$0440	Environmental Agency (1992)
		Miscellaneous oil products	Lubricant oil	$0451	Environmental Agency (1992)
			Other heavy oil products	$0452	Environmental Agency (1992)
			Petroleum coke	$0455	Environmental Agency (1992)
			Galvanic furnace gas	$0456	Values of converter furnace gas
			Refinery gas	$0457	Environmental Agency (1992)
			Liquefied petroleum gas (LPG)	$0458	Weighted average of theoretical CEFs of propane and butane based on the share of these matters in indigenous production and imports of the fuel
Gaseous fuels	Natural Gas		Liquefied natural gas (LNG)	$0510	Weighted average of CEFs by production area based on the share of imports by country
			Indigenous natural gas	$0520	Kainou (2005)
			Indigenous natural gas	$0521	Values of indigenous natural gas
			Coal mining gas	$0522	Environmental Agency (1992)
			Boil off gas from crude oil	$0523	Values of indigenous natural gas
	City Gas		City gas	$0610	Estimated 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
(Reference)	Biomass		Woods	$N131	Actual measurements provided by JPA
			Waste woods	$N132	
			Bioethanol	$N134	Theoretical carbon emission factor of ethanol in normal condition
			Biodiesel	$N135	
			Thermal use of black liquor	$N136	Actual measurements provided by JPA
			Gas biomass	$N137	Theoretical carbon emission factor of methane in normal 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

Table 3-13 References and methodologies of carbon emission factors for fuel combustion (FY2013-2017)

Fuel				Code	FY2013-2017
Solid fuels	Coal	Steel making coal		$0110	Weighted average of CEFs of coking coal and PCI coal using consumptions of the fuels
		Coking coal		$0111	Simple average of CEFs obtained from actual measurements provided by JISF
		Pulverized coal injection (PCI) coal		$0112	Simple average of CEFs obtained from actual measurements provided by JISF
		Imported steam coal		$0121	Same as imported steam coal for general use
		Imported steam coal for general use		$0122	Weighted average of CEF using receipts. The CEF were estimated from actual measurements provided by FEPC.
		Imported steam coal for power generation use		$0123	Same as imported steam coal for general use
		Indigenous produced steam coal		$0124	Weighted average of CEF using receipts. The CEF were estimated from actual measurements provided by FEPC.
		Hard coal, anthracite & lignite		$0130	Estimated by interpolating by the approximate equation of imported steam coal
	Coal Products	Coke		$0211	Simple average of CEFs obtained from actual measurements provided by JISF
		Coal tar		$0212	Continuous use of the current value
		Coal briquette		$0213	Values of hard coal, anthracite & lignite
		Coke oven gas		$0221	Simple average of CEFs estimated from actual measurements provided by JISF
		Blast furnace gas		$0222	Values based on the carbon balance in blast furnace and converter furnace in the *General Energy Statistics*
		Converter furnace gas		$0225	Simple average of CEFs estimated from actual measurements provided by JISF
Liquid fuels	Oil	Crude oil for refinery use		$0310	Same as crude oil for refinery use
		Crude oil for refinery use		$0311	Weighted average of brand-specific CEFs based on imports by brand. The brand-specific CEFs were estimated by the approximate equation of crude oil based on brand-specific GCV obtained from actual measurements provided by PAJ.
		Residual and straight run fuel oil for refinery use		$0312	
		Crude oil for power generation use		$0320	Weighted average of monthly CEFs using monthly receipts. The monthly CEFs were estimated by approximate equation of crude oil using GCV from *Electric Power Statistics* (ANRE).
		Bituminous mixture fuel		$0321	Continuous use of the current value
		Natural gas liquid (NGL) / condensate		$0330	Weighted average of brand-specific CEFs based on imports and shipments by brand. The brand-specific CEFs were estimated by approximate equation of crude oil using brand-specific GCV obtained from actual measurements provided by PAJ.
		NGL/condensate for refinery use		$0331	
		NGL/condensate for power generation use		$0332	
		NGL/condensate for petrochemical use		$0333	
	Oil Products	Fuel oil	Pure naphtha	$0420	Value of regular gasoline, which is simple average of CEF obtained from actual measurements provided by PAJ
			Reformate	$0421	Value of premium gasoline, which is simple average of CEF obtained from actual measurements provided by PAJ
			Gasoline (crude oil origin)	$0431	Weighted average of CEFs of regular and premium gasoline using domestic shipments by type. The CEF of each gasoline were obtained from actual measurements provided by PAJ.
			Gasoline (biofuel blended)		Values calculated by weighted average of emission factors of crude oil origin and biomass origin based on the share of domestic consumption
			Jet fuel oil	$0432	Weighted average of CEFs of kerosene type jet fuel and gasoline type jet fuel using the final consumptions by type in the *General Energy Statistics*. The CEFs of each type were obtained from actual measurements provided by PAJ.
			Kerosene	$0433	Simple average of CEFs obtained from actual measurements provided by PAJ
			Gas oil or diesel oil (crude oil origin)	$0434	Simple average of CEFs obtained from actual measurements provided by PAJ
			Gas oil or diesel oil (biofuel blended)		Weighted average of emission factors of crude oil origin and biomass origin based on the share of domestic consumption
			Fuel oil A	$0436	Simple average of CEFs obtained from actual measurements provided by PAJ
			Fuel oil C	$0437	Same as fuel oil C for general use
			Fuel oil B	$0438	Estimated by interpolating by approximate equation of oil products using GCV obtained from actual measurements provided by PAJ
			Fuel oil C for general use	$0439	Simple average of CEFs obtained from actual measurements provided by PAJ
			Fuel oil C for power generation use	$0440	Estimated by approximate equation of oil products using GCV from *Electric Power Statistics* (ANRE).
		Miscellaneous oil products	Lubricant oil	$0451	Estimated by interpolating by approximate equation of oil products based on GCV obtained from actual measurements provided by PAJ
			Other heavy oil products	$0452	Estimated by interpolating by approximate equation of oil products based on GCV estimated from energy balance of slack fuel oil input and fuel oil C output
			Petroleum coke	$0455	Simple average of CEFs obtained from actual measurements provided by JCIA
			Galvanic furnace gas	$0456	Values of converter furnace gas
			Refinery gas	$0457	Simple average of CEFs estimated from actual measurements provided by PAJ
			Liquefied petroleum gas (LPG)	$0458	Weighted average of theoretical CEFs of propane and butane using domestic supply amount of each gas
Gaseous fuels	Natural Gas	Liquefied natural gas (LNG)		$0510	Weighted average of CEFs by production area using imports by country. The CEFs by production area were estimated from *Gas Industry Handbook* (JGA).
		Indigenous natural gas		$0520	Weighted average of CEFs by gas field using productions by gas field. The CEFs by gas field were estimated from actual measurements provided by JNGA.
		Indigenous natural gas		$0521	Values of indigenous natural gas ($0520)
		Coal mining gas		$0522	Weighted average of CEFs by gas field using productions by gas field. The CEFs by gas field were estimated from actual measurements provided by JNGA.
		Boil off gas from crude oil		$0523	Values of indigenous natural gas ($0520)
	City Gas	City gas		$0610	Estimated 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
(Reference)	Biomass	Woods		$N131	Simple average of CEFs obtained by actual measurements provided by JPA
		Waste woods		$N132	
		Bioethanol		$N134	Theoretical carbon emission factor of ethanol in SATP condition
		Biodiesel		$N135	
		Thermal use of black liquor		$N136	Actual measurements provided by JPA
		Gas biomass		$N137	Theoretical carbon emission factor 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

Table 3-14 References and methodologies of carbon emission factors for fuel combustion (FY2018 onward)

Fuel				Code	FY2018 onward
Solid fuels	Coal		Steel making coal	$0110	Weighted average of CEFs of coking coal and PCI coal using consumptions of the fuels
			Coking coal	$0111	Simple average of CEFs obtained from actual measurements provided by JISF
			Pulverized coal injection (PCI) coal	$0112	Simple average of CEFs obtained from actual measurements provided by JISF
			Imported steam coal	$0121	Same as imported steam coal for general use
			Imported steam coal for general use	$0122	Weighted average of CEF using receipts. The CEF were estimated from actual measurements provided by FEPC.
			Imported steam coal for power generation use	$0123	Same as imported steam coal for general use
			Indigenous produced steam coal	$0124	Weighted average of CEF using receipts. The CEF were estimated from actual measurements provided by FEPC.
			Hard coal, anthracite & lignite	$0130	Continuous use of the current value
	Coal Products		Coke	$0211	Simple average of CEFs obtained from actual measurements provided by JISF
			Coal tar	$0212	Continuous use of the current value
			Coal briquette	$0213	Continuous use of the current value
			Coke oven gas	$0221	Simple average of CEFs estimated from actual measurements provided by JISF
			Blast furnace gas	$0222	Values based on the carbon balance in blast furnace and converter furnace in the *General Energy Statistics*
			Converter furnace gas	$0225	Simple average of CEFs estimated from actual measurements provided by JISF
Liquid fuels	Oil		Crude oil for refinery use	$0310	Same as crude oil for refinery use
			Crude oil for refinery use	$0311	Weighted average of brand-specific CEFs based on imports by brand. The brand-specific CEFs were estimated by the approximate equation of crude oil based on brand-specific GCV obtained from actual measurements provided by PAJ.
			Residual and straight run fuel oil for refinery use	$0312	
			Crude oil for power generation use	$0320	Weighted average of monthly CEFs using monthly receipts. The monthly CEFs were estimated by approximate equation of crude oil using GCV from *Electric Power Statistics* (ANRE).
			Bituminous mixture fuel	$0321	Continuous use of the current value
			Natural gas liquid (NGL) / condensate	$0330	Weighted average of brand-specific CEFs based on imports and shipments by brand. The brand-specific CEFs were estimated by approximate equation of crude oil using brand-specific GCV obtained from actual measurements provided by PAJ.
			NGL/condensate for refinery use	$0331	
			NGL/condensate for power generation use	$0332	
			NGL/condensate for petrochemical use	$0333	
	Oil Products		Pure naphtha	$0420	Continuous use of the current value
			Reformate	$0421	Continuous use of the current value
		Fuel oil	Gasoline (crude oil origin)	$0431	Weighted average of CEFs of regular and premium gasoline using domestic shipments by type. The CEF of each gasoline were obtained from actual measurements provided by PAJ.
			Gasoline (biofuel blended)		Values calculated by weighted average of emission factors of crude oil origin and biomass origin based on the share of domestic consumption
			Jet fuel oil	$0432	Weighted average of CEFs of kerosene type jet fuel and gasoline type jet fuel using the final consumptions by type in the *General Energy Statistics*. The CEFs of each type were obtained from actual measurements provided by PAJ.
			Kerosene	$0433	Continuous use of the current value
			Gas oil or diesel oil (crude oil origin)	$0434	Continuous use of the current value
			Gas oil or diesel oil (biofuel blended)		Values calculated by weighted average of emission factors of crude oil origin and biomass origin based on the share of domestic consumption
			Fuel oil A	$0436	Continuous use of the current value
			Fuel oil C	$0437	Same as fuel oil C for general use
			Fuel oil B	$0438	Continuous use of the current value
			Fuel oil C for general use	$0439	Continuous use of the current value
			Fuel oil C for power generation use	$0440	Estimated by approximate equation of oil products using GCV from *Electric Power Statistics* (ANRE).
		Miscellaneous oil products	Lubricant oil	$0451	Continuous use of the current value
			Other heavy oil products	$0452	Estimated by interpolating by approximate equation of oil products based on GCV estimated from energy balance of slack fuel oil input and fuel oil C output
			Petroleum coke	$0455	Continuous use of the current value
			Galvanic furnace gas	$0456	Values of converter furnace gas
			Refinery gas	$0457	Continuous use of the current value
			Liquefied petroleum gas (LPG)	$0458	Weighted average of theoretical CEFs of propane and butane using domestic supply amount of each gas
Gaseous fuels	Natural Gas		Liquefied natural gas (LNG)	$0510	Weighted average of CEFs by production area using imports by country. The CEFs by production area were estimated from actual measurements provided by FEPC and JGA.
			Indigenous natural gas	$0520	Weighted average of CEFs by gas field using productions by gas field. The CEFs by gas field were estimated from actual measurements provided by JNGA.
			Indigenous natural gas	$0521	Values of indigenous natural gas ($0520)
			Coal mining gas	$0522	Continuous use of the current value
			Boil off gas from crude oil	$0523	Values of indigenous natural gas ($0520)
	City Gas		City gas	$0610	Estimated 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
(Reference)	Biomass		Woods	$N131	Continuous use of the current value
			Waste woods	$N132	
			Bioethanol	$N134	Continuous use of the current value
			Biodiesel	$N135	Continuous use of the current value
			Thermal use of black liquor	$N136	Continuous use of the current value
			Gas biomass	$N137	Continuous use of the current value

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 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), Kainou (2014), and Agency for Natural Resources and Energy (2020).

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

The evaluation results in Kainou (2005) were adopted for setting emission factors. In the choice of carbon emission factors, an adequacy assessment of emission factors was conducted 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
2) Evaluation and analysis by comparison with the *Revised 1996 IPCC Guidelines* default values
3) Group evaluation and analysis by carbon balance using the *General Energy Statistics*

The summaries of evaluations are indicated below.

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

The validity of carbon emission factors 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 carbon emission factors are required to be evaluated are hydrocarbons containing a few impurities, and because a physicochemical correspondence exists between the gross calorific values of pure hydrocarbons and carbon emission factors.

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

The validity of carbon emission factors is judged by using the *Revised 1996 IPCC Guidelines* default values or the *2006 IPCC Guidelines* reference values[10] 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, carbon emission factors 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 fuel-specific carbon emission factors for some petroleum and coal product factor groups can be evaluated using the *General Energy Statistics* to analyze the carbon balance in coal and oil 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.

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

The values through the survey conducted by METI and MOE on the calorific values (CV) and carbon

[10] 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.

emission factors (CEF) 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 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 current values.

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

The CEFs from FY2018 onward were established in combination of the CVs, based on the survey conducted by METI and MOE on the CV and CEF in FY2017 through FY2019. The fuels to be revised were selected, considering that the major revision of the CV and CEF 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 work load of the measurements and impact on emissions.

The CV and CEF were established basically by the following methods: (1) They were established in

place of the current values using the data provided by industry organizations; (2) They were established in place of the current values using the existing statistics and references, the estimation equations, and other means; (3) The current 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 CV and CEF 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.

(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

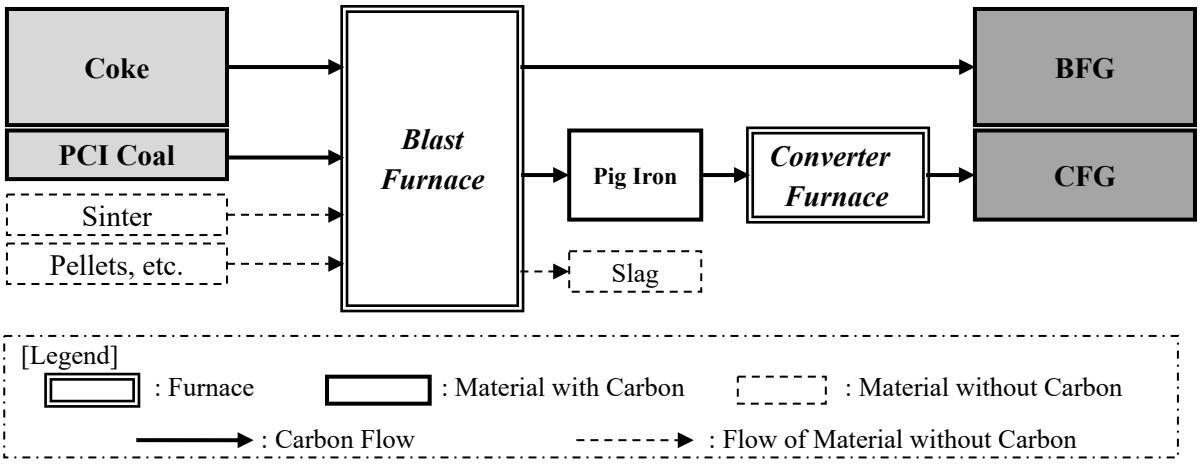

Figure 3-3 Overview of carbon flow for iron & steel manufacturing

Table 3-15 Calculation process of emission factors for BFG

Steel process gas		1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Note
Input																	
PCI coal	kt-C	1,650	2,619	3,351	3,014	3,444	4,401	4,283	4,180	4,206	4,250	4,094	4,043	2,965	4,039	3,491	A
Coke	kt-C	12,739	11,400	12,221	11,497	11,194	10,870	10,917	10,270	10,196	9,739	9,586	9,273	7,833	8,764	7,899	B
Input total	kt-C	14,389	14,019	15,572	14,511	14,637	15,271	15,200	14,449	14,402	13,989	13,680	13,316	10,799	12,803	11,390	C: A + B
Output																	
CFG (LDG)	kt-C	2,541	2,359	2,726	2,804	2,798	2,955	2,941	2,778	2,770	2,589	2,552	2,478	2,066	2,308	2,113	D
Difference	kt-C	11,848	11,660	12,846	11,707	11,839	12,316	12,260	11,671	11,632	11,400	11,127	10,838	8,733	10,494	9,277	E: C - D
Output																	
BFG	PJ	434.8	433.5	481.8	441.4	448.7	464.5	461.7	440.1	438.9	429.8	423.2	412.4	331.1	399.3	353.1	F
EF BFG	t-C/TJ	27.2	26.9	26.7	26.5	26.4	26.5	26.6	26.5	26.5	26.5	26.3	26.3	26.4	26.3	26.3	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 supplier, 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 supplier).

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)

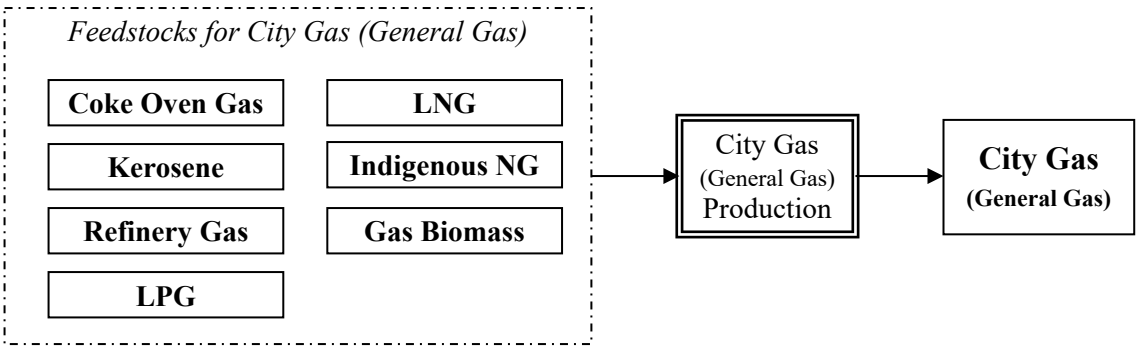

Figure 3-4 Manufacturing flow for city gas (general gas)

Table 3-16 Calculation process of emission factors for city gas (general gas)

City gas		1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Note
Input																	
COG	kt-C	211	134	105	22	0	0	0	0	0	0	0	0	0	0	0	a1
Kerosene	kt-C	200	275	69	6	0	0	0	0	0	0	0	0	0	0	0	a2
Refinery gas	kt-C	186	199	186	145	89	67	56	37	48	43	46	77	81	83	87	a3
LPG	kt-C	1,957	2,129	1,809	1,092	786	930	992	818	837	947	965	942	932	1,108	1,350	a4
LNG	kt-C	6,473	9,429	12,051	17,146	21,357	21,709	21,863	21,868	22,907	23,252	22,682	21,960	21,239	22,085	21,241	a5
Indigenous NG	kt-C	551	661	848	1,190	1,603	1,498	1,479	1,435	1,415	1,347	1,187	1,048	991	950	854	a6
Input total	kt-C	9,577	12,827	15,068	19,601	23,834	24,205	24,390	24,159	25,205	25,589	24,879	24,028	23,243	24,226	23,531	A: Σa
Output																	
City gas	PJ	664.7	892.3	1,061.1	1,392.0	1,700.3	1,724.3	1,737.3	1,722.1	1,796.5	1,822.5	1,781.9	1,720.8	1,664.7	1,732.9	1,678.5	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	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* were used for the activity data. Table 3-17 shows the trend of energy consumption.

Table 3-17 Energy consumptions in Energy Industries (1.A.1) (unit: PJ)

Fuel	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Liquid fuels	2,596	2,198	1,618	1,669	1,352	1,866	1,465	1,312	1,154	1,021	880	778	675	782	785
Solid fuels	1,235	1,542	1,951	2,586	2,757	3,121	3,056	3,038	3,045	3,103	2,924	2,857	2,752	2,900	2,884
Gaseous fuels	1,564	1,786	2,167	2,021	2,624	3,488	3,552	3,300	3,394	3,218	3,033	2,846	2,927	2,642	2,501
Other fossil fuels	IE	IE	0	5	5	0	1	1	1	1	1	1	1	1	1
Biomass	0	0	0	26	28	31	32	32	48	84	92	140	156	186	203
Total	5,395	5,526	5,737	6,308	6,766	8,506	8,106	7,683	7,642	7,428	6,930	6,621	6,510	6,511	6,374

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

The *General Energy Statistics* (Energy Balance Table) provides a comprehensive overview of domestic energy supply and demand to grasp what are converted from energy sources, such as coal, oil and natural gas, 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 *General Energy Statistics* shows the main energy sources used in Japan as “Columns” and the supply, transformation and consumption sectors as “Rows” in a matrix. Specifically, the columns comprise 13 major categories (coal, coal products, crude oil, oil products, natural gas, city gas, renewable energy (excl. hydro), hydraulic power generation (excl. pumped), pumped storage, effective recovery use of wasted energy, nuclear power generation, electricity, and heat) and the necessary sub-categories and a more detailed breakdown of the sub-categories. The rows comprise 3 major sectors: primary energy supply (primary supply), energy transformation & own use (conversion), and final energy consumption (final consumption). The rows also contain 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 complete Energy Balance Tables for the years since FY1990 are available on the following internet site:

https://www.enecho.meti.go.jp/statistics/total_energy/results.html#headline2 (Japanese version only)

Please refer to the simplified energy balance tables provided in Annex 3 (A3.2).

For the activity data for energy industries, the data reported in the following sectors in the *General Energy Statistics* were used: “manufacture of coal products” [#210000]; “oil products” [#220000]; “gas conversion and production” [#230000]; “power generation” [#240000] which reports energy consumption associated with electric power generation by electric power suppliers; “heat supply” [#270000] which provides energy consumption associated with heat energy and cold energy by electric power suppliers or thermal energy suppliers; “own use, coal products” [#301100] which reports energy consumption associated with captive (own) use of energy industries; “own use, oil products” [#301200]; “own use, gas conversion and production” [#301300]; “own use, power generation” [#301400]; “own use, heat supply” [#301500].

In addition, fossil fuel consumption of “Auto power production” in “production, transmission and distribution of electricity” [#255330] is also included in the energy industries from FY1990 to FY2015. 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 mainly 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 3-18 shows the correspondence between the sectors of Japan’s Energy Balance Table from the *General Energy Statistics* and those of the CRT.

Table 3-18 Correspondence between sectors of Japan’s Energy Balance Table 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 2015)	#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 and miscellaneous	#253175
		Auto steam generation, Manufacture of coal products and miscellaneous	#263175
		Final energy consumption; Manufacture of coal products and 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 value*

The gross calorific values (GCV) used in *General Energy Statistics* are adopted. Table 3-19 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 and 2018.

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 3-19 Trends in gross calorific value of each fuel type

Fuel	Code	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Solid fuels (coal based fuels)																	
Coal	$0100																
Steel making coal	$0110	MJ/kg	31.8	30.5	29.0	29.0	28.9	28.7	28.7	28.7	28.7	28.7	28.7	28.7	28.8	28.7	28.7
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	28.9	28.9	28.9	28.9	28.9
Pulverized coal injection (PCI) coal	$0112	MJ/kg	31.8	30.5	28.2	28.2	28.2	28.0	28.0	28.0	28.0	28.0	28.3	28.3	28.3	28.3	28.3
Imported steam coal	$0121	MJ/kg	26.0	26.0	26.6	25.7	25.7	26.0	26.0	26.0	26.0	26.0	26.1	26.1	26.1	26.1	26.1
Imported steam coal for general use	$0122	MJ/kg	26.0	26.0	26.6	25.7	25.7	26.0	26.0	26.0	26.0	26.0	26.1	26.1	26.1	26.1	26.1
Imported steam coal for power generation use	$0123	MJ/kg	24.9	26.1	26.4	25.5	25.3	26.0	25.5	25.3	25.1	25.0	24.8	24.5	24.4	24.8	24.9
Indigenous produced steam coal	$0124	MJ/kg	24.3	24.3	22.5	22.5	22.5	25.3	25.3	25.3	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	27.8	27.8	27.8	27.8	27.8
Coal Products	$0200																
Coke	$0211	MJ/kg	30.1	30.1	30.1	29.4	29.4	29.2	29.2	29.2	29.2	29.2	29.0	29.0	29.0	29.0	29.0
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	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	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	18.9	18.9	18.9	18.4	18.4	18.4	18.4	18.4
Blast furnace gas	$0222	MJ/m^3	3.5	3.6	3.6	3.4	3.4	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2	3.2
Converter furnace gas	$0225	MJ/m^3	8.4	8.4	8.4	8.4	8.4	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
Liquid fuels (oil based fuels)																	
Crude oil	$0300																
Crude oil for refinery use	$0310	MJ/L	38.3	38.3	38.2	38.1	38.2	38.2	38.2	38.2	38.2	38.2	38.2	38.1	38.1	38.1	38.1
Crude oil for refinery use	$0311	MJ/L	38.3	38.3	38.2	38.1	38.2	38.2	38.2	38.2	38.2	38.2	38.2	38.1	38.1	38.1	38.1
Residual and straight run fuel oil for refinery use	$0312	MJ/L	38.3	38.3	38.2	38.1	38.2	41.3	40.9	40.6	40.8	40.3	40.2	40.1	39.9	39.8	39.0
Crude oil for power generation use	$0320	MJ/L	39.1	39.2	39.6	38.5	39.7	39.3	39.4	39.8	40.0	39.5	39.8	40.1	40.4	40.5	39.3
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	22.4	22.4	22.4
Natural gas liquid (NGL) / condensate	$0330	MJ/L	35.7	35.5	35.4	35.0	34.8	34.8	34.7	34.6	34.8	34.5	34.5	34.6	34.6	34.5	35.9
NGL/condensate for refinery use	$0331	MJ/L	35.7	35.5	35.4	35.0	34.8	34.8	34.7	34.7	34.8	34.6	34.5	34.7	34.6	34.6	35.9
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	34.2	34.2	34.2	34.2	34.2	34.5	34.5
NGL/condensate for petrochemical use	$0333	MJ/L	35.7	35.5	35.4	35.0	34.8	34.6	34.5	34.4	34.7	34.4	34.3	34.3	34.3	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	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	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	33.4	33.4	33.4
Gasoline (biofuel blended)[2]		MJ/L	34.6	34.6	34.6	34.6	34.5	33.3	33.3	33.2	33.2	33.2	33.2	33.2	33.1	33.2	33.2
Jet fuel oil	$0432	MJ/L	36.4	36.4	36.7	36.7	36.7	36.3	36.3	36.2	36.3	36.4	36.4	36.3	36.3	36.3	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	36.5	36.5	36.5	36.5	36.5
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	38.0	38.0	38.0	38.0	38.0
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	38.0	38.0	38.0	38.0	38.0
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	38.9	38.9	38.9	38.9	38.9
Fuel oil C	$0437	MJ/L	40.2	40.3	40.3	40.3	40.4	41.2	40.9	41.4	41.0	41.0	41.1	41.0	41.1	41.0	41.0
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	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	40.9	41.4	41.0	41.0	41.1	41.0	41.1	41.0	41.0
Fuel oil C for power generation use	$0440	MJ/L	41.1	41.1	41.3	41.2	41.3	41.2	41.4	41.0	41.5	41.6	41.6	41.7	41.6	41.5	41.5
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	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	39.9	40.4	40.0	40.0	40.1	40.0	40.1	40.0	40.0
Oil coke	$0455	MJ/kg	35.6	35.6	35.6	29.9	29.9	33.3	33.3	33.3	33.3	33.3	33.3	33.3	33.3	34.1	34.1
Galvanic furnace gas	$0456	MJ/m^3	8.4	8.4	8.4	8.4	8.4	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5
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	46.1	46.1	46.1	46.1	46.1
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	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	54.5	54.5	54.5	54.7	54.7	54.7	54.7	54.7
Indigenous natural gas	$0520	MJ/m^3	42.1	42.4	42.6	42.9	44.7	39.6	39.6	39.6	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	39.6	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	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	39.6	39.6	39.6	38.4	38.4	38.4	38.4	38.4
City gas	$0600																
City gas	$0610	MJ/m^3	41.9	41.9	41.1	44.8	44.8	40.8	40.8	40.7	40.7	40.8	40.0	40.0	39.9	40.0	40.4
Small scale community gas	$0620	MJ/m^3	105.4	103.6	102.3	101.5	101.1	96.0	95.7	95.3	95.3	95.0	94.8	94.9	94.3	94.1	94.2
(Reference) Biomass	$N130																
Woods	$N131	MJ/kg	15.4	15.4	15.4	19.9	17.4	17.6	17.2	17.0	13.1	12.9	13.6	14.8	14.5	14.8	14.2
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	17.1	17.1	17.1	17.1	17.1
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	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	23.4	23.4	23.4	23.4	23.4	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	13.6	13.6	13.6	13.6	13.6
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	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.

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

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 FY2017 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 −4% to +2% for CO_2 emissions from combustion of solid, liquid and gaseous fuels as a whole for the fuel combustion category. See section 7.4.3 for the uncertainty of CO_2 emissions from waste incineration for energy purposes and with energy recovery.

- ***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

Subtracting the amount of CO_2, captured for direct utilization as products such as dry ice and liquified carbonated gas, from the emissions from “Petroleum refining (1.A.1.b)”, the emissions for the period of FY1990-2021 were recalculated.

Due to the updates of the activity data and the emission factors based on the update of the *General Energy Statistics*, the emissions for the period of FY1990-2021 were 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 FY2005-FY2021 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*

There is no change of the estimation methodology, which influences CO_2 emissions, for compiling the *General Energy Statistics* in FY2022.

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 FY2021 data that were updated during the compilation of the *General Energy Statistics* in FY2022.

Table 3-20 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. 2022 after the annual revision were applied.)	$0300 Crude oil, $0500 Natural Gas; #110000 Indigenously Produced, #120000 Imports, #160000 Exports, #190000 Stockpile Change / Supply $0400 Oil Products, #222000 Oil Refinery
2	*Trade Statistics of Japan*	$0100 Coal, $0200 Coal Products, $0455 Petroleum Coke, $0458 LPG, $0510 LNG, $N130 Biomass; #120000 Imports, #160000 Exports
3	*Current Survey of Energy Consumption* (The data for Jan. - Mar. 2022 after the annual revision were 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	*Statistical Survey on Farm Management*	Estimation for #611100 Agriculture
5	*Statistical Survey on Agriculture Commodity Price Index*	Estimation for #611100 Agriculture
6	*Survey on Petroleum Products Retail Price*	Estimation for #611100 Agriculture, #611200 Forestry, #611300 Fishery Except Aquaculture
7	Heavy fuel oil for water passenger transport	$0435 Heavy Fuel Oil; #814000 Water Passenger Transport
8	*Railway Statistical Yearbook*	$0434 Diesel oil; $1200 Electricity; #813000 Railway Passenger Transport, #852000 Railway Freight Transport
9	Coal Consumption of Steam Locomotive	$0122 Imported Steam Coal for General Use, #813000 Railway Passenger Transport
10	Motorcycle consumption	#812000 Motorcycle

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

In addition, duplication was found through new survey on some part of miscellaneous use reported in *Power Generation and Receiving Monthly Report*, the duplication was retroactively eliminated.

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 "Unable to classify" under the Commercial Industry 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, Commercial Industry, Transportation can slightly changes 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.

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 is in progress.

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 3-21 were employed based on data obtained from surveys conducted in Japan (Table 3-22) 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 O_2 concentration in exhaust gas, as shown in the equation below.

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

Co_2 : O_2 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 3-23, Table 3-24). 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 3-21 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, kWh	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
Electricity	kWh		3,600		a

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 3-22 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 3-23 CH_4 emission factors for different fuels and furnaces in GCV basis (unit: kg-CH_4/TJ)

				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
Fuel			Code[1)]	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 3-24 N_2O emission factors for different fuels and furnaces in GCV basis (unit: kg-N_2O/TJ)

Fuel			Code 1)	Boilers: Boiler (other than fluidized-bed boiler)	Boilers: Normal pressure fluidized-bed boiler	Boilers: Pressurized fluidized-bed boiler	Industrial furnaces: Blast furnace (except for smelting copper, lead, and zinc)	Industrial furnaces: Oil and gas furnaces	Industrial furnaces: Catalytic regenerator	Industrial furnaces: Coke oven	Industrial furnaces: Other industrial furnaces	Internal-combustion engines: Gas turbine	Internal-combustion engines: Diesel engine	Internal-combustion engines: Gas engine, gasoline engine
				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 3-23 and Table 3-24.

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 3-21.

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 3-25 Emission factor of CH_4 from coking furnace lids, desulfurization towers, and desulfurization recycling towers

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Emission factors	kg-CH_4/t	0.238	0.238	0.119	0.043	0.031	0.039	0.038	0.036	0.033	0.031	0.027	0.030	0.028	0.034	0.034

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 3-26.

Table 3-26 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.

In the recommendation by UNFCCC inventory review on Japan's inventory submission in 2018 (FCCC/ARR/2018/JPN, paragraph E.12), the ERT noted that the IEFs of gaseous fuels for oil refinery 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). 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, in the same recommendation, the ERT also pointed out that 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 3-27 Coke production amount

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Coke production	kt	47,338	42,279	38,511	38,009	37,036	35,082	33,785	32,439	33,138	32,587	32,659	32,640	29,287	30,219	28,709

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

➢ *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***

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.

● ***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 addition, the Expert Review Team strongly recommended that Japan provided additional

information in its annual submission to transparently justify the appropriateness of the measurements to the current boiler types/technologies in the individual review of the 2013 submission. (FCCC/ARR/2013/JPN)

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.

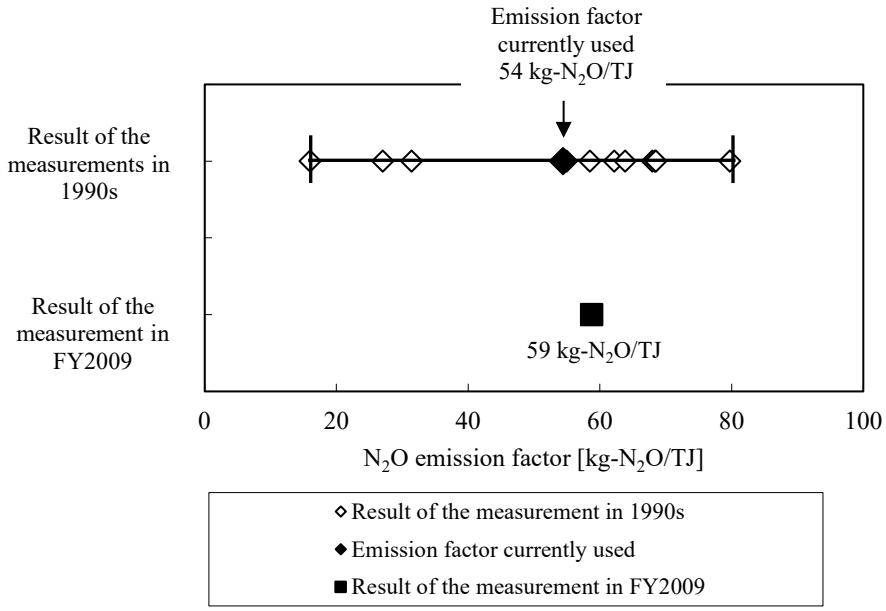

Figure 3-5 Comparison of the 1990s and FY2009 measurement results

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 FY2020 survey results of *General Survey of the Emissions of Air Pollutants* were adopted, the CH_4 and N_2O emissions in FY2018-2021 were recalculated. Since the activity data in the *General Energy Statistics* were revised, the CH_4 emissions for FY2006-2021 and the N_2O emissions for FY1990-2021 were recalculated. Since the emission factor of coking furnace lid and other facilities for FY2021 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 FY2022, CO_2 emissions from this category accounted for 234,600 kt-CO_2, and represented 20.7% of Japan's total GHG emissions (excluding LULUCF). The iron and steel (1.A.2.a) accounts for 49.0%, and is the largest source within the manufacturing industries and construction category in FY2022.

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).

The energy consumption and emissions from waste incineration with energy recovery are reported in fuel combustion (1.A.) as "other fossil fuels" and "biomass" in accordance with the *2006 IPCC Guidelines*.

The estimation method, emission factors and activity data for emissions from waste incineration with energy recovery are the same as those used in the waste incineration (5.C.1.) in accordance with the *2006 IPCC Guidelines*. Please refer to Chapter 7 for further details on the estimation methods.

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*.

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. These captured amounts are reported as "CO_2 amount captured" in solid fuels of "Iron and steel (1.A.2.a)", liquid fuels of "Chemicals (1.A.2.c)", solid fuels of "Pulp, paper and print (1.A.2.d)" or solid fuels of "Non-metallic minerals (1.A.2.f)", and the amount is subtracted from the emissions. 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.

- ***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 3-28 Energy consumptions in Manufacturing Industries and Construction category (1.A.2) (unit: PJ)

Fuel	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Liquid fuels	1,960	2,114	1,909	1,544	1,050	1,020	963	890	837	816	824	771	743	794	779
Solid fuels	2,130	2,054	2,034	2,051	2,043	2,087	2,051	2,000	1,889	1,863	1,828	1,802	1,560	1,693	1,529
Gaseous fuels	227	344	408	599	629	611	594	595	603	601	630	601	578	599	597
Other fossil fuels	86	99	115	174	203	214	221	224	221	228	233	241	231	237	231
Biomass	227	227	240	273	298	309	303	300	272	281	286	286	259	276	264
Total	4,629	4,837	4,705	4,641	4,223	4,241	4,131	4,009	3,821	3,790	3,802	3,701	3,371	3,598	3,401

The activity data for the manufacturing industry sectors were calculated by totaling the energy consumption from production activities in factories and offices (final energy consumption: #6xxxxx[11]),

[11] x indicates any number.

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*. Because the energy consumption for production activities in factories and offices contained a certain amount used as raw materials (non-energy and feedstock use: #95xxxx), this amount was subtracted.

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 3-29 shows the correspondence between the sectors of Japan's Energy Balance Table and those of the CRT (1.A.2).

Table 3-29 Correspondence between sectors of Japan's Energy Balance Table 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	#253250
	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	#263260
	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.

c) Uncertainties 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

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

Subtracting the amount of CO_2, captured and directly utilized as liquified carbonated gas, from the emissions from "Iron and steel (1.A.2.a)", the emissions for the period of FY1990-FY2021 were recalculated. Subtracting the amount of CO_2, captured and fixed within environmentally friendly concrete, from the emissions from "Non-metallic minerals (1.A.2.f)", the emissions in FY2021 were recalculated.

Due to the updates of the activity data and the emission factors based on the update of the *General Energy Statistics*, the emissions for the period of FY2006-FY2021 were recalculated.

Updating the statistical data and improving the estimation methodology in the waste sector, CO_2 emissions from other fossil fuels in FY2005-FY2021 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 machineries.

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 3-23 and Table 3-24, 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 values of European Environment Agency (EEA, 2016) (Table 3-1, 1.A.2.g.vii) 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
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) Uncertainties 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

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

Since the FY2020 survey results of *General Survey of the Emissions of Air Pollutants* were adopted, the CH_4 and N_2O emissions in FY2018-2021 were recalculated. Since the activity data for FY2006-2021 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 FY2021 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 FY2022, CO_2 emissions from this category accounted for 185,040 kt-CO_2, and represented 16.3% of Japan's total GHG emissions (excluding LULUCF). The road transportation (1.A.3.b) accounts for 88.9% and is the largest within the Transport category in FY2022.

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).

The carbon emission factor for liquid fuels (diesel oil) in 1.A.3.b (Road transportation) is the lowest in Annex I Parties for two reasons. One is because the quality standard for diesel oil in Japan is different from other countries. Crude oil with high sulfur content imported from the Middle East must be decomposed and go through ultra-deep desulfurization to become low-sulfur diesel oil (<10 ppm) according to Japanese automobile exhaust gas regulations. The other reason is because gas oil used for purposes other than road transport is called "fuel oil A" to distinguish it from diesel oil. The carbon balance of Japanese petroleum refineries including diesel oil and fuel oil A nearly matches according to statistics, so these carbon emission factors are not irregular.

Please refer to the quality standard for diesel oil in Japan provided in Annex 3 (Section A3.3).

➢ *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 combusted.

● ***Activity Data***

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

Fuel	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Liquid fuels	2,982	3,581	3,735	3,514	3,286	3,135	3,065	3,049	3,024	2,999	2,967	2,908	2,581	2,599	2,704
Solid fuels	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gaseous fuels	0	0	1	4	5	4	4	3	3	2	2	2	1	1	1
Other fossil fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biomass	NO	NO	NO	0	9	10	12	15	18	19	20	19	20	20	20
Total	2,983	3,581	3,736	3,518	3,299	3,149	3,081	3,067	3,045	3,021	2,988	2,928	2,602	2,620	2,725

➢ *Fuels such as gasoline and diesel oil*

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

The values subtracting final energy consumption reported under 'non-energy and feedstock use' [#953000] from energy consumption reported under 'air transport' [#815000] [#854000], 'road transport' [#811000] [#851000] [#811500] [#812000], 'railway transport' [#813000] [#852000] and 'water transport' [#814000] [#853000] in Japan's Energy Balance Table (*General Energy Statistics*) are used for activity data. Because energy consumption reported under 'non-energy and feedstock use' was used for purposes other than combustion and was considered not emitting CO_2, these values were deducted. (see Table 3-33)

Table 3-33 Correspondence between sectors of Japan's Energy Balance Table 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; Freight truck and lorry	#851000
			Non-energy and feedstock use; Transportation (bus, freight 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[12], 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[13] 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 (0.92% for engine oils for automobiles and 83% for marine diesel engine oil).

[12] 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) to ensure time-series consistency.

[13] Lubricants sold to consumers, for FY1990-2001.

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]

Table 3-34 Consumption of total loss type engine oils

Item		Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Two stroke engine oil for automobiles	LC_1	TJ	207	215	210	194	183	158	154	142	135	137	149	149	144	142	128
Cylinder oil for navigation	LC_2	TJ	5,318	5,503	7,144	6,250	4,627	3,502	3,301	3,124	2,843	2,766	3,095	3,036	2,831	2,602	2,228
Total sales of lubricants	DS	1000 kL	3,439	3,292	3,090	2,886	2,485	2,159	2,130	2,058	1,994	2,021	2,241	2,182	2,017	2,036	1,811
Proportion of sales of engine oils for automobiles	R_1	-	23%	25%	26%	26%	28%	28%	28%	26%	26%	26%	26%	26%	27%	27%	27%
Proportion of sales of marine diesel engine oils	R_2	-	6.5%	7.1%	9.8%	9.1%	7.9%	6.8%	6.5%	6.4%	6.0%	5.8%	5.8%	5.9%	5.9%	5.4%	5.2%
Gross calorific value of lubricants	GCV	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	40.2	40.2	40.2

c) Uncertainties 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

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 and the emission factors based on the update of the *General Energy Statistics*, the emissions for the period of FY2019-FY2021 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* (Vol. 2, page 3.70, Table 3.6.9) are used for the emission factors of CH_4 and N_2O during LTO. As for during cruising, the default values given in the *2006 IPCC Guidelines* (Vol. 2, page 3.64, Table 3.6.5) are used. (See Table 3-35)

➢ *Aviation gasoline*

The default values given in the *2006 IPCC Guidelines* (Vol. 2, page 3.64, Table 3.6.5) 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 Guidelines*, 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Number of LTO cycle	1000 LTO	669	783	865	895	882	993	1,006	997	994	999	1,003	1,002	627	793	1,005
Jet fuel consumption during cruise	1000 kL	1,621	2,425	2,742	3,031	2,629	2,933	2,996	3,005	3,069	3,140	3,172	3,400	1,553	2,045	2,875
Aviation gasoline consumption	1000 kL	5.3	6.0	4.3	7.7	1.9	1.9	1.7	1.7	1.7	1.9	2.6	2.8	2.4	2.4	2.5

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

Aircraft type	Unit	2001	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
B737-300/400/500	1000 LTO	123	103	84	131	132	80	68	38	54	15	7	3	4
B737-800		NO	NO	97	118	130	166	165	178	210	157	134	168	258
B747SR		43	30	3	1	NO	1	1	NO	NO	NO	NO	2	3
B747-400		56	54	22	14	8	5	7	5	2	1	2	NO	NO
B767-300		146	103	101	87	79	75	73	80	82	52	26	33	51
B777-200/300		69	76	89	93	87	78	74	71	74	46	19	19	28
A320		59	47	48	95	102	103	97	54	54	63	71	90	138

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

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

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 a correction of categorization of emission factors for some types of small aircrafts since FY2016, an update of the total number of LTO in FY2019 and FY2020 in the *Airport Management Status Study Report* and an update of the number of LTO by aircraft type in FY2021 in the *PRTR Outside Notification Emissions Estimated Data*, the CH_4 and N_2O emissions from jet fuel for these periods were recalculated. Also, due to an update of the *General Energy Statistics*, the CH_4 and N_2O emissions from jet kerosene for the period of FY2019-FY2021 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 vehicle	Light vehicle used for transportation of people	Yes	-	-	-
Passenger vehicle	Regular vehicle or small vehicle used for transportation of people, with a capacity of 10 persons or less	Yes	Yes	Yes	Yes
Bus	Regular vehicle or small vehicle used for transportation of people, with a capacity of 11 persons or more	Yes	Yes	-	Yes
Light cargo truck	Light vehicle used for transportation of cargo	Yes	-	-	-
Small cargo truck	Small vehicle used for transportation of cargo	Yes	Yes	-	Yes (Cargo truck)
Regular cargo truck	Regular vehicle used for transportation of cargo	Yes	Yes	-	
Special-purpose vehicle	Regular, small or light vehicle used for special purposes, including flushers, advertising vans, hearses, and others	Yes	Yes	-	Yes
Motorcycle	Two-wheeled vehicle	Yes	-	-	-

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 vehicle and passenger vehicle
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	Bus, light cargo truck, small cargo truck, regular cargo truck, and special-purpose vehicle
1.A.3.b.iv. Motorcycles	Motorcycle
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 3.2.4.2.a) and Motorcycles (section 3.2.4.2.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[14]. 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[15] as combined mode emission factors[16] by vehicle exhaust gas regulation[17] 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 the *GHGs Estimation Methods Committee Report Part 2 – Transportation* (MOE, August 2006).

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

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

[16] 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

[17] The regulated gases are air pollutants such as CO, non-methane hydrocarbons (NMHC), NOx and particulate matter (PM).

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

Vehicle type \ Fuel	Gasoline		Diesel		Natural gas	
	CH_4	N_2O	CH_4	N_2O	CH_4	N_2O
Light passenger vehicle	JAMA etc. data	JAMA etc. data				
Passenger vehicle	JAMA etc. data	JAMA etc. data	JAMA etc. data	JAMA etc. data	JAMA data	The EF of small cargo truck is used considering the standard of vehicle type
Bus	2006GL	2006GL	Measured data	2006GL	JAMA data	Established by correcting the EF of regular cargo truck by the equivalent inertial weight ratio considering vehicle weight.
Light cargo truck	JAMA etc. data	JAMA etc. data				
Small cargo truck	JAMA etc. data	JAMA etc. data	JAMA etc. data	JAMA etc. data		Established based on the actual measured data (classified as cargo truck)
Regular cargo truck	2006GL	2006GL	JAMA etc. data	JAMA etc. data	JAMA data	
Special-purpose vehicle	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 truck and running pattern of special-purpose vehicle.	

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 vehicle are the same as those of gasoline passenger vehicle.

Table 3-42 CH_4 emission factors for road transportation

Fuel	Vehicle type	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Gasoline	Light passenger vehicle	mg-CH_4/km	8.3	8.3	8.2	6.9	5.0	4.2	4.0	3.8	3.6	3.5	3.4	3.3	3.3	3.3	3.3
	Passenger vehicle (non-hybrid)		14.5	14.5	14.3	11.3	8.0	6.6	6.3	6.0	5.7	5.5	5.3	5.1	5.0	4.9	4.8
	Passenger vehicle (hybrid)		NO	NO	NO	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.9	2.0	2.1	2.1	2.2
	Bus		14														
	Light cargo truck		18.7	18.7	18.0	11.7	7.2	5.8	5.5	5.2	4.9	4.7	4.5	4.3	4.2	4.0	3.9
	Small cargo truck		21.2	21.2	21.2	14.5	8.7	6.8	6.2	5.8	5.4	5.0	4.7	4.4	4.2	4.0	3.9
	Regular cargo truck		14														
	Special-purpose vehicle		14														
Diesel	Passenger vehicle		11.3	12.2	12.6	12.8	12.8	12.9	12.7	12.4	12.1	12.1	11.8	11.1	10.5	10.1	9.8
	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	17.0	17.0	17.0
	Small cargo truck		9.6	10.7	10.1	8.7	8.3	7.9	7.8	7.7	7.6	7.5	7.4	7.3	7.2	7.1	7.0
	Regular cargo truck		17.0	16.0	15.0	13.9	11.1	9.6	9.0	8.5	7.9	7.4	6.9	6.4	5.9	5.6	5.2
	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	13.0	13.0	13.0
LPG	Passenger vehicle		14.5	14.5	14.3	11.3	8.0	6.6	6.3	6.0	5.7	5.5	5.3	5.1	5.0	4.9	4.8
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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Gasoline	Light passenger vehicle	mg-N_2O/km	14.2	14.2	13.9	9.3	5.2	3.6	3.2	2.9	2.6	2.4	2.2	2.1	2.0	2.0	1.9
	Passenger vehicle (non-hybrid)		23.7	23.7	20.3	12.2	6.3	4.4	4.0	3.7	3.4	3.2	3.0	2.9	2.8	2.7	2.6
	Passenger vehicle (hybrid)		NO	NO	NO	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	1.0	1.1	1.1
	Bus		25														
	Light cargo truck		23.7	23.7	21.7	12.8	7.3	5.7	5.3	5.0	4.7	4.4	4.2	4.0	3.8	3.7	3.6
	Small cargo truck		21.1	21.6	21.8	13.1	7.8	6.1	5.6	5.2	4.9	4.6	4.3	4.1	3.9	3.7	3.6
	Regular cargo truck		25														
	Special-purpose vehicle		25														
Diesel	Passenger vehicle		5.7	4.7	4.4	4.4	4.9	5.4	5.3	5.1	4.9	4.8	4.7	4.5	4.3	4.2	4.1
	Bus		3.0														
	Small cargo truck		9.3	10.3	11.1	11.7	12.2	12.5	12.6	12.7	12.8	12.8	12.9	13.0	13.0	13.1	13.1
	Regular cargo truck		15.0	15.0	14.9	16.9	31.8	35.2	36.4	37.6	38.6	39.3	39.7	40.1	40.2	40.2	40.2
	Special-purpose vehicle		3.0														
LPG	Passenger vehicle		23.7	23.7	20.3	12.2	6.3	4.4	4.0	3.7	3.4	3.2	3.0	2.9	2.8	2.7	2.6
Natural gas	Passenger vehicle		0.2														
	Bus		38														
	Cargo truck		13														
	Special-purpose vehicle		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 vehicle (PV) from gasoline PV, the distance traveled by hybrid PV is estimated by multiplying the number of the vehicle 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 vehicle, 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 vehicle by each vehicle type reported in the *Statistics of AIRIA/ Number of Motor Vehicles*.

Table 3-44 Distance traveled of automobile

Fuel	Vehicle type	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Gasoline	Light passenger vehicle	Billion vehicle-km	16	41	72	106	137	150	157	161	170	176	180	181	163	159	165
	Passenger vehicle (non-hybrid)		273	304	343	349	319	303	282	273	267	260	255	244	209	193	204
	Passenger vehicle (hybrid)		NO	NO	NO	3	14	38	48	58	67	78	88	97	91	95	111
	Bus		0.09	0.03	0.02	0.04	0.31	0.19	0.19	0.21	0.21	0.21	0.22	0.23	0.17	0.19	0.20
	Light cargo truck		91	90	80	78	75	77	78	76	76	75	73	71	66	62	65
	Small cargo truck		29	20	20	21	22	23	23	23	21	21	21	21	20	18	20
	Regular cargo truck		0	0	0	1	1	1	1	1	1	1	1	1	1	1	1
	Special-purpose vehicle		1	1	1	1	3	3	2	2	2	2	3	3	2	3	3
Diesel	Passenger vehicle		40	63	55	29	10	8	8	9	9	11	12	14	13	14	16
	Bus		7	7	6	7	6	6	6	6	6	6	6	5	4	4	4
	Small cargo truck		44	49	45	33	23	23	22	22	20	20	19	19	18	18	19
	Regular cargo truck		58	68	72	69	63	59	59	59	59	60	60	60	56	58	59
	Special-purpose vehicle		9	14	17	17	21	21	21	21	21	21	21	21	19	20	21
LPG	Passenger vehicle		18	17	15	14	12	10	10	9	8	8	7	6	4	4	4
Natural gas	Passenger vehicle	Million vehicle-km	0.05	0.10	1.93	5.91	6.00	3.01	2.17	1.57	1.17	0.70	0.28	0.19	0.09	0.06	0.06
	Bus		NO	1.9	15	48	52	39	34	28	22	15	11	9	5	3	3
	Cargo truck		0.22	10	79	254	303	265	254	230	198	170	141	110	85	68	57
	Special-purpose vehicle		0.05	2.2	18	57	67	62	56	49	39	33	27	23	17	13	12

- ***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.

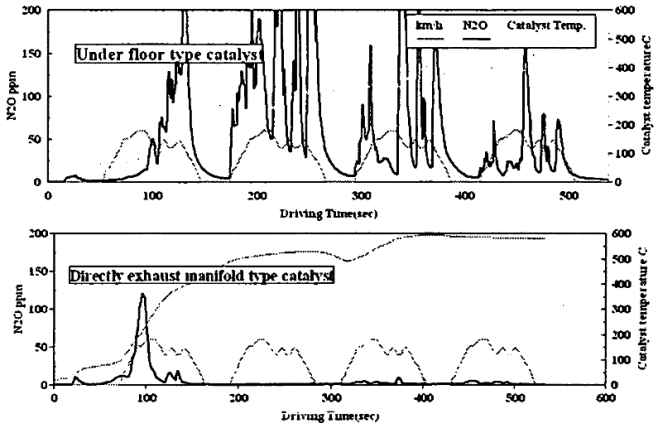

Figure 3-6 Difference of N_2O emissions by catalyst fitting position

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) Uncertainties and Time-series Consistency

- ***Uncertainties***

The emission factors of road transportation vehicle 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 sample error rate of the Motor Vehicle Fuel Consumption Survey shown at the Service Statistics and Business Statistics Section Meeting by Cabinet Office, Government of Japan 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 vehicle 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 vehicle 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***

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.

- ***Verification***

On the annual review in 2014 (FCCC/ARR/2014/JPN, paragraph 40), the ERT recommended to provide additional information on the annual number of vehicles by type, the annual mileage per vehicle and the fuel efficiency per vehicle type. The ERT also recommended to compare the annual mileage and fuel efficiency by vehicle category with the fuel consumption reported by the energy balance to ensure that no discrepancies occur.

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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Gasoline	Light passenger vehicle	1000 vehicles	2,715	5,966	10,084	14,350	18,004	20,230	21,026	21,477	21,761	22,051	22,325	22,528	22,736	22,850	23,071
	Passenger vehicle (non-hybrid)		29,140	33,891	37,794	40,104	37,594	35,023	33,793	32,685	31,733	30,688	29,525	28,413	27,469	26,416	25,334
	Passenger vehicle (hybrid)		NO	NO	NO	253	1,404	3,823	4,685	5,559	6,544	7,513	8,453	9,281	10,014	10,805	11,655
	Bus		8	3	2	5	9	13	14	15	16	16	17	18	18	19	19
	Light cargo truck		12,312	11,377	9,958	9,548	8,923	8,708	8,624	8,520	8,421	8,345	8,322	8,279	8,284	8,299	8,365
	Small cargo truck		2,820	2,144	1,901	1,988	1,826	1,772	1,760	1,750	1,750	1,747	1,742	1,725	1,709	1,692	1,666
	Regular cargo truck		41	38	39	90	128	140	146	150	153	155	157	160	162	163	164
	Special-purpose vehicle		141	198	393	330	287	291	293	297	299	302	304	309	313	317	322
Diesel	Passenger vehicle		2,994	4,924	4,254	2,126	905	730	761	855	953	1,063	1,197	1,318	1,437	1,528	1,609
	Bus		238	240	233	225	216	212	212	214	215	215	214	211	202	196	191
	Small cargo truck		3,711	4,002	3,480	2,545	1,954	1,824	1,801	1,780	1,767	1,755	1,749	1,746	1,748	1,749	1,759
	Regular cargo truck		2,164	2,544	2,534	2,350	2,105	2,100	2,116	2,130	2,151	2,169	2,197	2,223	2,243	2,258	2,266
	Special-purpose vehicle		628	804	994	903	820	818	822	829	840	850	856	862	869	873	877
LPG	All types		318	303	286	295	257	232	224	216	207	194	178	161	145	133	124
Natural gas	Passenger vehicle		0.01	0.01	0.2	0.6	0.7	0.3	0.2	0.2	0.1	0.1	0.03	0.02	0.01	0.01	0.01
	Bus		NO	0.04	0.3	1.1	1.2	0.9	0.8	0.7	0.6	0.4	0.3	0.2	0.2	0.1	0.1
	Cargo truck		0.01	0.5	3.9	12.8	15.0	12.9	12.1	11.0	9.5	8.2	7.0	5.7	4.9	3.9	3.5
	Special-purpose vehicle		0.004	0.2	1.5	4.8	5.6	4.9	4.4	3.9	3.3	2.8	2.3	1.9	1.5	1.3	1.1

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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Gasoline	Light passenger vehicle	1000 km /vehicle	5.8	6.8	7.2	7.4	7.6	7.4	7.5	7.5	7.8	8.0	8.1	8.0	7.1	7.0	7.2
	Passenger vehicle (non-hybrid)		9.4	9.0	9.1	8.7	8.5	8.6	8.3	8.3	8.4	8.5	8.6	8.6	7.6	7.3	8.1
	Passenger vehicle (hybrid)[1)]		NO	NO	NO	10.1	10.2	10.0	10.3	10.5	10.3	10.4	10.5	10.5	9.0	8.8	9.5
	Bus		11.9	9.3	9.0	8.6	34.7	14.9	14.2	14.5	13.6	12.9	12.7	12.5	9.3	10.1	11.0
	Light cargo truck		7.4	7.9	8.0	8.2	8.4	8.9	9.0	8.9	9.1	9.0	8.8	8.6	8.0	7.5	7.7
	Small cargo truck		10.3	9.5	10.3	10.5	12.2	13.1	13.2	13.1	12.3	12.2	12.3	12.3	11.7	10.9	12.3
	Regular cargo truck		8.8	7.7	6.9	6.7	11.0	9.9	9.2	9.4	9.0	8.7	8.7	8.7	7.4	7.5	7.0
	Special-purpose vehicle		4.7	3.5	3.3	3.9	9.9	8.9	8.4	8.3	8.1	8.2	8.3	8.2	7.4	8.0	8.0
Diesel	Passenger vehicle		13.3	12.8	13.0	13.7	11.4	11.1	10.4	10.1	9.7	10.0	10.2	10.5	9.2	9.3	9.7
	Bus		28.9	27.6	27.9	28.9	28.6	28.2	27.9	27.4	26.5	26.0	25.8	25.3	18.7	18.7	22.3
	Small cargo truck		11.8	12.2	12.9	12.9	11.8	12.4	12.3	12.1	11.5	11.3	11.1	11.1	10.2	10.1	10.8
	Regular cargo truck		26.7	26.8	28.6	29.5	29.9	28.1	27.9	27.9	27.5	27.4	27.2	26.8	24.9	25.9	25.9
	Special-purpose vehicle		14.6	16.9	17.2	18.9	25.3	25.9	25.9	25.9	25.2	24.8	24.6	24.2	22.4	23.3	23.9
LPG	All types		56.6	55.5	52.7	46.4	47.3	44.3	43.8	42.8	40.9	41.6	41.5	40.4	26.1	27.9	34.5
Natural gas	Passenger vehicle		10.2	9.8	9.8	9.2	8.9	9.0	8.8	8.9	8.9	9.0	9.2	9.2	8.1	7.8	8.6
	Bus		NO	47.6	45.9	44.9	43.3	41.9	41.3	39.9	38.3	37.2	36.7	36.1	26.8	26.0	31.2
	Cargo truck		18.7	18.9	20.2	19.9	20.2	20.6	21.0	20.9	20.9	20.6	20.1	19.1	17.5	17.2	16.5
	Special-purpose vehicle		11.1	11.2	12.0	11.8	12.0	12.7	12.7	12.6	11.8	11.7	11.6	11.6	10.8	10.3	11.3

Note: Estimated by dividing the distance traveled on Table 3-44 by number of vehicle 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Gasoline	Light passenger vehicle	km/L	14.2	12.9	12.0	12.6	12.6	13.3	13.5	13.7	14.0	14.1	14.4	14.8	15.1	15.0	15.1
	Passenger vehicle (non-hybrid)[1)]	km/L	10.0	9.2	9.0	9.8	9.8	10.0	10.1	10.2	10.3	10.4	10.5	10.5	10.6	10.6	10.8
	Passenger vehicle (hybrid)	km/L	NO	NO	NO	IE	16.3	15.7	15.5	16.0	16.2	16.5	16.9	16.9	17.1	16.8	16.8
	Bus[2)]	km/L	4.1	3.9	4.1	4.3	5.8	6.5	6.7	6.8	7.1	7.3	7.6	7.7	7.7	7.5	7.8
	Light cargo truck	km/L	12.3	11.4	11.1	11.7	12.1	12.0	12.0	12.1	12.3	12.4	12.6	12.8	13.0	12.9	13.2
	Small cargo truck[3)]	km/L	8.2	7.7	8.2	8.5	9.3	9.1	9.0	9.0	9.2	9.3	9.4	9.7	9.9	9.8	9.9
	Regular cargo truck	km/L	4.4	4.2	4.4	4.6	IE	IE	IE	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	IE	IE	IE
Diesel	Passenger vehicle	km/L	9.7	7.8	7.0	6.9	9.0	9.0	9.2	9.3	9.6	10.0	10.5	10.9	12.3	12.7	12.7
	Bus	km/L	3.6	3.4	3.4	3.6	3.6	3.5	3.5	3.6	3.5	3.6	3.6	3.6	3.4	3.4	3.4
	Small cargo truck	km/L	9.7	10.0	9.7	10.1	9.1	8.7	8.6	8.6	8.6	8.7	8.7	8.7	8.6	8.6	8.8
	Regular cargo truck	km/L	3.3	3.2	3.4	3.7	3.7	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.8	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	4.0	4.0	4.0	4.0	4.0
LPG	All types	km/L	6.0	5.6	5.3	5.4	5.4	5.3	5.4	5.4	5.5	5.5	5.6	5.6	5.8	5.9	6.4
Natural gas	All types[4)]	km/m^3	4.1	4.1	4.1	4.1	4.1	4.2	4.2	4.2	4.2	4.1	4.1	4.0	4.0	3.9	3.9

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 vehicle is included until FY2009.
2) Passenger car for business-noncargo-use and special-purpose car for private-noncargo-use are included since FY2010.
3) Regular cargo truck and special-purpose car 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, MOE, Bureau of Environment of Tokyo Metropolitan Government, and National Institute for Environmental Studies. Therefore, the emission factors were revised for gasoline hybrid passenger vehicles since FY2003, gasoline and LPG passenger vehicles since FY2005, and gasoline light passenger vehicles and diesel passenger vehicles since FY2018. In response to these revisions, the CH_4 and N_2O emissions for the period of FY2003-FY2021 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[18] 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 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)	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)	2.4	0.47	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)

➢ *"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.

[18] The regulated gases are CO, hydrocarbons (HC) and NOx.

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

Vehicle type (displacement)	3rd 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)	32.3	5.6	15.8	11.2	33	15
Motor-driven cycles class 2 (51cc-125cc)	30.0	17.3	18.3	4.2		
Mini-sized motorcycles (126cc-250cc)	51.3	14.7	30.2	13.7		
Small-sized motorcycles (Over 250cc)	78.0	21.3	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 vehicle 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 vehicle 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 vehicle of each year by each past year is obtained, and the number of owned vehicle 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 vehicle 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 (Displacement)	Emission control by regulation	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Distance traveled	Motor-driven cycles class 1 (50cc and under)	3rd regulation	Million vehicle-km	NO	NO	NO	NO	NO	NO	NO	NO	NO	522	856	955	1,108	1,309	1,443
		1st & 2nd regulation		NO	NO	1,773	4,165	3,643	3,325	3,248	2,829	2,646	1,905	1,434	933	693	531	382
		Uncontrolled		10,623	6,268	3,153	753	112	29	18	10	6	3	2	1	0	0	0
	Motor-driven cycles class 2 (51cc-125cc)	3rd regulation		NO	NO	NO	NO	NO	NO	NO	NO	NO	531	1,091	1,250	1,577	1,881	2,112
		1st & 2nd regulation		NO	NO	243	1,237	2,192	2,877	2,992	2,909	2,993	2,427	1,970	1,257	1,008	755	591
		Uncontrolled		2,060	1,853	1,568	686	172	61	39	23	14	8	5	2	1	1	0
	Mini-sized motorcycles (126cc-250cc)	3rd regulation		NO	NO	NO	NO	NO	NO	NO	NO	NO	478	926	1,206	1,674	2,003	2,315
		1st & 2nd regulation		NO	NO	565	2,664	3,127	3,141	3,208	3,268	3,277	2,494	2,131	1,617	1,352	1,052	857
		Uncontrolled		6,111	3,577	2,209	1,055	330	147	109	79	56	35	23	14	9	5	3
	Small-sized motorcycles (over 250cc)	3rd regulation		NO	NO	NO	NO	NO	NO	NO	NO	NO	474	920	1,235	1,634	1,991	2,498
		1st & 2nd regulation		NO	NO	317	1,662	2,751	2,883	3,037	3,471	3,568	2,896	2,552	2,017	1,761	1,418	1,184
		Uncontrolled		3,568	3,083	2,505	1,292	559	271	212	179	136	93	69	44	31	20	13
Number of startup	Motor-driven cycles class 1 (50cc and under)	3rd regulation	Million	NO	NO	NO	NO	NO	NO	NO	NO	NO	110	180	222	257	283	317
		1st & 2nd regulation		NO	NO	349	739	626	577	564	550	513	400	301	217	161	115	84
		Uncontrolled		1,838	1,131	621	134	19	5	3	2	1	1	0	0	0	0	0
	Motor-driven cycles class 2 (51cc-125cc)	3rd regulation		NO	NO	NO	NO	NO	NO	NO	NO	NO	58	119	164	207	229	401
		1st & 2nd regulation		NO	NO	31	140	228	274	285	325	334	264	214	165	132	92	112
		Uncontrolled		285	255	203	78	18	6	4	3	2	1	0	0	0	0	0
	Mini-sized motorcycles (126cc-250cc)	3rd regulation		NO	NO	NO	NO	NO	NO	NO	NO	NO	28	54	77	107	117	204
		1st & 2nd regulation		NO	NO	41	177	193	179	183	204	204	146	124	104	86	62	75
		Uncontrolled		361	223	159	70	20	8	6	5	4	2	1	1	1	0	0
	Small-sized motorcycles (over 250cc)	3rd regulation		NO	NO	NO	NO	NO	NO	NO	NO	NO	10	20	38	50	63	123
		1st & 2nd regulation		NO	NO	19	78	111	95	87	111	114	62	55	62	54	45	58
		Uncontrolled		187	177	154	60	23	9	6	6	4	2	1	1	1	1	1

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

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 vehicle, 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

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

The number of motor-driven cycles owned for FY2021 were obtained. Actual values of emission factors for Motor-driven cycles class 2 which comply with the 3rd 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Diesel oil	1000 kL	356	313	270	248	218	205	199	198	189	197	186	186	178	171	171
Coal	kt	1.3	1.2	1.7	1.4	1.7	1.5	1.5	1.5	1.6	1.5	1.4	1.5	0.6	0.6	0.6

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

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

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

The emissions for FY2021 were recalculated due to a revision of the energy consumption of 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, Table 3.5.3, IMO (2009) page 28, IMO (2014) page 288

- ***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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Diesel oil	1000 kL	133	208	204	195	154	142	157	148	147	155	149	150	109	109	109
Fuel oil A	1000 kL	1,602	1,625	1,728	1,324	1,007	994	984	980	1,013	1,010	993	1,020	1,039	1,209	1,314
Fuel oil B	1000 kL	526	215	152	63	18	14	12	9	7	7	5	3	0	0	0
Fuel oil C	1000 kL	2,446	3,002	3,055	2,873	2,482	2,487	2,482	2,386	2,392	2,347	2,361	2,300	2,175	2,132	2,077

- ***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) Uncertainties and Time-series Consistency

- ***Uncertainties***

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

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

Because it is judged that the use of emission factors, obtained by multiplying the correction factors derived from IMO (2014), etc. by the default values, better reflect the emissions from domestic navigation in Japan than the use of the default values in the *2006 IPCC Guidelines*, the emission factors are revised, and the emissions were recalculated for whole time-series. The emissions for FY2020-FY2021 were recalculated due to a revision of the energy consumption of the *General Energy Statistics*. See Chapter 10 for impact on trend.

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 FY2022, CO_2 emissions from this category accounted for 127,646 kt-CO_2, and represented 11.2% of Japan's total GHG emissions (excluding LULUCF). The commercial/institutional (1.A.4.a) accounts for 51.1%, and is the largest subcategory within the "Other sectors" category in FY2022.

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).

The energy consumption and emissions from waste incineration with energy recovery are reported in fuel combustion (1.A.) as "other fossil fuels" and "biomass" in accordance with the *2006 IPCC Guidelines*.

The estimation method, emission factors and activity data for emissions from waste incineration with energy recovery are the same as those used in the waste incineration (5.C.1) in accordance with the *2006 IPCC Guidelines*. Please refer to Chapter 7 for further details on the estimation methods.

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 commercial industry (#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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Liquid fuels	1,921	2,080	2,190	2,222	1,572	1,441	1,347	1,291	1,279	1,286	1,213	1,181	1,242	1,125	1,036
Solid fuels	3	2	1	1	19	15	12	12	29	21	81	71	70	70	68
Gaseous fuels	418	537	649	731	835	836	832	846	850	909	870	893	815	860	840
Other fossil fuels	196	219	257	278	243	248	246	239	274	278	260	268	258	250	248
Biomass	15	18	22	44	59	65	73	84	64	68	72	67	54	68	54
Total	2,553	2,856	3,118	3,277	2,729	2,606	2,510	2,472	2,495	2,562	2,495	2,479	2,439	2,373	2,245

Table 3-56 Correspondence between sectors of Japan's Energy Balance Table 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 (except for Production, transmission and distribution of electricity [#255330] (until 2015), Agriculture, fishery, mining and construction [#251000] and Manufacturing [#252000])	#250000
			Auto steam generation (except for Agriculture, fishery, mining and construction [#261000] and Manufacturing [#262000])	#260000
			Final energy consumption; Commercial industry	#650000
			Non-energy and feedstock use; Commercial	#951800
	1.A.4.b Residential		Final energy consumption; Residential	#700000
			Non-energy and feedstock use; Household	#952000
	1.A.4.c Agriculture/forestry/fishing			
		i Stationary	Auto power generation; Agriculture, fishery, mining and construction	#251000
			Auto steam generation; Agriculture, fishery, mining and construction	#261000
			Final energy consumption; Agriculture, forestry and fishery [#610000]; stationary sources	
			Non-energy and feedstock use; Agriculture, fishery, mining and construction	#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) Uncertainties 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

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 and the emission factors based on the update of the *General Energy Statistics*, the emissions for the period of FY2006-FY2021 were 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 FY2005-FY2021 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 3-23 and Table 3-24 (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 values on Table 3.5.3 "Default water-borne navigation CH_4 and N_2O emission factors" in the *2006 IPCC Guidelines* vol. 2, page3.50.

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) Uncertainties 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

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

Since the FY2020 survey results of *General Survey of the Emissions of Air Pollutants* were adopted, the CH_4 and N_2O emissions in FY2018-2021 were recalculated. Since the activity data for FY2006-2021 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 FY2021 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 these sources is applied for waste incineration (5.C.1.) 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 Waste types whose emissions are estimated for "Waste Incineration and Energy Use (Reported in the Energy Sector) (1.A.)"

Category	Waste type			Fuel type to be allocated to CRT	Treatment type		CO_2	CH_4	N_2O
1.A.4. (7.4.3.1)[7]	Municipal solid waste (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]		
		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	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]		
	Industrial waste (IW)	Waste oil	Fossil-fuel derived oil	Other fossil fuels		Incinerator	○	○	○
			Animal and vegetable oil	Biomass			NA[1]	○	○
		Plastics	Fossil-fuel derived plastics	Other fossil fuels			○	○	○
			Biomass-based plastics	Biomass[8]			NA[1]	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]	○	○
		Textile	Synthetic textile	-			IE[5]	IE[5]	IE[5]
			Natural fiber	Biomass			NA[1]	○	○
		Sludge	Sewage sludge	-			NO	NO	NO
			Other than sewage sludge	Biomass			NA[1]	○	○
	Specially controlled industrial waste			-			IE[5]	IE[5]	IE[5]
1.A.1, 1.A.2 and 1.A.4 (7.4.3.2)[7]	Municipal solid waste	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		-			NO	NO	NO
	Industrial waste	Waste oil	Fossil-fuel derived oil	Other fossil fuels			○	○	○
			Animal and vegetable oil	Biomass			NA[1]	○	○
		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 and 1.A.2 (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 CRT.
2) CH_4 and N_2O emissions from incineration of municipal solid waste 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 "Specially controlled industrial waste" incineration without energy recovery
6) Included in the fossil-fuel derived fraction
7) For details of categories to be reported in the CRT, see descriptions on each section.
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 are 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 3-61 Reporting categories in the energy sector whose emissions are estimated for waste incineration and energy use

Treatment type	Waste type		Application breakdown	Major application	Reporting category on 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	Alternative fuel or raw material in coke oven	1.A.1.c. Manufacture of solid fuels	○	IE[4)]	NO[5)]
			Gasification	Fuel	1.A.2.g. Other	○	NE[6)]	NE[6)]
	Industrial waste	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	Alternative fuel or 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	Refuse-derived fuel (RDF)		(Unclassified)	Fuel use (including power generation)	1.A.2.g. Other [1)]	○	○	○
	Refuse paper and plastic fuel (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.1.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 detail, see Table 3-60.
3) Blast furnace gas generated from steel industry is entirely recovered.
4) These emissions are included in “solid fuels” in the same category 1.A.1.c.
5) N_2O is likely not produced since the atmosphere in coke oven is normally at least 1,000 degree 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 3-62 shows the greenhouse gas emissions from waste incineration and energy use (reported on energy sector) (1.A.).

Table 3-62 GHG emissions from waste incineration and energy use (reported in the energy sector) (1.A.)

Category		Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
1.A.1. Energy industries	a. Public electricity and heat production	kt-CO_2	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	b. Petroleum refining	kt-CO_2	NO	NO	0.6	6.4	5.8	4.5	5.0	6.1	4.5	5.0	0.3	0.1	0.6	NO	NO
	c. Manufacture of solid fuels and other energy industries	kt-CO_2	NO	NO	15	246	247	NO	24	41	35	45	24	34	33	34	32
1.A.2. Manufacturing industries and construction	a. Iron and steel	kt-CO_2	NO	NO	312	639	549	474	580	562	590	626	532	570	412	486	547
	b. Non-ferrous metals	kt-CO_2	119	63	51	17	2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	c. Chemicals	kt-CO_2	14	64	89	67	73	82	65	68	63	65	63	48	29	20	6
	d. Pulp, paper and print	kt-CO_2	NO	56	114	998	1,804	1,930	1,986	2,044	2,089	2,150	2,181	2,073	2,055	2,157	2,114
	e. Food processing, beverages and tobacco	kt-CO_2	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	f. Non-metallic minerals	kt-CO_2	197	492	879	1,088	1,324	1,453	1,636	1,590	1,711	1,780	1,965	2,050	2,047	2,112	2,154
	g. Other	kt-CO_2	3,878	4,474	4,462	5,874	5,624	5,608	5,357	5,742	5,399	5,434	5,827	5,995	5,679	5,780	5,437
1.A.4	a. Commercial/institutional	kt-CO_2	6,505	7,146	9,043	8,406	6,799	7,552	7,172	7,258	8,174	8,546	7,908	8,616	8,542	8,530	8,424
Total		kt-CO_2	10,712	12,294	14,966	17,341	16,427	17,104	16,826	17,312	18,066	18,651	18,502	19,387	18,797	19,117	18,714
1.A.1. Energy industries	a. Public electricity and heat production	kt-CH_4	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	b. Petroleum refining	kt-CH_4	NO	NO	1.7.E-06	1.8.E-05	1.6.E-05	1.3.E-05	1.4.E-05	1.7.E-05	1.2.E-05	1.4.E-05	8.6.E-07	3.2.E-07	1.6.E-06	NO	NO
	c. Manufacture of solid fuels and other energy industries	kt-CH_4	NO	NO	IE	IE	IE	NO	IE	IE	IE	IE	IE	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	1.4.E-03	1.4.E-03	1.6.E-03	1.7.E-03	1.6.E-03	2.8.E-04	2.8.E-05	5.7.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	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	1.8.E-04	1.9.E-04	1.7.E-04	1.7.E-04	1.6.E-04	1.2.E-04	6.4.E-05	3.9.E-05	1.7.E-05
	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	5.4.E-03	5.6.E-03	5.7.E-03	5.9.E-03	6.0.E-03	5.7.E-03	5.7.E-03	6.0.E-03	5.9.E-03
	e. Food processing, beverages and tobacco	kt-CH_4	IE	IE	IE	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	0.26	0.25	0.27	0.28	0.31	0.32	0.32	0.33	0.34
	g. Other	kt-CH_4	1.8	1.8	2.2	2.9	4.2	4.8	5.3	5.0	4.9	5.2	5.1	5.5	5.4	5.4	5.4
1.A.4	a. Commercial/institutional	kt-CH_4	0.54	0.54	0.60	0.15	0.14	0.15	0.15	0.14	0.15	0.15	0.14	0.14	0.14	0.13	0.13
Total		kt-CH_4	2.3	2.4	3.0	3.3	4.6	5.2	5.7	5.4	5.4	5.7	5.5	6.0	5.9	5.9	5.8
		kt-CO_2 eq.	66	67	83	91	128	145	159	151	150	158	155	167	164	164	163
1.A.1. Energy industries	a. Public electricity and heat production	kt-N_2O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	b. Petroleum refining	kt-N_2O	NO	NO	1.1.E-05	1.2.E-04	1.0.E-04	8.1.E-05	9.0.E-05	1.1.E-04	8.0.E-05	9.1.E-05	5.6.E-06	2.1.E-06	1.0.E-05	NO	NO
	c. Manufacture of solid fuels and other energy industries	kt-N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
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	1.7.E-03	1.6.E-03	1.7.E-03	1.9.E-03	2.0.E-03	1.9.E-03	3.4.E-04	3.4.E-05	6.7.E-05
	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	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	1.7.E-03	1.9.E-03	1.5.E-03	5.8.E-03	6.5.E-03	6.8.E-03	8.2.E-03	7.8.E-03	2.7.E-04
	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	6.2.E-02	6.1.E-02	6.4.E-02	6.7.E-02	6.8.E-02	6.5.E-02	6.3.E-02	6.8.E-02	6.7.E-02
	e. Food processing, beverages and tobacco	kt-N_2O	IE	IE	IE	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	2.3.E-02	2.2.E-02	2.4.E-02	2.5.E-02	2.7.E-02	2.8.E-02	2.8.E-02	2.9.E-02	3.0.E-02
	g. Other	kt-N_2O	5.8.E-02	5.1.E-02	5.3.E-02	6.1.E-02	6.8.E-02	7.4.E-02	7.9.E-02	7.7.E-02	7.5.E-02	7.8.E-02	7.8.E-02	8.3.E-02	8.0.E-02	8.1.E-02	7.9.E-02
1.A.4	a. Commercial/institutional	kt-N_2O	1.2	1.3	1.6	1.1	0.9	1.0	1.0	0.9	1.0	1.0	1.0	1.0	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	1.2	1.2	1.1	1.2	1.1	1.1	1.1
		kt-CO_2 eq.	337	370	434	331	291	297	298	284	318	323	303	309	297	289	282

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 FY2022, GHG emissions from fugitive emissions from fuels were 1,166 kt-CO_2 eq. and accounted for 0.1% of Japan's total GHG emissions (excluding LULUCF). The emissions have decreased by 80.5% 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 have comprised less than 5% of domestic supply since FY1990.

Table 3-63 Emission trends of the fugitive emissions subsector (1.B)

Gas	Category		Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
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	0.5	0.5	0.5	0.5	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	2.2	2.5	2.6	2.8	3.0	2.8	3.0	0.0
		c. Other (Uncontrolled Combustion and Burning Coal Dump)		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	1.B.2 Oil and Natural Gas	a. Oil		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
		b. Natural Gas		0.7	0.8	0.9	1.2	1.3	1.2	1.1	1.1	1.1	1.2	1.1	1.0	0.9	0.9	0.9
		c. Venting and Flaring		91.7	112.9	136.5	186.7	245.1	242.6	228.4	241.8	264.6	284.8	260.8	237.4	212.3	177.4	155.1
		d. Other (Geothermal Generation)		104.4	409.2	386.6	341.9	251.2	215.2	237.9	200.1	210.5	170.0	181.7	162.6	191.9	191.9	191.9
	Total		kt-CO_2	203	526	527	532	500	462	470	446	479	459	447	404	408	374	348
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	21.7	20.9	20.7	21.2	19.1	18.3	18.0	18.1	17.5
		b. Fuel Transformation		3.4	3.3	2.7	1.8	1.4	1.2	1.1	1.0	1.0	0.9	0.9	0.9	0.8	0.7	0.7
		c. Other (Uncontrolled Combustion and Burning Coal Dump)		NO	NO	NO	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	0.6	0.6	0.6	0.6	0.6	0.5	0.5	0.5
		b. Natural Gas		7.7	8.6	9.8	12.0	12.7	11.2	10.5	10.6	11.3	11.4	10.7	9.9	9.0	9.1	8.5
		c. Venting and Flaring		2.1	2.6	2.3	2.6	2.6	2.3	2.1	2.1	2.1	2.1	1.9	1.9	1.9	1.8	1.6
		d. Other (Geothermal Generation)		0.2	0.8	0.7	0.7	0.5	0.4	0.5	0.4	0.4	0.3	0.4	0.3	0.4	0.4	0.4
	Total		kt-CH_4	206.6	113.7	79.6	44.3	40.5	37.1	36.5	35.6	36.0	36.6	33.5	31.9	30.5	30.6	29.2
			kt-CO_2 eq.	5,784	3,183	2,229	1,240	1,133	1,040	1,023	997	1,009	1,025	938	893	854	855	817
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	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	2.E-03	2.E-03	2.E-03	2.E-03	2.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	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	NA,IE	NA,IE	NO,IE	NO,IE	NO,IE	NO,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	5.E-04	5.E-04	5.E-04	5.E-04	5.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	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	3.E-03	2.E-03	2.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	0.73	0.68	0.64	0.63	0.59	0.57	0.54	0.48	0.46
	Total of all gases		kt-CO_2 eq.	5,988	3,712	2,758	1,774	1,634	1,502	1,494	1,443	1,489	1,485	1,386	1,298	1,263	1,230	1,166
(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	43.6	40.6	37.3	36.3	34.1	33.5	31.0	26.9	26.8

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 3-64 Emission factors for mining activities: underground mines

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	Remarks
Coal production of underground mines (A)	kt	9,471	8,118	4,016	1,635	1,225	1,103	1,124	980	1,102	1,275	660	459	565	799	616	Survey by J-COAL
CH_4 total emissions (B)	10^6m^3	262	92	57	4.2	2.0	1.9	2.3	2.4	2.4	2.9	1.5	1.3	1.2	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	1.5	1.6	1.6	1.9	1.0	0.9	0.8	0.9	0.9	=(B)*0.67
Emission factor	kg-CH_4/t	19	8	9	1.7	1.1	1.1	1.4	1.6	1.4	1.5	1.5	1.9	1.4	1.1	1.4	=(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 3-65 Trends in coal production

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Total coal production	kt	10,676	8,814	4,625	2,146	1,782	1,824	1,903	1,774	1,855	1,991	1,307	1,014	1,042	1,192	1,035
Surface mines		1,205	695	610	511	557	721	778	795	753	716	647	555	477	393	419
Underground mines		9,471	8,118	4,016	1,635	1,225	1,103	1,124	980	1,102	1,275	660	459	565	799	616

- ***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 3-66 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 3-67 Trends in CH_4 recovery from mining activities

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Recovery	1000 m^3	50,139	11,112	9,810	2,044	941	826	448	844	955	482	301	293	303	303	303

- ***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) Uncertainties and Time-series Consistency

- ***Uncertainties***

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

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.

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

Due to the revision of coal production, post-mining emissions for FY2021 were recalculated. See Chapter 10 for impact on trend.

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 3-65).

c) Uncertainties and Time-series Consistency

● ***Uncertainties***

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

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

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 3-68 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 3-69 Production Amount of Charcoal

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Charcoal Production	kt	83.2	82.3	67.4	44.9	34.1	29.6	27.7	25.9	23.7	23.1	21.7	21.3	19.8	17.2	17.1

- ***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 : Unrepored 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 the all 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 3-19).

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 3-70 Flaring Amount of Coke Oven Gas not Reported to the *Current Survey of Energy Consumption*

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Unreported flaring amount of COG	TJ	11.6	25.5	38.8	38.5	41.2	52.9	54.3	55.9	61.6	65.3	69.4	74.1	70.6	75.6	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) Uncertainties and Time-series Consistency

- ***Uncertainties***

- ***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)) 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

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

Since the charcoal production amount for FY2021 in *Basic Data for Special Forest Product* were revised, the CH_4 and N_2O emissions in that year 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. 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 "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 "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. 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 3-71 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[19]) 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 *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral*

[19] Light, liquid hydrocarbon that is produced from natural gas wells associated with natural gas production

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 3-72 Amount of oil production excluding condensate from offshore and onshore oil fields

Item		Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Oil production excluding condensate	Offshore	1000 kL	175	391	167	76	78	70	82	76	67	70	59	104	89	84	84
	Onshore	1000 kL	245	232	218	295	215	195	180	164	152	141	136	142	165	138	98

- ***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 "Production and Gathering (1.B.2.b.ii)" and "Processing (1.B.2.b.iii)", because emission factors of these categories include emission from condensate production.

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

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

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

Since emission factors were changed from the default values of the *2006 IPCC Guidelines* to the default values of the *2019 Refinement*, CO_2, CH_4 and N_2O emissions were recalculated for all years. Since the activity data for FY2021 in the *Natural Gas Data Yearbook* were revised, the CO_2, CH_4 and N_2O 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. 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[20].

- ***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 3-73 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 3-74 Production of crude oil and condensate in Japan

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Oil production excluding condensate	1000 kL	420	623	386	370	293	265	262	240	219	210	195	247	254	222	182
Condensate production		234	243	375	541	560	403	365	339	331	336	301	278	259	252	229
Oil production (total)		655	866	761	911	853	668	626	578	549	546	496	524	513	473	410

[20] As the default values of tanker trucks and rail cars are higher than those of pipelines, this assumption does not lead to underestimation.

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

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

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

There have been no recalculations of emissions from this category.

f) Category-specific Planned Improvements

No improvements are planned.

3.3.2.1.d. 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 3-75 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 3-76 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 3-77 Amount of crude oil and NGL refined in Japan

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Oil and NGL refined	10^6m^3	204	241	242	241	209	200	189	188	191	184	177	174	139	147	156

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

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***

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.

- ***Verification***

In 2022, the ERT recommended that Japan explain the rationale for its selection of the lowest value of the default emission factors (EFs) shown in the *2006 IPCC Guidelines* for fugitive emissions during the refining process. The rationale including history is 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 3-78 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

The notation key for N_2O was changed from "NA" to "IE" for all years.

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[21] 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.

[21] 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).

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.

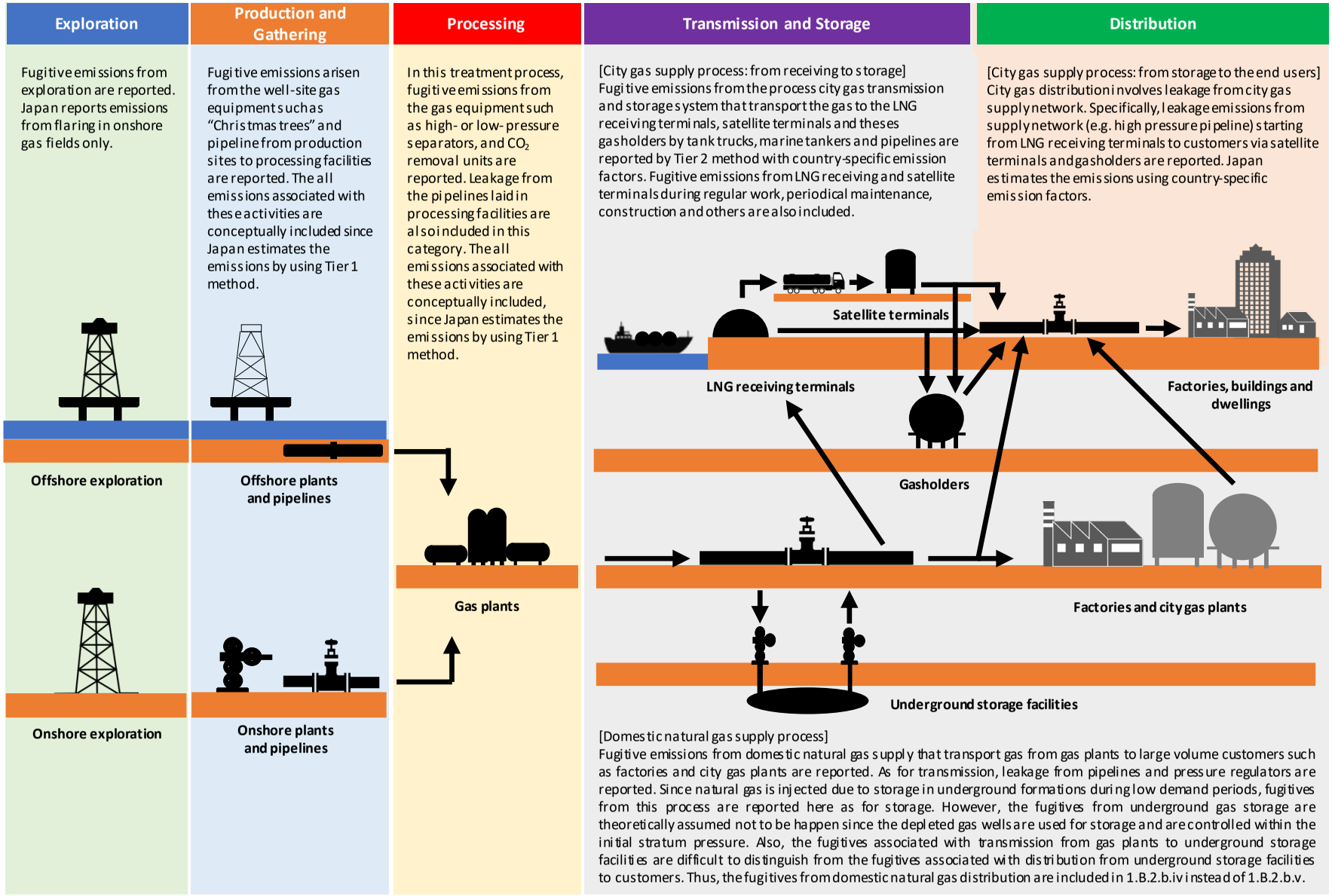

Figure 3-7 Supply network and inventory categorization of natural gas

3.3.2.2.a. 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 "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 3-79 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.

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

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

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

The emissions of CO_2, CH_4, and N_2O were recalculated for all years by changing the emission factors from the default values in the *2006 IPCC Guidelines* to the default values in the *2019 Refinement*, and by changing the activity data to the number of onshore explorative wells.

f) Category-specific Planned Improvements

No improvements are planned.

3.3.2.2.b. 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.

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 "3.3.2.3.b. Venting (Gas) (1.B.2.c.i.2.)" for CO_2 emissions from venting associated with natural gas production and "3.3.2.2.d. (Natural gas) Transmission and Storage (1.B.2.b.iv.)" for CH_4 emissions from venting associated with natural gas production, respectively. 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 3-80 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%)	0.07 (3.60*2%)	0
	Flare [2)]		0	3.31 (3.60*92%)	6.1×10^{-5} (100%)
Gathering [1)] (onshore)	Leaks		3.20	0.35	
	Flare [2)]				6.0×10^{-6}
Offshore	Leaks		0.68 (2.94*23%)	0	0
	Flare [2)]		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 flaring are reported in "Flaring (Gas) (1.B.2.c.ii.2)" of the CRT.

- ***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 3-81 Natural gas production

Item		Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Natural gas production	Offshore	10^6m^3	342	374	350	361	188	196	197	190	176	148	113	120	87	83	83
	Onshore		1,724	1,863	2,149	2,779	3,155	2,744	2,549	2,525	2,621	2,777	2,544	2,347	2,202	2,179	2,026
	Total		2,066	2,237	2,499	3,140	3,343	2,940	2,746	2,715	2,797	2,926	2,657	2,467	2,290	2,262	2,108

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

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

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

The CO_2, CH_4, and N_2O emissions were recalculated for all years due to the change in emission factors from the default values of the *2006 IPCC Guidelines* to the default values of the *2019 Refinement*.

Since the activity data for FY2021 in the *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. 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 3-82 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 3-81).

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

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

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

The CO_2, CH_4, and N_2O emissions were recalculated for all years due to the change in emission factors from the default values of the *2006 IPCC Guidelines* to the default values of the *2019 Refinement*. See

Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

3.3.2.2.d. 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 3-83 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 3-83 The method of estimating emission factors of natural gas transmission

<table>
<tr><th>Fiscal year</th><th>Relocation and building work of pipeline</th><th>Release of gas used to operate pressure regulators</th></tr>
<tr><td>1990 - 2003</td><td colspan="2">The same value as FY2004 is consistently used.</td></tr>
<tr><td>2004</td><td colspan="2">Estimated by dividing the actual CH_4 emissions in FY2004 by the sales volume of natural gas in the same fiscal year.</td></tr>
<tr><td>2005 - 2007</td><td>Estimated by interpolating the emission factor in FY2004 and that in FY2008 which is estimated by the same method as FY2004.</td><td rowspan="2">Estimated by interpolating the emission factor in FY2004 and that in FY2011 which is estimated by the same method as FY2004.</td></tr>
<tr><td>2008 - 2010</td><td>Estimated by dividing the actual CH_4 emissions in each fiscal year by the sales volume of natural gas in the same fiscal year.</td></tr>
<tr><td>2011 -</td><td colspan="2">Estimated by dividing the actual CH_4 emissions in each fiscal year by the sales volume of natural gas in the same fiscal year.</td></tr>
</table>

As a result of the above estimation, the emission factors in each fiscal year are estimated as shown on the Table 3-84.

Table 3-84 Estimation result of emission factors of natural gas transmission

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Pipeline relocation & installation	$t\text{-}CH_4/10^6m^3$	0.220	0.220	0.220	0.190	0.071	0.062	0.070	0.115	0.217	0.077	0.129	0.119	0.029	0.073	0.063
Gas for operating pressure regulators	$t\text{-}CH_4/10^6m^3$	0.087	0.087	0.087	0.077	0.028	0.009	0.005	0.001	0.001	0.001	0.001	0.003	0.003	0.003	0.002
Total	$t\text{-}CH_4/10^6m^3$	0.306	0.306	0.306	0.267	0.099	0.071	0.075	0.116	0.218	0.078	0.131	0.122	0.032	0.075	0.065

- ***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 3-85 Sales amount of natural gas

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Natural gas sales amount	10^6m^3	2,067	2,339	2,617	3,329	4,020	3,790	3,792	3,709	3,806	4,000	3,980	3,903	3,768	3,902	3,664

- ***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 3-86 LNG and natural gas used for the feedstock of city gas

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
LNG consumption with city gas production	PJ	464	676	864	1,230	1,531	1,555	1,567	1,567	1,641	1,665	1,635	1,584	1,532	1,593	1,532
Natural gas consumption with city gas production	PJ	40	48	61	86	115	107	106	103	101	96	85	75	71	68	61

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

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

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

Since the *General Energy Statistics* were updated, the CH_4 emissions for FY2021 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

3.3.2.2.e. 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 3-16, 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 3-87 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 3-87 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 3-88 Sales amount of city gas

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Sales amount of city gas	PJ	643	877	1,064	1,419	1,644	1,667	1,681	1,671	1,738	1,776	1,740	1,692	1,654	1,723	1,684
Calorific value per volume	MJ/m^3N	41.9	41.9	41.1	44.8	44.8	36.9	36.9	36.8	36.8	36.9	36.2	36.1	36.1	36.2	36.5
Sales amount of city gas in volume	10^6m^3N	15,367	20,952	25,899	31,684	36,705	45,228	45,596	45,426	47,249	48,158	48,135	46,830	45,829	47,568	46,165

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

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***

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.

- ***Verification***

During the review held in 2022, the ERT recommended that Japan described its national circumstances relating to natural gas distribution, and explain the logical basis for using a CH_4 EF that is significantly lower than the default value of the *2006 IPCC Guidelines* (1.1×10^{-3} kt-$CH_4/10^6m^3$).

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 for FY2021 in the *Current Survey of Production Concerning Gas Industry* were revised, the CH_4 emissions in FY2021 were recalculated. Since the activity data in and after FY2013 were aligned using NTP, the CH_4 emissions for the period 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 gas pipe work in buildings, but because these emissions are included in those of "Natural Gas Distribution (distribution through the city gas network) (1.B.2.b.v)", emissions from this source are reported as "IE."

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 (of Oil) (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. 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).

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. Emissions from venting in the natural gas industry in Japan are considered to occur during the stage of production, processing and transmission of natural gas. Of these, CH_4 emissions from production and transmission are reported together in "Transmission and Storage (1.B.2.b.iv)" of natural gas. See "3.3.2.2.d. 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 "Transmission and Storage (1.B.2.b.iv)" of natural gas. Emissions from venting associated with natural gas processing are reported in this category (1.B.2.c.i.2), but see "3.3.2.2.c. Processing (1.B.2.b.iii)" for details including estimation methods. 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 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 Japan Petroleum Development Association 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 Japan Petroleum Development Association 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 3-89 Emission factors of natural gas field venting

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Emission factor	kg-CO_2/m^3	0.133	0.117	0.126	0.114	0.120	0.122	0.124	0.128	0.129	0.127	0.129	0.128	0.122	0.101	0.088

- ***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 3-90 Production amount of natural gas from Minami-Nagaoka and Katagai gas field

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Natural gas production from Minami-nagaoka and Katagai gas field	10^6 m^3	432	657	789	1,229	1,660	1,664	1,542	1,598	1,761	1,944	1,755	1,593	1,474	1,457	1,457

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

As for emissions from venting (natural gas), actual measurement emission data provided by Japan Petroleum Development Association 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 *Japan Petroleum Development Association* 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 *Japan Petroleum Development 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 procedures are summarized in Annex 4.

e) Category-specific Recalculations

The CO_2 emissions were recalculated for FY2018 due to the revision in the measured data for that year. See Chapter 10 for impact on trend.

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 in the oil industry (1.B.2.c.i.1.) and the natural gas industry (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 "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. 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.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, however, the emissions are not estimated because the actual situation in Japan is not clear.

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" 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 3-91.

Table 3-91 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Matsukawa	12.2	0.025	1,884	1,493	1,708	1,115	813	872	857	666	412	610	737	604	683	683	683
Ohtake	3.1	0.006	1,173	995	995	774	789	937	885	867	935	1,013	955	721	468	468	468
Ohnuma	0.6	0.002	694	682	535	651	600	537	521	489	521	510	522	507	506	506	506
Onikobe	2.6	0.008	1,018	1,015	1,035	982	1,185	357	381	334	402	NO	NO	NO	NO	NO	NO
Hatchobaru 1	6.5	0.013	2,883	2,366	2,598	2,602	2,287	2,347	1,887	1,963	2,097	1,729	1,365	2,129	2,417	2,417	2,417
Hatchobaru 2	5.8	0.011	2,514	2,686	2,532	2,452	2,291	2,342	2,264	2,209	1,848	2,107	1,646	1,693	2,532	2,532	2,532
Kakkonda 1	0.3	0.001	3,498	3,126	1,966	2,021	1,535	1,374	1,400	1,362	1,455	1,371	881	1,228	1,248	1,248	1,248
Kakkonda 2	0.4	0.001	NO	209	1,823	2,004	1,440	1,269	1,225	1,142	1,058	1,286	1,171	1,212	884	884	884
Suginoi	8.5	0.019	220	284	203	144	129	147	136	140	137	110	115	122	122	122	122
Mori	28.1	0.053	1,367	1,990	1,981	1,501	1,068	1,001	1,105	934	1,015	1,121	1,001	869	711	711	711
Kirishima International Hotel	1.1	0.003	48	97	70	NO	30	68	38	NO	NO	NO	NO	NO	NO	NO	NO
Uenotai	6.5	0.014	NO	1,882	2,070	1,601	482	1,784	1,717	1,512	1,521	1,449	1,501	1,203	1,443	1,443	1,443
Yamakawa	5.8	0.012	NO	1,451	1,336	639	1,026	989	702	744	1,031	1,047	1,034	879	1,191	1,191	1,191
Sumikawa	1.4	0.004	NO	3,234	2,846	2,908	2,611	2,038	2,903	2,903	2,676	2,334	2,082	2,100	2,372	2,372	2,372
Yanaizu-Nishiyama	68.8	0.130	NO	3,912	3,425	3,197	2,229	1,626	1,998	1,537	1,691	1,064	1,363	904	1,230	1,230	1,230
Ohgiri	0.4	0.001	NO	219	2,373	2,306	2,286	1,969	2,073	1,928	1,910	1,457	1,892	1,943	1,777	1,777	1,777
Takigami	1.9	0.004	NO	NO	2,111	2,075	2,239	2,374	2,087	2,422	2,299	2,239	2,059	2,249	2,184	2,184	2,184
Hachijo-jima	18.1	0.041	NO	NO	187	156	152	149	151	147	153	165	76	NO	NO	NO	NO
Kuju	8.5	0.019	NO	NO	10	136	124	120	58	108	108	108	108	108	108	108	108
Waita	8.5	0.019	NO	NO	NO	NO	NO	NO	NO	148	174	181	193	207	195	195	195
Wasabizawa	8.5	0.019	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	1,978	2,096	2,096	2,096

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

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

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

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). There are five projects of CO_2 injected underground in the past in Japan. 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 3-92 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 3-93 CO_2 emissions from CO_2 transport and storage (1.C)

CRT Category		1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
1.C.1 Transport of CO_2	a. Pipelines	NE	NO	NO	NE	NO	NO	NO	NO	NA	NA	NA	NA	NO	NO	NO
	b. Ships	NO	NO	NO	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	NO	NO	NO
1.C.2 Injection and storage	a. Injection	NE	NO	NO	NE	NO	NO	NO	NO	NA	NA	NA	NA	NO	NO	NO
	b. Storage	NE	NE	NE	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	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 pipeline.

According to the interview to the entities of the projects shown in Table 3-92, the fugitive emissions in the stage of CO_2 transport by pipeline 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 3-92 (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 3-92, 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 3-92, 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 ratio of stored CO_2 in a storage reservoir to the injected CO_2 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 3-94 Amount of CO_2 captured for geological storage

Injection site	Unit	1990	1991	1992	1993	1997	1998	1999	2003	2004	2005	2006	2007	2016	2017	2018	2019	2020	2021	2022	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	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	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	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	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	NO	NO	NO	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 transformation in industrial processes releases GHGs into the atmosphere. This chapter describes the methodologies of estimating industrial process and product use emissions shown in Table 4-1. The estimation methods, emission factors, activity data, etc of each source are considered and approved by the breakout groups on Energy and Industrial Processes, and F-gases, 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 Magnesia 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		○	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			○						
	2.D.2	Paraffin Wax Use			○						
	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	Dry Ice			○						
			Welding			○						
			Cooling			○						
			Other			○						

In FY2022, total GHG emissions from this sector amounted to approximately 93,426 kt-CO_2 eq., and accounting for 8.2% of national total emissions (excluding LULUCF) in Japan. The emissions of CO_2,

CH_4, and N_2O from this sector have decreased by 43.6% compared to FY1990. The emissions of HFCs, PFCs, SF_6, and NF_3 from this sector have increased by 54.8% 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					CS	OTH		
2.F. Product uses as substitutes for ODS								
2.G. Other product manufacture and use					CS	OTH		
2.H. Other	CS	NA						
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 FY2022, emissions from this category were 29,005 kt-CO_2 and represented 2.6% of total GHG emissions (excluding LULUCF). The emissions decreased by40.5% compared to FY1990.

Table 4-3 CO_2 Emissions from Mineral Industry (2.A.)

Gas				Units	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
CO_2	2.A.1	Cement production		kt-CO_2	38,701	42,142	35,086	32,280	24,321	26,805	26,557	25,936	25,969	26,429	26,183	25,328	24,490	24,396	22,479
	2.A.2	Lime production		kt-CO_2	6,674	5,795	5,900	6,646	6,285	5,767	5,812	5,477	5,504	5,583	5,615	5,200	4,504	4,892	4,650
	2.A.3	Glass production		kt-CO_2	313	283	233	244	188	212	209	211	206	213	217	198	164	168	148
	2.A.4	Other process uses of carbonates	Ceramics	kt-CO_2	928	1,065	980	771	880	966	955	829	758	748	647	645	698	759	823
			Other uses of soda ash	kt-CO_2	119	118	102	79	62	46	49	47	48	43	47	44	36	38	40
			Other - Desulfurization of Exhaust Gas and Chemical Products	kt-CO_2	1,978	1,285	1,187	1,093	940	1,135	1,096	1,026	935	924	856	817	811	833	864
	Total			kt-CO_2	48,714	50,689	43,487	41,112	32,676	34,930	34,678	33,526	33,421	33,940	33,565	32,232	30,703	31,085	29,005

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
$CaCO_3 \rightarrow CaO + CO_2$
$MgCO_3 \rightarrow MgO + CO_2$

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-clinker]
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 does 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 (established by the following equation)
EF_{MgO}	: $MgCO_3$-origin CO_2 emission factor (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)
CaO_{Waste}	: CaO content of waste and other materials
M	: Production amount of clinker

$$EF_{MgO} = (MgO_{Cl} - MgO_{Cl\text{-}Waste}) \times 1.092$$

$$MgO_{Cl\text{-}Waste} = W_{dry} \times MgO_{waste} / M$$

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)
MgO_{Waste}	: MgO content of waste and other materials
M	: Production amount of clinker

- ***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 2000 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 - 17.1%	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 - 37.2%	6.4 - 43.9%	1.0 - 1.1%
Slag	Blast furnace slag (water granulated)	5.0 - 16.9%	40.0 - 42.4%	4.7 - 5.8%
	Blast furnace slag (slow-cooled)	5.5 - 16.4%	40.8 - 41.5%	6.1 - 6.5%
	Steelmaking slag	7.7 - 14.3%	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 - 14.3%	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 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
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	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	1.7	1.8	1.8	1.6	1.6	1.6
CaO content in clinker excluding waste origin CaO	%	63.3	63.3	63.0	63.9	64.1	64.1	64.1	64.2	64.1	64.1	64.0	64.0	64.2	64.2	64.2
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	0.785	0.785	0.785
Emission factor	t-CO_2/t	0.497	0.497	0.495	0.501	0.503	0.503	0.503	0.504	0.503	0.503	0.502	0.502	0.504	0.504	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	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	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	1.0	1.0	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	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	0.011	0.011	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	0.515	0.516	0.515	0.515	0.514	0.514	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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Consumption of limestone (actual)	kt (dry)	89,366	97,311	81,376	-	-	-	-	-	-	-	-	-	-	-	-
Clinker production (actual)	kt	-	-	69,528	63,003	47,279	52,105	51,573	50,307	50,436	51,351	50,979	49,293	47,522	47,338	43,650
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) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainty of the CO_2 emission factor and activity data for cement production, the default value

given 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.

[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 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.

> 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Limestone consumption (dry)	kt	15,595	13,540	13,785	15,527	14,684	13,474	13,579	12,797	12,860	13,045	13,119	12,150	10,524	11,430	10,866

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 as 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 FY2021. 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) : 84.3142
・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	Corresponding sectors (Limestone)	Corresponding sectors (Dolomite)	Corresponding sectors (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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Limestone consumption (dry)	kt	66	42	26	31	17	23	23	23	22	24	25	20	12	13	9
Dolomite consumption (dry)	kt	264	250	203	221	184	203	201	202	199	204	207	192	166	169	152
Soda ash consumption (dry)	kt	358	320	257	279	217	249	245	247	241	250	255	230	187	192	166

➢ ***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) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 as 6%.

- ***Time-series consistency***

For activity data, the same source-data are used as much as possible throughout the time series. 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 FY2021, 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	Corresponding sectors in the *Adjusted Price Transaction Table* (Limestone)	Corresponding sectors in the *Adjusted Price Transaction Table* (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 to 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Limestone consumption (dry)	kt	438	1,107	1,135	463	365	630	737	720	664	683	617	591	658	699	891
Dolomite consumption (dry)	kt	1,561	1,227	1,020	1,204	1,527	1,462	1,339	1,087	989	950	797	818	866	959	914

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 (FY2020 to FY2021) and dolomite consumption (FY2021) in the *Adjusted Price Transaction Table*. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.2.4.2. 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) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 as 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

Recalculations occurred for FY2021 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	Corresponding sectors in the *Adjusted Price Transaction Table* (Limestone)		Corresponding sectors in the *Adjusted Price Transaction Table* (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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Limestone consumption																
For desulfurization of exhaust gas (dry)	kt	1,950	2,163	1,842	2,077	1,840	2,124	1,975	1,853	1,726	1,700	1,594	1,530	1,490	1,528	1,516
For chemical products (dry)	kt	2,458	713	812	367	260	421	482	451	375	376	331	307	332	341	425
Dolomite consumption																
For chemical products (dry)	kt	82	43	42	37	34	33	31	25	23	22	18	19	20	22	21

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 for FY2020 to 2021 due to the updates of limestone consumption data for desulfurization of exhaust gas and for chemical products. The update of dolomite consumption for chemical products also contributed to recalculations for FY2021. 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.), Petrochemical and carbon black production (2.B.8.), Fluorochemical production (2.B.9.), and Other (2.B.10.).

In FY2022, emissions from this category were 3,972 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 had decreased by 74.3% compared to FY1990. The total of HFCs, PFCs, SF_6, and NF_3 had decreased by 98.9% compared to 1990.

Table 4-14 Emissions from Chemical Industry (2.B.)

Gas				Units	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
CO_2	2.B.1	Ammonia production		kt-CO_2	2,449	2,475	2,315	1,501	1,465	1,269	1,261	1,298	959	1,019	778	1,021	753	1,106	909
	2.B.5	Carbide production	Silicon carbide	kt-CO_2	C	C	C	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	C	C	C
	2.B.6	Titanium dioxide production		kt-CO_2	102	39	53	59	62	60	62	53	58	58	59	57	49	60	57
	2.B.8	Petrochemical and carbon black production	Methanol	kt-CO_2	56	51	NO	NO	NO	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	C	C	C
			Ethylene dichloride and vinyl chloride monomer	kt-CO_2	150	171	193	200	184	148	150	169	170	175	172	176	174	177	169
			Ethylene oxide	kt-CO_2	171	204	273	278	248	269	248	239	219	248	222	234	210	226	167
			Acrylonitrile	kt-CO_2	440	476	536	509	524	364	342	315	319	323	341	334	306	325	293
			Carbon black	kt-CO_2	1,633	1,563	1,590	1,659	1,505	1,294	1,253	1,161	1,168	1,230	1,259	1,178	980	1,198	1,153
			Phthalic anhydride	kt-CO_2	117	124	118	81	60	59	58	60	58	61	58	60	51	57	53
			Maleic anhydride	kt-CO_2	123	138	163	114	102	89	88	90	91	94	92	85	79	92	82
	2.B.10	Other	Hydrogen production	kt-CO_2	6	21	39	34	34	28	24	27	29	29	29	21	20	17	17
			Utilization of carbonated gas	kt-CO_2	39	45	42	39	41	51	51	53	56	59	62	64	58	58	68
	Total			kt-CO_2	6,110	6,090	6,026	5,205	4,856	4,224	4,139	4,012	3,665	3,859	3,610	3,752	3,093	3,809	3,458
CH_4	2.B.5	Carbide production	Silicon carbide	kt-CH_4	C	C	C	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	NO	NO	NO
			Ethylene	kt-CH_4	C	C	C	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	NO	NO	NO
			Ethylene oxide	kt-CH_4	C	C	C	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	C	C	C
			Styrene	kt-CH_4	C	C	C	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	1.01	1.27	1.07	1.01	0.91	1.00	0.95	1.08	0.94
	Total			kt-CO_2 eq.	42	42	38	38	41	32	28	36	30	28	25	28	27	30	26
N_2O	2.B.2	Nitric acid production		kt-N_2O	2.47	2.46	2.57	2.52	1.81	1.54	1.55	1.40	1.28	1.16	1.07	1.02	0.68	0.86	0.70
	2.B.3	Adipic acid production		kt-N_2O	24.20	24.03	12.56	1.68	1.66	0.77	0.48	0.38	0.49	0.30	0.20	0.31	1.14	0.16	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	1.26	0.90	0.50	0.55	0.43	0.51	0.40	0.47	0.37
			Glyoxal	kt-N_2O	C	C	C	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	C	C	C
	Total			kt-N_2O	32.28	32.43	21.30	8.58	6.08	4.22	3.28	2.68	2.27	2.01	1.70	1.85	2.22	1.50	1.14
	Total			kt-CO_2 eq.	8,555	8,595	5,645	2,275	1,612	1,120	870	709	601	533	450	490	589	397	301
Total of CO_2, CH_4, and N_2O				kt-CO_2 eq.	14,707	14,726	11,709	7,518	6,509	5,375	5,038	4,757	4,296	4,420	4,085	4,269	3,709	4,236	3,786
Gas				Units	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
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	20	25	20	32	10	11	118	110	4
			Fugitive emissions	kt-CO_2 eq.	1	503	264	407	115	119	91	75	136	86	81	108	69	109	63
	Total			kt-CO_2 eq.	13,347	18,483	13,408	898	160	132	111	100	156	118	90	119	187	220	66
PFCs	2.B.9	Fluorochemical production	Fugitive emissions	kt-CO_2 eq.	304	840	1,499	955	227	100	97	104	88	73	79	58	67	72	67
SF_6			Fugitive emissions	t	152.23	197.00	36.00	40.80	8.30	4.07	2.70	2.30	2.20	1.78	2.00	1.76	2.28	2.00	1.44
				kt-CO_2 eq.	3,577	4,630	846	959	195	96	63	54	52	42	47	41	54	47	34
NF_3			Fugitive emissions	t	0.16	1.00	7.00	72.10	76.90	86.40	56.09	23.50	25.10	13.61	3.37	1.12	0.88	1.39	1.19
				kt-CO_2 eq.	3	16	113	1,161	1,238	1,391	903	378	404	219	54	18	14	22	19
Total of F-gases				kt-CO_2 eq.	17,231	23,968	15,866	3,972	1,820	1,719	1,174	636	700	453	271	237	322	361	186

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

Emission of CH_4 from the ammonia production has 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

Emission 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 fuels 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.

$$E = \Sigma_i (AD_i \times GCV_i \times EF_i \times 44/12) - R_{ccs} - R_{urea} - R_u$$

E : CO_2 emissions from ammonia production [kt-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 when producing ammonia

Item		Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Naphtha	GCV	MJ/L	33.63	33.63	33.57	33.55	33.53	33.31	33.31	33.31	33.31	33.31	33.31	33.31	33.31	33.31	33.31
	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	18.63	18.63	18.63
LPG	GCV	MJ/kg	50.53	50.63	50.70	50.75	50.77	50.07	50.09	50.10	50.10	50.11	50.10	50.10	50.12	50.13	50.12
	CEF	t-C/TJ	16.54	16.51	16.49	16.48	16.47	16.38	16.37	16.36	16.36	16.35	16.36	16.36	16.34	16.34	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	46.12	46.12	46.12	46.12	46.12
	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	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	39.62	39.62	39.62	38.38	38.38	38.38	38.38	38.38
	CEF	t-C/TJ	13.90	13.90	13.90	13.90	13.90	13.97	13.97	13.97	13.97	13.97	13.91	13.91	13.91	13.91	13.91
Coal	GCV	MJ/kg	25.95	25.95	26.60	25.70	25.70	25.97	25.97	25.97	25.97	25.97	26.08	26.08	26.08	26.08	26.08
	CEF	t-C/TJ	24.71	24.71	24.71	24.71	24.71	24.42	24.42	24.42	24.42	24.42	24.29	24.29	24.29	24.29	24.29
Oil coke	GCV	MJ/kg	35.58	35.58	35.60	29.90	29.90	33.29	33.29	33.29	33.29	33.29	33.29	33.29	33.29	34.11	34.11
	CEF	t-C/TJ	25.35	25.35	25.35	25.35	25.35	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.50	24.80	24.80
LNG	GCV	MJ/kg	54.54	54.53	54.52	54.51	54.49	54.46	54.46	54.46	54.46	54.46	54.70	54.71	54.73	54.73	54.71
	CEF	t-C/TJ	13.94	13.95	13.94	13.94	13.95	13.96	13.95	13.96	13.96	13.96	13.87	13.87	13.86	13.86	13.87
COG	GCV	MJ/m^3	21.51	21.57	21.27	21.42	21.32	18.87	18.87	18.87	18.87	18.87	18.38	18.38	18.38	18.38	18.38
	CEF	t-C/TJ	10.99	10.99	10.99	10.99	10.99	10.93	10.93	10.93	10.93	10.93	10.88	10.88	10.88	10.88	10.88

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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Naphtha	kL	189,714	477,539	406,958	92,453	70,067	71,494	66,079	73,612	18,421	NO	NO	NO	NO	NO	NO
LPG	t	226,593	45,932	5,991	NO	NO	NO	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	NO	NO	NO
Natural gas	10^3m^3	C	100,468	86,873	77,299	41,640	47,956	51,858	17,498	637	979	1,011	906	941	278	947
Coal	t	C	209,839	726	1,239	629	919	787	362	891	483	928	450	845	499	934
Oil coke	t	C	273,125	420,862	353,983	394,116	401,721	426,743	468,684	416,722	462,107	371,819	454,952	347,107	450,097	367,225
LNG	t	C	46,501	23,395	165,606	157,918	168,155	127,824	122,453	131,446	122,081	122,818	122,555	132,158	131,465	148,381
COG	10^3m^3	C	35,860	55,333	NO	NO	NO	NO	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) Uncertainties and Time-series Consistency

- ***Uncertainty***

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. As a result, the uncertainty of emissions are 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

CO_2 recoveries for liquefied CO_2 and for dry ice are newly estimated and subtracted from CO_2 emissions from ammonia production, resulting in recalculations for all years. See Chapter 10 for impact on trend.

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 nitric acid production amount 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
EFs for nitric acid production	kg-N_2O/t	3.50	3.51	3.92	4.18	3.58	3.55	3.54	3.60	3.59	3.27	3.26	3.28	3.00	3.47	3.21

- ***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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Nitric acid production	kt	706	701	656	602	506	434	437	388	356	355	328	311	227	248	218

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 as 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.

➢ ***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) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 as 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 as 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 have 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) given by Japan Chemical Industry Association was used.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 as 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

There have been no source-specific recalculations.

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) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 as 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 recent were used as activity data. There is no production from FY2012 onward.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 as 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) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 *2006 IPCC Guidelines* was used. As a result, the uncertainty for emissions was estimated as 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 as 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) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 as 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 to 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
CI	: Coke input amount
CO	: Carry-over amount (Raw material left over without reacting)
CC	: Carbon content of coke
EF	: CO_2 emission factor
AD	: Titanium dioxide production amounts

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.)

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) is used.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 as 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) given 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) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 as -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

[2] The assumption was set based on a flaring efficiency of 98% shown in the *IPCC GPG* (Table 2.16 note e).

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.

- ***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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Ethylene production	kt	5,966	6,951	7,566	7,549	6,999	6,764	6,687	6,780	6,286	6,459	6,186	6,282	6,043	6,102	5,482

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 as 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

There have been no source-specific recalculations.

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 the ethylene. (See below)

$$C_2H_4 + 0.5O_2 + 2HCl \rightarrow C_2H_4Cl_2 + H_2O$$
$$[C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O]$$

The ethylene dichloride is cracked to produce chloroethylene monomer, a precursor of polyvinyl chloride, and hydrochloric acid. The ethylene dichloride is cracked to produce chloroethylene monomer, a precursor of polyvinyl chloride, and hydrochloric acid. Since the 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/tVCM 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 waste 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
VCM production amount	kt	2,316	2,648	2,976	3,098	2,850	2,286	2,315	2,616	2,621	2,706	2,664	2,713	2,690	2,735	2,615

Table 4-23 1,2-Dichloroethane production amount

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
1,2-Dichloroethane production	kt	2,683	3,014	3,346	3,639	3,155	2,733	2,730	3,003	3,012	3,158	3,113	3,297	3,263	3,451	3,279

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 as -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 of 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.

$$E_{CO_2} = EO \times EF - R$$

E_{CO2}	: CO_2 emissions from ethylene oxide production
EO	: Ethylene oxide production amount per year
EF	: CO_2 emissions per ethylene oxide production amount
R	: CO_2 recoveries from ethylene oxide production

  - ***CH_4***

Following the Tier 1 method of 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Ethylene oxide production	kt	714	795	961	1,001	843	915	894	923	882	945	893	878	790	818	618

  - ***CH_4***

The ethylene oxide production amount at the one manufacturer is used. The data is confidential.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainty for the CO_2 emission factor, the default value of 10% 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% 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

Recalculations occurred due to the updates in the amount of CO_2 recovered from ethylene oxide production for all years. See Chapter 10 for impact on trend.

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 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Acrylonitrile production amount	kt	602	652	734	697	718	499	468	431	437	443	467	457	420	445	402

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 is 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 the 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Carbon black production	kt	793	759	772	805	730	628	608	563	567	597	611	572	476	582	560

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

The uncertainty for the emission factor for carbon black 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 carbon black production 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), 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Styrene production	kt	2,227	2,952	3,020	3,375	3,019	2,539	2,518	2,260	1,952	2,100	1,994	1,980	1,874	1,898	1,496

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 as 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 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 [mol %]	Maleic Anhydride [mol %]	Other [mol %]	CO_2 * [mol %]	EF * [t-CO_2/t]
Oxidation of naphthalene	87-91	3-5	1	2-8	0.19
Oxidation of o-xylene	80-83	4-6	1-2	10-16	0.54

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 The weighted average EF based on productive capacity of phthalic anhydride

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
EFs for phthalic anhydride production	t-CO_2/t	0.39	0.39	0.41	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37	0.37

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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Phthalic anhydride production	kt	300	319	288	216	160	158	156	159	156	163	155	160	137	151	142

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainty of the emission factor, a 197% value, derived from the upper/lower limits of the theoretical value of the yield 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 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 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 [mol %]	CO_2 * [mol %]	EF * [t-CO_2/t]
Oxidation of benzene	70-80	20-30	0.74
Oxidation of n-butane	55-60	40-45	1.65

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 The weighted average EF based on productive capacity of maleic anhydride

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
EFs for maleic anhydride production	t-CO_2/t	1.20	1.20	1.23	1.11	1.11	1.04	1.04	1.04	1.04	1.04	1.04	1.06	1.06	1.06	1.06

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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Maleic anhydride production	kt	103	116	132	103	93	86	85	87	88	90	89	80	74	87	77

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainty of the emission factor, a 213% value, derived from the upper/lower limits of the theoretical value of the yield 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Production of HCFC-22	t	60,122	81,000	95,271	65,715	46,149	47,546	51,753	49,116	48,833	52,646	56,933	57,872	44,733	53,326	55,255
Rate of generation of HFC-23	%	2.13%	2.13%	1.70%	1.90%	2.01%	1.41%	1.46%	1.46%	1.38%	1.47%	1.80%	1.88%	2.06%	1.81%	2.04%
Emission rate to production of HCFC-22	%	1.79%	1.79%	1.11%	0.06%	0.01%	0.002%	0.003%	0.004%	0.003%	0.005%	0.001%	0.002%	0.021%	0.017%	0.001%
Emissions	t	1,076.27	1,450.00	1,060.00	39.60	3.60	1.10	1.60	2.00	1.60	2.60	0.80	0.90	9.50	8.90	0.30
	kt-CO_2 eq.	13,346	17,980	13,144	491	45	14	20	25	20	32	10	11	118	110	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 in preventing 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 production amounts, and by using data on the emission rate to the production of HCFC-22 from 1995, and extrapolating for these years.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

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.

[3] *Documents of the first meeting of the Group for global warming chemicals, Risk Management Sub-Group, Chemicals Council* (MITI).

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	2014	2015	2016	2017	2018	2019	2020	2021	2022
HFCs Emissions	kt-CO_2 eq.	1	503	264	407	115	119	91	75	136	86	81	108	69	109	63

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	2014	2015	2016	2017	2018	2019	2020	2021	2022
PFCs Emissions	kt-CO_2 eq.	304	840	1,499	955	227	100	97	104	88	73	79	58	67	72	67

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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Production of SF_6	t	1,848.36	2,392.00	1,556.00	2,313.00	2,201.00	2,128.00	1,997.00	2,027.00	2,002.74	1,680.39	1,658.00	1,573.00	1,260.00	1,307.20	1,229.80
Emissions	t	152.23	197.00	36.00	40.80	8.30	4.07	2.70	2.30	2.20	1.78	2.00	1.76	2.28	2.00	1.44
	kt-CO_2 eq.	3,577	4,630	846	959	195	96	63	54	52	42	47	41	54	47	34

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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Production of NF_3	t	6.00	37.00	208.00	1,663.00	3,642.00	4,148.00	4,660.08	4,963.00	4,365.50	4,649.40	4,718.90	3,828.70	4,037.00	4,191.00	4,172.00
Emissions	t	0.16	1.00	7.00	72.10	76.90	86.40	56.09	23.50	25.10	13.61	3.37	1.12	0.88	1.39	1.19
	kt-CO_2 eq.	3	16	113	1,161	1,238	1,391	903	378	404	219	54	18	14	22	19

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) Uncertainties and Time-series Consistency

- ***Uncertainty***

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.

Table 4-39 Emission factors for hydrogen production

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
EFs for hydrogen production	t-CO_2/10^3Nm^3	0.82	0.83	0.83	0.88	0.87	0.86	0.85	0.85	0.84	0.86	0.86	0.84	0.83	0.82	0.83

- ***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 Japan Industrial and Medical Gases Association.

Table 4-40 Hydrogen production amount

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Hydrogen production	10^3Nm^3	7,431	25,116	46,562	37,911	38,889	32,170	28,394	32,257	34,235	34,095	33,574	24,788	23,567	20,348	21,019

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 as 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

The emission factor for FY2021 was revised, resulting in recalculations. See Chapter 10 for impact on trend.

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 recoveries for liquefied CO_2 subtracted from the CO_2 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.), 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.), Aluminum 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 FY2022, emissions from this category were 5,509 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 had decreased by 28.6% compared to FY1990. The total of HFCs, PFCs and SF_6 had decreased by 37.4% compared to 1990.

Table 4-41 Emissions from Metal Industry (2.C.)

Gas				Units	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
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	160	132	143	170	175	139	91	189	195
			Limestone and dolomite use in iron and steel production	kt-CO_2	6,884	6,492	6,537	6,222	5,919	5,950	5,861	5,705	5,634	5,542	5,420	5,143	4,799	5,051	4,840
			By-product gas flaring in iron and steel production	kt-CO_2	25	56	102	174	243	256	245	223	213	192	181	168	133	149	136
			Utilization of carbonated gas	kt-CO_2	26	29	28	42	41	40	38	39	41	39	39	44	33	37	37
	2.C.3	Aluminium production		kt-CO_2	58	29	11	11	8	5	1	NO	NO	NO	NO	NO	NO	NO	NO
	Total			kt-CO_2	7,292	6,935	6,868	6,679	6,363	6,391	6,305	6,098	6,032	5,943	5,815	5,493	5,056	5,427	5,208
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	0.59	0.55	0.55	0.59	0.60	0.54	0.49	0.56	0.54
	2.C.2	Ferroalloys production		kt-CH_4	0.19	0.14	0.13	0.13	0.12	0.13	0.12	0.12	0.11	0.11	0.11	0.11	0.08	0.10	0.08
	Total			kt-CH_4	0.92	0.85	0.80	0.80	0.71	0.73	0.71	0.67	0.66	0.70	0.71	0.65	0.57	0.66	0.61
	Total			kt-CO_2 eq.	26	24	22	23	20	20	20	19	18	20	20	18	16	19	17
Total of CO_2 and CH_4				kt-CO_2 eq.	7,317	6,958	6,891	6,702	6,383	6,412	6,324	6,117	6,050	5,962	5,835	5,512	5,072	5,445	5,226
Gas				Units	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
HFCs	2.C.4	Magnesium production		kt-CO_2 eq.	NO	NO	NO	NO	NO	1	1	1	1	1	2	1	1	2	1
PFCs	2.C.3	Aluminium production		kt-CO_2 eq.	301	153	39	32	23	14	3	NO	NO	NO	NO	NO	NO	NO	NO
SF_6	2.C.4	Magnesium production		t	6.43	5.00	43.00	48.42	12.88	7.00	8.00	10.00	13.80	10.80	12.00	11.00	13.00	14.00	12.00
				kt-CO_2 eq.	151	118	1,011	1,138	303	165	188	235	324	254	282	259	306	329	282
Total of F-gases				kt-CO_2 eq.	453	271	1,050	1,170	325	180	192	236	325	255	284	260	307	331	283

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	2014	2015	2016	2017	2018	2019	2020	2021	2022
1.A.2.a (Energy sector - iron and steel)	kt-CO_2	150,622	142,999	152,022	154,093	153,145	157,541	155,085	148,849	142,731	139,734	136,157	134,124	111,963	124,783	114,875
2.C.1 (IPPU sector - iron and steel production)	kt-CO_2	7,234	6,905	6,857	6,668	6,355	6,386	6,304	6,098	6,032	5,943	5,815	5,493	5,056	5,427	5,208
Total of CO_2	kt-CO_2	157,856	149,904	158,879	160,761	159,500	163,927	161,389	154,947	148,762	145,677	141,972	139,618	117,019	130,210	120,083

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 3-61.

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 category Fuel combustion (1.A.).

CO_2 emissions from carbon electrodes during aluminium production are accounted for under Aluminum 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 from carbon electrodes of furnaces

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
#A Import	t	12,341	18,463	11,363	15,075	17,321	19,960	19,226	18,209	19,773	16,653	15,720	18,056	17,380	23,099	21,195
#B Domestic production	t	211,933	186,143	184,728	216,061	205,081	180,322	180,555	151,979	141,193	161,919	160,049	119,233	76,338	103,026	107,547
#C Export	t	87,108	92,812	107,998	138,409	139,757	128,435	121,079	103,834	90,664	104,032	100,268	72,307	44,578	46,239	50,859
#D Electric furnaces gas	t	39,983	14,300	33,201	26,700	39,017	32,146	34,760	30,444	31,273	28,049	27,806	27,022	24,397	28,195	24,727
Domestic consumptions (#A + #B - #C - #D)	t	97,184	97,493	54,892	66,028	43,629	39,700	43,941	35,910	39,029	46,491	47,695	37,959	24,743	51,692	53,156
CO_2 emissions	kt-CO_2 eq.	356	357	201	242	160	145	161	132	143	170	175	139	91	189	195

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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Electric furnaces	TJ	57,564	55,986	52,457	52,747	45,793	46,786	46,156	42,919	43,045	46,109	46,697	41,978	38,160	43,839	42,000

c) Uncertainties and Time-series Consistency

1) CO_2

- ***Uncertainty***

Because all CO_2 from electric arc furnaces are 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 as 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***

The uncertainty for the emission factor has been estimated as 163% and the uncertainty for activity data has been estimated as 5% (see chapter 3). As a result, the uncertainty for CH_4 emissions has been estimated as 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	Corresponding sectors in the *Adjusted Price Transaction Table* (Limestone)		Corresponding sectors in the *Adjusted Price Transaction Table* (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 steel and refining

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Limestone consumption (dry)	kt	14,421	13,588	13,616	12,610	11,813	11,827	11,640	11,329	11,144	10,942	10,680	10,177	9,590	9,995	9,627
Dolomite consumption (dry)	kt	1,144	1,089	1,160	1,430	1,532	1,585	1,569	1,529	1,551	1,544	1,532	1,412	1,231	1,388	1,283

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 as 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 (FY2020 to 2021) and dolomite (FY2021) consumption data in the *Adjusted Price Transaction Table*. 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.

$$E = \Sigma_i (AD \times GCV \times EF \times 44/12)$$

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 3-19)

- ***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 the by-product gas flaring unaccounted in the *General Energy Statistics*

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Blast furnace gas	Million Nm^3	23	22	22	29	36	37	35	31	29	26	24	22	16	19	17
Converter furnace gas	Million Nm^3	14	41	80	139	195	211	203	185	177	159	150	139	111	124	113

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 from flaring of by-product gas 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

There have been no source-specific recalculations.

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 recoveries for liquefied CO_2 subtracted from the CO_2 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.), 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.

$$EF = C_{CH_4} \times G \times MW / V_m / H$$

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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Electric furnaces (for Ferroalloys)	TJ	14,456	10,699	10,181	10,072	9,510	9,956	9,102	9,228	8,507	8,362	8,894	8,766	6,404	8,017	5,909

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

The uncertainty for the emission factor has been estimated as 163% and the uncertainty for activity data has been estimated as 5% (see chapter 3). As a result, the uncertainty for CH_4 emissions has been estimated as 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. Aluminum Production (2.C.3.)

4.4.3.1. By-product emissions (2.C.3.a.)

a) Category Description

CO_2 generated in association with aluminum 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 aluminum refining. However, estimation methodology for the conventional Bayer process used in Japan is not considered in the *2019 Refinement*.

PFCs are emitted during aluminum 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 aluminum 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 aluminum 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 aluminum 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* was used.

The equation prescribed in the Tier 2a method of the *2019 Refinement*, and its associated slope coefficients set by technology, together with the weight fraction of gases was 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 aluminum production amounts

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015 onward
PFC-14 (CF_4) EF	kg-PFC-14/t	1.181	1.181	0.804	0.663	0.647	0.643	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	0.050	NA
Production of aluminium	t	34,100	17,338	6,500	6,490	4,670	2,950	588	0

Reference: *Yearbook of Minerals and Non-Ferrous Metals Statistics* (METI), *Documents of Fluorocarbons etc Measures Working Group*

- ***Activity Data***

The aluminum 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, aluminum production amounts given in the *Yearbook of Minerals and Non-Ferrous Metals Statistics* were used.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

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

Recalculations of PFC emissions occurred due to the corrections of the emission factor for 1990 to 1994. See chapter 10 for impact on trend.

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 aluminum 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Consumption of HFC-134a	t	0	0	0	0	0	0.9	0.9	0.6	0.8	1.0	1.2	1.0	0.9	1.2	0.9
Consumption of SF_6	t	6.4	5.0	43.0	48.4	12.9	7.0	8.0	10.0	13.8	10.8	12.0	11.0	13.0	14.0	12.0

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) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 FY2022, emissions from this category were 2,328 kt-CO_2 and represented 0.2% of Japan's total GHG emissions (excluding LULUCF). The emissions had increased by 5.5% 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
CO_2	2.D.1	Lubricant use		kt-CO_2	510	527	532	491	451	397	387	358	338	342	373	371	358	351	315
	2.D.2	Paraffin wax use		kt-CO_2	50	37	36	36	35	28	26	25	24	24	26	27	23	28	23
	2.D.3	Other	Urea-based catalysts	kt-CO_2	NO	NO	NO	0	3	8	10	12	15	17	20	24	25	29	32
			NMVOC incineration	kt-CO_2	1,648	1,986	2,273	2,504	2,410	2,385	2,234	2,213	2,323	2,426	2,456	2,344	2,115	2,087	1,959
	Total			kt-CO_2	2,207	2,551	2,841	3,031	2,898	2,817	2,657	2,608	2,700	2,809	2,875	2,766	2,521	2,495	2,328

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 oxidation 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Consumption of engine oil (for types other than total loss types)	TJ	35,328	36,727	37,057	34,083	31,256	26,582	25,928	23,897	22,607	22,888	25,003	24,929	24,040	23,538	21,077
Consumption of grease	TJ	3,152	2,503	2,435	2,658	2,622	2,478	2,486	2,464	2,337	2,164	2,146	1,945	1,863	1,998	1,914

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainty of emission factors, a 50% default value in the *2006 IPCC Guidelines* was applied for both lubricants and grease. For the uncertainty of the activity data, a 5% default value 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 consumption of engine oil for types other than total loss types for all years. Update of the emission factor for FY2021 also contributed to recalculations. 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)

$$E_{CO_2} = PW \times CC_{Wax} \times ODU_{Wax} \times 44/12$$

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) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainty of emission factors, a 100% default value in the *2006 IPCC Guidelines* was applied. For the uncertainty of the activity data, a 5% default value 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

Recalculations occurred due to the updates of activity data and emission factor for FY2021. See chapter 10 for impact on trend.

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)

$$E_{CO_2} = AD \times 12/60 \times P \times 44/12$$

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].

$$AD = \Sigma_i (N_i \times L_i \times R \times D)$$

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) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 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).

[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.

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*

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 is 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. From FY2015, an average carbon content for this category (0.64) is used.

- ***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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Paints	kt	266	289	331	339	296	263	260	285	303	329	308	304	286	267	275
Cleaning agents	kt	85	100	90	108	65	45	48	46	53	55	55	53	50	42	43
Printing solvents	kt	172	195	237	234	231	232	220	219	210	210	202	191	164	169	163
Chemical products	kt	51	79	131	150	182	190	183	193	201	204	221	207	193	205	199
Other	kt	155	208	209	302	336	366	346	367	381	394	424	413	369	380	370

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

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

The amounts of domestic supply of solvents and NMVOC emissions into the atmosphere were updated due to updates in the *VOC Inventory* and the *Yearbook of Current Production Statistics – Chemical Industry*, etc, resulting in recalculations for FY2018 to FY2021. 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 2022, emissions from this category were 2,788 kt-CO_2 eq. and represented 0.2% of Japan's total GHG emissions (excluding LULUCF). The N_2O emissions are 33.8 times of 1990. The total of HFCs, PFCs, SF_6, and NF_3 had decreased by 0.2% compared to 1990.

Table 4-55 Emissions from Electronics Industry (2.E.)

Gas			Units	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
N_2O	2.E.1	Semiconductor	kt-N_2O	0.05	0.10	0.15	0.38	0.60	0.95	0.99	1.13	1.22	1.18	1.03	1.04	1.14	1.63	1.69
	Total		kt-CO_2 eq.	13	25	39	99	160	252	263	299	323	312	273	276	302	431	448
Gas			Units	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
HFCs	2.E.1	Semiconductor	kt-CO_2 eq.	55	415	432	312	217	129	129	124	141	152	142	132	150	110	96
	2.E.2	Liquid crystals	kt-CO_2 eq.	0.001	0.2	2	2	3	2	2	2	2	2	2	1	1	1	1
	Total		kt-CO_2 eq.	55	416	434	315	220	131	131	126	143	153	144	133	151	111	97
PFCs	2.E.1	Semiconductor	kt-CO_2 eq.	1,286	3,443	5,905	4,126	1,973	1,393	1,461	1,429	1,551	1,655	1,627	1,549	1,675	1,413	1,452
	2.E.2	Liquid crystals	kt-CO_2 eq.	28	78	192	137	42	68	81	78	64	76	71	67	69	70	52
	Total		kt-CO_2 eq.	1,314	3,521	6,097	4,263	2,015	1,461	1,542	1,507	1,615	1,731	1,698	1,617	1,744	1,483	1,503
SF_6	2.E.1	Semiconductor	t	35.65	46.13	67.73	49.94	20.14	15.15	14.09	15.18	16.07	16.71	14.42	13.44	14.60	12.78	12.73
	2.E.2	Liquid crystals	t	4.81	6.22	38.48	31.22	11.79	7.45	8.38	8.39	6.87	7.13	7.32	6.45	6.09	5.64	5.28
	Total		t	40.46	52.36	106.21	81.16	31.93	22.60	22.47	23.57	22.94	23.84	21.74	19.89	20.69	18.42	18.01
	Total		kt-CO_2 eq.	951	1,230	2,496	1,907	750	531	528	554	539	560	511	467	486	433	423
NF_3	2.E.1	Semiconductor	t	1.43	8.81	5.21	8.43	9.98	5.79	7.10	7.78	9.88	10.38	12.55	13.75	16.20	18.10	18.83
	2.E.2	Liquid crystals	t	0.15	0.91	3.83	4.10	1.53	1.24	1.52	1.29	1.14	1.28	1.23	1.09	1.10	1.10	0.87
	Total		t	1.58	9.71	9.04	12.53	11.51	7.03	8.62	9.07	11.02	11.66	13.78	14.83	17.31	19.20	19.70
	Total		kt-CO_2 eq.	25	156	145	202	185	113	139	146	177	188	222	239	279	309	317
Total of F-gases			kt-CO_2 eq.	2,346	5,323	9,172	6,687	3,170	2,237	2,340	2,332	2,474	2,632	2,574	2,456	2,660	2,336	2,341

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 equal all N_2O shipment amounts for semiconductor/liquid crystal manufacturing.

$E = AD$

E : N_2O emissions during semiconductor/liquid crystal manufacturing
AD : N_2O shipped for semiconductor/liquid crystal manufacturing use

- ***Emission Factors***

Emissions equal activity data, and therefore no emission factor has been established.

- ***Activity Data***

The N_2O shipment amounts for semiconductor/liquid crystal manufacturing given in the website of Japan Industrial and Medical Gases Association is used as activity data.

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
E_i : Emissions from unreacted input gas i from the production process
BPE_k : Emissions from by-product k generated from the conversion of all input gases i
EAB_i : CF_4 emissions from combustion emissions control systems when NF_3 is used in RPC processes or F_2 is used
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)]
h : Heel factor[2)]
U : Use rate of gas[3)]
a : Fraction of gas controlled[2)]
d : Fraction of gas destroyed[3)]
UT : Fraction of uptime of emissions control systems [2)]
B : By-production rate[3)]
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 Japan Electronics and Information Technology Industries Association.
2) Data provided by METI
3) Default value of the *2019 Refinement* (Vol. 3 Table 6.7 and Table6.17)
4) Default value of the *2019 Refinement* (Vol. 3 chap. 6, page 30)

Regarding the treatment of the heel (remaining amount in the shipment container after use), 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 fraction of gas controlled is not reported here due to confidentiality reasons.

Table 4-56 Indices related to emissions of F-gases from manufacturing of semiconductors

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
HFC-23 purchased	t	0.1	48	49	42	67	67	77	86	83	84	85	73	81	90	96
HFC-32 purchased	t	0	0	0	0	0	0	0	0	13	26	54	76	95	117	130
HFC-41 purchased	t	0	0	0	0	0	0	0	0	3	8	14	19	25	28	29
PFC-14 purchased	t	113	313	300	232	265	218	254	285	317	365	376	369	407	421	424
PFC-116 purchased	t	76	210	561	393	194	118	105	96	102	126	93	80	86	77	76
PFC-218 purchased	t	0.01	0.03	10	182	167	106	117	111	108	130	127	108	106	111	112
PFC-c318 purchased	t	0.2	0.6	39	25	36	42	53	63	70	107	167	208	266	310	382
SF_6 purchased	t	70	91	132	97	77	58	65	68	73	87	87	84	96	95	106
NF_3 purchased	t	9	54	106	407	861	905	1,055	1,232	1,310	1,597	1,876	2,010	2,283	2,561	2,692
C_5F_8 purchased	t	0	0	0	0	0	0	0	0	0	0	1	0.8	0.5	1	1
C_4F_6 purchased	t	0	0	0	0	0	0	0	0	0	0	128	190	247	313	312
COF_2,F_2 purchased	t	0	0	0	0	0	0	0	0	0	0	0	0	0	19	12
Heel factor	%	10%	10%	10%	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%	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%	0%	0%	0%
HFC emissions	kt-CO_2 eq.	55	415	432	312	217	129	129	124	141	152	142	132	150	110	96
PFC emissions	kt-CO_2 eq.	1,286	3,443	5,905	4,126	1,973	1,393	1,461	1,429	1,551	1,655	1,627	1,549	1,675	1,413	1,452
SF_6 emissions	kt-CO_2 eq.	838	1,084	1,592	1,174	473	356	331	357	378	393	339	316	343	300	299
NF_3 emissions	kt-CO_2 eq.	23	142	84	136	161	93	114	125	159	167	202	221	261	291	303

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 4-57 Use rate of gases during semiconductor manufacturing and fraction of gas controlled

Gas	Use rate	Fraction of gas controlled	Gas	Use rate	fraction of gas controlled
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 4-58 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 4-58 HFCs and PFCs by-production rate during semiconductor manufacturing (Cont.)

Input Gas / By-product 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) Uncertainties and Time-series Consistency

- ***Uncertainty***

Because all N_2O used during semiconductor/liquid crystal manufacturing 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. For the uncertainty of activity data, a 5% default value in the *2006 IPCC Guidelines* were used.

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***

For N_2O, the shipment amounts are taken from what is reported by Japan Industrial and Medical Gases Association in a consistent manner 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 HFCs, PFCs, SF_6 and NF_3 occurred due to the update of the estimation method for all years. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

For N_2O, there is a possibility of over-estimation, since emissions are equal to all N_2O shipment amounts for semiconductor/liquid crystal manufacturing.

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 manufacturing are included under Semiconductor (2.E.1.), and therefore are reported as “IE”.

b) Methodological Issues

- ***Estimation Method***

The Tier 2a method of 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.))”.

Japan Electronics and Information Technology Industries Association 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
FC : Purchased amount of gas
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
FC : Purchased amount of gas
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 4-59 Indices related to emissions of F-gases from manufacturing of liquid crystals

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
HFC-23 purchased	t	0.0003	0.1	0.7	1.6	1.1	1.3	1.5	1.1	1.1	1.1	1.3	1.2	0.9	0.7	1.0
PFC-14 purchased	t	7.5	20.7	47.3	77.8	93.7	154.5	191.7	177.1	151.8	185.0	176.4	164.0	174.9	193.6	136.9
PFC-116 purchased	t	0.1	0.4	2.7	9.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PFC-c318 purchased	t	0	0	0	0.8	1.6	1.4	1.8	1.1	1.1	1.1	0.6	0.9	0.9	0.4	0.5
SF_6 purchased	t	8.9	11.5	85.3	101.4	176.9	107.4	126.2	126.6	109.6	116.4	117.0	98.6	95.1	87.1	84.4
NF_3 purchased	t	1.3	8.1	106.9	232.2	764.1	783.8	918.9	808.0	691.9	813.2	767.0	664.5	718.1	805.7	630.7
Process supply rate	%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
HFC emissions	kt-CO_2 eq.	0.0006	0.2	2	2	3	2	2	2	2	2	2	1	1	1	1
PFC emissions	kt-CO_2 eq.	28	78	192	137	42	68	81	78	64	76	71	67	69	70	52
SF_6 emissions	kt-CO_2 eq.	113	146	904	734	277	175	197	197	161	168	172	152	143	133	124
NF_3 emissions	kt-CO_2 eq.	2	15	62	66	25	20	25	21	18	21	20	17	18	18	14

Reference: *Documents of Fluorocarbons etc Measures Working Group*, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Table 4-60 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 4-61 CHF_3, CF_4, and C_2F_6, by-production rate 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.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 (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 Japan Electronics and Information Technology Industries Association 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 amount 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 2022, emissions from this category were 47,372 kt-CO_2 eq., and represented 4.2% of Japan’s total GHG emissions (excluding LULUCF). The emissions are 11.2 times of 1990.

Table 4-62 Emissions from Product Uses as Substitutes for ODS (2.F.)

Gas			Units	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
HFCs	2.F.1	Refrigeration and air conditioning	kt-CO_2 eq.	NO	841	2,713	8,198	19,322	27,521	30,898	34,059	36,159	37,524	38,890	40,918	42,464	43,266	42,810
	2.F.2	Foam blowing agents	kt-CO_2 eq.	1	452	440	829	1,538	1,957	2,082	2,179	2,323	2,454	2,558	2,610	2,571	2,586	2,591
	2.F.3	Fire protection	kt-CO_2 eq.	NO	NO	4	7	8	8	9	9	8	9	9	9	9	9	9
	2.F.4	Aerosols	kt-CO_2 eq.	NO	1,365	2,835	1,592	653	473	485	519	561	574	522	548	626	568	426
	2.F.5	Solvents	kt-CO_2 eq.	NO	NO	NO	6	61	110	124	127	131	117	119	124	128	129	129
	Total		kt-CO_2 eq.	1	2,657	5,993	10,631	21,581	30,070	33,599	36,893	39,183	40,678	42,098	44,208	45,799	46,559	45,966
PFCs	2.F.5	Solvents	kt-CO_2 eq.	4,228	11,684	2,834	2,542	1,567	1,395	1,411	1,394	1,350	1,366	1,384	1,429	1,343	1,279	1,406
Total of All Gases			kt-CO_2 eq.	4,230	14,341	8,826	13,173	23,148	31,465	35,009	38,287	40,533	42,043	43,482	45,637	47,142	47,838	47,372

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 (https://www.jraia.or.jp/english/index.html) confirmed with its member companies that no use of PFC was found in imported commercial refrigeration also for the previous years.

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 4-64, 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. (Table 4-64).

Methods for HFC emissions from commercial refrigeration below are applied to each type of device and refrigerant.

- ***Emissions from manufacturing***

$$E_{manufacturing} = \Sigma \left(N_{produced} \times m_{manufacturing} \times x_{manufacturing} \right)$$

$E_{manufacturing}$: Emissions from manufacturing

[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.

$N_{produced}$: Number of devices produced
$m_{manufacturing}$: Amount of refrigerant contained
$x_{manufacturing}$: Fugitive refrigerant ratio from manufacturing

➢ *Emissions from installation*

$$E_{installation} = \Sigma (N_{installation} \times m_{installation} \times x_{installation})$$

$E_{installation}$: Emissions from installation
$N_{installation}$: Number of devices charged at installation site
$m_{installation}$: Amount of refrigerant contained
$x_{installation}$: Fugitive refrigerant ratio from installation

➢ *Emissions from operation*

$$E_{operation} = \Sigma (N_{operated} \times m_{operation} \times x_{operation}) - R_{operation}$$

$E_{operation}$: Emissions from operation (includes emissions during servicing, accidents, and breakdowns)
$N_{operated}$: Number of devices operated
$m_{operation}$: Amount of refrigerant contained
$x_{operation}$: Fugitive refrigerant ratio from operation
$R_{operation}$: Amount collected during servicing

➢ *Emissions from disposal*

$$E_{disposal} = \Sigma (N_{disposed} \times x_{disposal}) - R_{disposal}$$

$E_{disposal}$: Emissions from disposal
$N_{disposed}$: Number of devices disposed
$x_{disposal}$: Average amount of refrigerant contained
$R_{disposal}$: Amount collected after use

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 4-63 Indices related to emissions of HFCs from commercial refrigeration

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Number of HFC devices produced	1,000 devices	NO	214	373	1,241	1,122	1,303	1,250	1,228	1,296	1,350	1,355	1,400	1,171	1,267	1,243
Average amount of refrigerant charged at production	g/device	372	372	586	3,281	3,280	3,413	3,539	3,473	3,358	3,329	3,480	3,627	3,684	3,488	3,537
Fugitive refrigerant ratio at production	%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.1%	0.3%	0.2%	0.2%	0.2%	0.2%	0.2%	0.1%	0.2%
Number of HFC devices charged in installation place	1,000 devices	NO	9	32	130	171	225	260	240	246	249	233	235	216	224	207
Average amount of refrigerant during installation	g/device	17,806	17,806	9,221	24,251	24,527	20,754	20,394	20,073	19,520	18,388	19,180	20,397	20,475	21,707	22,522
Fugitive refrigerant ratio during installation	%	1.2%	1.2%	1.4%	1.8%	1.6%	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%	1.7%
Number of HFC devices operated	1,000 devices	NO	375	1,957	6,770	11,843	14,653	15,498	16,215	16,939	17,642	18,253	18,813	19,050	19,340	19,552
Amount of refrigerant during operation	g/device	1,012	1,012	1,043	4,549	5,934	6,559	6,764	6,917	7,028	7,083	7,147	7,267	7,348	7,399	7,461
Fugitive refrigerant ratio during operation	%	7.3%	7.3%	7.4%	5.3%	5.9%	6.2%	6.3%	6.4%	6.1%	5.8%	5.6%	5.3%	5.2%	5.1%	4.8%
Number of HFC devices disposed	1,000 devices	NO	1	23	127	398	581	665	751	817	896	977	1,075	1,150	1,201	1,238
Amount of HFCs collected under law during maintenance	t	NO	NO	NO	NO	548	682	759	772	861	979	1,016	1,066	990	993	1,179
Amount of HFCs collected under law after use	t	NO	NO	NO	183	269	689	668	735	952	1,158	1,296	1,499	1,712	1,844	2,242
Emissions from manufacturing	kt-CO_2 eq.	NO	3	8	132	192	216	247	218	219	199	183	183	160	161	154
Emissions from stocks	kt-CO_2 eq.	NO	36	241	3,210	10,112	15,304	17,044	18,355	18,642	18,613	18,536	18,321	18,081	17,710	16,832
Emissions from disposal	kt-CO_2 eq.	NO	3	47	541	2,597	3,523	4,469	5,684	6,907	7,843	9,082	10,937	12,496	13,311	13,550
Emissions	kt-CO_2 eq.	NO	42	296	3,883	12,901	19,043	21,761	24,256	25,768	26,655	27,801	29,441	30,737	31,182	30,537

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: The weighted average GWP for manufacturing in 2022 is 1,761, 2,403 for stocks, and 2,088 for disposal. Emissions are calculated by gas but are reported as an unspecified mix due to confidentiality reasons.

Table 4-64 Type of HFC and emission factors during operation, by type of commercial refrigeration

Type of commercial refrigeration		Type of HFC	Amount of refrigerant	Emission factor		Share in the number of HFC devices operated
				- 2015[3)]	2016 -	(2022)
Large-size refrigerators	Centrifugal refrigerating machines	HFC-134a, R404A, etc	300 - 2,300 kg	7%	5.3%	0.02%
	Screw refrigerating machines	Same as above	Same as above	12%	8.9%	0.04%
Mid-size refrigerators	Separately-installed refrigeration showcases	R-404A, R-410A, etc	20 - 41 kg	16%	8.9%	7%
	Refrigeration units	R-404A, etc	2 - 30 kg	17%	8.9%	2%
	Condensing units	R-404A, R-410A, etc	Same as above	13%	8.9%	1%
	Chilling units for refrigerators	R-407C, R-410A, etc	Same as above	6%	0.8%	0.4%
	Other[1)]	R-404A, HFC-134a, etc	Same as above	15%	8.9%	2%
Commercial air conditioning devices	Packaged air conditioners for buildings	R-410A, R-407C, etc	37 kg	3.5%	2.9%	9%
	Packaged air conditioners for stores	R-410A, R-32, etc	3 - 43 kg	3%	1.0%	42%
	Packaged air conditioners for facilities	R-410A, R-407C, etc	Same as above	4.5%	1.8%	3%
	GHPs	R-410A, R-407C, etc	Same as above	5%	2.7%	2%
	Chilling units for air conditioners	R-410A, etc	Same as above	6%	0.8%	0.4%
Small-size refrigerators	Built-in refrigeration showcases	R-404A, HFC-134a, etc	0.1 - 3 kg	2%	1.0%	11%
	Other[2)]	HFC-134a, R-410A, etc	Same as above	Same as above	Same as above	20%

Reference: Committee for Greenhouse Gas Emissions Estimation Methods in FY2023

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

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) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainties of the emission factors, the 30% upper limit value for electrical equipment 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 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 fugitive refrigerant ratios during operation, etc for 2016 to 2021 and the updates of the number of devices charged at installation sites due to the addition of gases, etc for 2018 to 2021. 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
$N_{produced}$	: Number of devices produced
$m_{manufacturing}$	: Amount of refrigerant contained
$x_{manufacturing}$	: 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
$N_{operated}$	: Number of devices operated
$m_{operation}$	: Amount of refrigerant contained
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
$N_{disposed}$	: Number of devices disposed
$m_{disposal}$	: Amount of refrigerant contained
η	: Collection rate
$m_{disposal\text{-}avg}$	: Average amount of refrigerant contained
R	: Amount collected

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 4-65 Indices related to emissions of HFCs from automatic vending machines

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Number of HFC devices produced	1,000 devices	NO	NO	272	355	173	10	8	7	7	6	6	5	2	2	0
Refrigerant charged per device	g	NO	NO	300	220	219	219	219	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%	0.3%	0.3%	0.3%
Number of devices operated	1,000 devices	NO	NO	284	1,999	2,279	1,530	1,068	748	431	330	187	140	66	48	40
Incidence rate	%	NO	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
Fugitive refrigerant ratio (failure)	%	NO	0.2	0.2	0.2	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 (fixing)	%	NO	0.009	0.009	0.006	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
Number of devices disposed	1,000 devices	NO	NO	NO	NO	286	273	299	266	264	196	188	148	77	20	9
Emissions from manufacturing	kt-CO_2 eq.	NO	NO	1	0.4	0.2	0.01	0.01	0.01	0.01	0.01	0.01	0.004	0.002	0.002	0.000
Emissions from stocks	kt-CO_2 eq.	NO	NO	0.1	1	0.5	0.3	0.2	0.1	0.1	0.1	0.03	0.02	0.01	0.01	0.01
Emissions from disposal	kt-CO_2 eq.	NO	NO	NO	NO	25	19	21	19	19	14	13	11	5	1	1
Emissions	t	NO	NO	0.39	0.54	16.05	15.16	16.49	14.69	14.51	10.80	10.33	8.13	4.22	1.10	0.48
	kt-CO_2 eq.	NO	NO	1	1	26	20	21	19	19	14	13	11	5	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) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainties of the emission factors, the 30% upper limit value for electrical equipment 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 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
$M_{manufacturing}$	: Total refrigerant contained at production
k	: Fugitive refrigerant ratio at production
$N_{operated}$	: Number of operated devices containing HFCs
$m_{operation}$	: Refrigerant contained per operated device
$x_{operation}$	: Fugitive refrigerant ratio from use
$N_{disposed}$	: Number of disposed devices containing HFCs
$m_{disposal}$	: Refrigerant contained per disposed device
R	: Collected amount of HFCs

The associated indices are given in the table below.

Table 4-66 Indices related to emissions of HFCs from domestic refrigeration

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Total HFCs charged in the year of production	t	NO	520	590	0.3	NO	NO	NO	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	NO	NO	NO
Number of operated HFC devices	1,000 devices	NO	7,829	33,213	41,796	28,085	17,637	14,520	11,691	9,182	7,045	5,280	3,862	2,747	1,881	1,229
Refrigerant charged per device at production	g	150	150	125	125	125	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%	0.3%	0.3%	0.3%
Number of HFC devices disposed	1,000 devices	NO	NO	177	1,839	3,588	3,204	2,850	2,451	2,027	1,620	1,249	929	672	467	321
Amount of HFCs collected under law	t/year	–	–	–	52	111	189	166	144	138	132	136	132	128	113	105
Emissions from manufacturing	kt-CO_2 eq.	NO	7	8	0.001	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Emissions from stocks	kt-CO_2 eq.	NO	5	16	20	14	9	7	6	4	3	3	2	1	1	1
Emissions from disposal	kt-CO_2 eq.	NO	NO	28	224	418	254	228	194	135	79	16	NO	NO	NO	NO
Emissions	kt-CO_2 eq.	NO	11	52	244	432	263	235	199	140	83	19	2	1	1	1

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) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainties of the emission factors, the 30% upper limit value for electrical equipment 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 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 4.7.1.2. Commercial Refrigeration (2.F.1.-). 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 4-67 Indices related to emissions of HFCs from transport refrigeration (railways)

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Number of HFC devices produced[1)]	devices	0	0	30	0	0	0	0	0	0	0	0	0	0	0	0
Refrigerant HFC charged per device at production[1)]	kg	0	0	3	3	3	3	3	3	3	3	3	3	3	3	3
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%	0.2%	0.2%	0.2%
Fugitive refrigerant ratio during use	%	0%	0%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%
Number of HFC devices disposed	devices	0	0	6	1	14	14	17	21	23	11	11	1	0	1	0
Refrigerant stock in device disposed	kg	0	0	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Collection rate	%	0	0	0%	31%	31%	34%	32%	38%	39%	38%	39%	38%	41%	40%	44%
Emissions from manufacturing	kt-CO_2 eq.	NO	NO	0.001	NO	NO	NO	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	0.6	0.6	0.6
Emissions from disposal	kt-CO_2 eq.	NO	NO	NO	NO	0.1	0.1	0.1	0.1	0.1	0.04	0.04	0.004	NO	0.004	NO
Emissions (railways)	kt-CO_2 eq.	NO	NO	0.1	0.4	1	1	1	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 4-68 Indices related to emissions of HFCs from transport refrigeration (vessels)

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
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%	0.2%	0.2%	0.2%
Fugitive refrigerant ratio during use	%	0%	0%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%
Collection rate	%	0%	0%	0%	31%	31%	34%	32%	38%	39%	38%	39%	38%	41%	40%	44%
Emissions from manufacturing	kt-CO_2 eq.	NO	NO	0.01	0.1	0.1	0.4	0.3	0.2	0.4	0.4	0.3	0.3	0.3	0.3	0.2
Emissions from stocks	kt-CO_2 eq.	NO	NO	1	24	77	163	177	192	208	225	251	275	298	310	319
Emissions from disposal	kt-CO_2 eq.	NO	NO	NO	NO	0.02	0.8	1.8	1.7	2.6	4.1	5.4	5.9	5.9	7.0	6.1
Emissions (vessels)	kt-CO_2 eq.	NO	NO	1	24	78	164	179	194	211	229	257	281	305	318	326

Reference: IPCC default values, *Report on Maritime Affairs* (Ministry of Land, Infrastructure, Transport and Tourism), etc.

c) Uncertainties and Time-series Consistency

- **Uncertainty**

Same as Commercial Refrigeration (2.F.1.a.).

- **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 corrections to the amount of fugitive refrigerants during use which was

used for the estimation of emissions (vessels) during use for 2006 to 2021. Updates in the *Railway Statistical Yearbook* for 2021 also contributed to recalculations. See Chapter 10 for impact on trend.

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
$N_{produced}$	: Number of devices produced
$m_{manufacturing}$	: Amount of refrigerant contained
$x_{manufacturing}$	: 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
$N_{operated}$	: Number of cars operated
$m_{operation}$	: Amount of refrigerant contained
$x_{operation}$	: 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
$N_{operated}$	: number of cars operated

$m_{operation}$: amount of refrigerant contained
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
$N_{destroyed}$: number of cars in completely destroyed
$m_{operation}$: amount of refrigerant contained at time of accident

➢ *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
$N_{disposed}$: number of cars disposed
$m_{disposal}$: amount of refrigerant contained
η : collection rate
$m_{disposal\text{-}avg}$: average amount of refrigerant contained
R : amount collected

Relevant indices are shown in Table below.

Table 4-69 Indices related to emissions of HFC-134a from car air conditioners

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Number of cars produced	1,000 devices	0	9,681	9,761	10,407	9,292	9,613	9,753	9,273	9,205	9,652	9,441	8,433	5,148	4,034	2,805
Fugitive refrigerant during production	g	4	4	4	3	1	1	1	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	72,813	73,272	73,861	74,282	74,398	73,763	72,333	70,309	67,345
Average refrigerant charged per device	g	700	700	615	548	497	497	497	497	497	497	497	497	497	497	497
Fugitive refrigerant ratio during use per year per device (normal car)	g	15	15	15	10	10	10	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%	4%	4%	4%
Fugitive refrigerant ratio from breakdown cars	%	50%	50%	50%	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	233	234	236	238	238	236	231	225	215
Average refrigerant charged in completely destroyed cars	g	681	681	610	522	448	417	409	404	400	394	388	384	379	374	366
Number of cars disposed	1,000 devices	0	116	789	2,058	2,895	2,835	2,839	2,694	2,666	2,927	2,941	2,920	2,763	2,667	2,384
Average refrigerant charged at time of disposal	g	676	676	593	522	444	412	393	380	370	360	349	347	339	337	334
Amount of HFC collected (under law from FY2002)	t/year	-	-	-	531	898	785	773	710	682	720	718	694	625	579	501
Emissions from manufacturing	kt-CO_2 eq.	NO	44	44	41	12	10	9	9	9	9	9	8	5	4	2
Emissions from stocks	kt-CO_2 eq.	NO	640	1,635	2,119	2,020	2,069	2,050	2,027	2,013	1,991	1,964	1,925	1,867	1,797	1,702
Emissions from disposal	kt-CO_2 eq.	NO	102	608	707	505	498	448	409	397	434	402	417	405	415	383
Emissions	kt-CO_2 eq.	NO	786	2,287	2,866	2,537	2,578	2,506	2,445	2,419	2,434	2,375	2,349	2,277	2,217	2,087

Reference: *Documents of Fluorocarbons etc Measures Working Group*, *Documents of the first meeting of the Breakout Group on F-gases (FY2013)*

Table 4-70 Indices related to emissions of HFCs from air conditioners (railways)

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
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%	0.2%	0.2%	0.2%
Fugitive refrigerant ratio during use	%	0%	5%	5%	5%	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	0.05	0.1	0.1	0.1	0.1	0.1	0.1
Emissions from stocks	kt-CO_2 eq.	NO	0.3	1.5	6.3	14.2	18.1	19.5	20.8	22.0	23.4	24.9	26.4	27.7	29.3	30.7
Emissions from disposal	kt-CO_2 eq.	NO	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.04	0.05	0.1	0.1	0.1	0.1	0.0
Emissions (railways)	kt-CO_2 eq.	NO	0.4	2	6	14	18	20	21	22	23	25	27	28	29	31

Reference: *Railway Statistical Yearbook*, *Yearbook of Railway Car Production Statistics* (Ministry of Land, Infrastructure, Transport and Tourism), IPCC default values, etc.

Table 4-71 Indices related to emissions of HFCs from air conditioners (vessels)

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
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%	0.2%	0.2%	0.2%
Fugitive refrigerant ratio during use	%	0%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%	20%
Collection rate	%	0%	0%	0%	0%	31%	34%	32%	38%	39%	38%	39%	38%	41%	40%	44%
Emissions from manufacturing	kt-CO_2 eq.	NO	0.0003	0.004	0.1	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.05	0.05
Emissions from stocks	kt-CO_2 eq.	NO	0.1	0.9	25.8	108.2	147.2	156.4	162.3	170.5	176.2	181.2	186.6	189.9	188.5	189.3
Emissions from disposal	kt-CO_2 eq.	NO	NO	NO	NO	0.01	0.1	0.3	0.2	0.4	0.6	0.8	1.2	1.6	2.6	2.4
Emissions (vessels)	kt-CO_2 eq.	NO	0.1	1	26	108	148	157	163	171	177	182	188	192	191	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) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 4.3.9.1. 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 of emission from car air conditioners occurred for 1992 to 1994, 1995, and 2016 to 2021, due to corrections to the number of cars produced, etc. For 2021, updates in the *Railway Statistical Yearbook* also contributed to recalculations. 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. The HFC-125 IEF fluctuation between 2009 and 2010 (-9.9%), and 2014 and 2015 (5.6%) is affected by the change in amounts collected at disposal.

➢ ***Emissions from manufacturing***

$$E_{manufacturing} = \Sigma \left(N_{produced} \times m_{manufacturing\text{-}avg} \times x_{manufacturing}\right)$$

$E_{manufacturing}$	: Emissions from manufacturing
$N_{produced}$	: Number of devices produced
$m_{manufacturing\text{-}avg}$	: Average amount of refrigerant contained
$x_{manufacturing}$	: 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
$N_{operated}$	: Number of devices operated
$m_{operation\text{-}avg}$	: Average amount of refrigerant contained
$x_{operation}$	: 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
$N_{disposed}$	: Number of devices disposed
$m_{disposal\text{-}avg}$	: Average amount of refrigerant contained
R	: Amount collected

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 4-72 Indices related to emissions of HFCs from stationary air-conditioning (household)

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Number of HFC devices produced	1,000 devices	NO	NO	1,077	3,981	3,460	3,920	3,507	4,160	4,080	4,193	4,358	3,891	4,078	3,406	3,624
Refrigerant charged per device	g	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Fugitive refrigerant ratio at production	%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
Number of devices operated	1,000 devices	NO	NO	1,726	26,091	61,540	83,349	89,020	94,197	99,157	104,067	109,193	113,317	117,693	120,810	123,383
Average refrigerant charged during use	g/device	NO	NO	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Fugitive refrigerant ratio during use	%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Number of devices disposed	1,000 devices	NO	NO	2	83	764	1,907	2,423	2,990	3,567	4,145	4,688	5,220	5,720	6,181	6,581
Average refrigerant stock in device disposed	g/device	NO	NO	954	911	841	803	796	792	795	796	804	815	825	830	832
Amount of HFCs collected under law	t/year	-	-	-	10	231	466	508	570	700	892	1,181	1,367	1,599	1,622	1,647
Emissions from manufacturing	kt-CO_2 eq.	NO	NO	4	15	12	10	6	5	3	3	3	2	2	2	2
Emissions from stocks	kt-CO_2 eq.	NO	NO	66	1,004	2,367	3,157	3,263	3,285	3,270	3,240	3,200	3,136	3,066	2,972	2,866
Emissions from disposal	kt-CO_2 eq.	NO	NO	3	128	844	2,120	2,749	3,471	4,135	4,665	5,014	5,480	5,850	6,352	6,769
Emissions	kt-CO_2 eq.	NO	NO	73	1,147	3,224	5,288	6,019	6,761	7,408	7,908	8,217	8,619	8,919	9,326	9,637

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) Uncertainties and Time-series Consistency

- ***Uncertainty***

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.

4.7.2. 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 4-73 Indices related to emissions of HFCs from urethane foam

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
HFC-134a use	t	NO	NO	167	224	66	28	14	12	NO	NO	NO	NO	NO	NO	NO
HFC-245fa use	t	NO	NO	NO	3,893	2,365	2,570	2,533	2,230	2,577	2,596	2,365	1,626	618	551	445
HFC-365mfc use	t	NO	NO	NO	1311	900	921	866	779	794	802	744	702	203	186	151
Leakage during foam blowing	%	10%	10%	10%	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%	4.5%	4.5%	4.5%
HFC-134a emissions	kt-CO_2 eq.	NO	NO	22	102	121	126	125	126	125	125	125	125	125	115	105
HFC-245fa emissions	kt-CO_2 eq.	NO	NO	NO	408	953	1,263	1,359	1,431	1,547	1,648	1,728	1,756	1,732	1,751	1,763
HFC-365mfc emissions	kt-CO_2 eq.	NO	NO	NO	132	322	427	456	480	509	539	563	587	572	578	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) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 4-74 Indices related to emissions of HFC-134a from extruded polystyrene foam

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
HFC-134a use	t	NO	NO	NO	26	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Foam productization rate	%	-	-	-	75%	75%	75%	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%	0.8%	0.8%	0.8%
Emissions during production	t	NO	NO	NO	6.50	NO	NO	NO	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	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	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	NO	NO	NO
Emission during use	kt-CO_2 eq.	NO	NO	NO	12	12	12	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	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) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 4-75 Indices related to emissions of HFC-134a from high expanded polyethylene foam

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
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	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	99.86	99.86	99.86
	kt-CO_2 eq.	1	450	419	166	130	130	130	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 4-76 Indices related to emissions of HFC-152a from high expanded polyethylene foam

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
HFC-152a use	t	0.04	14.00	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Emissions	t	0.04	14.00	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	kt-CO_2 eq.	0.005	2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	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) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 halogen 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 4-77 References for the Emission factor of fire extinguishers
(The emission ratio of halon fire extinguishers)

	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 4-78 Actual data of halon extinguishing agents used for establishing the emission factor

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Recycled amounts (R)	t						1,426	842	693	775	1,120	900	584	649	584	517
Emissions from recycling operation (E1)	t						11	6	5	6	8	6	4	4	4	3
Emissions from events other than recycling operation, such as accidents (E2)	t						11	7	10	6	10	19	12	7	12	9

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 4-79 The installation amounts of the HFC extinguishing agents

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Installation amounts of HFC-23	t	NO	NO	56.29	19.02	10.84	4.03	9.58	13.18	7.11	6.05	6.62	0.76	0.12	1.79	NO
Cumulative amounts of HFC-23 installed	t	NO	NO	306.38	478.27	523.12	536.67	546.25	559.43	566.54	572.59	579.21	579.97	580.09	581.88	581.88
Installation amounts of HFC-227ea	t	NO	NO	44.74	31.95	24.25	43.53	45.78	52.57	15.34	46.55	9.42	36.21	16.45	11.39	10.27
Cumulative amounts of HFC-227ea installed	t	NO	NO	225.28	391.73	522.44	639.97	685.75	738.32	753.66	800.21	809.63	845.84	862.29	873.68	883.95

➢ ***Emissions from disposal***

The amounts of installation and registration of HFC extinguishing agents provided by the Syoubou Kankyo Network were used.

Table 4-80 Amount of installation/registration of HFC extinguishing agents

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Installation amounts of HFC-23	t					10.84	4.03	9.58	13.18	7.11	6.05	6.62	0.76	0.12	1.79	0.00
Registration amounts of HFC-23	t					42.58	54.38	63.88	75.01	82.35	87.63	93.66	93.54	91.51	92.84	91.84
Installation amounts of HFC-227ea	t					24.25	43.53	45.78	52.57	15.34	46.55	9.42	36.21	16.45	11.39	10.27
Registration amounts of HFC-227ea	t					123.48	243.86	274.07	339.41	354.68	408.27	417.93	453.63	469.93	481.41	491.61

For years prior to 2008 due where data was not available, see the section “Estimation Method”.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

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

Emissions from disposal were newly estimated. See Chapter 10 for impact on trend.

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 4-81 Indices related to emissions of HFC-134a from MDI

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Usage of domestic MDI	t	NO	NO	1.40	0.90	1.07	0.60	0.90	0.59	0.91	0.60	0.75	0.74	0.75	0.60	0.75
Usage of imported MDI	t	NO	NO	42.00	70.70	57.05	46.04	42.36	41.34	39.16	34.17	35.03	32.73	34.55	30.47	28.16
Amount collected and destroyed	t	NO	NO	0.10	1.90	2.52	0.72	0.23	3.56	0.42	0.13	0.03	0.07	0.04	0.34	0.96
HFC-134a emissions	t	NO	NO	37.20	62.75	55.52	47.23	44.91	39.35	40.72	37.38	35.35	34.66	34.48	32.94	29.15
	kt-CO_2 eq.	NO	NO	48	82	72	61	58	51	53	49	46	45	45	43	38

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 4-82 Indices related to emissions of HFC-227ea from MDI

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Usage of domestic MDI	t	NO	NO	NO	41.00	35.96	25.11	21.02	22.96	21.41	17.84	18.43	19.63	20.06	19.76	19.19
Usage of imported MDI	t	NO	NO	3.60	2.10	0.42	0.73	0.38	18.75	20.16	27.48	26.17	37.86	39.85	30.51	33.39
Amount collected and destroyed	t	NO	NO	NO	1.20	0.80	0.77	0.54	0.70	0.23	0.33	0.32	0.09	0.02	0.05	0.03
HFC-227ea emissions	t	NO	NO	1.80	48.05	33.14	26.93	23.93	31.70	41.94	43.95	45.41	51.54	59.16	55.15	51.87
	kt-CO_2 eq.	NO	NO	6	161	111	90	80	106	140	147	152	173	198	185	174

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) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 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.

4.7.4.2. 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 is 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 4-83 Indices related to emissions of HFC-134a from aerosols

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Potential emissions	t	NO	1,300.00	2,044.10	604.40	199.92	168.00	223.00	206.00	236.00	193.00	159.00	226.00	246.00	183.00	98.00
Fugitive emissions during production	t	NO	NO	80.20	24.90	8.08	7.00	12.00	15.00	22.00	35.00	38.50	37.00	48.00	44.50	21.00
Emissions in the year produced, during use	t	NO	650.00	1,022.05	302.20	99.96	84.00	111.50	103.00	118.00	96.50	79.50	113.00	123.00	91.50	49.00
Remaining (emissions in the next year)	t	NO	650.00	1,022.05	302.20	99.96	84.00	111.50	103.00	118.00	96.50	79.50	113.00	123.00	91.50	49.00
HFC-134a emissions	t	NO	1,050.00	2,137.10	908.15	223.04	174.85	207.50	229.50	243.00	249.50	214.50	229.50	284.00	259.00	161.50
	kt-CO_2 eq.	NO	1,365	2,778	1,181	290	227	270	298	316	324	279	298	369	337	210

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 4-84 Indices related to emissions of HFC-152a from aerosols

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Potential emissions	t	NO	NO	34.10	1,299.50	558.00	320.00	353.00	279.00	328.00	276.00	226.00	142.00	27.00	30.00	30.00
Fugitive emissions during production	t	NO	NO	1.10	28.90	638.00	249.00	185.00	108.50	68.00	89.00	75.00	45.50	17.00	1.00	NO
Emissions in the year produced, during use	t	NO	NO	17.05	649.75	279.00	160.00	176.50	139.50	164.00	138.00	113.00	71.00	13.50	15.00	15.00
Remaining (emissions in the next year)	t	NO	NO	17.05	649.75	279.00	160.00	176.50	139.50	164.00	138.00	113.00	71.00	13.50	15.00	15.00
HFC-152a emissions	t	NO	NO	18.15	1,216.95	1,299.00	680.00	521.50	424.50	371.50	391.00	326.00	229.50	101.50	29.50	30.00
	kt-CO_2 eq.	NO	NO	3	168	179	94	72	59	51	54	45	32	14	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 4-85 Indices related to emissions of HFC-245fa from aerosols

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017 onward
Potential emissions	t	NO	NO	NO	0.80	0.39	0.17	1.10	0.28	NO	NO
Fugitive emissions during production	t	NO	NO	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	0.55	0.14	NO	NO
Remaining (emissions in the next year)	t	NO	NO	NO	0.40	0.19	0.09	0.55	0.14	NO	NO
HFC-245fa emissions	t	NO	NO	NO	0.55	0.35	0.63	0.64	0.69	0.14	NO
	kt-CO_2 eq.	NO	NO	NO	0.5	0.3	0.5	0.5	0.6	0.1	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 4-86 Indices related to emissions of HFC-365mfc from aerosols

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017 onward
Potential emissions	t	NO	NO	NO	1.12	NO	NO	0.24	0.24	NO	NO
Fugitive emissions during production	t	NO	NO	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	0.12	NO	NO
Remaining (emissions in the next year)	t	NO	NO	NO	0.56	NO	NO	0.12	0.12	NO	NO
HFC-365mfc emissions	t	NO	NO	NO	0.74	NO	0.14	0.12	0.24	0.12	NO
	kt-CO_2 eq.	NO	NO	NO	1	NO	0.1	0.1	0.2	0.1	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 4-87 Indices related to emissions of HFC-43-10mee from aerosols

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017 onward
Potential emissions	t	NO	NO	NO	NO	NO	NO	0.50	0.34	NO	NO
Fugitive emissions during production	t	NO	NO	NO	NO	NO	NO	0.02	0.01	NO	NO
Emissions in the year produced, during use	t	NO	NO	NO	NO	NO	NO	0.25	0.17	NO	NO
Remaining (emissions in the next year)	t	NO	NO	NO	NO	NO	NO	0.25	0.17	NO	NO
HFC-43-10-mee emissions	t	NO	NO	NO	NO	NO	NO	0.27	0.43	0.17	NO
	kt-CO_2 eq.	NO	NO	NO	NO	NO	NO	0.4	0.7	0.3	NO

Reference: Data provided by METI

Table 4-88 Indices related to emissions of HFC-227ea from aerosols

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016 onward
Potential emissions	t	NO	NO	NO	NO	NO	NO	2.08	NO	NO
Fugitive emissions during production	t	NO	NO	NO	NO	NO	NO	0.12	NO	NO
Emissions in the year produced, during use	t	NO	NO	NO	NO	NO	NO	1.04	NO	NO
Remaining (emissions in the next year)	t	NO	NO	NO	NO	NO	NO	1.04	NO	NO
HFC-227ea emissions	t	NO	NO	NO	NO	NO	NO	1.16	1.04	NO
	kt-CO_2 eq.	NO	NO	NO	NO	NO	NO	4	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) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 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 due to the addition of gases for 2014 to 2016 and onward. See Chapter 10 for impact on trend.

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 4-89 Number of dry cleaning machines using Solkane Dry and average solvent amount used

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Cumulative number of specialized and mixed-use machines	units	0	0	0	12	121	216	234	246	259	268	272	283	292	297	298
Average solvent use per year (specialized)	kg/unit	0	0	0	673	673	678	713	699	692	602	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 2022 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 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) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 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 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 FY2022, emissions from this category were 1,567 kt-CO_2 eq. and represented 0.1% of Japan's total GHG emissions (excluding LULUCF). The total emissions of N_2O from this category had decreased by 62.7% compared to FY1990. The total of HFCs, PFCs and SF_6 had decreased by 83.8% compared to 1990.

Table 4-90 Emissions from Other Product Manufacture and Use (2.G.)

Gas			Units	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
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	1.11	0.22	0.22	0.23	0.21	0.27	0.28	0.33	0.35
	Total		kt-CO_2 eq.	245	374	291	228	85	67	294	58	58	62	56	70	75	87	92
Gas			Units	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
HFCs	2.G.4	PFCs and HFCs from Waterproofing electronic circuits	kt-CO_2 eq.	6	5	6	4	3	2	2	2	3	2	2	5	5	6	6
PFCs	2.G.2	Other-Railway silicon rectifiers	kt-CO_2 eq.	NO	NO	NO	0.2	4	9	8	7	18	17	33	41	48	58	60
	2.G.4	PFCs and HFCs from Waterproofing electronic circuits	kt-CO_2 eq.	15	12	15	10	7	5	6	5	6	5	6	11	12	12	13
SF_6	2.G.1	Electrical equipment	t	355.81	460.46	127.62	40.70	30.03	29.75	27.84	29.18	28.74	27.19	25.09	25.12	25.06	26.20	24.72
	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	1.23	1.23	1.23
		Accelerators	t	30.77	35.16	34.49	35.69	33.89	35.18	35.12	34.40	33.52	34.04	34.63	34.70	33.33	33.39	33.50
	Total		t	386.58	495.62	163.34	77.61	65.15	66.16	64.19	64.80	63.49	62.46	60.95	61.05	59.62	60.82	59.45
	Total		kt-CO_2 eq.	9,085	11,647	3,839	1,824	1,531	1,555	1,508	1,523	1,492	1,468	1,432	1,435	1,401	1,429	1,397
Total of F-gases			kt-CO_2 eq.	9,106	11,665	3,860	1,839	1,545	1,571	1,524	1,537	1,518	1,492	1,474	1,492	1,466	1,506	1,475

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 4-91 Indices related to emissions of SF_6 from electrical equipment

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Emissions during manufacturing	kt-CO_2 eq.	7,264	9,400	2,362	569	227	166	175	225	185	146	122	116	103	92	88
SF_6 emissions during use, maintenance, and disposal	kt-CO_2 eq.	1,098	1,421	638	388	479	533	479	460	491	493	467	474	486	524	493

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) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 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 updates of SF_6 amounts purchased and assembly fugitive rate, etc for 2004 to 2015. 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
D : Decrease of SF_6 in the container on board the AWACS
M : SF_6 leakage during acquisition/replacement of SF_6 container on AWACS
R : SF_6 collected/destroyed
I : Net increase in AWACS fleet charge

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) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 production 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
N : Number of accelerators
U : SF_6 use factor
C : SF_6 charge factor
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 4-92 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]	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 4-93 SF_6 emission factor for particle accelerators at university/research facilities

Item	1990-2004	2005-2009	2010-2014	2015-2019	2019-2022
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 4-94 Number of accelerators by type

Item	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Number of particle accelerators (University/Research facilities)	188	214	212	209	218	225	222	241	245	242	239	239	239	239	239
Number of particle accelerators (Industrial use)	143	164	145	181	174	188	190	193	183	191	198	198	198	198	198
Number of particle accelerators (Medical use)	531	641	754	857	926	1,068	1,081	1,108	1,114	1,146	1,132	1,132	1,132	1,132	1,132
Number of small-scale (below 1MeV) electron accelerators	243	276	314	282	218	201	197	201	196	192	196	198	200	202	206

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) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 production 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 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) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainty of the emission factor from railway silicon rectifiers, 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 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 anesthetics, 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
S : N_2O shipped for medical use
U : Amount of laughing gas used in hospitals equipped with N_2O destruction units
DR : Destruction rate

- ***Emission Factors***

It is assumed that all of the N_2O used as medical gas escapes into the atmosphere, unless collected. Therefore, no emission factor has been established.

- ***Activity Data***

The amount of shipments of N_2O for anesthetics (calendar year basis) is given in the *Statistics of Production by Pharmaceutical Industry* (Ministry of Health, Labour and Welfare). This is used for 2005 and preceding years, and 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 4-95 Laughing gas shipment amount and N_2O collected in domestic hospitals

Item	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Laughing gas shipment amount	926,030	1,411,534	1,099,979	859,389	320,110	253,218	1,111,265	219,011	219,011	234,691	211,842	265,728	283,333	330,111	345,452
N_2O collected in domestic hospitals	NO	NO	NO	NO	914	509	NO	NO	NO	NO	NO	NO	NO	NO	NO

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

Because all N_2O used for anesthetics 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 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) *Japan Electronics Packaging and Circuits Association*

The emission factor for each gas used for the estimation are as shown in the following table.

Table 4-96 Emission factors for estimation of 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) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainties of the emission factors for PFCs and HFCs, 200%, the upper limit value of the Tier 1 method for semiconductors 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.

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. 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 FY2022, emissions from this category were 885 kt-CO_2 and represented 0.1% of Japan's total GHG emissions (excluding LULUCF). The emissions had increased by 1.3% compared to FY1990.

Table 4-97 Emissions from Other (2.H.)

Gas				Units	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
CO_2	2.H.2	Food and beverages industry		kt-CO_2	94	107	100	104	91	103	99	110	115	115	120	124	121	124	126
	2.H.3	Emissions from imported carbonated gas		kt-CO_2	0.3	0.3	0.2	0.2	1	11	10	14	28	26	25	21	16	7	10
		Utilization of carbonated gas	Dry ice	kt-CO_2	285	286	306	316	332	361	366	371	368	372	371	359	348	369	342
			Welding	kt-CO_2	283	321	301	316	323	309	302	321	321	323	309	301	261	254	269
			Cooling	kt-CO_2	113	128	120	111	75	74	72	74	74	72	65	65	66	58	60
			Other	kt-CO_2	99	112	105	97	58	45	49	64	68	74	69	75	72	83	79
			Environmentally friendly concrete[1)]	kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	-0.001	-0.0004	NO	-0.01	-0.01
	Total			kt-CO_2	874	954	933	944	880	904	898	954	972	982	959	945	884	894	885

Note: 1) CO_2 fixing concrete during manufacturing

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 (FY2022)

Source categories		Emissions [kt-CO_2] (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	31,730	−	581	+	0	→	31,149
1.A.2.a.	Iron and steel	114,349		21		0		114,327
2.B.1.	Ammonia production	1,250		341		0		909
2.B.8.d.	Ethylene oxide production	204		37		0		167
2.B.10.	Chemical industry—Other	17		0		68		86
2.C.1.	Iron and steel production	5,171		0		37		5,208
2.H.2.	Food and Beverages Industry	0		0		126		126
2.H.3.-	Utilization of Carbonated Gas							
	Dry ice	0		0		342		342
	Welding	0		0		269		269
	Cooling	0		0		60		60
	Other	0		0		79		79
Total		152,721		980		980		152,721

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 in FY2023 with the cooperation of Japan Industrial and Medical Gases Association and the DryIce Maker Association.

a) Amount of CO_2 Recovery

For the amount of CO_2 recoveries for liquefied CO_2, the breakdown of CO_2 production amounts by sources provided by the Japan Industrial and Medical Gases Association was used. 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, 2014, and 2020 to 2021, interpolation using the composition ratios of the breakdown by the sources from other fiscal years were applied, and then recoveries were estimated by multiplying the total production for each of the fiscal years by the above interpolated composition ratios. For fiscal years lacking data on total recoveries - 1990, 1991, and 1993 to 1995, interpolation using the total production of the other fiscal years was used.

Table 4-98 CO_2 recoveries for liquefied CO_2 by the breakdown of the sources

Sources (Categories)	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Petroleum refining (1.A.1.b.)	kt	242	275	307	359	353	334	315	326	336	348	340	360	326	339	366
Iron (1.A.2.a.)	kt	69	98	84	75	8	9	17	28	26	23	24	21	21	21	21
Ammonia (2.B.1.)	kt	279	311	260	222	238	247	233	241	240	246	226	236	213	210	214
Ethylene oxide (2.B.8.d.)	kt	65	58	45	52	30	33	46	66	72	64	73	56	50	44	37

For the amounts of CO_2 recoveries for dry ice, domestic shipment 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 fiscal years lacking data on domestic shipment amounts for before FY2009, estimates were made by multiplying the carbonated gas production for each of fiscal year given in the *Yearbook of Current Production Statistics - Chemical Industry* by the ratio of domestic shipment to the carbon dioxide production in FY2010. For the breakdown of dry ice by the sources, estimates were made by multiplying the total shipment of dry ice for each of the fiscal years by the composition ratio of petroleum refining and ammonia production for liquid CO_2, using the CO_2 recoveries for liquefied CO_2 by the sources.

Table 4-99 Dry ice domestic shipment amounts and the breakdown of the sources

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Dry ice shipment amount	kt	285	286	306	316	332	361	366	371	368	372	371	359	348	369	342
Sources (categories)																
Petroleum refining (1.A.1.b.)	kt	132	134	166	195	198	208	210	213	214	218	223	217	210	227	215
Ammonia production (2.B.1.)	kt	152	152	141	121	134	154	155	158	153	154	148	142	138	141	126

b) Amount of CO_2 Utilized

For utilized liquefied CO_2, the breakdown of actual shipment amounts for liquefied CO_2 by the uses given by the website of Japan Industrial and Medical Gases Association was used, based on the assumption that the utilized liquefied CO_2 amounts are equal to the production.

Table 4-100 The breakdown of domestic utilized amounts of CO_2 by use for liquefied CO_2 and categories to which they are allocated

Uses (Allocated category)	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Chemical (2.B.10.b.-)	kt	39	45	42	39	41	51	51	53	56	59	62	64	58	58	68
Iron (2.C.1.f.-)	kt	26	29	28	42	41	40	38	39	41	39	39	44	33	37	37
Beverage (2.H.2.)	kt	94	107	100	104	91	103	99	110	115	115	120	124	121	124	126
Feeding (2.H.3.-)	kt	283	321	301	316	323	309	302	321	321	323	309	301	261	254	269
Cooling (2.H.3.-)	kt	113	128	120	111	75	74	72	74	74	72	65	65	66	58	60
Other (2.H.3.-)	kt	99	112	105	97	58	45	49	64	68	74	69	75	72	83	79

Note: For FY1990 to FY2003, estimates of utilized amounts of CO_2 by use were made by multiplying the total recoveries for each fiscal year by the composition ratio for FY2004.

For the amounts of utilized CO_2 for dry ice, all dry ice shipments are allocated under the Emissions from Imported Carbonated Gas (2.H.3.-) category.

4.9.2. Food and Beverages Industry (2.H.2.)

Of the amount of CO_2 recoveries for liquefied CO_2 subtracted from the CO_2 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.), 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 were established since the activity data is directly the emissions.

- ***Activity Data***

The import quantities of carbon dioxide in the *Trade Statistics of Japan* was used for estimating emissions.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

No emission factor has been set because all CO_2 are 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***

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.

4.9.4. Utilization of Carbonated Gas (2.H.3.-)

a) Category Description

CO_2 is emitted from use of liquid CO_2 and dry ice.

b) Methodological Issues

- ***Estimation Method***

Of the amount of CO_2 recoveries for liquefied CO_2 subtracted from the CO_2 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.), all utilized amounts for welding, cooling and other uses are allocated under this category. All CO_2 recoveries for dry ice subtracted from CO_2 emissions from Petroleum refining

(1.A.1.b.) and Ammonia production (2.B.1.) are assumed to be emitted into the atmosphere, and therefore are allocated under this category. See section 4.9.1. for details.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

Because all utilized carbonated gas is assumed to escape into the atmosphere, no emission factor has been set. Therefore, the uncertainty for activity data is also the uncertainty for emissions. For the uncertainty of activity data, a 2% default value given by *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

CO_2 emissions were newly estimated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.9.5. Environmentally Friendly Concrete

Japan's Plan for Global Warming Countermeasures (Cabinet approved on October 22, 2021) includes the promotion of innovation in CCU, etc, and therefore methods for reflecting CO_2 reduction in the inventory using various CCU technologies are under consideration by the Committee for the Greenhouse Gas Emission Estimation Methods. As a result of consideration, the amount of CO_2 fixation by environmentally friendly concrete are estimated and subtracted from the emissions from the category where the CO_2 was recovered for the manufacturing of the environmentally friendly concrete.

Table 4-101 Amount of CO_2 fixation by environmentally friendly concrete

Item and allocated of category	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
CO_2 fixing concrete during manufacturing																
2.H.3.-	t	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.79	0.42	NO	5.94	7.70
Concrete using CO_2-origin material																
1.A.2.c	t	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.06
1.A.2.d	t	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	1.02
1.A.2.f	t	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	1.34	2.80
Concrete using biochar																
4.H.	t	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	5.89

4.9.5.1. CO_2 Fixing Concrete During Manufacturing (2.H.3.-)

a) Category Description

This category deals with the amount of CO_2 forcibly fixed inside concrete as calcium carbonates, during manufacturing. At present, one product 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 average measurements by product and by specification, because the amount of CO_2 fixation fluctuates depending on the mixture ratio of the CO_2 fixing concrete product and/or the manufacturing technique, 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 [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]

- ***Fixation factors***

CO_2 fixation factors are established by the 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 factor is confidential.

- ***Activity Data***

The production amount by each of the specifications of the product provided by the manufacturer was used. The AD is confidential.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the uncertainty of fixation factors, -17% to 10% based on the results of analysis of samples of CO_2 fixation 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 in the *2006 IPCC Guidelines* was applied. As a result, the uncertainty of CO_2 fixations was estimated as -13% to 8%.

- ***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

The amount of CO_2 fixation were newly estimated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.9.5.2. Concrete Using CO_2-origin Material (1.A.2.c., 1.A.2.d., 1.A.2.f.)

a) Category Description

This category deals with the amount of CO_2 fixed inside the concrete manufactured by using carbonate

material that fixes CO_2. At present, one product 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 consumption amount of CO_2-origin material for concrete using CO_2-origin material by the average CO_2 fixation factor for CO_2-origin material (Equation 1).

When the consumption amount is not available, the amount of CO_2 fixation is estimated by multiplying the production amount of concrete using CO_2-origin material by the CO_2 fixation factor per unit of the production of concrete (Equation 2). Estimations were made per same type and mixture ratio of the CO_2-origin material because the amount of CO_2 fixation fluctuates depending on the type and/or combination (mixture) of the CO_2-origin material.

(Equation 1) $F_{CO2} = \Sigma_k (m_k \times F_k)$

F_{CO2} : Amount of CO_2 fixation by the concrete using CO_2-origin material [t-CO_2]
m_k : Consumption amount of the CO_2-origin material k [t]
f_k : Amount of CO_2 fixation per unit weight of the CO_2-origin material k [t-CO_2/t]

(Equation 2) $F_{CO2} = \Sigma_i (V_i \times f_i)$

F_{CO2} : Amount of CO_2 fixation by the concrete using CO_2-origin material [t-CO_2]
V_i : Volume of production of concreate type i [m^3]
f_i : Amount of CO_2 fixation per unit volume of concreate i [t-CO_2/m^3]

- ***Fixation Factor***

For the product estimated by Equation 1, the amount of CO_2 fixation per unit weight was established, based on the consideration of the purity of $CaCO_3$ of the materials used in the product for each of the fiscal years, provided by the manufacturer of the CO_2-origin material.

For the product estimated by Equation 2, the CO_2 fixation factors for each year were established by taking a weighted average of the CO_2 fixation amounts by product and per unit volume, by the amount of concrete production, based on the records on mixtures of the concreate, etc, provided by the manufacturer of the concrete product.

The CO_2 fixation factor is confidential.

- ***Activity Data***

For the product estimated by Equation 1, the consumption amount of the CO_2-origin material, estimated by using the amount of CO_2-origin material per unit volume mixed into the concrete, provided by the manufacturer of the concrete product was used.

For the product estimated by Equation 2, the production volume of the concrete was used.

The AD is confidential.

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

For the product estimated by Equation 1, 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 provided by the manufacturer of the material was applied. For the uncertainty of activity data, the default value of 5% for the Tier 3 method for chemical industry in the *2006 IPCC Guidelines* was applied. As a result, the uncertainty of CO_2 fixations was estimated as -6% to 6%.

For the product estimated by Equation 2, the uncertainty of fixation factors, -2% to 2% based on the result of analysis of CO_2 fixation in the actual manufacturing data provided by the manufacturer of the concrete product was applied. For the uncertainty of activity data, the default value of 5% for the Tier 3 method for chemical industry in the *2006 IPCC Guidelines* was applied. As a result, the uncertainty of CO_2 fixations was estimated as -4% to 3%.

- ***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

The amount of CO_2 fixation were newly estimated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.9.5.3. 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 are 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]

$$Outflow_{n+k,i} = Inflow_{n,i}$$

k : Lifetime of the product using biochar i [year]
Note: A 65-year service life was used based on the standard level planned service life, given in the *Japanese Architectural Standard Specification* by the Architectural Institute of Japan.

- ***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) Uncertainties and Time-series Consistency

- ***Uncertainty***

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 in the *2006 IPCC Guidelines* was applied. As a result, the uncertainty of CO_2 fixations was estimated as -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

The amount of CO_2 fixation were newly estimated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

Information on the service life and disposal of the product using biochar will be collected and the methodology will be revised as appropriate.

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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 FY2022 were 33,510 kt-CO_2 eq., comprising 3.0% of total emissions (excluding LULUCF). The value represents a 14.7% decrease from FY1990.

Tier of methodology used in Agriculture sector are showed in Table 5-1.

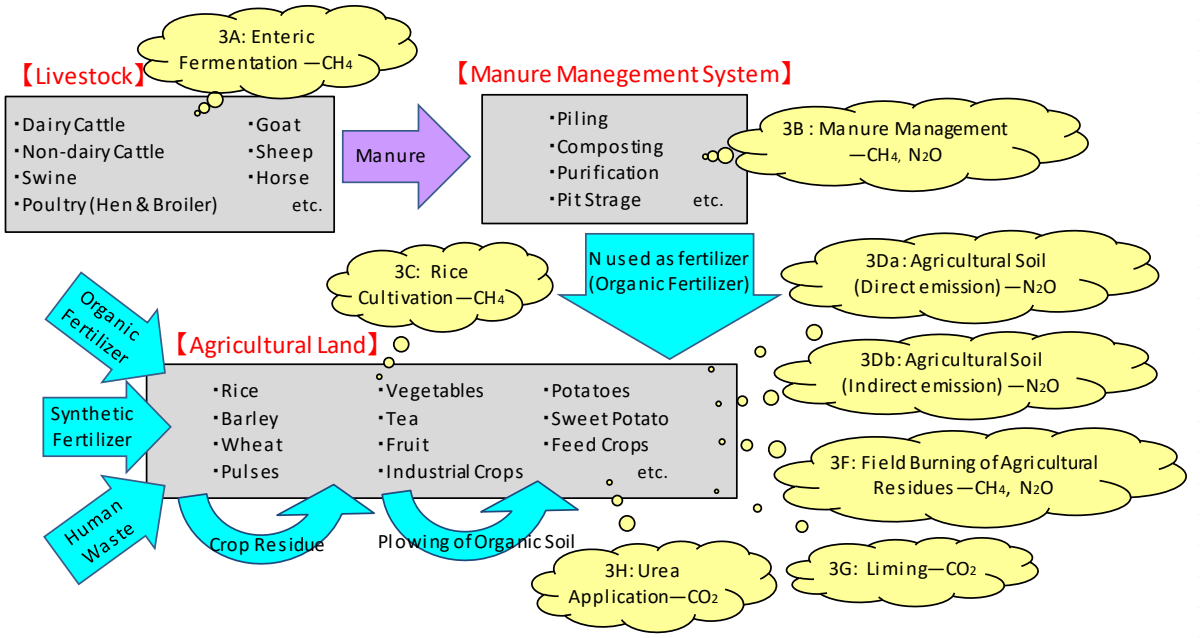

Figure 5-1 Relationships among the categories in the agricultural sector

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 FY2022 were 8,661 kt-CO_2 eq., comprising 0.8% of total emissions (excluding LULUCF). The value represents a decrease by 17.9% 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
CH_4	3.A.1.- Dairy cattle	kt-CH_4	192.1	184.4	171.2	162.9	146.3	139.7	137.0	136.4	133.5	133.5	133.4	134.9	135.5	137.6	135.0
	3.A.1.- Non-dairy cattle		166.5	172.2	171.7	168.0	166.5	154.8	150.0	150.3	151.1	151.7	150.7	153.0	155.2	157.0	160.2
	3.A.2. Sheep		0.167	0.115	0.097	0.071	0.159	0.138	0.140	0.140	0.143	0.158	0.162	0.170	0.160	0.190	0.190
	3.A.3. Swine		15.9	13.9	13.7	13.5	13.7	13.4	13.2	13.0	13.1	12.9	12.8	12.9	13.0	12.5	12.5
	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	0.006	0.006	0.006	0.006
	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	0.1	0.1	0.1
	3.A.4.- Horses		2.1	2.1	1.9	1.6	1.3	1.3	1.2	1.3	1.3	1.4	1.4	1.4	1.3	1.2	1.2
	Total	kt-CH_4	376.9	372.7	358.7	346.0	328.1	309.5	301.7	301.4	299.2	299.8	298.6	302.5	305.3	308.6	309.3
		kt-CO_2eq.	10,554	10,437	10,042	9,689	9,186	8,665	8,449	8,438	8,378	8,393	8,361	8,471	8,547	8,642	8,661

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 three months, the calculation of the CH_4 emissions associated with enteric fermentation includes cattle aged three months or older (cattle under three 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 6 months old			Calculation excludes 6/24 of the population which was assumed to be 6 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*.
		3 to 6 months old			Comprising 4/24 of the population under 2 years old.	
		Under 3 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 6 months old			Calculation excludes 6/12 of the population which was assumed to be 6 months to 1 year old for under 1 year old and addition of the population under 1 year old.	
		3 to 6 months old			Comprising 4/12 of the population under 1 year old.	
		Under 3 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 6 months old		Calculation excludes 6/12 of the population which was assumed to be 6 months old or younger; therefore covering 6/12 of the population under 1 year old.	
			3 to 6 months old		Comprising 4/12 of the population under 1 year old.	
			Under 3 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 same month age of Wagyu (Male)	
			3 to 6 months old		Same as same month age of Wagyu (Male)	
			Under 3 months old		Same as same month age of Wagyu (Male). Excluded from CH_4 emission estimation.	
		Dairy breeds	Dairy breeds	Over 6 months old	Calculation excludes 6/24 of the population which was assumed to be 6 months old or younger; therefore covering 18/24 of the population under 2 years old.	Cattle of dairy breeds for meat such as Holsteins.
				3 to 6 months old	Comprising 4/24 of the population under 2 years old.	
				Under 3 months old	Covering 2/24 of the population under 2 years old. Excluded from CH_4 emission estimation.	
			Hybrid	Over 6 months old	Same as same month age of Dairy breeds	F1 hybrid for beef which female dairy breeds are delivered with crossing with male beef breed cattle.
				3 to 6 months old	Same as same month age of Dairy breeds	
				Under 3 months old	Same as same month 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 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 ages in month 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. Average ages in month for primipara for all years were described in the *Record of dairy herd performance test*, however, the record of average ages in month 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 age in month for each type of cattle included in the *Japanese Feeding Standard*.

Table 5-4 Equation to estimate dry matter intake (*DMI*) by cattle

Type of cattle		Equation
Dairy cattle	Lactating	Since 2006: $DMI = 1.3922 + 0.05839 \times W^{0.75} + 0.40497 \times FCM$ $DMI = 1.9120 + 0.07031 \times W^{0.75} + 0.34923 \times FCM$ (Primipara) $FCM = (15 \times FAT / 100 + 0.4) \times MILK$ Before 2006: $DMI = 2.98120 + 0.00905 \times W + 0.41055 \times FCM$ $FCM = (15 \times FAT / 100 + 0.4) \times MILK$
	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 49mths old: $DMI = [0.1067 \times W^{0.75} + (0.0639 \times W^{0.75} \times DG) / (0.78 \times q + 0.006)] / (q \times 4.4)$ $q = 0.4213 + 0.1491 \times DG$ For 49mths old and over: $DMI = [0.1119 \times W^{0.75} + (0.0639 \times W^{0.75} \times DG) / (0.78 \times q + 0.006)] / 1.81$ 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)	Since 2008: $DMI = -3.481 + 2.668 \times DG + 4.548 \times 10^{-2} \times W - 7.207 \times 10^{-5} \times W^2 + 3.867 \times 10^{-8} \times W^3$ Before 2008: $DMI = [0.1124 \times W^{0.75} + (0.0546 \times W^{0.75} \times DG) / (0.78 \times q + 0.006)] / \{q \times (1.653 - 0.00123 \times W)\} / (q \times 4.4)$ $q = 0.5304 + 0.0748 \times DG$
	Wagyu (F)	$DMI = [0.1108 \times W^{0.75} + (0.0609 \times W^{0.75} \times DG) / (0.78 \times q + 0.006)] / (q \times 4.4)$ $q = 0.5018 + 0.0956 \times DG$
	Dairy breeds (over 6 months old)	$DMI = [0.1291 \times W^{0.75} + (0.0510 \times W^{0.75} \times DG) / (0.78 \times q + 0.006)] / (q \times 4.4)$ $q = (0.933 + 0.00033 \times W) \times (0.498 + 0.0642 \times DG)$
	Dairy breeds (3 to 6 months old)	$DMI = [0.1291 \times W^{0.75} + \{(1.00 + 0.030 \times W^{0.75}) \times DG\} / (0.78 \times q + 0.006)] / (q \times 4.4)$ $q = (0.859 - 0.00092 \times W) \times (0.790 + 0.0411 \times DG)$
	Hybrid	$DMI = [0.1208 \times W^{0.75} + (0.0531 \times W^{0.75} \times DG) / (0.78 \times q + 0.006)] / (q \times 4.4)$ $q = (0.933 + 0.00033 \times W) \times (0.498 + 0.0642 \times DG)$

Note: *W*: Weight, *FCM*: Fat Corrected Milk, *FAT*: Fat content in milk, *MILK*: Milk Yield,
DG: Daily Gain, *q*: Energy metabolic rate
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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Milk yield	Multipara (3 and more)	kg/head/day	21.9	23.6	24.7	26.6	26.9	27.4	28.0	28.6	28.7	28.8	28.8	29.7	30.0	30.5	30.5
	Secundipara	kg/head/day	21.4	23.1	24.2	26.0	26.4	26.9	27.3	27.9	28.0	28.1	28.1	29.0	29.2	29.7	29.8
	Primipara	kg/head/day	18.5	19.9	20.9	22.4	22.7	23.1	23.5	24.0	24.2	24.5	24.3	25.2	25.2	25.7	25.6
Fat content in milk		%	3.7	3.8	3.9	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	4.0	4.0

Table 5-6 Weight by cattle (*W*) [kg /head]

Type of cattle			1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Dairy cattle		Lactating (Multipara (3 and more))	653.8	653.5	673.7	673.4	685.6	685.2	684.7	684.7	684.3	683.9	683.9	683.6	683.3	682.8	682.4
		Lactating (Secundipara)	598.4	601.6	622.6	622.6	623.9	623.9	623.9	623.9	623.4	622.5	623.0	622.0	622.0	621.1	620.1
		Lactating (Primipara)	517.2	528.0	551.1	538.3	523.6	524.6	523.6	523.6	522.6	521.6	520.5	520.5	519.5	518.5	518.5
		Non-lactating	601.0	602.4	625.3	618.5	623.3	620.1	618.7	617.4	616.8	616.9	616.3	614.4	612.7	611.7	611.3
		Heifer: under 2 yr, over 6 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	376.1	376.1	376.1
		Heifer: 3 to 6 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	137.8	137.8	137.8
Non-dairy cattle	Breeding	2 yr and over	471.1	471.1	512.8	512.8	512.8	512.8	512.8	512.8	512.8	512.8	512.8	512.8	512.8	512.8	512.8
		Under 2 yr, over 6 mth	314.9	314.9	383.0	383.0	383.0	383.0	383.0	383.0	383.0	383.0	383.0	383.0	383.0	383.0	383.0
		3 to 6 mth	118.4	118.4	127.2	127.2	127.2	127.2	127.2	127.2	127.2	127.2	127.2	127.2	127.2	127.2	127.2
	Fattening cattle	Wagyu (M): 1 yr and over	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8	562.8
		under 1 yr, over 6 mth	257.0	257.0	257.0	257.0	257.0	257.0	257.0	257.0	257.0	257.0	257.0	257.0	257.0	257.0	257.0
		3 to 6 mth	120.5	120.5	120.5	120.5	120.5	120.5	120.5	120.5	120.5	120.5	120.5	120.5	120.5	120.5	120.5
		Wagyu (F): 1 yr and over	382.4	382.4	456.4	456.4	456.4	456.4	456.4	456.4	456.4	456.4	456.4	456.4	456.4	456.4	456.4
		under 1 yr, over 6 mth	219.8	219.8	266.0	266.0	266.0	266.0	266.0	266.0	266.0	266.0	266.0	266.0	266.0	266.0	266.0
		3 to 6 mth	118.4	118.4	127.2	127.2	127.2	127.2	127.2	127.2	127.2	127.2	127.2	127.2	127.2	127.2	127.2
		Dairy breed: over 6 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	479.8	479.8	479.8
		3 to 6 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	160.4	160.4	160.4
		Hybrid: over 6 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	479.8	479.8	479.8
		3 to 6 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	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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Dairy cattle		Lactating	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		Non-lactating	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
		Heifer: under 2 yr, over 6 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	0.58	0.58	0.58
		Heifer: 3 to 6 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	0.93	0.93	0.93
Non-dairy cattle	Breeding	2 yr and over	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		Under 2 yr, over 6 mth	0.50	0.50	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
		3 to 6 mth	0.74	0.74	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
	Fattening cattle	Wagyu (M): 1 yr and over	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62	0.62
		under 1 yr, over 6 mth	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07	1.07
		3 to 6 mth	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81
		Wagyu (F): 1 yr and over	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29	0.29
		under 1 yr, over 6 mth	0.71	0.71	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
		3 to 6 mth	0.74	0.74	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
		Dairy breed: over 6 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	0.93	0.93	0.93
		3 to 6 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	1.14	1.14	1.14
		Hybrid: over 6 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	0.93	0.93	0.93
		3 to 6 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	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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Dairy cattle		Lactating (Multipara (3 and more))	17.5	18.3	19.1	19.9	20.0	20.1	20.3	20.6	20.7	20.7	20.7	21.1	21.2	21.4	21.6
		Lactating (Secundipara)	16.9	17.7	18.4	19.3	19.2	19.4	19.6	19.8	19.8	19.9	19.9	20.3	20.4	20.6	20.7
		Lactating (Primipara)	14.9	15.7	16.4	17.0	17.4	17.6	17.7	17.9	17.9	18.0	18.0	18.3	18.3	18.5	18.5
		Non-lactating	10.2	10.2	10.6	10.5	10.6	10.5	10.5	10.5	10.5	10.5	10.5	10.4	10.4	10.4	10.4
		Heifer: under 2 yr, over 6 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	7.7	7.7	7.7
		Heifer: 3 to 6 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	3.8	3.8	3.8
Non-dairy cattle	Breeding	2 yr and over	7.7	7.7	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
		Under 2 yr, over 6 mth	6.3	6.3	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4
		3 to 6 mth	3.4	3.4	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7
	Fattening cattle	Wagyu (M): 1 yr and over	8.2	8.2	8.2	8.2	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7
		under 1 yr, over 6 mth	6.5	6.5	6.5	6.5	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.9
		3 to 6 mth	3.6	3.6	3.6	3.6	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
		Wagyu (F): 1 yr and over	5.6	5.6	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
		under 1 yr, over 6 mth	4.7	4.7	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
		3 to 6 mth	3.0	3.0	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
		Dairy breed: over 6 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	8.5	8.5	8.5
		3 to 6 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	4.4	4.4	4.4
		Hybrid: over 6 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	8.3	8.3	8.3
		3 to 6 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	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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Dairy cattle		Lactating (Multipara (3 and more))	122.9	125.9	127.7	129.8	129.9	130.3	130.7	131.6	131.4	131.5	131.5	132.6	132.4	132.8	133.0
		Lactating (Secundipara)	120.5	123.8	125.8	128.1	128.0	128.5	128.9	129.9	129.6	129.7	129.7	131.0	130.8	131.3	131.5
		Lactating (Primipara)	112.7	116.4	118.9	121.1	122.6	123.0	123.4	124.4	124.3	124.5	124.3	125.7	125.3	125.9	126.0
		Non-lactating	86.3	86.6	89.0	88.2	88.7	88.4	88.2	88.3	88.0	88.0	88.0	88.0	87.6	87.5	87.4
		Heifer: under 2 yr, over 6 mth	63.4	64.7	66.9	67.8	68.0	68.0	68.0	68.1	68.0	68.0	68.0	68.1	68.0	68.0	68.0
		Heifer: 3 to 6 mth	29.1	29.3	30.4	33.8	34.4	34.4	34.4	34.5	34.4	34.4	34.4	34.5	34.4	34.4	34.4
Non-dairy cattle	Breeding	2 yr and over	68.3	68.5	70.7	70.7	70.7	70.7	70.7	70.9	70.7	70.7	70.7	70.9	70.7	70.7	70.7
		Under 2 yr, over 6 mth	56.9	57.0	66.0	66.0	66.0	66.0	66.0	66.1	66.0	66.0	66.0	66.1	66.0	66.0	66.0
		3 to 6 mth	30.3	30.3	33.7	33.7	33.7	33.7	33.7	33.8	33.7	33.7	33.7	33.8	33.7	33.7	33.7
	Fattening cattle	Wagyu (M): 1 yr and over	72.1	72.3	72.1	72.1	68.5	68.5	68.5	68.7	68.5	68.5	68.5	68.7	68.5	68.5	68.5
		under 1 yr, over 6 mth	58.8	59.0	58.8	58.8	61.7	61.7	61.7	61.8	61.7	61.7	61.7	61.8	61.7	61.7	61.7
		3 to 6 mth	33.0	33.1	33.0	33.0	29.4	29.4	29.4	29.4	29.4	29.4	29.4	29.4	29.4	29.4	29.4
		Wagyu (F): 1 yr and over	51.0	51.2	57.2	57.2	57.2	57.2	57.2	57.3	57.2	57.2	57.2	57.3	57.2	57.2	57.2
		under 1 yr, over 6 mth	43.1	43.2	53.7	53.7	53.7	53.7	53.7	53.8	53.7	53.7	53.7	53.8	53.7	53.7	53.7
		3 to 6 mth	26.7	26.8	30.9	30.9	30.9	30.9	30.9	31.0	30.9	30.9	30.9	31.0	30.9	30.9	30.9
		Dairy breed: over 6 mth	74.2	74.4	74.2	74.2	74.2	74.2	74.2	74.4	74.2	74.2	74.2	74.4	74.2	74.2	74.2
		3 to 6 mth	40.2	40.3	40.2	40.2	40.2	40.2	40.2	40.3	40.2	40.2	40.2	40.3	40.2	40.2	40.2
		Hybrid: over 6 mth	73.0	73.2	73.0	73.0	73.0	73.0	73.0	73.2	73.0	73.0	73.0	73.2	73.0	73.0	73.0
		3 to 6 mth	42.1	42.2	42.1	42.1	42.1	42.1	42.1	42.2	42.1	42.1	42.1	42.2	42.1	42.1	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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Dairy cattle		Lactating (Multipara (3 and more))	510	467	447	391	374	334	324	317	308	309	309	296	293	293	284
		Lactating (Secundipara)	260	250	241	229	196	202	191	194	193	194	190	186	192	200	194
		Lactating (Primipara)	313	318	283	280	235	236	235	241	234	228	231	233	241	244	236
		Non-lactating	332	299	249	231	195	185	184	185	179	176	171	185	184	188	182
		Heifer: under 2 yr, over 6 mth	491	445	379	379	351	328	328	306	307	316	323	339	334	335	344
		Heifer: 3 to 6 mth	109	99	84	84	78	73	73	68	68	70	72	75	74	75	77
		Heifer: under 3 mth	55	49	42	42	39	36	36	34	34	35	36	38	37	37	38
Dairy cattle total			**2,068**	**1,927**	**1,725**	**1,636**	**1,467**	**1,395**	**1,371**	**1,345**	**1,323**	**1,328**	**1,332**	**1,352**	**1,356**	**1,371**	**1,356**
Non-dairy cattle	Breeding	2 yr and over	612	591	555	536	575	520	505	511	511	517	528	528	528	528	528
		Under 2 yr, over 6 mth	84	69	68	71	78	62	61	64	69	75	79	79	79	79	79
		3 to 6 mth	12	9	8	9	11	9	9	9	12	12	13	13	13	13	13
		Under 3 mth	6	4	4	5	5	5	4	5	6	6	6	6	6	6	6
	Fattening cattle	Wagyu (M): 1 yr and over	368	412	385	374	409	381	368	371	374	379	380	384	389	403	406
		under 1 yr, over 6 mth	125	133	114	119	127	115	112	109	110	116	120	135	139	126	140
		3 to 6 mth	83	89	76	80	85	77	75	72	73	77	80	90	93	84	94
		under 3 mth	42	44	38	40	42	38	37	36	37	39	40	45	46	42	47
		Wagyu (F): 1 yr and over	197	265	246	290	336	328	313	293	310	312	310	306	319	343	354
		under 1 yr, over 6 mth	102	105	93	89	101	91	89	86	81	84	89	103	109	95	108
		3 to 6 mth	68	70	62	59	67	60	59	57	54	56	60	69	72	63	72
		under 3 mth	34	35	31	30	34	30	30	29	27	28	30	34	36	32	36
		Dairy breed: over 6 mth	665	541	333	351	309	276	259	249	235	221	206	201	188	185	176
		3 to 6 mth	148	120	74	78	69	61	58	55	52	49	46	45	42	41	39
		under 3 mth	74	60	37	39	34	31	29	28	26	25	23	22	21	21	20
		Hybrid: over 6 mth	140	267	511	438	362	363	362	379	391	388	371	372	394	416	427
		3 to 6 mth	31	59	114	97	81	81	80	84	87	86	82	83	88	93	95
		under 3 mth	16	30	57	49	40	40	40	42	43	43	41	41	44	46	47
Non-dairy cattle total			**2,805**	**2,901**	**2,806**	**2,755**	**2,763**	**2,567**	**2,489**	**2,479**	**2,499**	**2,514**	**2,503**	**2,555**	**2,605**	**2,614**	**2,687**

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

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.

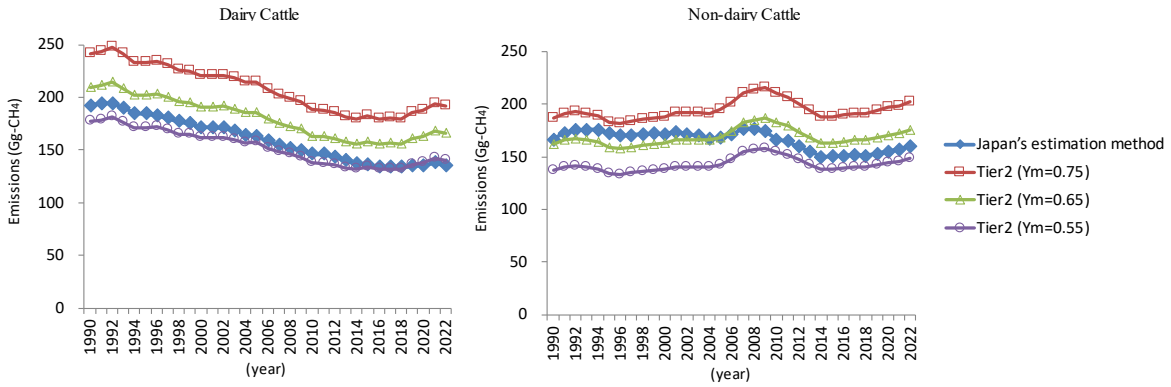

Figure 5-2 Comparison between results of Japan's estimation method and IPCC Tier 2 method

e) Category-specific Recalculations

Since the population of dairy cattle by calving in *Record of Dairy Herd Performance Test* was updated, the emissions from dairy cattle for FY2021 were recalculated. 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 2004, 2009 and 2014 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 heads]

Livestock species	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Sheep	21	14	12	9	20	17	17	18	18	20	20	21	20	24	24
Goats	26	19	22	16	19	20	20	17	16	19	20	20	20	22	22
Swine	11,335	9,900	9,788	9,620	9,768	9,537	9,424	9,313	9,346	9,189	9,156	9,223	9,290	8,950	8,956
Horses	116	118	105	87	75	74	69	74	75	76	78	78	73	68	68
Buffalo	0.21	0.12	0.10	0.08	0.08	0.10	0.11	0.11	0.12	0.11	0.11	0.12	0.12	0.11	0.11

Note: For swine, data in FY2009 and FY2014 were interpolated.

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

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 FY2021 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 FY2022 are 2,709 kt-CO_2 eq. and 3,419 kt-CO_2 eq., comprising 0.2% and 0.3% of total emissions (excluding LULUCF), respectively. The value represents a decrease by 28.5% for CH_4 and a decrease by 11.5% 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
CH_4	3.B.1.- Dairy cattle	kt-CH_4	107.0	103.1	96.5	94.5	86.8	82.7	81.1	81.0	79.3	79.4	79.4	80.7	81.1	82.6	81.2
	3.B.1.- Non-dairy cattle		3.7	3.8	3.9	4.3	4.9	5.2	5.3	5.5	5.8	6.1	6.2	6.3	6.3	6.4	6.5
	3.B.2. Sheep		0.006	0.004	0.003	0.002	0.006	0.005	0.005	0.005	0.005	0.006	0.006	0.006	0.006	0.007	0.007
	3.B.3. Swine		22.2	19.3	17.7	12.5	8.7	8.0	7.8	7.6	7.4	7.5	7.3	6.8	6.8	6.5	6.5
	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	0.0002	0.0002	0.0002
	3.B.4.- Goats		0.005	0.004	0.004	0.003	0.004	0.004	0.004	0.003	0.003	0.004	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	0.2	0.2	0.2
	3.B.4.- Poultry		2.0	1.9	1.9	2.1	2.4	2.5	2.4	2.4	2.4	2.5	2.5	2.5	2.5	2.5	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	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	0.0005	0.0005	0.0005
	Total	kt-CH_4	135.2	128.4	120.2	113.6	102.9	98.5	96.8	96.7	95.1	95.7	95.7	96.4	96.8	98.2	96.7
		kt-CO_2 eq.	3,786	3,595	3,365	3,180	2,881	2,759	2,711	2,707	2,664	2,679	2,680	2,701	2,711	2,750	2,709
N_2O	3.B.1.- Dairy cattle	kt-N_2O	2.1	2.1	2.1	2.3	2.4	2.3	2.2	2.2	2.1	2.1	2.1	2.1	2.1	2.1	2.1
	3.B.1.- Non-dairy cattle		2.4	2.5	2.5	2.6	2.7	2.4	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.3	2.4
	3.B.2. Sheep		IE	IE	IE	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	4.2	4.1	4.1	4.2	4.2	4.2	4.2	4.1	4.0
	3.B.4.- Buffalo		0.0001	0.0001	0.0001	0.0000	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	3.B.4.- Goats		IE	IE	IE	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	IE	IE	IE
	3.B.4.- Poultry		1.1	1.1	1.1	1.1	1.2	1.0	1.0	1.0	1.0	1.0	0.9	0.9	0.9	0.9	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	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	0.0001	0.0001	0.0001
	3.B.5. Indirect emissions		5.2	4.8	4.5	4.1	3.9	3.7	3.6	3.6	3.6	3.7	3.7	3.7	3.7	3.7	3.5
	Total	kt-N_2O	14.6	13.7	13.3	14.0	14.7	13.6	13.3	13.2	13.1	13.3	13.1	13.2	13.2	13.1	12.9
		kt-CO_2 eq.	3,865	3,638	3,529	3,702	3,890	3,617	3,525	3,494	3,472	3,516	3,474	3,486	3,497	3,472	3,419
Total of all gases		kt-CO_2 eq.	7,651	7,234	6,894	6,882	6,771	6,376	6,236	6,201	6,136	6,194	6,154	6,187	6,208	6,222	6,128

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]
$EF_{N2O\text{-}n}$: Emission factor for management system *n* [g-N_2O-N/g-N]
$A_{N2O\text{-}n}$: 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.

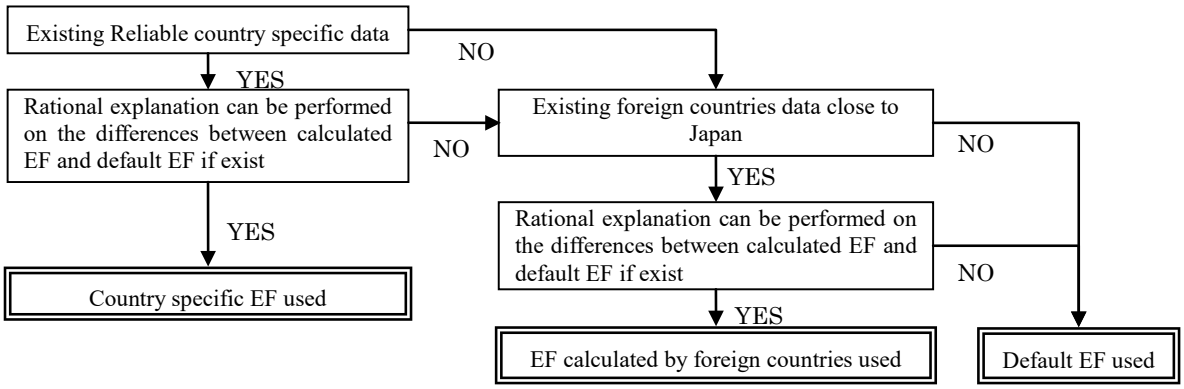

Figure 5-3 Decision tree for determination of EF

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)	0.0 %	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 Month
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 Month

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.

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 %					D[1)]	0.5 %			Sw
Composting – Intensive windrow (urine)	1.0 %						—			
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 2018 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.

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"

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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Pit storage	2.47%	2.44%	2.42%	2.40%	2.37%	2.37%	2.37%	2.36%	2.36%	2.36%	2.35%	2.35%	2.34%	2.34%	2.34%
Methane fermentation	3.22%	3.17%	3.14%	3.11%	3.06%	3.06%	3.05%	3.05%	3.04%	3.03%	3.03%	3.02%	3.02%	3.01%	3.01%

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). 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
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	46.8	47.3	47.4	47.5	47.5	48.2	48.4	48.8	49.1
			Lactating (Secundipara)	40.3	41.8	43.3	44.8	44.7	45.0	45.3	45.8	45.9	46.0	46.0	46.7	46.8	47.3	47.5
			Lactating (Primipara)	36.7	38.2	39.5	40.6	41.4	41.6	41.8	42.2	42.3	42.5	42.4	42.9	42.9	43.3	43.4
			Non-lactating	27.9	27.9	28.7	28.5	28.6	28.5	28.5	28.4	28.4	28.4	28.4	28.3	28.3	28.2	28.2
			Heifer: under 2 yr, over 6 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	23.2	23.2	23.2
			Heifer: 3 to 6 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	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	16.9	16.9	16.9	16.9	16.9	17.0	17.0
			Lactating (Secundipara)	17.1	17.1	17.2	17.2	17.2	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.1	17.2
			Lactating (Primipara)	18.8	18.8	18.9	18.9	18.8	18.8	18.7	18.7	18.7	18.7	18.7	18.7	18.7	18.7	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	15.3	15.3	15.3
			Heifer: under 2 yr, over 6 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	12.5	12.5	12.5
			Heifer: 3 to 6 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	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	186.0	189.1	189.6	190.1	190.4	194.7	195.5	198.2	199.6
			Lactating (Secundipara)	148.5	157.4	165.5	174.3	173.9	175.7	177.6	180.5	180.8	181.3	181.3	185.5	186.3	188.9	190.2
			Lactating (Primipara)	128.6	136.7	144.1	150.2	154.7	156.1	157.4	159.5	160.1	160.9	160.3	163.6	163.7	165.8	166.1
			Non-lactating	82.7	83.0	86.8	85.6	86.4	85.9	85.7	85.5	85.4	85.4	85.3	85.0	84.7	84.5	84.4
			Heifer: under 2 yr, over 6 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	58.5	58.5	58.5
			Heifer: 3 to 6 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	24.9	24.9	24.9
		Urine	Lactating (Multipara (3 and more))	76.1	81.0	83.2	87.9	89.5	90.8	92.1	93.5	93.9	94.2	94.2	96.4	96.9	98.0	98.2
			Lactating (Secundipara)	85.8	90.2	92.2	96.6	98.4	99.6	100.7	102.1	102.3	102.6	102.5	104.5	105.0	106.1	106.3
			Lactating (Primipara)	88.8	92.5	94.4	98.7	92.8	94.2	95.5	97.2	97.9	98.8	98.4	101.0	101.3	103.0	102.7
			Non-lactating	98.6	98.8	103.1	101.9	102.8	102.2	101.9	101.7	101.5	101.6	101.5	101.1	100.8	100.6	100.5
			Heifer: under 2 yr, over 6 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	71.1	71.1	71.1
			Heifer: 3 to 6 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	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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Non-dairy cattle	Amount of excretion [kg/head/day]	Feces	Breeding: 2 yr and over	17.4	17.4	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2
			under 2 yr, over 6 mth	12.6	12.6	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2
			3 to 6 mth	5.9	5.9	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7
			Wagyu (M): 1 yr and over	12.3	12.3	12.3	12.3	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8	10.8
			under 1 yr, over 6 mth	8.4	8.4	8.4	8.4	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3
			3 to 6 mth	5.0	5.0	5.0	5.0	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
			Wagyu (F): 1 yr and over	10.0	10.0	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2	11.2
			under 1 yr, over 6 mth	7.2	7.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2
			3 to 6 mth	4.5	4.5	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7	4.7
			Dairy breed: over 6 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	14.6	14.6	14.6
			3 to 6 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	8.2	8.2	8.2
			Hybrid: over 6 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	14.4	14.4	14.4
			3 to 6 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	9.7	9.7	9.7
		Urine	Breeding: 2 yr and over	7.1	7.1	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4	7.4
			under 2 yr, over 6 mth	5.8	5.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8
			3 to 6 mth	3.1	3.1	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
			Wagyu (M): 1 yr and over	7.6	7.6	7.6	7.6	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1	7.1
			under 1 yr, over 6 mth	6.0	6.0	6.0	6.0	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
			3 to 6 mth	3.3	3.3	3.3	3.3	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
			Wagyu (F): 1 yr and over	5.2	5.2	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
			under 1 yr, over 6 mth	4.3	4.3	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4	5.4
			3 to 6 mth	2.7	2.7	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1	3.1
			Dairy breed: over 6 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	7.8	7.8	7.8
			3 to 6 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	4.0	4.0	4.0
			Hybrid: over 6 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	7.7	7.7	7.7
			3 to 6 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	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	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8
			under 2 yr, over 6 mth	46.1	46.1	56.2	56.2	56.2	56.2	56.2	56.2	56.2	56.2	56.2	56.2	56.2	56.2	56.2
			3 to 6 mth	21.5	21.5	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3	24.3
			Wagyu (M): 1 yr and over	63.5	63.5	63.5	63.5	59.1	59.1	59.1	59.1	59.1	59.1	59.1	59.1	59.1	59.1	59.1
			under 1 yr, over 6 mth	48.1	48.1	48.1	48.1	51.3	51.3	51.3	51.3	51.3	51.3	51.3	51.3	51.3	51.3	51.3
			3 to 6 mth	23.7	23.7	23.7	23.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7	20.7
			Wagyu (F): 1 yr and over	40.1	40.1	46.4	46.4	46.4	46.4	46.4	46.4	46.4	46.4	46.4	46.4	46.4	46.4	46.4
			under 1 yr, over 6 mth	32.5	32.5	42.7	42.7	42.7	42.7	42.7	42.7	42.7	42.7	42.7	42.7	42.7	42.7	42.7
			3 to 6 mth	18.7	18.7	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0	22.0
			Dairy breed: over 6 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	61.3	61.3	61.3
			3 to 6 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	31.8	31.8	31.8
			Hybrid: over 6 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	60.2	60.2	60.2
			3 to 6 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	33.2	33.2	33.2
		Urine	Breeding: 2 yr and over	73.9	73.9	76.7	76.7	74.9	74.9	74.9	74.9	74.9	74.9	74.9	74.9	74.9	74.9	74.9
			under 2 yr, over 6 mth	57.5	57.5	69.4	69.4	70.6	70.6	70.6	70.6	70.6	70.6	70.6	70.6	70.6	70.6	70.6
			3 to 6 mth	35.5	35.5	43.6	43.6	54.3	54.3	54.3	54.3	54.3	54.3	54.3	54.3	54.3	54.3	54.3
			Wagyu (M): 1 yr and over	76.9	76.9	76.9	76.9	71.9	71.9	71.9	71.9	71.9	71.9	71.9	71.9	71.9	71.9	71.9
			under 1 yr, over 6 mth	65.1	65.1	65.1	65.1	71.6	71.6	71.6	71.6	71.6	71.6	71.6	71.6	71.6	71.6	71.6
			3 to 6 mth	41.0	41.0	41.0	41.0	48.2	48.2	48.2	48.2	48.2	48.2	48.2	48.2	48.2	48.2	48.2
			Wagyu (F): 1 yr and over	49.8	49.8	57.2	57.2	57.2	57.2	57.2	57.2	57.2	57.2	57.2	57.2	57.2	57.2	57.2
			under 1 yr, over 6 mth	44.8	44.8	57.5	57.5	60.4	60.4	60.4	60.4	60.4	60.4	60.4	60.4	60.4	60.4	60.4
			3 to 6 mth	33.9	33.9	42.3	42.3	51.6	51.6	51.6	51.6	51.6	51.6	51.6	51.6	51.6	51.6	51.6
			Dairy breed: over 6 mth	84.2	84.2	84.2	84.2	85.5	85.5	85.5	85.5	85.5	85.5	85.5	85.5	85.5	85.5	85.5
			3 to 6 mth	57.2	57.2	57.2	57.2	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8	61.8
			Hybrid: over 6 mth	82.0	82.0	82.0	82.0	83.0	83.0	83.0	83.0	83.0	83.0	83.0	83.0	83.0	83.0	83.0
			3 to 6 mth	57.0	57.0	57.0	57.0	65.8	65.8	65.8	65.8	65.8	65.8	65.8	65.8	65.8	65.8	65.8

Table 5-21 Amount of excretion (*Ex*) and amount of nitrogen in excretion (*Nex*) from swine

Item				Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Swine	Excretion	Feces	Growing-finishing	kg/head/day	1.7	1.7	1.7	1.7	1.8	1.8	1.8	1.8	1.8	1.8	1.8	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	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	3.7	3.7	3.9	3.9	3.9	3.9	3.9	3.8
			Breeding	kg/head/day	5.5	5.5	5.5	5.2	5.1	4.9	4.8	4.8	4.8	4.8	4.8	4.7	4.7	4.7	4.6
	Nitrogen	Feces	Growing-finishing	g-N/head/day	14.0	14.0	13.3	13.3	13.6	13.7	13.7	13.6	13.5	14.1	14.1	14.3	14.2	14.3	14.2
			Breeding	g-N/head/day	20.2	20.2	20.2	19.4	19.7	19.8	19.8	19.7	19.7	19.7	19.7	19.8	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	24.1	24.0	23.9	25.3	25.2	25.3	25.2	25.3	24.8
			Breeding	g-N/head/day	36.0	35.6	35.7	33.8	33.0	31.8	31.3	31.1	31.1	31.1	30.9	30.7	30.7	30.7	30.1

Table 5-22 Nitrogen content in feces excreted from Hen and Broiler (*Nex*)

Item				Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Poultory	Excretion	Hen	Adult	kg/head/day	0.086	0.087	0.088	0.088	0.087	0.095	0.094	0.091	0.092	0.094	0.092	0.090	0.087	0.087	0.086
			Poult	kg/head/day	0.041	0.041	0.039	0.040	0.040	0.042	0.042	0.041	0.041	0.042	0.042	0.041	0.040	0.040	0.039
		Broiler		kg/head/day	0.097	0.098	0.098	0.096	0.101	0.094	0.092	0.089	0.088	0.087	0.085	0.084	0.083	0.083	0.082
	Nitrogen	Hen	Adult	g-N/head/day	2.18	2.16	2.06	1.93	1.86	1.82	1.79	1.78	1.79	1.80	1.77	1.73	1.71	1.71	1.69
			Poult	g-N/head/day	1.04	1.03	0.97	0.98	1.01	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
		Broiler		g-N/head/day	2.06	2.04	1.95	1.75	1.86	1.56	1.54	1.53	1.52	1.54	1.47	1.45	1.45	1.47	1.44

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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Hen	188,786	190,634	186,202	180,697	178,546	174,806	175,270	175,733	178,900	184,350	184,917	184,145	183,373	182,661	172,265

Note: Data of non-surveyed year (in 2009, 2014 and 2019) were interpolated.
Reference: *The Livestock Statistics*

Table 5-25 Livestock population for broiler [1000 heads]

Item	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Livestock Population in statistics (broiler)	142,740	118,123	106,311	103,687											
Number of Shipment (broiler)				606,898	633,799	653,999	661,030	669,899	680,392	688,314	703,814	715,656	728,009	735,530	737,217
Livestock Population used in this inventory (broiler)	142,740	118,123	106,311	103,687	98,913	102,066	103,163	104,547	106,185	107,421	109,840	111,688	113,616	114,790	115,053

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 and CP used in calculation for nitrogen contents are common to feces and urine.

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 5-28 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 non-dairy 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 is from Table 5-8 described above. CP is calculated with formula 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	$F = F_{dry} / (1\text{-}MC)$ $F_{dry} = DMI \times (1 - TDN\%)$ 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: See notation and references of Table 5-28 below.

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 $CP2 = (26.6 + 5.3 \times FAT) \times MILK / 0.65$ $CFA = 1 + MILK / 15 \times 0.04$
	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 2008	$CP = NP / EP$ $NP = FN \times 6.25 + UN \times 6.25 + SP + RP$ $FN = 4.80 \times DMI$ $UN = 0.44 \times W^{0.5}$ $SP = 0.2 \times W^{0.6}$ $RP = DG \times (235 - 0.195 \times W)$ (Dairy breeds) $RP = DG \times (235 - 0.234 \times W)$ (Hybrid and 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)) 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) $CP = DCPR / 0.65$ $DCPR = 53 \times MILK$
	Since 2008	$CP = (MCP / 0.85 + MPu / 0.80) / 1.15$ $MCP = 100 \times TDN$ (except Breeding cows) $MCP = 130 \times TDN$ (Breeding cows) $MPu = MPR - MPd$ $MPR = MPm + MPg$ $MPd = 0.8 \times 0.8 \times MCP$ $MPm = (FN \times 6.25 + UN \times 6.25 + SP) / 0.67$ $FN = 4.80 \times DMI - Adj$ $UN = 0.44 \times W^{0.5}$ $SP = 0.2 \times W^{0.6}$ $MPg = RP / 0.492$ $RP = DG \times (235 - 0.195 \times W)$ (Dairy breeds) $RP = DG \times (235 - 0.234 \times W)$ (Hybrid and 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)) $Adj = (100 \times TDN \times 0.64 \times 0.25 \times 0.5) / 6.25$ (Other than breeding cows)

		Equation
		$Adj = (130 \times TDN \times 0.64 \times 0.25 \times 0.5) / 6.25$ (Breeding cows) (Dairy breeds under 200kg of body weight) $CP = NP / EP$ $NP = FN \times 6.25 + UN \times 6.25 + SP + RP$ $FN = 4.80 \times DMI$ $UN = 0.44 \times W^{0.5}$ $SP = 0.2 \times W^{0.6}$ $RP = DG \times (235 - 0.234 \times W)$ 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) $MP\ell = (38 \times MILK) / 0.65$

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)
N_f: Nitrogen content in feces (kg/day)
Nu: Nitrogen content in urine (kg/day)
CP: Crude protein (g)
F_{dry} : Feces dry weight (kg/day)
MC: Percentage of moisture contents in feces (%)
TDN%: Percentage of total digestible nutrients
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)
TDN: Total digestible nutrients (kg/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

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 2005) $N_{PR} = (-0.121 \times W + 119.2 \times WG + 25.5) / 6.25$ (Growing-finishing pigs since 2005) $N_{PR} = ((5.78 \times NWG + 103.87) / 5.56) / 6.25$ (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 (%)
i: Body weight class for growing-finishing pigs
Day: Total days of raising (day)
AVW: Averaged body weight (kg)
u: Proportion of urine to excretion
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) *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	$F_{dry} = Intake \times Dry \times (1\text{-}DR\%)$ 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) and in the *Survey of current status for livestock manure management system and others 2019*, (MAFF, 2021). 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	~1999	2009	2019
Dairy cattle	60.0%	45.5%	30.9%	40.0%	54.5%	69.1%
Non-dairy cattle	7.0%	4.8%	2.5%	93.0%	95.2%	97.5%
Swine	70.0%	73.9%	76.3%	30.0%	26.1%	23.7%
Hen	100.0%	100.0%	100.0%	—	—	—
Broiler	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*

Table 5-33 Proportion of manure management system by type of livestock (dairy cattle, non-dairy cattle and swine) (MS_n)

State of Manure (Separated or Mixed)		Treating method	Dairy cattle			Non-dairy cattle			Swine		
			~1999	2009	2019	~1999	2009	2019	~1999	2009	2019
Separated	Feces	Sun drying	2.8%	2.0%	2.7%	1.5%	0.9%	2.1%	7.0%	0.7%	0.8%
		Thermal drying	0%	0%	0.0%[3)]	0%	0%	0.0%	0.7%	0.1%	0.0%
		Carbonization			—			—			—
		Composting	9.0%	6.6%	9.0%	11.0%	8.1%	4.7%	62.0%	48.2%	57.9%
		Open Composting			7.9%			4.5%			26.3%
		Closed Composting			1.0%			0.2%			31.6%
		Piling	88.0%	90.1%	87.3%	87.0%	89.8%	92.9%	29.6%	49.3%	39.9%
		Pit storage (within a month)			0.5%			0.1%			0.1%
		Pit storage (over a month)			0.0%			0.1%			—
		Incineration	0.2%	0%	0.1%	0.5%	—	—	0.7%	0.6%	0.9%
		Methane fermentation		—[2)]	0.3%		—	—		0.1%	0.1%
		public sewage		0%	0.0%		—	—		—	—
		Industrial waste treatment			0.0%			0.0%			0.1%
		Pasturage		0%			—			—	
		Other		1.3%			1.2%			1.0%	0.01%
	Urine	Sun drying		0%			0%			0%	
		Composting (urine)	1.5%	1.7%	8.6%	9.0%	1.2%	19.3%	10.0%	5.4%	7.9%
		Open Composting			6.2%			17.8%			7.1%
		Closed Composting			2.5%			1.5%			0.9%
		Purification	2.5%	5.1%	5.4%	2.0%	4.4%	7.8%	45.0%	76.3%	84.3%
		Discharge			3.2%			7.2%			71.1%
		Reuse			2.1%			0.5%			13.2%
		Pit storage	96.0%	89.6%	82.1%	89.0%	91.4%	68.2%	45.0%	15.3%	6.0%
		PS (within a month)			12.4%			10.3%			2.0%
		PS (over a month)			69.7%			58.0%			4.0%
		Methane fermentation		1.9%	2.7%		0%	4.5%		0.5%	1.0%
		Public sewage		0.8%	1.1%		0.6%	0.2%		0.4%	0.6%
		Industrial waste treat.			0.0%			—			0.0%
		Other		0.9%	0.1%		2.4%	0.0%		2.1%	0.0%

State of Manure (Separated or Mixed)	Treating method	Dairy cattle			Non-dairy cattle			Swine		
		~1999	2009	2019	~1999	2009	2019	~1999	2009	2019
Mixed	Sun drying	4.4% [1)]	1.1%	1.9%	3.4% [1)]	0.7%	1.3%	6.0%	0.2%	0.2%
	Thermal drying	0%	0%	0.0%	0%	0%	—	0%	0%	—
	Carbonization			—			0.0%			—
	Composting (urine)	18.7% [1)]	22.9%	12.0%	21.8% [1)]	10.8%	14.5%	29.0%	21.3%	23.2%
	Open Composting			11.2%			13.6%			13.7%
	Closed Composting			0.7%			0.9%			9.5%
	Piling	13.1% [1)]	50.8%	45.1%	73.2% [1)]	85.7%	77.4%	20.0%	51.4%	52.1%
	Purification	0.3% [1)]	0.2%	0.2%	0%	0%	0.0%	22.0%	18.5%	12.9%
	Discharge			0.0%			0.0%			11.7%
	Reuse			0.2%			—			1.1%
	Pit storage	57.0% [1)]	15.4%	32.2%	0.6% [1)]	0.1%	5.4%	23.0%	4.0%	5.9%
	PS (within a month)			6.5%			1.8%			3.2%
	PS (over a month)			25.7%			3.6%			2.8%
	Incineration		0.1%	0.0%		0%	0.0%		0%	0.1%
	Methane fermentation		1.7%	5.9%		0%	0.1%		2.0%	4.4%
	Public sewage		0.1%	0.0%		0%	0.0%		0.7%	0.8%
	Industrial waste treat.			0.1%			0.1%			0.4%
	Pasturage	6.5% [1)]	6.5%	2.5%	1.1% [1)]	1.1%	1.2%		0%	0.0%
	Other		1.2%	0.0%		1.6%	0.0%		1.9%	0.0%

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*

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 2009 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 (Separated or Mixed)		Treating method	Hen			Broiler		
			~1999	2009	2019	~1999	2009	2019
Separated	Feces	Sun drying	30.0%	8.2%	4.1%	15.0%	2.5%	0.8%
		Thermal drying	3.0%	2.2%	0.9%	0.0%	1.1%	0.3%
		Carbonization			0.2%			0.9%
		Composting	42.0%	49.6%	52.0%	5.1%	19.3%	10.8%
		Open Composting			29.0%			9.4%
		Closed Composting			23.0%			1.4%
		Piling	23.0%	36.8%	35.3%	66.9%	36.6%	27.3%
		Pit storage (within a month)			1.1%			2.3%
		Pit storage (over a month)			1.1%			1.3%
		Incineration	2.0%	1.6%	2.9%	13.0%	30.4%	46.8%
		Methane fermentation		—	0.1%		0.1%	0.3%
		Public sewage		—	—		—	—
		Industrial waste treatment			2.0%			5.8%
		Pasturage		0%	0.0%		0.1%	—
		Other		1.6%	0.2%		9.9%	3.5%

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 and dry lot”, “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 lidded 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.
		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)	Liquid system	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)	Liquid system	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)	Liquid system	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) Uncertainties and Time-series Consistency

- ***Uncertainties***

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 very higher than other Annex I Parties. 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 FY2021 were updated, the emissions from dairy cattle, swine and hen for FY2021 were recalculated. A number of broiler shipment were revised, emission factors for "Carbonization" and "Composting" for hen and broiler were established using country specific values and default values in the *2019 Refinement*, therefore, the emissions for the whole time-series 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: *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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Rabbit	15	16	21	19	18	18	18	18	18	18	18	18	18	18	18
Mink	155	11	6	1	1	1	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) Uncertainties and Time-series Consistency

- ***Uncertainties***

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

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 horses were updated, the emissions from sheep, goats and horse for FY2021 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 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+NOx-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 NOx 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Dairy cattle	26.6	26.1	24.6	23.4	20.5	19.7	19.5	19.6	19.2	19.3	19.3	19.7	19.8	20.3	19.9
Non-dairy cattle	22.3	23.0	23.0	22.5	22.5	20.8	20.2	20.2	20.3	20.4	20.2	20.5	20.8	21.0	21.5
Swine	53.1	46.1	43.5	39.2	37.3	35.6	34.8	34.1	33.9	34.6	34.4	34.8	34.8	33.6	33.2
Poultry (Hen, Broiler)	134.0	124.4	111.5	99.7	98.1	90.4	89.4	89.8	91.2	93.7	92.7	91.5	91.2	91.0	86.5
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	0.02	0.02	0.02
Total	236.1	219.5	202.7	184.8	178.4	166.5	163.8	163.7	164.5	168.0	166.6	166.5	166.6	166.0	161.2

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

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*, 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 FY2021. Since a number of broiler shipment from FY2015 were revised, the emission from FY2015 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 FY2022 are 13,068 kt-CO_2 eq., comprising 1.2% of total emissions (excluding LULUCF). The value represents a decrease by 3.8% from FY1990.

Table 5-43 CH_4 emissions from rice cultivation (3.C.)

Gas	Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
CH_4	3.C.1.- Continuously flooded	kt-CH_4	68.5	74.9	69.1	67.6	68.3	67.6	67.8	67.0	67.6	67.0	66.3	65.4	65.5	65.3	63.8
	3.C.1.- Intermittently flooded		416.6	448.8	418.0	421.1	419.1	415.5	416.3	410.6	417.6	416.0	413.7	411.1	412.1	411.7	402.9
	Total	kt-CH_4	485.2	523.7	487.0	488.6	487.4	483.1	484.1	477.6	485.1	483.0	480.0	476.5	477.6	477.0	466.7
		kt-CO_2 eq.	13,585	14,663	13,636	13,682	13,649	13,527	13,554	13,374	13,584	13,523	13,440	13,343	13,373	13,356	13,068

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.

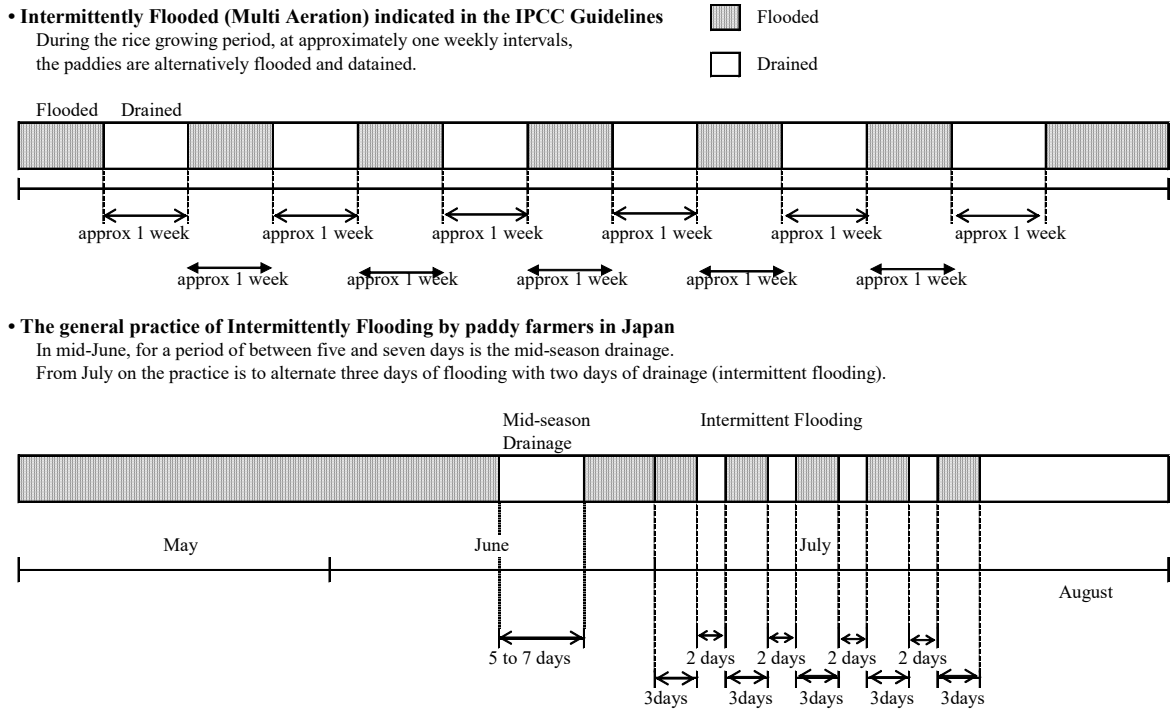

Figure 5-4 Comparison of water management regime in Japan and intermittent flooding (multi aeration) indicated in the *2006 IPCC Guidelines*

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.

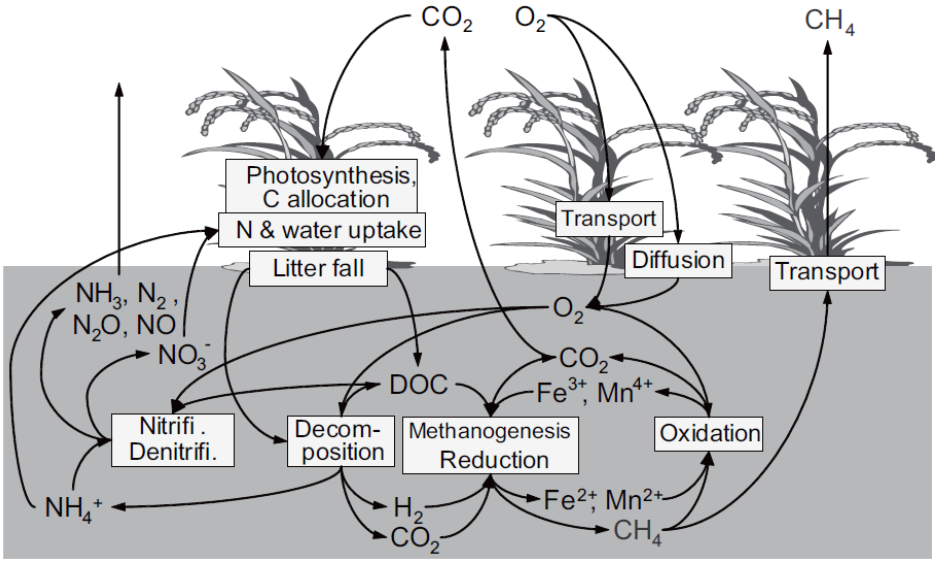

Figure 5-5 Conceptual scheme of the DNDC-Rice model
Reference: Fumoto et al. (2010)

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)
- 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

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.

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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Rice straw	Hokkaido	1.73	1.74	1.92	2.03	2.12	1.96	1.98	2.06	2.09	2.09	2.06	1.99	2.02	2.03	2.02
	Tohoku	1.49	1.73	2.02	2.11	2.07	1.95	1.96	2.05	2.11	2.12	2.13	2.09	2.13	2.14	2.11
	Hokuriku	2.69	2.62	2.74	2.82	2.75	2.45	2.43	2.49	2.53	2.54	2.55	2.49	2.52	2.53	2.50
	Kanto	1.32	1.49	1.77	1.96	1.96	1.80	1.79	1.85	1.88	1.89	1.90	1.87	1.89	1.89	1.87
	Tokai and Kinki	2.01	1.98	2.22	2.33	2.23	2.01	2.04	2.13	2.23	2.24	2.22	2.17	2.19	2.19	2.17
	Chugoku and Shikoku	1.74	1.83	2.10	2.13	2.15	1.93	1.91	1.98	2.01	2.02	1.94	1.84	1.86	1.86	1.84
	Kyusyu and Okinawa	1.17	1.14	1.26	1.36	1.40	1.24	1.25	1.30	1.32	1.32	1.32	1.29	1.31	1.31	1.29
Compost	Hokkaido	1.69	1.86	2.10	2.05	2.18	1.87	1.98	1.88	2.00	1.93	1.85	2.07	1.91	2.04	1.97
	Tohoku	1.69	1.86	2.10	2.05	2.18	1.87	1.98	1.88	2.00	1.93	1.85	2.07	1.91	2.04	1.97
	Hokuriku	1.69	1.86	2.10	2.05	2.18	1.87	1.98	1.88	2.00	1.93	1.85	2.07	1.91	2.04	1.97
	Kanto	1.69	1.86	2.10	2.05	2.18	1.87	1.98	1.88	2.00	1.93	1.85	2.07	1.91	2.04	1.97
	Tokai and Kinki	1.69	1.86	2.10	2.05	2.18	1.87	1.98	1.88	2.00	1.93	1.85	2.07	1.91	2.04	1.97
	Chugoku and Shikoku	1.69	1.86	2.10	2.05	2.18	1.87	1.98	1.88	2.00	1.93	1.85	2.07	1.91	2.04	1.97
	Kyusyu and Okinawa	1.69	1.86	2.10	2.05	2.18	1.87	1.98	1.88	2.00	1.93	1.85	2.07	1.91	2.04	1.97

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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Poorly drained field, Continuously flooded	Rice straw	Hokkaido	585	588	636	665	690	647	652	676	682	682	675	654	663	665	662
		Tohoku	573	636	714	739	727	696	699	722	739	742	745	734	744	746	739
		Hokuriku	741	725	753	772	754	684	679	694	702	705	708	693	701	703	696
		Kanto	181	202	237	260	259	240	238	246	250	251	252	248	251	251	249
		Tokai and Kinki	436	429	477	499	478	435	441	459	479	482	477	467	472	472	466
		Chugoku and Shikoku	422	439	491	499	501	458	455	468	474	476	460	440	445	445	440
		Kyusyu and Okinawa	158	155	169	181	186	167	168	174	176	177	177	173	175	175	173
	Compost	Hokkaido	574	621	686	670	708	621	654	624	657	638	618	678	634	669	649
		Tohoku	627	673	736	721	758	673	705	676	708	689	670	729	686	720	700
		Hokuriku	507	548	603	590	622	548	576	550	579	562	545	596	559	589	571
		Kanto	226	248	277	270	287	248	263	249	264	255	246	273	254	269	260
		Tokai and Kinki	372	406	454	443	470	407	430	409	433	419	404	448	416	441	427
		Chugoku and Shikoku	411	445	492	481	508	446	469	448	471	457	443	486	455	480	465
		Kyusyu and Okinawa	221	242	271	264	281	243	257	244	258	250	241	268	248	264	255
	No-amendment	Hokkaido	114	114	114	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	175	175	175
		Hokuriku	113	113	113	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	18	18	18
		Tokai and Kinki	35	35	35	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	77	77	77
		Kyusyu and Okinawa	16	16	16	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	652	676	682	682	675	654	663	665	662
		Tohoku	547	610	687	711	700	669	672	694	711	715	717	706	716	718	711
		Hokuriku	552	539	562	578	563	505	501	513	520	522	525	513	519	520	515
		Kanto	164	182	213	234	233	216	215	221	226	226	227	224	227	227	224
		Tokai and Kinki	352	346	386	405	388	352	357	371	388	391	387	378	382	382	378
		Chugoku and Shikoku	377	393	441	448	450	411	407	419	426	427	412	394	398	398	394
		Kyusyu and Okinawa	139	136	148	159	162	146	147	152	154	154	155	151	153	153	152
	Compost	Hokkaido	574	621	686	670	708	621	654	624	657	638	618	678	634	669	649
		Tohoku	600	646	709	694	730	646	678	649	681	662	643	701	659	693	673
		Hokuriku	359	392	438	427	454	393	416	395	418	404	390	433	402	426	412
		Kanto	204	223	250	243	259	223	237	225	238	230	222	246	229	243	235
		Tokai and Kinki	300	328	367	358	381	328	348	330	350	338	326	362	336	357	345
		Chugoku and Shikoku	367	399	442	432	457	399	421	401	423	410	397	437	408	431	417
		Kyusyu and Okinawa	192	210	235	229	243	210	223	211	224	216	209	232	215	228	221
	No-amendment	Hokkaido	114	114	114	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	153	153	153
		Hokuriku	33	33	33	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	17	17	17
		Tokai and Kinki	21	21	21	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	57	57	57
		Kyusyu and Okinawa	19	19	19	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	385	400	405	405	400	387	392	394	392
		Tohoku	423	471	530	549	540	516	519	536	549	552	553	545	553	554	549
		Hokuriku	556	543	566	581	566	510	506	517	525	526	529	517	523	525	519
		Kanto	122	135	157	172	171	159	158	163	166	166	167	165	166	167	165
		Tokai and Kinki	198	194	217	228	218	197	200	209	218	220	218	213	215	215	212
		Chugoku and Shikoku	166	174	196	199	201	182	180	186	189	190	183	174	176	176	174
		Kyusyu and Okinawa	131	129	141	151	155	139	140	145	147	147	147	144	146	146	144
	Compost	Hokkaido	335	365	407	397	421	366	386	367	389	376	364	402	374	396	383
		Tohoku	463	499	547	536	564	499	523	501	526	511	497	541	509	535	519
		Hokuriku	366	399	444	433	459	399	422	401	424	411	397	438	408	432	418
		Kanto	151	164	183	179	189	164	174	165	175	169	163	181	168	178	172
		Tokai and Kinki	167	184	206	201	214	184	195	185	196	189	183	203	188	200	193
		Chugoku and Shikoku	162	176	197	192	204	176	187	177	188	182	176	194	181	191	185
		Kyusyu and Okinawa	185	202	227	221	235	203	215	204	216	209	202	224	208	221	213
	No-amendment	Hokkaido	39	39	39	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	119	119	119
		Hokuriku	46	46	46	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	17	17	17
		Tokai and Kinki	6	6	6	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	17	17	17
		Kyusyu and Okinawa	12	12	12	12	12	12	12	12	12	12	12	12	12	12	12
One day drained field, Intermittently flooded	Rice straw	Hokkaido	236	237	259	272	284	264	266	277	280	280	277	267	271	272	271
		Tohoku	297	333	378	392	385	367	369	382	392	394	395	389	395	395	392
		Hokuriku	403	393	410	421	410	369	366	375	380	381	383	375	379	380	376
		Kanto	90	100	116	127	126	117	117	120	122	123	123	121	123	123	121
		Tokai and Kinki	89	87	98	103	98	89	90	94	98	99	98	96	97	97	95
		Chugoku and Shikoku	88	92	105	107	107	97	96	99	101	101	98	93	94	94	93
		Kyusyu and Okinawa	75	73	80	86	88	79	80	82	84	84	84	82	83	83	82
	Compost	Hokkaido	231	252	281	275	292	252	267	254	269	260	251	278	258	274	265
		Tohoku	328	354	390	382	403	354	372	356	374	363	353	386	362	381	370
		Hokuriku	264	288	321	313	332	289	305	290	307	297	287	317	295	313	302
		Kanto	111	121	135	131	139	121	128	122	129	125	120	133	124	131	127
		Tokai and Kinki	75	83	93	90	96	83	88	83	88	85	82	92	85	90	87
		Chugoku and Shikoku	86	94	105	103	109	94	100	95	100	97	94	104	96	102	99
		Kyusyu and Okinawa	105	115	129	126	134	116	123	116	123	119	115	128	118	126	121
	No-amendment	Hokkaido	21	21	21	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	71	71	71
		Hokuriku	31	31	31	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	15	15	15
		Tokai and Kinki	2	2	2	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	5	5	5
		Kyusyu and Okinawa	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7

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	2014	2015	2016	2017	2018	2019	2020	2021	2022
4 hour drained field, Continuously flooded	Rice straw	Hokkaido	308	310	338	355	369	344	347	361	365	365	361	349	354	355	353
		Tohoku	385	431	488	506	497	475	477	493	506	508	510	502	509	511	506
		Hokuriku	529	516	538	553	539	485	481	492	499	501	503	492	498	499	494
		Kanto	163	180	209	228	228	211	210	216	220	221	222	219	221	221	219
		Tokai and Kinki	212	208	232	243	233	212	215	224	233	235	233	227	230	230	227
		Chugoku and Shikoku	225	235	266	270	271	247	245	252	256	257	248	236	239	239	236
		Kyusyu and Okinawa	157	154	169	181	185	166	167	173	176	176	176	172	174	174	173
	Compost	Hokkaido	302	329	367	358	380	329	348	331	350	339	328	362	337	357	345
		Tohoku	424	458	504	493	520	458	481	460	484	470	456	498	467	492	477
		Hokuriku	348	379	422	412	437	380	401	382	403	390	378	417	388	411	398
		Kanto	201	218	243	237	251	218	231	219	232	225	217	240	223	236	229
		Tokai and Kinki	180	197	221	215	229	198	209	199	211	203	196	218	202	215	207
		Chugoku and Shikoku	220	239	266	260	275	239	253	240	254	246	238	263	245	259	251
		Kyusyu and Okinawa	222	243	272	265	282	243	258	244	259	250	242	269	249	264	255
	No-amendment	Hokkaido	33	33	33	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	97	97	97
		Hokuriku	43	43	43	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	27	27	27
		Tokai and Kinki	13	13	13	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	27	27	27
		Kyusyu and Okinawa	13	13	13	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	193	201	203	203	201	194	197	198	197
		Tohoku	268	301	342	355	349	333	334	346	355	357	358	352	358	359	355
		Hokuriku	356	347	362	372	362	326	323	331	335	336	338	330	334	335	332
		Kanto	111	123	144	157	157	145	145	149	151	152	153	150	152	152	151
		Tokai and Kinki	119	117	130	137	131	119	120	125	131	132	131	128	129	129	128
		Chugoku and Shikoku	156	163	184	187	188	170	169	174	177	178	171	163	165	165	163
		Kyusyu and Okinawa	93	91	100	107	109	98	99	102	104	104	104	102	103	103	102
	Compost	Hokkaido	167	183	205	200	212	183	194	184	195	189	182	202	188	199	192
		Tohoku	296	320	354	346	365	321	337	322	339	329	319	350	327	345	335
		Hokuriku	232	253	282	276	293	253	268	255	269	261	252	279	259	275	266
		Kanto	138	150	167	163	173	150	159	151	160	154	149	165	154	163	157
		Tokai and Kinki	101	111	124	121	129	111	117	111	118	114	110	122	113	120	116
		Chugoku and Shikoku	152	165	184	180	191	165	175	166	176	170	164	182	169	179	173
		Kyusyu and Okinawa	131	144	161	157	167	144	153	145	154	148	143	159	147	157	151
	No-amendment	Hokkaido	14	14	14	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	59	59	59
		Hokuriku	22	22	22	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	16	16	16
		Tokai and Kinki	6	6	6	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	17	17	17
		Kyusyu and Okinawa	7	7	7	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". 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.

Table 5-46 Area of paddy fields by region (*A*) [kha]

	Item	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Conventional midseason drainage	Hokkaido	146	163	135	119	115	113	112	111	108	107	106	106	105	103	102
	Tohoku	525	539	456	444	429	419	419	414	413	412	412	412	408	407	403
	Hokuriku	258	260	221	218	213	215	216	214	213	212	213	213	212	211	210
	Kanto	386	390	336	331	322	324	323	322	320	318	316	314	312	310	308
	Tokai and Kinki	261	264	217	208	199	198	196	182	179	177	178	177	176	174	172
	Chugoku and Shikoku	236	232	187	182	178	175	173	170	167	165	162	159	157	155	152
	Kyusyu and Okinawa	246	251	207	206	202	203	201	199	196	195	192	192	190	188	186
	Total	2,058	2,098	1,758	1,708	1,657	1,647	1,639	1,609	1,597	1,586	1,579	1,572	1,560	1,549	1,531
Prolonged midseason drainage	Hokkaido	—	—	—	—	—	—	—	0	0	0	0	0	0	0	0
	Tohoku	—	—	—	—	—	—	—	2	1	1	1	1	3	3	3
	Hokuriku	—	—	—	—	—	—	—	0	0	0	0	0	0	0	0
	Kanto	—	—	—	—	—	—	—	0	0	0	0	0	0	1	1
	Tokai and Kinki	—	—	—	—	—	—	—	11	12	13	11	12	11	11	11
	Chugoku and Shikoku	—	—	—	—	—	—	—	0	0	0	0	0	0	0	0
	Kyusyu and Okinawa	—	—	—	—	—	—	—	0	0	0	0	0	0	0	0
	Total	—	—	—	—	—	—	—	13	14	14	12	13	15	15	15

Note: Upon the estimation, Tokai and Kinki regions are aggregated as one region

Reference: *Statistics of Cultivated and Planted Area* (MAFF) and *the Direct Payments for Environmentally Friendly Agriculture* (MAFF)

Table 5-47 Proportion of drainage (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*

Table 5-48 Proportion of water regime (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 in Japan (f_O)

Item	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Straw amendment	63%	70%	71%	72%	74%	84%	85%	83%	82%	82%	82%	84%	83%	83%	84%
Various compost amendment	17%	10%	9%	8%	9%	7%	6%	5%	6%	6%	6%	5%	6%	6%	5%
No-amendment	20%	20%	20%	20%	17%	9%	9%	12%	12%	12%	12%	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) Uncertainties and Time-series Consistency

- ***Uncertainties***

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.

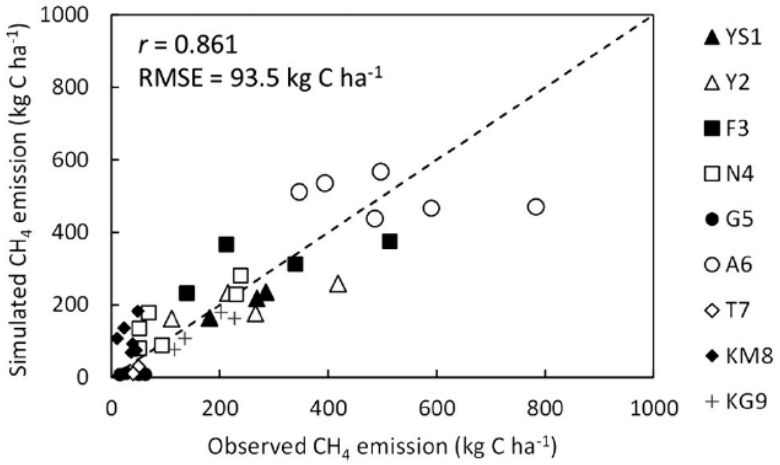

Figure 5-6 Comparison of annual methane emission between values obserbed and values simulated by the DNDC-Rice model

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

Emissions since FY2019 were recalculated due to the revisions in the amount of organic matter application for DNDC-Rice model since FY2019. 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 FY2022 are 5,203 kt-CO_2 eq., comprising 0.5% of total emissions (excluding LULUCF). The value represents a decrease by 21.9% 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
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	4.1	3.9	3.9	3.9	3.9	3.8	3.8	3.8	3.8
		2. Organic N fertilizers		5.5	5.2	5.0	4.4	4.8	4.7	4.8	5.3	5.3	5.5	5.4	5.1	5.2	5.1	5.1
		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	0.1	0.1	0.1
		4. Crop residues		1.4	1.4	1.5	1.4	1.2	1.2	1.2	1.2	1.1	1.1	1.1	1.1	1.1	1.1	1.1
		5. Mineralization		1.5	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.3	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	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	2.9	3.0	3.0	3.0	3.0	2.9	3.0	3.0	3.0
		2. N leaching and run-off		6.4	5.9	5.7	5.4	5.1	5.0	5.0	5.0	4.9	5.0	5.0	4.9	4.9	4.9	4.9
	Total		kt-N_2O	25.1	23.2	22.3	20.9	20.1	19.9	19.8	20.2	20.0	20.3	20.1	19.7	19.7	19.7	19.6
			kt-CO_2 eq.	6,658	6,138	5,903	5,527	5,317	5,277	5,241	5,343	5,310	5,373	5,339	5,214	5,224	5,212	5,203

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 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 1993, 1998 and 2002. Time-series data were prepared by interpolating calculated values by estimated fertilizer amount data of three years into from 1993 to 2002 and deferring the 1993 data for previous years and the 2002 data for subsequent years (see Table 5-55).

For paddy rice, the data of synthetic fertilizer application amount for unit area for each 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Total N amount in synthetic fertilizer	611,955	527,517	487,406	471,190	409,590	409,918	394,629	372,339	374,879	374,879	374,879	374,879	374,879	374,879	374,879
N amounut in synthetic fertilizer applied (forest soil)	288	248	229	222	193	193	186	175	176	176	176	176	176	176	176
N amounut in synthetic fertilizer applied (agricultural soil)	611,667	527,269	487,177	470,968	409,397	409,725	394,443	372,164	374,703	374,703	374,703	374,703	374,703	374,703	374,703

Note: This amount includes synthetic fertilizer with nitrification inhibitor.
Reference: Total N amount: *Yearbook of Fertilizer Statistics (Pocket Edition)*
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]

Item	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
N amount in synthetic fertilizer with nitrification inhibitor	NE	NE	4,030	4,290	4,940	7,800	4,550	5,070	5,330	5,070	5,590	6,045	5,785	6,084	6,084

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	2014	2015	2016	2017	2018	2019	2020	2021	2022
N amount in synthetic fertilizers application per area (rice)	9.65	8.71	7.34	6.62	5.95	6.10	5.97	5.85	5.85	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	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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Vegetables	620.1	564.4	524.9	476.3	465.4	453.4	452.1	448.9	444.1	441.7	437.3	432.5	424.9	419.8	412.5
Paddy rice (for grain)	2,055.0	2,106.0	1,763.0	1,702.0	1,625.0	1,597.0	1,573.0	1,505.0	1,478.0	1,465.0	1,470.0	1,469.0	1,462.0	1,403.0	1,355.0
Fruit	346.3	314.9	286.2	265.4	246.9	237.0	233.8	230.2	226.7	222.7	218.4	214.9	211.0	207.7	204.2
Tea	58.5	53.7	50.4	48.7	46.8	45.4	44.8	44.0	43.1	42.4	41.5	40.6	39.1	38.0	36.9
Potatoes	115.8	104.4	94.6	86.9	82.5	79.7	78.3	77.4	77.2	77.2	76.5	74.4	71.9	70.9	71.4
Pulse	256.6	155.5	191.8	193.9	189.0	178.5	181.0	187.6	187.7	187.9	185.4	183.6	183.3	184.0	188.3
Feed crops	1,096.0	1,013.0	1,026.0	1,030.0	1,012.0	1,012.0	1,019.0	1,072.0	1,082.0	1,084.9	1,068.6	1,059.1	1,052.6	1,102.5	1,130.0
for Pasture land	646.7	660.7	644.7	630.6	616.7	611.1	607.7	606.5	603.4	601.1	598.8	596.9	595.2	593.5	591.4
Sweet potato	60.6	49.4	43.4	40.8	39.7	38.6	38.0	36.6	36.0	35.6	35.7	34.3	33.1	32.4	32.3
Wheat	366.4	210.2	236.6	268.3	265.7	269.5	272.7	274.4	275.9	273.7	272.9	273.0	276.2	283.0	290.6
Coarse cereal (incl. buckwheat)	29.6	23.4	38.4	45.9	49.7	62.9	61.4	59.7	62.2	64.5	65.5	67.1	68.3	67.2	67.3
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	2.0	2.0	2.0
Industrial crops	142.9	124.5	116.3	110.3	104.8	98.5	97.8	98.8	99.3	100.3	98.2	97.3	97.9	99.9	99.0
Tobacco	30.0	26.4	24.0	19.1	15.0	8.9	8.6	8.3	8.0	7.6	7.1	6.5	6.1	5.7	3.6
Upland rice	18.9	11.6	7.1	4.5	2.9	1.7	1.4	1.2	0.9	0.8	0.8	0.7	0.6	0.6	0.5
Total	5,256.2	4,783.7	4,408.5	4,295.1	4,147.4	4,085.0	4,063.9	4,046.1	4,023.2	4,006.3	3,979.9	3,954.9	3,928.9	3,916.6	3,893.6

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 2017 excluded the value of "Potatoes". The values of "Vegetable", "Fruit", "Pulse", "Feed crops" and "Coarse cereal" in 2017 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) Uncertainties and Time-series Consistency

- ***Uncertainties***

For the emission factors, uncertainty (113%) estimated in the reference of EFs, Akiyama et al. (2006), 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

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 with Japan's EF and the default EF in the IPCC Guidelines is described in the section 'Emission factors' above.

e) Category-specific Recalculations

Statistics of Cultivated and Planted Area and *Crop Statistics* for FY2020 and FY2021 were revised, emissions for FY2020 and FY2021 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, 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}) 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 ($F_{Total\text{-}AW}$).

$$F_{AM} = F_{Total\text{-}AW} - F_{PRP} - F_{PSW} - F_{N_2O} - F_{NH_3+NOx} - F_{disposal}$$

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).

Table 5-58 Nitrogen amount in livestock manure applied to agricultural soil (F_{AM}) [t-N]

Item	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Total nitrogen amount in animal waste ($F_{Total\text{-}AW}$)	683,190	642,484	604,830	569,646	554,199	521,676	511,887	511,445	511,798	520,932	517,661	521,374	522,727	521,121	511,837
Nigrtogen amount in excretion from grazing livestock and for public swedge ($F_{PRPI}+F_{PRP}$)	12,987	12,836	12,024	11,653	11,365	10,592	10,025	10,119	9,907	9,890	9,851	9,693	9,425	9,251	9,230
Amount of N_2O-N released from manure (excluing excretion from grazing livestock and for public sweage) (F_{N2O})	5,977	5,663	5,636	6,302	6,845	6,354	6,172	6,098	6,033	6,090	6,011	6,040	6,066	6,015	5,953
Amount of NH_3-N and NOx-N released from manure (excluing excretion from grazing livestock and for public sweage) ($F_{NH3}+F_{Nox}$)	236,054	219,528	202,664	184,778	178,364	166,498	163,830	163,718	164,529	168,030	166,569	166,521	166,620	165,971	161,177
Nitrogen amount not to applied to farm field ($F_{disposal}$)	40,698	35,271	36,112	46,106	55,675	52,428	51,253	50,690	50,681	52,300	51,927	52,555	52,686	51,239	50,298
Nitrogen amount in livestock manure applied to agricultural soil (F_{AM})	387,474	369,185	348,394	320,806	301,949	285,804	280,607	280,820	280,647	284,621	283,302	286,566	287,930	288,647	285,178

- ***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)* 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)* 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Animal derived fertilizers	384.1	389.4	341.0	262.7	268.3	298.3	268.2	300.6	310.0	285.4	287.5	277.2	268.2	220.7	220.7
Fish residue	111.5	88.6	89.0	73.9	62.2	60.0	51.7	52.9	54.7	53.3	61.8	53.2	51.4	37.1	37.1
Bone meal	113.1	134.2	112.8	11.4	16.7	16.2	18.5	20.0	22.3	20.0	18.4	22.5	15.5	13.7	13.7
Other animal derived	159.5	166.6	139.2	177.5	189.4	222.1	198.1	227.7	233.0	212.1	207.4	201.6	201.3	170.0	170.0
Plant derived fertilizers	635.9	725.7	982.4	494.8	1,064.3	1,203.7	1,455.4	1,852.7	1,810.9	2,012.0	1,981.9	1,569.6	1,712.6	1,753.2	1,753.2
Soybean oil residue	3.5	4.7	28.9	1.1	209.5	167.7	265.0	477.0	494.5	491.3	484.8	494.6	488.4	492.4	492.4
Canola oil residue	451.0	437.2	620.7	241.0	221.4	288.4	399.5	474.8	486.8	449.3	420.1	414.6	403.4	440.1	440.1
Other plant derived	181.4	283.8	332.8	252.7	633.5	747.6	790.9	900.9	829.6	1,071.4	1,077.0	660.4	820.7	820.8	820.8
Sludge	787.3	935.2	817.7	1,287.4	1,395.6	1,355.5	1,292.9	1,395.7	1,351.7	1,377.8	1,358.0	1,345.9	1,261.5	1,259.8	1,381.9

Reference: *Yearbook of Fertilizer Statistics (Pocket Edition)*

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	2014	2015	2016	2017	2018	2019	2020	2021	2022
From livestock manure (F_{AM})	387,474	369,185	348,394	320,806	301,949	285,804	280,607	280,820	280,647	284,621	283,302	286,566	287,930	288,647	285,178
From sewage sludge (F_{SEW})	21,257	25,250	22,078	34,760	37,682	36,599	34,907	37,685	36,497	37,202	36,666	36,339	34,059	34,016	37,312
From human waste (F_{FU})	10,394	4,747	2,116	874	427	286	273	231	204	223	260	234	197	200	200
From composting sub-material ($F_{COMPsub}$)	18,316	15,514	11,485	11,217	8,864	8,879	7,700	6,816	6,774	6,480	6,578	6,471	6,589	6,247	6,231
From other organic fertilizers (F_{OOA})	57,128	60,790	71,314	43,685	76,006	83,796	96,378	123,560	122,844	130,034	128,575	108,916	114,802	113,401	113,401
Total (Nitrogen amount applied to agricultural soil as organic N fertilizer) (F_{ON})	494,569	475,485	455,387	411,343	424,929	415,363	419,864	449,112	446,965	458,560	455,381	438,525	443,578	442,511	442,324

➢ *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}) is calculated by multiplying the total nitrogen amount in organic fertilizers applied to agricultural soil above (F_{ON}) by the proportion of nitrogen amount to be applied to crop type *i* for the total nitrogen (F_{ON}) (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.

$$F_{ONi} = F_{ON} \times \frac{(RA_i \times RF_i / 10)}{\sum (RA_i \times RF_i / 10)}$$

F_{ONi} : Nitrogen amount of organic fertilizer applied to agricultural soil for crop type *i* [t-N]
F_{ON} : Total nitrogen amount in organic fertilizers applied to agricultural soil [t-N]
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 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 organic fertilizer applied and time-series data were prepared (see Table 5-55). 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 for tea [kg-N/10a]

Item	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
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	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) Uncertainties and Time-series Consistency

- ***Uncertainties***

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 -38~96%.

- ***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.

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, crop residues for composting sub-materials, and the distribution amount of other organic fertilizer for FY2021 were updated/revised, the emissions from livestock manure, composting sub-materials, and other organic fertilizers for FY2021 were recalculated. The emissions from livestock manure for the whole time-series were recalculated, due to the establishment in emission factors by type of organic N fertilizers. 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 ($Frac_{BGR-Y}$), 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.

$$A_{Rice} = Residue \times N_{AG} + Y \times DRY \times Frac_{BGR-Y} \times N_{BG}$$

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
$Frac_{BGR-Y}$: 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 assumed that it carried out by one fifth in every year in all area of tea field, 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) Chinese cabbage: 0.071% c) Cabbage: 0.183% e) Lettuce: 0.164% c) Onion: 0.019% b), c)		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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Proportion removed from field	32.1	32.1	32.1	32.1	37.8	41.0	41.0	37.9	40.2	38.5	39.5	37.2	37.2	36.3	39.8
Proportion burned in field	13.5	13.5	13.5	13.5	10.6	8.8	8.3	8.0	7.7	7.7	6.9	7.5	7.6	8.5	8.0

Note: Calculated from each prefecture data

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

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

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.

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 combustion factor was revised to that in the *2019 Refinement*, emissions for the whole time series 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.

$$N_2O - N_{direct_N_{Mineral_{i,j}}} = EF_{N2O_N_{i,j}} \times A_{i,j}$$

$N_2O\text{-}N_{direct\text{-}NMineral_{i,j}}$	: 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, orchard and tea plantations)
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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Intended paddy field	2,630	2,572	2,499	2,417	2,359	2,322	2,313	2,301	2,284	2,268	2,252	2,238	2,222	2,205	2,189
Hokkaido	190	189	187	180	178	178	178	178	177	177	177	176	176	176	176
Tohoku	575	580	577	564	557	541	539	535	532	528	525	523	520	517	514
Kanto	485	476	465	445	429	422	420	418	415	412	409	406	403	399	396
Hokuriku	317	305	296	288	282	280	279	278	277	276	275	274	273	272	271
Tokaiand Kinki	366	351	337	325	313	309	307	305	303	301	297	295	293	291	288
Chugoku and Shikoku	338	323	303	291	282	277	276	274	271	269	267	265	262	259	256
Kyusyu and Okinawa	360	348	334	324	317	315	314	313	309	305	302	299	296	292	289
Intended upland field	1,163	1,115	1,100	1,105	1,124	1,122	1,119	1,114	1,112	1,105	1,100	1,094	1,088	1,084	1,080
Hokkaido	389	367	371	380	393	396	397	398	399	400	401	401	402	402	402
Tohoku	135	132	129	129	131	129	129	128	127	126	125	124	124	123	123
Kanto	291	286	287	284	282	278	276	273	271	268	265	262	260	258	256
Hokuriku	23	21	21	22	24	25	25	25	25	25	25	25	25	24	24
Tokaiand Kinki	55	53	53	56	58	60	60	60	60	60	60	59	59	59	59
Chugoku and Shikoku	59	56	50	50	53	53	53	52	52	52	51	50	49	48	47
Kyusyu and Okinawa	211	201	189	184	182	180	179	178	177	175	173	172	170	169	167
Intended grassland	3.94	9.02	11.78	13.37	14.47	22.54	21.53	21.07	14.34	14.32	14.29	14.28	14.26	14.23	14.20
Hokkaido	3.83	8.60	11.11	12.52	12.81	14.68	17.31	18.22	13.30	13.28	13.26	13.26	13.25	13.23	13.22
Tohoku	0.10	0.40	0.54	0.64	1.16	5.29	2.85	1.91	0.70	0.69	0.68	0.67	0.66	0.66	0.65
Kanto	0.003	0.009	0.03	0.04	0.10	0.54	0.28	0.19	0.07	0.08	0.09	0.09	0.09	0.09	0.09
Hokuriku	0.004	0.006	0.010	0.015	0.03	0.14	0.07	0.05	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Tokaiand Kinki	0.0003	0.00004	0.004	0.010	0.03	0.15	0.08	0.05	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Chugoku and Shikoku	0	0	0.006	0.007	0.03	0.18	0.10	0.07	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Kyusyu and Okinawa	0	0.01	0.08	0.15	0.31	1.57	0.83	0.56	0.21	0.21	0.20	0.20	0.19	0.18	0.18

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

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

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 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 2006 and since 2016.

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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Intended paddy field	131.6	129.8	129.1	127.3	125.3	125.1	125.2	125.2	125.1	125.1	125.2	125.2	125.2	125.1	125.1
Intended upland field	16.4	16.7	17.0	16.9	16.8	16.6	16.5	16.5	16.5	16.4	16.4	16.4	16.4	16.3	16.3
Intended grassland (Hokkaido)	1.1	1.2	1.2	1.2	1.1	1.3	1.5	1.6	1.2	1.2	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	0.010	0.006	0.002	0.002	0.002	0.002	0.002	0.002	0.002

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

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, 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 *2019 Refinement*, Vol.11, page 11.11) 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. Since the emission factors for intended upland field and intended grassland were revised to that in the *2019 Refinement*, emissions for the whole time series were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

5.5.2. 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)* 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Urea-based	115,620	107,917	106,712	125,170	117,267	136,391	129,924	136,622	132,424	132,424	132,424	132,424	132,424	132,424	132,424
Ammonium-based	465,738	393,888	363,180	286,181	245,364	239,123	228,585	208,505	224,393	224,393	224,393	224,393	224,393	224,393	224,393
Ammonium-nitrate-based	8,010	7,090	3,947	2,207	989	1,105	889	713	3,160	3,160	3,160	3,160	3,160	3,160	3,160
Other	22,300	18,374	13,338	57,410	45,778	33,105	35,045	26,325	14,726	14,726	14,726	14,726	14,726	14,726	14,726

Reference: Yearbook of Fertilizer Statistics (Pocket Edition)

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	2014	2015	2016	2017	2018	2019	2020	2021	2022
From synthetic N fertilizers applied to soil (F_{SN}×$Frac_{GASF}$)	57,455	50,074	46,726	48,095	42,304	43,285	41,675	40,105	39,593	39,593	39,593	39,593	39,593	39,593	39,593
From organaic N fertilizers (F_{ON}×$Frac_{GASM3}$)	103,859	99,852	95,631	86,382	89,235	87,226	88,171	94,313	93,863	96,298	95,630	92,090	93,151	92,927	92,888
From excretion from grazing livestock (F_{PRP}×$Frac_{GASM4}$)	2,727	2,696	2,506	2,342	2,220	2,058	1,940	1,959	1,913	1,904	1,894	1,856	1,800	1,767	1,765
Total (nitrogen amount volatilized as ammonia and nitrogen oxides (A)	164,042	152,622	144,863	136,819	133,759	132,569	131,786	136,377	135,369	137,794	137,117	133,539	134,544	134,287	134,246

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

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

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 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 distribution amount of other organic fertilizer for FY2021 were updated/revised, the emissions from organic N fertilizers and that from excretion from grazing livestock for FY2021 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 researches 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
From synthetic N fertilizers applied to soil (F_{SN}×$Frac_{LEACH}$)	146,800	126,545	116,922	113,032	98,255	98,334	94,666	89,319	89,929	89,929	89,929	89,929	89,929	89,929	89,929
From organaic N fertilizers (F_{ON}×$Frac_{LEACH}$)	118,697	114,116	109,293	98,722	101,983	99,687	100,767	107,787	107,272	110,054	109,292	105,246	106,459	106,203	106,158
From excretion from grazing livestock (F_{PRP}×$Frac_{LEACH}$)	3,117	3,081	2,864	2,676	2,537	2,351	2,217	2,239	2,187	2,175	2,165	2,121	2,057	2,019	2,018
From crop residue (F_{CR}×$Frac_{LEACH}$)	36,041	35,620	37,982	34,989	30,032	30,451	29,687	29,358	28,105	27,957	27,754	28,353	27,792	27,965	27,453
From mineralization (F_{SOM}×$Frac_{LEACH}$)	66,321	64,680	62,933	61,187	60,045	59,287	59,059	58,764	58,322	57,917	57,514	57,163	56,777	56,354	55,967
Total (nitrogen amount by leachingand run-off) (A)	370,976	344,042	329,994	310,606	292,853	290,111	286,396	287,467	285,814	288,033	286,653	282,812	283,012	282,470	281,523

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

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

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 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, the amount of rice straw and rice chaff plowed into soil, and the distribution amount of other organic fertilizers for FY2021 were updated/revised, the emissions from organic N fertilizers, excretion from grazing livestock, and crop residue for FY2021 were recalculated. Since the combustion factor for crop residues was revised to that in the *2019 Refinement*, emissions for the whole time series 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 FY2022 are 30.3 kt-CO_2 eq. and 8.3 kt-CO_2 eq., comprising 0.003% and 0.001% of total emissions (excluding LULUCF), respectively. The value represents a decrease by 61.1% and 63.4% 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
CH_4	3.F.1. Cereals	Wheet	kt-CH_4	0.46	0.22	0.33	0.42	0.23	0.26	0.25	0.28	0.22	0.25	0.19	0.27	0.26	0.33	0.28
		Barley		0.12	0.07	0.07	0.06	0.05	0.04	0.04	0.04	0.03	0.04	0.03	0.04	0.04	0.05	0.05
		Maize		0.06	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.04	0.04	0.03	0.03
		Rice		1.71	1.79	1.21	0.90	0.61	0.66	0.60	0.49	0.50	0.41	0.47	0.44	0.44	0.42	0.42
		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	0.01	0.01	0.01
	3.F.2. Pulses	Soybeans		0.11	0.05	0.10	0.10	0.10	0.09	0.10	0.11	0.11	0.11	0.10	0.10	0.10	0.11	0.11
		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	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	0.02	0.02	0.02
		Sugarbeet		0.04	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.03	0.04	0.04	0.04	0.04	0.04	0.04
		Other tubers and roots		0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	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	0.03	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	0.07	0.07	0.07	0.07	0.07
		Other crops		0.03	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.005	0.005	0.004
	Total		kt-CH_4	2.78	2.47	2.01	1.76	1.22	1.29	1.23	1.16	1.09	1.05	1.02	1.10	1.08	1.14	1.08
			kt-CO_2 eq.	77.9	69.1	56.2	49.2	34.3	36.0	34.5	32.5	30.4	29.3	28.5	30.7	30.1	31.9	30.3
N_2O	3.F.1. Cereals	Wheet	kt-N_2O	0.0120	0.0057	0.0087	0.0109	0.0059	0.0066	0.0066	0.0073	0.0057	0.0065	0.0050	0.0071	0.0067	0.0085	0.0074
		Barley		0.0031	0.0019	0.0019	0.0016	0.0012	0.0011	0.0010	0.0010	0.0009	0.0010	0.0008	0.0011	0.0011	0.0013	0.0012
		Maize		0.0016	0.0012	0.0011	0.0010	0.0009	0.0009	0.0010	0.0009	0.0008	0.0009	0.0008	0.0009	0.0009	0.0008	0.0008
		Rice		0.0581	0.0607	0.0410	0.0306	0.0206	0.0222	0.0203	0.0166	0.0168	0.0139	0.0158	0.0150	0.0150	0.0142	0.0142
		Other cereals		0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0003	0.0003	0.0003	0.0003
	3.F.2. Pulses	Soybeans		0.0027	0.0014	0.0026	0.0027	0.0027	0.0024	0.0027	0.0028	0.0029	0.0030	0.0027	0.0027	0.0027	0.0029	0.0029
		Other pulses		0.0013	0.0010	0.0008	0.0007	0.0006	0.0006	0.0006	0.0006	0.0004	0.0005	0.0005	0.0005	0.0005	0.0004	0.0005
	3.F.3. Tubers and roots	Potatoes		0.0009	0.0008	0.0007	0.0007	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0006	0.0005	0.0005	0.0005
		Sugarbeet		0.0011	0.0010	0.0010	0.0011	0.0008	0.0009	0.0009	0.0010	0.0008	0.0010	0.0010	0.0011	0.0010	0.0011	0.0009
		Other tubers and roots		0.0007	0.0005	0.0005	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0003	0.0003	0.0003
	3.F.4.	Sugarcane		0.0008	0.0007	0.0006	0.0005	0.0006	0.0005	0.0005	0.0005	0.0007	0.0005	0.0005	0.0005	0.0006	0.0006	0.0005
	3.F.5. Other	Vegetables		0.0026	0.0024	0.0022	0.0020	0.0018	0.0018	0.0019	0.0018	0.0018	0.0018	0.0018	0.0018	0.0017	0.0018	0.0017
		Other crops		0.0009	0.0007	0.0005	0.0004	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001
	Total		kt-N_2O	0.086	0.078	0.062	0.053	0.037	0.039	0.037	0.034	0.032	0.030	0.030	0.032	0.031	0.033	0.031
			kt-CO_2 eq.	22.74	20.73	16.35	13.98	9.69	10.22	9.73	9.01	8.51	8.06	7.97	8.48	8.33	8.70	8.33
Total of all gases			kt-CO_2 eq.	100.68	89.81	72.57	63.20	43.96	46.21	44.23	41.49	38.92	37.38	36.44	39.20	38.48	40.55	38.67

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*, 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, Tabaco	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*
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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Rice straw	438.2	536.9	429.1	276.6	149.3	183.4	161.7	144.2	152.8	129.3	136.1	123.3	129.7	115.6	115.6
Rice chaff	581.3	528.3	291.3	260.3	212.9	206.6	193.9	147.5	142.6	114.2	140.7	140.7	132.8	134.3	134.3
Total	1,019.5	1,065.2	720.4	536.9	362.2	390.0	355.6	291.7	295.4	243.5	276.8	264.0	262.5	249.9	249.9

Reference: Calculated from each prefecture data

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

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

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 emission factor of rice straw was revised and combustion factor of other crops removed from field and burned in field was updated, the emissions for whole time series 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 FY2022 were 203 kt-CO_2, comprising 0.02% of total emissions (excluding LULUCF). The value represents a decrease by 63.1% from FY1990.

Table 5-80 CO_2 emissions from agricultural lime application (3.G.)

Gas	Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
CO_2	3.G.-Limestone	kt-CO_2	550	303	332	231	242	379	362	258	252	293	241	241	232	223	201
	3.G.-Dolomite		0.3	0.5	0.5	0.6	1.0	1.1	1.0	0.8	0.8	0.9	0.9	0.9	0.8	2.0	1.7
	Total	kt-CO_2	550	304	333	231	243	380	363	259	253	294	242	242	233	225	203

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, 11.27, Figure11.4).

$$E = (M_{Limestone} \times EF_{Limestone} + M_{Dolomite} \times EF_{Dolomite}) \times 44/12$$

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 Guideline*s, 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* published by the Association of Agriculture and Forestry Statistics. Based on expert judgment, all of the "Calcium carbonate fertilizer" and 70% of each of "Fossil seashell fertilizer", "Crushed limestone" and "Seashell fertilizer" 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Applied Limestone	1,250	689	755	524	550	860	822	586	573	665	548	549	527	508	458
Applied Dolomite	0.7	1.1	1.1	1.4	2.0	2.2	2.0	1.7	1.7	2.0	1.9	1.9	1.8	4.3	3.5

Reference: Estimated from the data described in *Yearbook of Fertilizer Statistics*

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

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

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

No recalculations are conducted.

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 ($(NH_3)_2CO$) 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 FY2022 were 208 kt-CO_2, comprising 0.02% of national total emissions (excluding LULUCF). The value represents an increase by 14.5% from FY1990.

Table 5-82 CO_2 emissions from urea fertilizer (3.H.)

Gas	Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
CO_2	3.H. Urea fertilization	kt-CO_2	182	170	168	197	184	214	204	215	208	208	208	208	208	208	208

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*, p.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 is used.

Table 5-83 Total demand for urea fertilizer in Japan [kt]

Item	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Amount of imported urea fertilizer	248	231	229	268	251	292	279	293	284	284	284	284	284	284	284

Reference: Estimated from the data described in *Yearbook of Fertilizer Statistics (Pocket Edition)*

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

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

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

No recalculations are conducted.

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”.

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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 FY2022 were 53,175 kt-CO_2 eq; which accounts for 4.7% of the total national emissions (excluding LULUCF). The net removals in FY2022 also represent a decrease of 26.9% compared to FY1990 and a decrease of 8.7% compared to FY2021. 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, decrease in the amount of carbon loss in mineral soils in cropland, and decrease of emissions due to the decrease in areas of forest land conversion. 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	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				

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 6-54).
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 FY2022 obtained by the methods shown in Table 6-2 is as follows; approximately 24.97 million ha for forest land, 3.99 million ha for cropland, 0.9 million ha for grassland, 1.35 million ha for wetlands, 3.90 million ha for settlements, and 2.69 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 FY2022, 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 0.24 million ha) 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,

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.

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 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 stock change method, which takes land expansion as a direct activity amount, is not used in its calculations.

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 transition 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 sub-categories, 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
Movement 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 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 by 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.

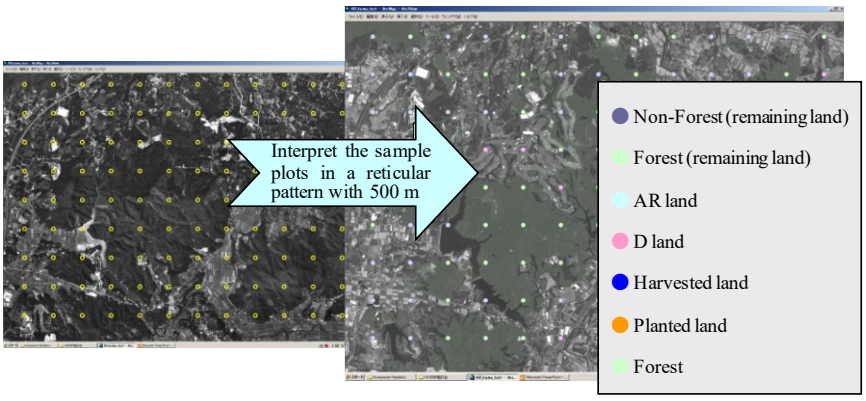

Figure 6-1 Identification of conversion between forest land and non-forest land by interpreting remote sensing images

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 (2015-2022)	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 transition matrix

Land-use transition matrix to determine land-use conversion 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 FY2022 are shown in the following Table 6-6 and Table 6-7, respectively. In addition, land-use matrix produced by accumulating land conversion between each land-use category, from the beginning of FY1990 to the end of FY2022, is shown in Table 6-8.

Table 6-6 Land-use transition matrix for Japan in FY1990 [kha]

at the beginning \ at the end	Forest land	Cropland	Grassland	Wetlands	Settlements	Other land	Total
Forest land	24,945.73	2.63	3.37	0.33	14.53	3.60	24,970.18
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	0.58	IE	NO	0.00	3,160.17	IE	3,160.75
Other land	0.58	2.33	2.95	0.09	0.76	2,511.89	2,518.60
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 transition matrix for Japan in FY2022 [kha]

at the beginning \ at the end	Forest land	Cropland	Grassland	Wetlands	Settlements	Other land	Total
Forest land	24,970.20	1.01	0.50	0.05	3.07	0.05	24,974.89
Cropland	NO	3,981.94	0.55	0.00	13.24	0.70	3,996.44
Grassland	NO	0.01	899.49	0.00	2.08	0.19	901.77
Wetlands	NO	NO	NO	1,349.93	IE	IE	1,349.93
Settlements	NO	IE	NO	0.00	3,878.60	IE	3,878.60
Other land	NO	4.26	0.82	0.01	NO	2,690.61	2,695.70
Total	24,970.20	3,987.21	901.36	1,350.00	3,897.00	2,691.55	37,797.33

Table 6-8 Land-use transition matrix of Japan for FY1990-FY2022 [kha]

at the beginning of FY1990 \ at the end of FY2022	Forest land	Cropland	Grassland	Wetlands	Settlements	Other land	Total
Forest land	24,869.50	22.14	22.60	16.65	225.98	51.66	25,208.52
Cropland	39.17	3,871.36	35.17	1.42	441.79	65.23	4,454.13
Grassland	11.76	1.77	813.18	0.24	52.99	8.79	888.73
Wetlands	0.14	0.87	0.64	1,326.99	IE	IE	1,328.64
Settlements	26.61	IE	NO	0.08	3,150.42	IE	3,177.12
Other land	23.03	91.07	29.78	4.61	25.82	2,565.88	2,740.19
Total	24,970.20	3,987.21	901.36	1,350.00	3,897.00	2,691.55	37,797.33
Net change of each land-use category (FY1990-FY2022)	-238.32	-466.92	12.64	21.36	719.88	-48.64	-

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

Prior to the sections describing detailed methods for each land-use category, basic parameters used for estimating carbon stock changes due to land-use conversions are shown here (Table 6-9 to Table 6-14) to avoid repeating these parameters in each subsequent section.

Table 6-9 Biomass stocks 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		155.8 [t-d.m./ha] (FY2022)	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”, Volume 4 of the *2006 IPCC Guidelines*).
	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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Forest land (before conversion)	t-d.m./ha	93.1	93.1	93.1	93.1	93.1	93.9	94.0	94.0	94.0	94.0	93.5	152.7	153.7	154.9	155.8

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 conversi-on	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", Volume 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	10.0 [t-C/ha]	Average value calculated using the results of the Forest Soil Inventory Survey (Ugawa et al. (2012)). Stocks in dead wood for fallen trees were calculated as 4.2 t-C/ha; fallen trees: stumps: standing dead trees = 42:33:25; thus, total stocks of dead wood were calculated as 4.2 *(100/42) = 10 t-C/ha.
	Cropland, grassland, wetlands, settlements, other land	0 [t-C/ha]	Default value (Section 5.3.2 etc. in Volume 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 Volume 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 Volume 4 of the *2006 IPCC Guidelines*, Tier 1)
	Settlements	0 [t-C/ha]	Default value (Section 8.3.2 in Volume 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 Volume 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 Volume 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 conversion. The measured data after 21 years from land 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 Volume 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 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 IPCC 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 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: Project for the Comprehensive Promotion of Environmental Research
[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.

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* (March 31, 2007) (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 sub-categories by reporting and by management type

Sub-categories by reporting	Sub-categories 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 FY2022 was about 24.97 million ha, representing about 66.1% of the total national land area. The net removal in this category in FY2022 was 59,763 kt-CO_2 (GHG emissions other than changes in carbon stocks are not included). This represents a decrease of 6.0% compared to FY2021, and a decrease of 36.6% 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
4.A. Forest land	Total	kt-CO_2	-94,291	-100,794	-100,787	-101,185	-89,497	-83,604	-80,507	-73,793	-68,999	-70,793	-68,983	-64,462	-65,851	-63,595	-59,763
	Living biomass	kt-CO_2	-88,232	-93,014	-93,810	-96,074	-80,325	-75,437	-72,667	-66,280	-61,779	-63,796	-62,204	-57,968	-59,578	-57,613	-54,029
	Dead wood	kt-CO_2	-2,860	-3,803	-2,837	-1,082	-3,541	-3,786	-3,864	-3,943	-4,037	-4,147	-4,249	-4,311	-4,408	-4,447	-4,510
	Litter	kt-CO_2	-2,697	-2,352	-1,774	-1,078	-323	27	129	228	304	343	380	429	474	518	564
	Mineral soil	kt-CO_2	-503	-1,625	-2,367	-2,950	-5,308	-4,407	-4,105	-3,799	-3,487	-3,195	-2,909	-2,613	-2,339	-2,053	-1,788
	Organic soil	kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.A.1. Forest land remaining Forest land	Total	kt-CO_2	-84,713	-96,616	-98,099	-99,212	-88,094	-82,310	-79,275	-72,627	-67,895	-69,754	-68,017	-63,574	-65,039	-62,860	-59,107
	Living biomass	kt-CO_2	-82,157	-90,347	-92,084	-94,808	-79,401	-74,576	-71,844	-65,500	-61,039	-63,092	-61,548	-57,361	-59,020	-57,103	-53,570
	Dead wood	kt-CO_2	-2,530	-3,658	-2,743	-1,012	-3,489	-3,739	-3,819	-3,900	-3,996	-4,108	-4,214	-4,278	-4,377	-4,419	-4,485
	Litter	kt-CO_2	-2,019	-2,055	-1,581	-934	-217	123	221	316	388	422	453	496	536	575	615
	Mineral soil	kt-CO_2	1,993	-556	-1,692	-2,458	-4,986	-4,119	-3,833	-3,544	-3,249	-2,975	-2,709	-2,432	-2,177	-1,912	-1,667
	Organic soil	kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.A.2. Land converted to Forest land	Total	kt-CO_2	-9,578	-4,178	-2,688	-1,973	-1,404	-1,294	-1,232	-1,166	-1,103	-1,040	-966	-889	-812	-735	-656
	Living biomass	kt-CO_2	-6,075	-2,667	-1,726	-1,266	-924	-861	-823	-780	-740	-703	-657	-607	-558	-510	-460
	Dead wood	kt-CO_2	-330	-145	-94	-70	-51	-47	-45	-43	-41	-38	-36	-33	-30	-28	-25
	Litter	kt-CO_2	-677	-298	-193	-144	-106	-97	-92	-88	-84	-79	-73	-68	-62	-57	-51
	Mineral soil	kt-CO_2	-2,496	-1,069	-675	-493	-322	-288	-272	-255	-238	-220	-200	-181	-162	-141	-120
	Organic soil	kt-CO_2	NO	NO	NO	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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Forest land	kha	24,950	24,897	24,876	24,992	24,966	25,173	25,114	24,906	24,809	24,876	24,915	24,926	24,985	24,971	24,970
Intensively managed forests	kha	10,288	10,356	10,331	10,337	10,285	10,241	10,225	10,202	10,126	10,140	10,140	10,115	10,100	10,076	10,060
Semi-natural forests	kha	13,354	13,220	13,195	13,316	13,361	13,369	13,381	13,401	13,389	13,426	13,441	13,458	13,465	13,474	13,479
Forests with less standing trees	kha	1,159	1,171	1,197	1,186	1,162	1,401	1,356	1,150	1,147	1,155	1,167	1,185	1,251	1,248	1,257
Bamboo	kha	149	150	153	154	159	162	152	153	147	155	167	168	169	173	174

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 FY2022 were 59,107 kt-CO_2 (GHG emissions other than changes in carbon stocks are not included). This represents a decrease of 30.2% compared to FY1990 and a decrease of 6.0% compared to FY2021. 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).

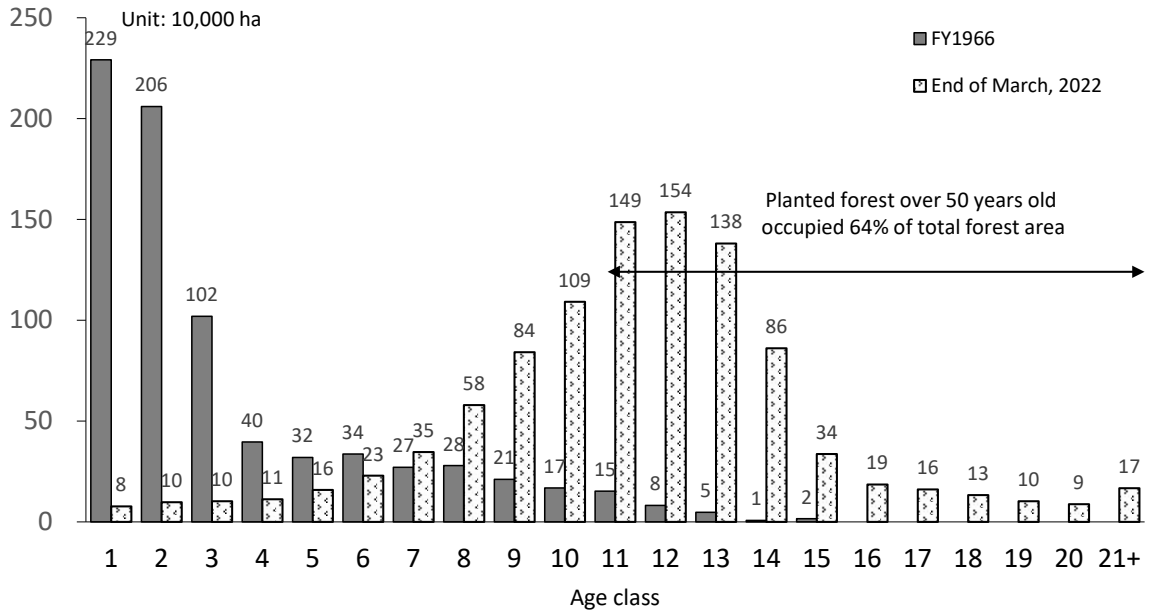

Figure 6-2 The distributions of age class structure of intensively managed forests

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.

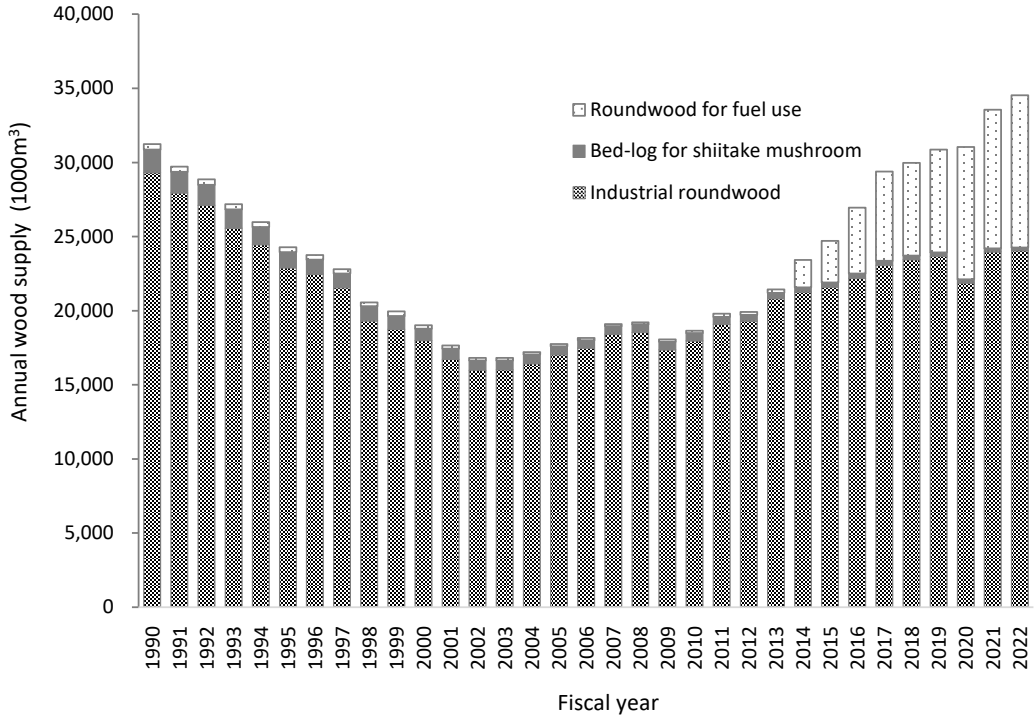

Figure 6-3 Changes in the supply of domestic wood (except logging residue)

Source: *Wood supply and demand chart* (FY2022) (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 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]

$$C_{F_LB} = \sum_j \{V_j \times D_j \times BEF_j \times (1 + R_j) \times CF\}$$

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)

$$V_j = \sum_m (A_{m,j} \times v_{m,j})$$

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 can be regarded 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 do 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 flat.

● ***Parameters***

➢ ***Volume per unit area***

The merchantable volume per unit area 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 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	0.314	0.51	
	Hinoki cypress	1.55	1.24	0.26	0.407		
	Sawara cypress	1.55	1.24	0.26	0.287		
	Japanese red pine	1.63	1.23	0.26	0.451		
	Japanese black pine	1.39	1.36	0.34	0.464		
	Hiba arborvitae	2.38	1.41	0.20	0.412		
	Japanese larch	1.50	1.15	0.29	0.404		
	Momi fir	1.40	1.40	0.40	0.423		
	Sakhalin fir	1.88	1.38	0.21	0.318		
	Japanese hemlock	1.40	1.40	0.40	0.464		
	Yezo spruce	2.18	1.48	0.23	0.357		
	Sakhalin spruce	2.17	1.67	0.21	0.362		
	Japanese umbrella pine	1.39	1.23	0.20	0.455		
	Japanese yew	1.39	1.23	0.20	0.454		
	Ginkgo	1.50	1.15	0.20	0.450		
	Exotic conifer trees	1.41	1.41	0.17	0.320		
	Other conifer trees	2.55	1.32	0.34	0.352		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	0.464		Applied to Okinawa prefecture
		1.40	1.40	0.40	0.423		Applied to prefectures other than above
Forests with standing trees (Broad leaf trees)	Japanese beech	1.58	1.32	0.26	0.573	0.48	
	Oak (evergreen tree)	1.52	1.33	0.26	0.646		
	Japanese chestnut	1.33	1.18	0.26	0.419		
	Japanese chestnut oak	1.36	1.32	0.26	0.668		
	Oak (deciduous tree)	1.40	1.26	0.26	0.624		
	Japanese poplar	1.33	1.18	0.26	0.291		
	Alder	1.33	1.25	0.26	0.454		
	Japanese elm	1.33	1.18	0.26	0.494		
	Japanese zelkova	1.58	1.28	0.26	0.611		
	Cercidiphyllum	1.33	1.18	0.26	0.454		
	Japanese big-leaf magnolia	1.33	1.18	0.26	0.386		
	Maple tree	1.33	1.18	0.26	0.519		
	Amur cork	1.33	1.18	0.26	0.344		
	Linden	1.33	1.18	0.26	0.369		
	Kalopanax	1.33	1.18	0.26	0.398		
	Paulownia	1.33	1.18	0.26	0.234		
	Exotic broad leaf trees	1.41	1.41	0.16	0.660		
	Japanese birch	1.31	1.20	0.26	0.468		
	Other broad leaf trees	1.37	1.37	0.26	0.469		Applied to Chiba, Tokyo, Kochi, Fukuoka, Nagasaki, Kagoshima, and Okinawa prefectures
		1.52	1.33	0.26	0.646		Applied to Mie, Wakayama, Oita, Kumamoto, Miyazaki, and Saga prefectures
		1.40	1.26	0.26	0.624		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***

➢ ***Determining the 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

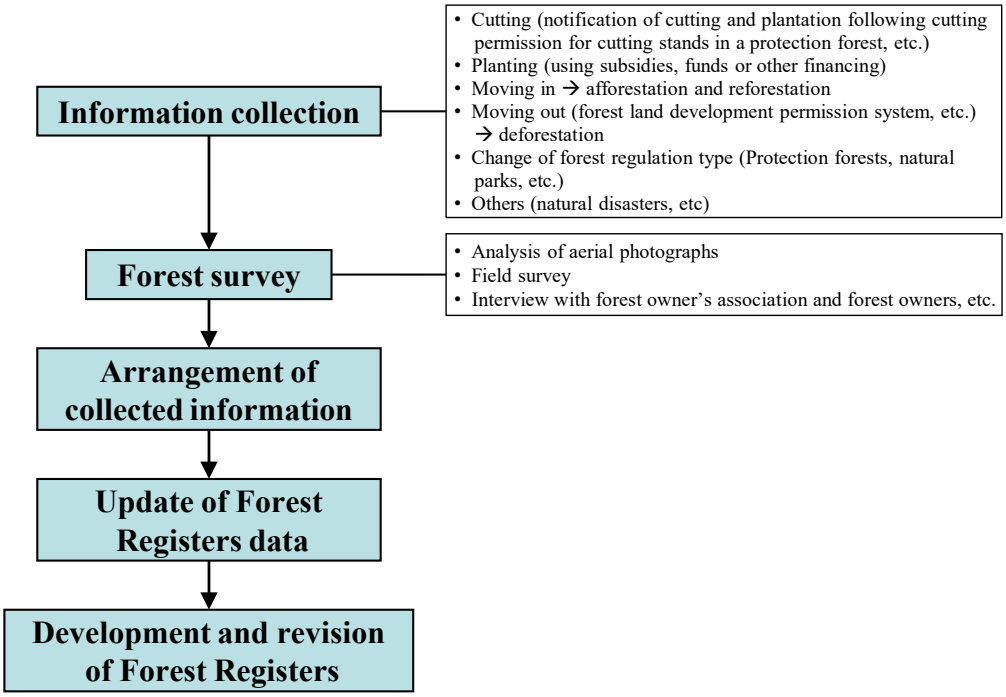

Figure 6-4 Procedures for developing and updating Forest Registers

2) Carbon Stock Changes in Dead Organic Matter and Soils in "Forest land remaining Forest land"

- ***Estimation Method***

➢ ***Carbon Stock Changes in Dry 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 by using the CENTURY-jfos model.

The carbon stock changes in 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 Dry 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

[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

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 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.

  During the reviews (ARR 2020 L.2 (L.4 2018) (L.11. 2016)), it was pointed out that the carbon stock of dead wood showed relatively higher values compared to the values of carbon stock of the living biomass in Japanese forests. To address the issue, mortality rate and decomposition rate of dead wood in CENTURY-jfos has been revised based on the results of forest soil inventory survey. The revision of the model resulted in the largely decreased carbon stock of dead wood in FY2022 compared to those reported before FY2021, that is, 10.6 t-C/ha in intensively managed forests and 6.1 t-C/ha in natural forests with an average of 8.0 t-C/ha. These values are within the range of carbon stock of dead wood reported by developed countries, which indicates that the revised model provides more realistic estimation.

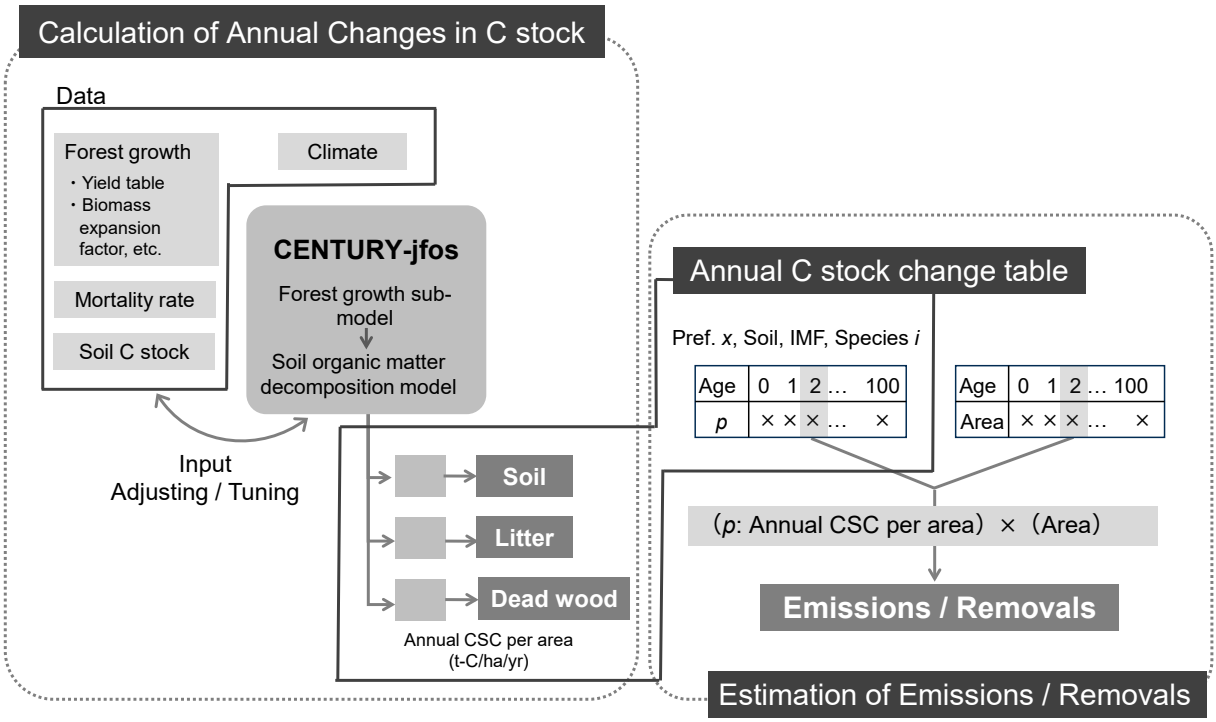

Figure 6-5 Estimation of emissions/removals in dead wood, litter and soils carbon pool

- ***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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Forest land	kha	66.2	65.5	65.4	66.0	66.2	66.3	66.3	66.4	66.4	66.5	66.6	66.7	66.7	66.8	66.8
Intensively managed forests	kha	NO	NO	NO	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	66.3	66.4	66.4	66.5	66.6	66.7	66.7	66.8	66.8
Forests with less standing trees	kha	NO	NO	NO	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	NO	NO	NO

c) Uncertainties 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 described 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 estimation of carbon stock changes in living biomass of forests with standing trees was ensured by using consistent methodologies, yield tables, and parameters for the whole time-series.

However, carbon stock changes in the pools of dead wood, litter, and mineral soils of the forests with standing trees were recalculated in accordance with the update in the CENTURY-jfos model from FY 2008 onward, while the recalculation of values for the preceding years will be addressed in the next submission.

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

- ***Recalculation due to revision of yield tables***

The revision of the yield tables for the intensively managed forests in the private forests, which are used to estimate volume per unit area, has been applied for the whole time series. Following the revision, carbon stock changes in living biomass in this category were recalculated from FY1990 to FY 2007 that was not addressed in the previous submission.

- ***Recalculation due to the update in CENTURY-jfos model***

Since the amount of dead organic matter was altered by the revision of the forest growth model, carbon stock changes in the pools of dead wood, litter and mineral soils were recalculated from FY 2008 onwards accordingly.

- ***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

Grasping the current state of forest through National Forest Inventory Survey and carbon stock of the pools of dead wood, litter, and mineral soil through National Forest Soil Survey are still ongoing, and efforts are underway to utilize these data to improve the accuracy of the model.

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 FY2022 were 656 kt-CO_2 (GHG emissions other than changes in carbon stock are not included). This represents a decrease of 93.1% compared to FY1990 and a decrease of 10.7% compared to FY2021. 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 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 change at the land conversion (loss) [t-C/yr]
$\Delta C_{LF_LB_SC}$	: Carbon stock gains due to biomass growth in 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] (default value=0)
$B_{b,i}$	: 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" uses 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 by 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 by 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 by using the forest areas obtained from the statistics in FY1970, FY1980 and FY1990 respectively.

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 by 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" by 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 on Cultivated and Cropland Area* after FY2017, the data is divided into fields based on the percentage of cropland from rice fields and fields in the *Movement 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 sub-land use category 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 on Cultivated and Cropland 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Land converted to Forest land	kha	4.53	4.53	4.53	4.53	3.07	0.99	0.99	0.96	0.96	0.27	0.08	0.08	0.08	NO	NO
Cropland converted to Forest land	kha	3.11	1.28	1.05	2.72	1.75	0.57	0.57	0.33	0.33	0.13	0.04	0.02	0.02	NO	NO
Rice field	kha	0.92	0.47	0.41	0.82	0.75	0.21	0.20	0.11	0.11	0.05	0.01	0.01	0.01	NO	NO
Upland field	kha	1.20	0.52	0.20	1.49	0.79	0.29	0.30	0.17	0.17	0.06	0.02	0.01	0.01	NO	NO
Orchards	kha	0.99	0.30	0.44	0.42	0.21	0.07	0.08	0.04	0.04	0.01	0.00	0.00	0.00	NO	NO
Grassland converted to Forest land	kha	0.27	0.25	0.30	0.82	0.72	0.28	0.28	0.48	0.48	0.10	0.03	0.06	0.06	NO	NO
Wetlands converted to Forest land	kha	NO	NO	NO	0.00	NO	0.01	0.01	0.01	0.01	NO	NO	NO	NO	NO	NO
Settlements converted to Forest land	kha	0.58	1.50	1.59	0.81	0.48	0.09	0.09	0.10	0.10	0.02	0.01	NO	NO	NO	NO
Other land converted to Forest land	kha	0.58	1.50	1.59	0.18	0.11	0.04	0.04	0.03	0.03	0.02	0.01	NO	NO	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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Area within the past 20 years after conversion	kha	554.0	243.5	157.9	118.0	86.4	79.2	75.6	72.1	68.5	64.2	59.8	55.3	50.9	46.3	41.8
Cropland converted to Forest land	kha	123.6	60.2	43.1	34.3	31.3	28.5	27.6	26.6	25.7	24.6	23.5	22.4	21.4	20.5	19.6
Grassland converted to Forest land	kha	17.6	9.1	6.5	5.8	7.9	9.2	9.3	9.5	9.8	9.6	9.4	9.1	8.9	8.7	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	0.1	0.1	0.1
Settlements converted to Forest land	kha	206.4	87.1	54.1	39.3	25.1	22.4	21.0	19.6	18.2	16.7	15.2	13.6	12.0	10.3	8.6
Wetlands converted to Forest land	kha	206.4	87.1	54.1	38.7	22.2	19.0	17.6	16.1	14.7	13.1	11.6	10.0	8.4	6.7	5.0
Area 21-40 years after conversion	kha	439.8	724.0	781.1	729.1	555.8	321.9	275.4	243.6	219.7	202.4	184.8	169.9	157.8	147.1	138.0
Cropland converted to Forest land	kha	201.8	270.0	286.8	235.8	123.6	75.9	66.6	60.2	55.5	52.2	48.8	45.9	43.1	40.6	38.3
Grassland converted to Forest land	kha	16.7	26.4	30.0	27.9	17.6	11.4	10.0	9.1	8.4	7.8	7.3	6.9	6.5	6.1	5.8
Settlements and other land converted to Forest land	kha	221.3	427.6	464.4	465.4	414.6	234.6	198.8	174.3	155.8	142.4	128.7	117.2	108.2	100.5	93.9

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."

$$\Delta C(l)_{LF} = \sum_i \left\{ \Delta A_{LF_i} \times (C(l)_{F20} - C(l)_i)/T(l) \right\}$$

$\Delta C(l)_{LF}$	: 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]
$C(l)_{F20}$	: 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 dry 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) Uncertainties 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 described 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

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

- ***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

Nothing in particular.

6.5. Cropland (4.B.)

Cropland is the land that produces annual and perennial crops; it includes temporarily fallow land. Cropland in Japan's inventory consists of rice fields, upland fields, orchards and dilapidated farmland.

In FY2022, Japan's cropland area was about 3.99 million ha, which is equivalent to about 10.7% of the national land. The area of organic soil in cropland is about 0.17 million ha. The emissions from this category in FY2022 were 4,819 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 39.9% compared to FY1990 and an increase of 19.7% compared to FY2021.

Table 6-27 Emissions and removals in cropland resulting from carbon stock changes

Category	Carbon pool	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
4.B. Cropland	Total	kt-CO_2	8,021	3,773	3,982	3,908	5,846	5,464	6,181	5,698	5,442	4,564	3,801	4,311	4,200	4,025	4,819
	Living biomass	kt-CO_2	699	347	182	207	282	189	185	244	241	174	204	250	304	446	453
	Dead wood	kt-CO_2	96	26	9	20	28	18	18	18	18	9	9	15	15	37	37
	Litter	kt-CO_2	47	13	4	10	14	9	9	9	9	4	4	7	7	18	18
	Mineral soil	kt-CO_2	5,934	2,159	2,572	2,473	4,342	4,073	4,795	4,253	4,001	3,205	2,413	2,867	2,702	2,353	3,142
	Organic soil	kt-CO_2	1,244	1,228	1,214	1,197	1,180	1,175	1,175	1,174	1,172	1,172	1,172	1,172	1,172	1,170	1,169
4.B.1. Cropland remaining Cropland	Total	kt-CO_2	7,372	3,551	3,880	3,727	5,630	5,348	6,062	5,561	5,304	4,497	3,741	4,168	4,048	3,662	4,447
	Living biomass	kt-CO_2	280	245	157	121	154	144	137	179	175	165	207	182	231	198	198
	Dead wood	kt-CO_2	NA	NA	NA	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	NA	NA	NA
	Mineral soil	kt-CO_2	5,934	2,159	2,572	2,473	4,342	4,073	4,795	4,253	4,001	3,205	2,413	2,867	2,702	2,353	3,142
	Organic soil	kt-CO_2	1,158	1,147	1,150	1,133	1,134	1,131	1,130	1,130	1,128	1,126	1,122	1,118	1,115	1,110	1,107
4.B.2. Land converted to Cropland	Total	kt-CO_2	650	222	102	181	216	117	119	137	138	68	60	143	152	363	372
	Living biomass	kt-CO_2	420	102	25	86	128	45	47	65	66	9	-3	68	73	248	255
	Dead wood	kt-CO_2	96	26	9	20	28	18	18	18	18	9	9	15	15	37	37
	Litter	kt-CO_2	47	13	4	10	14	9	9	9	9	4	4	7	7	18	18
	Mineral soil	kt-CO_2	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	Organic soil	kt-CO_2	86	81	64	64	46	44	45	44	44	46	50	54	57	60	62

Table 6-28 Areas of cropland

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Cropland	kha	4,764	4,582	4,430	4,333	4,268	4,199	4,183	4,172	4,148	4,126	4,101	4,084	4,060	4,015	3,987
Rice fields	kha	2,846	2,745	2,641	2,556	2,496	2,465	2,458	2,446	2,431	2,418	2,405	2,393	2,380	2,366	2,352
Upland fields	kha	1,275	1,225	1,188	1,173	1,169	1,161	1,156	1,151	1,149	1,142	1,138	1,134	1,130	1,126	1,123
Orchards	kha	475	408	357	332	311	300	296	292	287	283	278	273	268	263	259
Dilapidated farmland	kha	167	204	244	272	292	273	273	283	281	283	280	284	282	260	253

6.5.1. Cropland remaining Cropland (4.B.1.)

a) Category Description

This category deals with carbon stock changes in cropland, which has remained as cropland for more than 20 years. Note that carbon stock changes in living biomass in orchards and in mineral soils include those from “land converted to Cropland”. The emissions from this subcategory in FY2022 were 4,447 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 39.7% compared to FY1990 and a decrease of 21.4% compared to FY2021. CO_2 emissions from mineral soil pool in FY2022 were 3,142 kt-CO_2; a 47.1% decrease compared to FY1990 and a 33.5% increase compared to FY2021. The trend on emissions in time-series data in this category 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 compost) 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 emission by the effect of carbon storage by biochar amendment

in FY2022 is 3.78 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 (Orchard)"

- ***Estimation Method***

➢ ***Carbon Stock Changes in Living Biomass in Rice Fields, Upland Fields and Dilapidated farmland***

As for carbon stock changes in living biomass, only perennial woody species are considered for estimation according to the section 5.2.1.1 in Volume 4 of the *2006 IPCC Guidelines*.

In rice fields and upland fields where annual crops are grown, the biomass increased by growth is lost by harvesting and decomposition in a short period of time, so it does not contribute to carbon stock storage over time. Therefore, it is not included in the calculation of carbon stock changes. In addition, the anthropogenic biomass carbon stock change was not considered and reported as zero or "NA" in the dilapidated farmland, since there is no direct human management for changing biomass stock.

➢ ***Carbon Stock Changes in Living Biomass in Orchard***

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 Volume 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 amount of carbon stocks changes with the area because the carbon stocks per unit area is fixed.

$$\Delta C_{C_{LB}} = C_{t+1} - C_t$$

$$C_t = \sum_j \left(A_{t,j} \times D_j \times W_j\right) \times \frac{10}{1000} \times CF$$

Note: 10/1000 is for unit conversion

ΔC_{C_LB}	: Carbon stock change in living biomass in Orchard [t-C/yr]
C_t	: Total Carbon stock in living biomass at time *t* [t-C]
A_t	: Cultivation area of orchard at time *t* [ha]
D	: Planting density [tree/10a]
W	: Dry matter weight of above-ground biomass per tree [kg/tree]
CF	: Carbon fraction of dry matter [t-C/t-d.m.]
j	: Type of orchard tree

- ***Parameters***

➢ ***Parameters for Living Biomass Estimation in Orchard tree***

Country specific parameters of the planting density, dry matter biomass weight per tree, and root-to- shoot ratio were set for major orchard trees based on existing research reports.

Dry matter biomass weight for tea tree are 48 t-d.m./ha; the dry matter biomass weight for fruit orchard

tree are 8 - 24 t-d.m./ha, the root-shoot ratio is 7:3 - 5:4. 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.

- ***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 ware 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 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 Volume 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 crop residue and organic 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 soil 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 Stock Changes in Mineral Soils Associated by Biochar Amendment***

Carbon stocks change in mineral soils in cropland by biochar amendments were estimated by applying Tier 2 method provided in *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories* (hereafter *2019 Refinement*). This estimation includes hard charcoal, soft charcoal, bamboo charcoal, fine coal and sawdust coal produced in Japan with Japanese materials.

Furthermore, since information on amount of biochar applied into each land subcategory level as well as information on the distinction of remaining land and converted land is not available, the carbon stock changes were estimated and 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} : Carbon stock changes in mineral soils land associated with biochar amendment in 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 Volume 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 : 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 Guideline*s. 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 fruit trees by either a method of cultivation by clean cultivation system or a method of cultivation by sod culture without cultivation 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 by 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 crop residue and organic manure. The input amount of crop 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 crop 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 are 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 farmland 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.

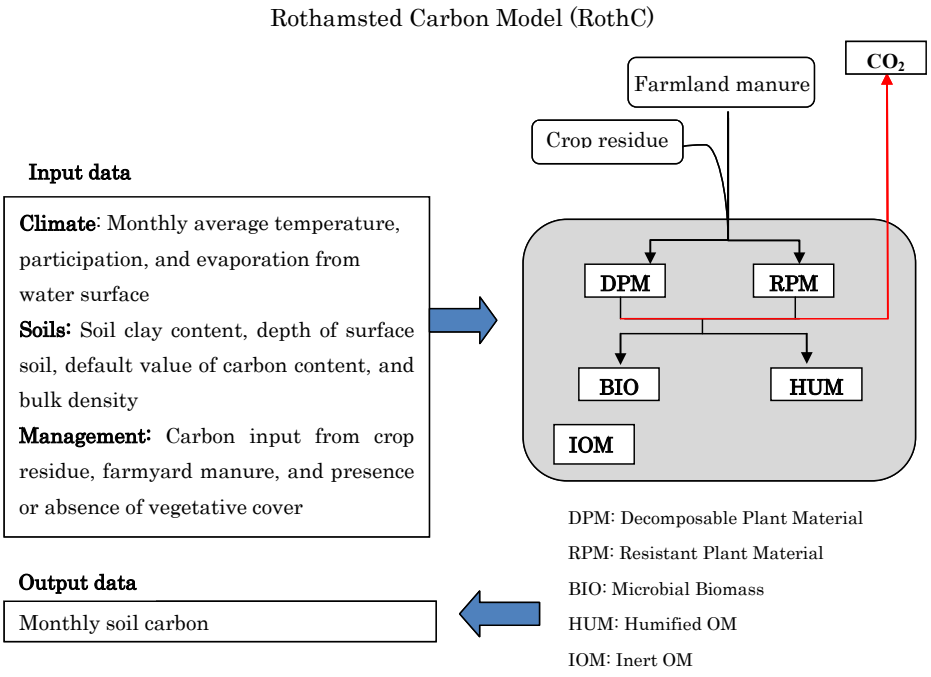

Figure 6-6 Roth C model

- ***Parameters of biochar (carbon content and fraction of carbon remaining after 100 years)***

As for organic carbon content of biochar, organic carbon content (0.778 t-C/t-d.m.)[5] at calcination temperatures of 350-450°C based on a domestic survey (Kurimoto et al., 2020) was used for bamboo charcoal. Except for bamboo charcoal, the default value (0.77 t-C/t-d.m.) of heat treatment process for wood material provided in the *2019 Refinement* (Table 4Ap.1), was applied.

Fraction of carbon remaining after 100 years is based on the firing temperature of each biochar in Japan and the default value provided in the *2019 Refinement* (Table 4Ap.2). The default value (0.89 t-C/t-C) corresponding to firing temperature of 600 ℃ or more was applied to hard charcoal, soft charcoal and sawdust coal, the default value (0.80t-C/t-C) corresponding to firing temperature of 450 to 600℃ to fine coal, and the value (0.65 t-C/t-C) of 350 to 600 ℃ to bamboo charcoal.

- ***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 6-29 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:
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.
3) 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.

- ***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 6-30 Parameters for calculating CO_2 emissions from organic soils (off-site)

Climate zone	$DOC_{FLUX_NATURAL}$ [t-C/ha/yr]	$DOC_{DRAINAGE}$	$Frac_{DOC-CO2}$	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

[5] Since information on bamboo charcoal production by firing temperature is not available, the data for firing temperatures between 350 and 450°C, which have the lowest organic carbon content, have been applied.

rice field with other crops planted and with no crops) and orchards; and the areas of organic soils in each divided area (Table 6-31) 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. In addition, since the amount of import and export of biochar for "agricultural use" is infinitesimal, import and export of biochar applied to cropland were not estimated.

- ***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 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 is used.

Table 6-31 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 6-31, 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 6-31 Areas of organic soils in cropland

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Cropland	kha	169.7	168.3	168.5	167.4	166.0	165.9	166.0	166.1	166.2	166.7	167.2	167.6	167.9	168.1	168.4
Rice fields	kha	131.6	129.8	129.1	127.3	125.3	125.1	125.2	125.2	125.1	125.1	125.2	125.2	125.2	125.1	125.1
Upland fields	kha	16.4	16.7	17.0	16.9	16.8	16.6	16.5	16.5	16.5	16.4	16.4	16.4	16.4	16.3	16.3
Orchards	kha	1.3	1.0	0.5	0.4	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.7	0.7
Dilapidated farmland	kha	20.4	20.8	22.0	22.8	23.6	23.8	23.9	24.0	24.2	24.7	25.1	25.4	25.7	26.0	26.4

c) Uncertainties and Time-series Consistency

- ***Uncertainty Assessment***

For the parameters and the activity data in biomass in orchards, the uncertainties of existing statistics and the default values described in the *2006 IPCC Guidelines* were applied. 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

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.

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 estimation method for the amount of crop residue input for Roth C and updating the data, carbon stock changes in soils per unit area after 2018 were recalculated.

- ***Changes in the methodologies for estimating un-surveyed cultivation areas of orchard trees in some prefectures***

Due to the abolition of conducting annual surveys on the cultivation areas of orchard trees in some prefectures since 2017, those missing data are complemented by an assumption. With the revision in estimation method of this assumption, the area of the orchard trees and the amount of change in carbon stock of biomass from FY2017 to FY2021 were recalculated.

- ***Recalculation of correction in area of mineral soils and organic soils***

The method of estimating the area converted to cropland was revised between 1983 and 2002, so the area converted from other land in each district was revised. With this recalculation, the carbon stock changes and the CO_2 emissions from organic and 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 FY2022 is 77.5 kha, which represents 0.2% of the national total area.

The emissions from this subcategory in FY2022 were 372 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 42.8% compared to FY1990

and an increase of 2.3% compared to FY2021. Emissions from land converted to croplands decreased significantly from 1990 to 1993, but have not changed much since then. This decrease in the early 1990s was mainly due to the decrease 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 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], default value=0
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], see Table 6-9.
j	: Land use in cropland subcategory after conversion (rice fields, upland fields) Note: Carbon stock changes accululated after conversion in Orchard is 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 6-32 Area of land converted to cropland within the past 1 year

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Land-use classification before conversion	kha	5.17	3.55	2.73	1.99	0.81	6.13	5.93	3.65	3.69	5.03	7.46	7.63	6.83	6.03	5.27
Forest land converted to Cropland	kha	2.63	0.71	0.24	0.55	0.78	0.49	0.49	0.50	0.50	0.23	0.23	0.40	0.40	1.01	1.01
Grassland converted to Cropland	kha	0.009	0.083	0.041	0.060	0.001	0.001	0.007	0.007	0.004	0.006	0.005	0.005	0.007	0.008	0.007
Wetlands converted to Cropland	kha	0.20	0.03	0.06	NO	NO	NO	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	IE	IE	IE
Other land converted to Cropland	kha	2.33	2.73	2.39	1.38	0.04	5.63	5.44	3.14	3.18	4.79	7.22	7.23	6.42	5.02	4.26
Land-use classification after conversion	kha	5.17	3.55	2.73	1.99	0.81	6.13	5.93	3.65	3.69	5.03	7.46	7.63	6.83	6.03	5.27
Rice fields	kha	0.218	1.215	1.365	0.321	0.033	4.287	3.978	2.025	1.686	3.322	3.974	4.031	3.711	3.464	2.828
Upland fields	kha	4.67	2.26	1.31	1.30	0.62	1.46	1.56	1.30	1.60	1.37	2.80	2.90	2.52	2.08	1.99
Orchards	kha	0.28	0.08	0.05	0.37	0.16	0.38	0.40	0.33	0.40	0.34	0.68	0.70	0.60	0.49	0.46

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 NIF survey (Forest Soil Inventory Survey) (Ugawa et al., 2012). 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 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 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 6-32).

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" using Tier 3 modeling method 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 6-33 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Area within the past 20 years after conversion	kha	230.9	164.9	98.6	70.4	46.6	47.2	47.8	47.9	49.8	53.2	59.4	64.3	68.4	73.3	77.5
Forest land converted to Cropland	kha	119.7	84.9	48.7	24.8	12.7	10.6	10.2	10.0	10.0	9.9	9.8	9.8	9.9	10.8	11.7
Rice fields	kha	22.8	13.2	0.8	0.4	0.2	0.5	0.6	0.8	1.0	1.1	1.2	1.4	1.6	2.1	2.6
Upland fields	kha	65.3	57.1	41.3	22.7	11.1	8.5	8.0	7.6	7.4	7.2	6.9	6.7	6.6	6.9	7.2
Orchards	kha	31.6	14.7	6.6	1.7	1.4	1.5	1.5	1.6	1.6	1.6	1.6	1.7	1.7	1.8	1.9
Grassland converted to Cropland	kha	34.1	16.6	2.1	1.8	1.7	1.2	0.8	0.7	0.6	0.6	0.5	0.5	0.4	0.4	0.3
Wetlands converted to Cropland	kha	10.4	2.5	1.1	0.7	0.7	0.6	0.6	0.5	0.5	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	IE	IE	IE
Other land converted to Cropland	kha	66.7	60.8	46.7	43.2	31.5	34.8	36.3	36.7	38.6	42.2	48.6	53.5	57.5	61.7	65.1
Area 21-40 years after conversion	kha	233.2	174.8	161.5	138.3	97.0	79.3	74.7	71.8	66.2	59.9	56.1	52.7	47.9	43.4	37.7
Forest land converted to Upland fields	kha	105.1	49.8	48.1	61.1	65.3	60.2	58.4	57.1	53.8	49.5	46.9	44.6	41.3	38.2	34.3
Forest land converted to Orchards	kha	128.1	124.9	113.4	77.2	31.6	19.2	16.3	14.7	12.5	10.5	9.2	8.1	6.6	5.2	3.4

➢ ***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) Uncertainties 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 described in the *2006 IPCC Guidelines*. The uncertainty was estimated as 20% 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

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

- ***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 FY2022, 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 FY2022 were 415 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 57.0% compared to FY1990 and an increase of 94.0% compared to FY2021.

Table 6-34 Emissions and removals from grassland resulting from carbon stock changes

Category	Carbon pool	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
4.C. Grassland	Total	kt-CO_2	964	51	-925	-341	130	1,069	1,680	1,346	1,052	813	533	611	420	214	415
	Living biomass	kt-CO_2	287	-11	-38	32	164	116	119	80	79	34	29	15	12	101	100
	Dead wood	kt-CO_2	124	18	5	17	45	32	32	22	22	13	13	7	7	18	18
	Litter	kt-CO_2	61	9	2	8	22	16	16	11	11	6	6	3	3	9	9
	Mineral soil	kt-CO_2	465	7	-923	-426	-128	874	1,477	1,195	911	731	457	559	370	57	259
	Organic soil	kt-CO_2	27	28	29	28	27	31	36	38	28	28	28	28	28	28	28
4.C.1. Grassland remaining Grassland	Total	kt-CO_2	478	25	-901	-403	-104	902	1,510	1,230	937	757	483	586	396	84	286
	Living biomass	kt-CO_2	NA	NA	NA	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	NA	NA	NA
	Litter	kt-CO_2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Mineral soil	kt-CO_2	465	7	-923	-426	-128	874	1,477	1,195	911	731	457	559	370	57	259
	Organic soil	kt-CO_2	13	18	22	23	24	28	33	35	26	26	26	26	26	27	27
4.C.2. Land converted to Grassland	Total	kt-CO_2	485	26	-24	62	234	167	170	116	115	56	51	26	23	130	129
	Living biomass	kt-CO_2	287	-11	-38	32	164	116	119	80	79	34	29	15	12	101	100
	Dead wood	kt-CO_2	124	18	5	17	45	32	32	22	22	13	13	7	7	18	18
	Litter	kt-CO_2	61	9	2	8	22	16	16	11	11	6	6	3	3	9	9
	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	IE,NO	IE,NO	IE,NO
	Organic soil	kt-CO_2	14.1	9.2	6.3	5.1	3.3	3.1	3.3	3.1	2.0	1.8	1.6	1.5	1.3	1.1	1.1

Table 6-35 Areas of grassland

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Grassland	kha	1,031.6	1,021.6	1,011.6	1,007.2	993.2	951.1	957.7	956.5	943.4	951.1	948.8	946.9	905.2	903.5	901.4
Pasture land	kha	646.7	660.7	644.7	630.6	616.7	611.1	607.7	606.5	603.4	601.1	598.8	596.9	595.2	593.5	591.4
Grazed meadow	kha	105.0	100.9	96.8	96.5	96.4	96.3	96.3	96.3	96.3	96.3	96.2	96.2	96.2	96.1	96.1
Wild land	kha	280.0	260.0	270.0	280.0	280.0	243.7	253.7	253.7	243.7	253.7	253.8	253.8	213.8	213.9	213.9

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 FY2022 were 286 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 40.2% compared to FY1990 value and an increase of 240.9% compared to FY2021. Regarding the trend of emissions and removals, a peak of removals was occurred in FY1999, then the amount of removals has been on a decreasing 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 by 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 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, 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 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 6-36 Area of organic soils in grassland

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Grassland	kha	56.3	56.3	57.9	58.1	57.5	55.7	56.0	56.0	55.5	55.9	55.9	55.8	53.9	53.9	53.8
Pasture land	kha	38.6	39.5	40.6	40.4	39.8	39.7	39.6	39.6	39.5	39.5	39.4	39.4	39.4	39.3	39.3
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	4.5	4.5	4.5
Wild land	kha	13.2	12.2	12.7	13.2	13.2	11.4	11.9	11.9	11.4	11.9	11.9	11.9	10.0	10.0	10.0

c) Uncertainties 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 described in the *Wetlands Guidelines* were applied to estimate CO_2 emissions from organic soil. As a result, the uncertainty was estimated as 9% 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

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

- ***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.

- ***Correction of input data used for Roth C model calculation***

Due to revision of the estimation method for the amount of crop residue, input data for Roth C model and update of data, carbon stock changes in soils per unit area after 2018 were recalculated. 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 FY2022 were 128.6 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 73.5% compared to FY1990 and a decrease of 0.9% compared to FY2021.

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 (Area)***

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 6-37) 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 6-38).

➢ ***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 Forestland***

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 conversion from settlements to grassland does not occur.

Table 6-37 Area of land converted to grassland within the past 1 year

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Land converted to Grassland	kha	8.5	3.3	2.6	2.4	1.9	1.3	1.3	1.1	1.4	1.6	2.2	2.0	2.0	2.0	1.9
Forest land converted to Grassland	kha	3.4	0.5	0.1	0.5	1.2	0.9	0.9	0.6	0.6	0.4	0.4	0.2	0.2	0.5	0.5
Cropland converted to Grassland	kha	1.9	1.0	1.5	1.7	0.7	0.3	0.3	0.4	0.5	0.5	0.4	0.4	0.5	0.6	0.6
Wetlands converted to Grassland	kha	0.3	0.02	0.05	NO	NO	NO	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	NO	NO	NO
Other land converted to Grassland	kha	2.95	1.75	0.93	0.23	0.00	0.15	0.14	0.13	0.24	0.68	1.42	1.43	1.24	0.88	0.82

Table 6-38 Area of land converted to grassland within the past 5 years

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Land converted to Grassland	kha	63.8	22.2	15.5	12.9	10.4	7.2	6.6	5.8	6.0	6.7	7.5	8.2	9.1	9.7	10.0
Forest land converted to Grassland	kha	24.2	5.0	1.7	1.0	5.4	4.4	4.0	3.4	3.5	3.3	2.8	2.1	1.7	1.6	1.7
Cropland converted to Grassland	kha	15.3	6.3	8.3	8.6	4.6	2.6	2.2	1.9	1.9	2.0	2.1	2.2	2.4	2.4	2.5
Wetlands converted to Grassland	kha	0.7	0.1	0.1	NO	0.2	NO	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	NO	NO	NO
Other land converted to Grassland	kha	23.6	10.8	5.4	3.3	0.2	0.2	0.3	0.5	0.7	1.3	2.6	3.9	5.0	5.6	5.8

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)3).

- ***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 (Area)***

The area of land converted to grassland during the past 20 years was used.

Table 6-39 Areas of land converted to grassland within the past 20 years

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Land converted to Grassland	kha	492.1	315.1	191.6	114.4	61.0	48.6	46.7	44.6	43.2	41.5	40.5	38.8	38.1	38.0	37.0
Forest land converted to Grassland	kha	219.3	141.7	84.3	32.0	13.2	10.9	11.4	11.5	11.7	11.7	11.6	11.4	11.5	11.9	12.2
Cropland converted to Grassland	kha	84.4	55.2	44.7	38.4	27.8	24.6	24.1	23.5	22.9	21.8	20.3	18.5	17.5	16.8	15.4
Wetlands converted to Grassland	kha	2.3	2.2	1.7	0.9	0.4	0.3	0.3	0.3	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	NO	NO	NO
Other land converted to Grassland	kha	186.1	116.0	60.9	43.0	19.7	12.7	11.0	9.4	8.4	7.8	8.4	8.6	8.9	9.2	9.2

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 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 conversion. Therefore, carbon stock pools in mineral soil was reported regardless of whether or not land 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).

[6] Cropland in the Japanese statistics includes pasture land which falls into grassland.

c) Uncertainties 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 described in the *2006 IPCC Guidelines*. The uncertainty was estimated as 22% 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. b) 1), time-series consistency for this subcategory is basically ensured.

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

- ***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.

- ***Recalculation of mineral soil area and organic soil area due to revisions***

The area converted from other lands in each district has been revised due to the revision of the method of estimating the area converted to cropland.

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 are lands that are covered with or soaked in water throughout the year. They do not fall into the categories of forest land, cropland, grassland, or settlements. The *2006 IPCC Guidelines* divides wetlands into three large groups: peat land for peat extraction, flooded land, and other wetlands.

In FY2022, Japan's wetland area was about 1.35 million ha, which is equivalent to about 3.6% of the national land. The emissions from this category in FY2022 were 339 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 35.8% compared to FY1990 and an increase of 0.3% compared to FY2021.

Table 6-40 Emissions and removals in wetlands resulting from carbon stock changes

Category	Carbon pool	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
4.D. Wetlands	Total	kt-CO_2	-528	-216	-57	-358	-291	-362	-361	-312	-311	-351	-350	-348	-324	-338	-339
	Living biomass	kt-CO_2	55	207	259	27	72	15	15	51	51	20	19	24	25	14	14
	Dead wood	kt-CO_2	12	45	56	6	16	3	3	11	11	4	4	3	3	2	2
	Litter	kt-CO_2	6	22	28	3	8	2	2	5	5	2	2	2	2	1	1
	Mineral soil	kt-CO_2	-601	-490	-400	-393	-386	-382	-381	-379	-378	-377	-375	-377	-354	-355	-356
	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	NA,NE,NO	NA,NE,NO	NA,NE,NO
4.D.1. Wetlands remaining Wetlands	Total	kt-CO_2	-601	-490	-401	-394	-386	-383	-381	-379	-378	-377	-376	-378	-355	-356	-357
	Living biomass	kt-CO_2	-0.5	-0.6	-0.6	-0.7	-0.2	-0.7	-0.6	0.0	-0.3	-0.3	-0.7	-0.6	-0.7	-0.7	-0.7
	Dead wood	kt-CO_2	-0.08	-0.09	-0.10	-0.12	-0.04	-0.11	-0.09	-0.01	-0.05	-0.05	-0.12	-0.10	-0.11	-0.11	-0.11
	Litter	kt-CO_2	-0.005	-0.006	-0.007	-0.008	-0.003	-0.007	-0.006	0.000	-0.003	-0.003	-0.008	-0.007	-0.007	-0.007	-0.007
	Mineral soil	kt-CO_2	-601	-490	-400	-393	-386	-382	-381	-379	-378	-377	-375	-377	-354	-355	-356
	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	NE,NO	NE,NO	NE,NO
4.D.2. Land converted to Wetlands	Total	kt-CO_2	73	275	344	36	96	20	20	67	67	26	26	30	30	17	17
	Living biomass	kt-CO_2	55	208	260	27	72	15	16	51	51	20	20	25	25	15	15
	Dead wood	kt-CO_2	12	45	56	6	16	3	3	11	11	4	4	3	3	2	2
	Litter	kt-CO_2	6	22	28	3	8	2	2	5	5	2	2	2	2	1	1
	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	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	NA,NE,NO	NA,NE,NO	NA,NE,NO

Table 6-41 Areas of wetlands

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Wetlands	kha	1,310	1,320	1,350	1,340	1,330	1,340	1,340	1,340	1,330	1,350	1,350	1,350	1,350	1,350	1,350
Organic soils managed for peat extraction	kha	NE	NE	NE	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	1,340	1,330	1,350	1,350	1,350	1,350	1,350	1,350
Other wetlands	kha	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

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.

For carbon stock change in organic soils managed for peat extraction in peat land, 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 mangrove forests in coastal wetlands that are not

included in the forest under forest planning, and seagrass meadows and macroalgal beds are covered under "Other wetlands remaining other wetlands". There are about 900 ha of mangrove forest in Okinawa prefecture and Kagoshima prefecture, which are not included in 4.A. Forest Land, are reported here. In seagrass meadows and macroalgal beds, long-term stored (over 100 years) organic carbon which was originally absorbed by seagrass meadows and macroalgal beds are estimated. The four carbon sequestration processes are different from carbon stock change estimation in carbon pools. But we reported all carbon sequestration amount under mineral soils carbon pool under "other wetlands remaining other wetlands" in order to archive consistent reporting with others considering major sequestration occur in sediment (soils). Living biomass and dead organic matter carbon pools were reported as "NA" because these carbon pools themselves do not contribute long-term carbon sequestration and carbon stock changes in both pools are assumed as zero.

Since the areas of mangrove forest and seagrass meadows and macroalgal beds are not part of the total land area in Japan by definition, they are not included in the area under this category.

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, we regarded that the emissions from peat extraction as "NE" in insignificant level of emissions. This value is below from threshold of *MPGs* and country specific standard of 90 kt-CO_2 (this value is 0.1 % of the removals from LULUCF sector in 2005). Please refer to Annex 6, for more information about our criteria for "NE".

2) Carbon Stock Changes in "Mangrove Forest"

i. Carbon Stock Changes in Living Biomass in "Mangrove Forest"

- ***Estimation Method***

Carbon stock change in living biomass in mangrove forest was estimated by using the gain-loss method of Tier 1. As stocked volume and volume of harvest in mangrove forest were not available, it assumed that carbon stock in land remaining mangrove forest has been stable, and the default value of the *Wetlands Guidelines* were used to set the average living biomass stocks of mangrove forests. Based on

this, Carbon stock gains in living biomass associated with mangrove area increasing, and carbon losses of living biomass associated with area decreasing were estimated. The change of mangrove habitat area was estimated by each community level.

- ***Parameters***

➢ ***Average living biomass stock and biomass growth***

For amount of above ground living biomass stock, above and below ground living biomass ratio (R), and carbon fraction factor (CF), the default values in the *Wetlands Guidelines* were used (Table 6-42). For annual above ground biomass growth, which is used for newly increased mangrove area, it is assumed that living biomass stock has increased linearly to reach the average steady state in 20 years, which is the general transition period of land-use change in IPCC Guidelines, because the growing period will be calculated as 4 years from default carbon stocks and annual increment mentioned in *Wetlands Guidelines,* and this was clearly too short to reach steady state.

Table 6-42 Parameters of living biomass in mangrove forest

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 grow to achieve 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 area of mangrove increase over the past 20 years was used to calculate the biomass increase, and the area of mangrove decrease in the relevant year was used to calculate the biomass loss. These areas were obtained by summing each mangrove community level of gross increase or decrease in habitat area.

A change in area of mangrove forest was calculated by combining data from various domestic surveys including the data sources shown in Table 6-43. The areas in community level were linearly interpolated between years of data available.

The mangroves reported in this category was those not covered under “4.A. Forest land” (non-forest mangroves). These areas were identified through a survey, and it was found that the ratio of non-forest mangroves area to all mangrove forest was almost stable over the period 1990 to the recent year. Thus, 36% was multiplied to the all mangrove forests area as well as emissions and removals for all mangrove forest in order to estimate the values to be reported under “4.D. Wetlands”

Table 6-43 Area in mangrove forest

Fiscal 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 "Mangrove Forest"

- ***Estimation Method***

Generally, it is considered that dead organic matter in mangrove forest has not been saturant and has accumulated, but accumulation ratio is not available in observations in mangrove forest at present. Therefore, it was assumed that amount of dead organic matter is stable in land remaining mangrove forest, and the averaged amount of dead organic matter in mangrove forest was estimated. Based on this, carbon stock gains of increasing dead organic matter associate with mangrove area increasing was estimated with an assumption that dead organic matter has linearly increased and to reach steady state in 20 years, which is the same period with living biomass. Also, carbon losses of dead organic matter associate with area decreasing were estimated by assuming that all amount of dead organic matter in mangrove that was lost in the year of area decreased.

- ***Parameters***

The default values of carbon stocks in mangrove for dead wood (10.7 t-C/ha) and litter (0.7 t-C/ha) on Table 4.7 in the *Wetlands Guidelines* were used.

- ***Activity Data***

A change in area of mangrove forest was used the data same with 2) Carbon Stock Changes in Living Biomass in "Mangrove Forest".

iii. Carbon Stock Changes in Soil in "Mangrove Forest"

- ***Estimation Method***

The *Wetlands Guidelines* provides default value as removal factor of soils for revegetation and creation of mangroves and also explains that this carbon accumulation of soils will continue until stocks are equivalent to soil carbon stocks in natural/undrained settings with mangrove vegetation. In mangrove forest, carbon input to soil is normally much larger than output. Therefore, we assumed that default removals factor of soils were applicable not only increased area since the year of data available (i.e around 1960), but for all area of mangroves. Thus, all area of mangroves were multiplied by removal factor as carbon stock in soil are increasing regularly.

Since mangrove forest is preserved in law in Japan, land-use changes (converted to settlements and cropland) have not occurred since 1990. But some mangrove area may decrease due to cutting mangrove trees which is overgrowth by direct or indirect human induced reasons or caused environmental disadvantage, and subject to natural disturbances. Soil carbon losses were estimated only the cases that mangrove area decreasing was accompanied with extraction of soils. The amount of soil carbon lost

was estimated by those had accumulated since planted of the relevant community. Soil carbon losses were not estimated for other cases of area decreasing caused by such as logging of the living biomass only, sedimentation due to environmental change, and fallen trees and vegetation removal by natural disturbance and so on.

- ***Parameters***

Since Japan located in north part of mangrove habitat, cooler region compared with other mangrove habitat in the world, we consider removal factor is smaller than the tropical and subtropical average. Removal factor was used the default value of 1.3 t-C/ha/yr (Minimum) on Table 4.12 in the *Wetlands Guidelines*.

Loss of carbon stocks in soils were used that amount of carbon stocks in soils estimated the removal factor multiplied by years from planted mangrove trees until dredging by the area of dredging which is conducted since 1990.

- ***Activity Data***

The total area of mangrove forest was used, which is same with the area used for estimating 2) Carbon Stock Changes in Living Biomass in "Mangrove Forest".

Area of dredging were estimated from the area of Ishikawa River from Masuno, et al. (2012) and Hiyagon from 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***

The *Wetlands Guidelines* provide guidance on estimating carbon stock changes associated with specific management activities for seagrass meadows in which carbon stock change occur in underlining soils of seagrass meadows. 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. We have developed Tier 3 ecosystem model on estimating long-term carbon sequestration (over 100 years[7]) through seagrass meadows and macroalgal beds in Japan considering these recent scientific knowledges. This model estimation implicitly covers management activity of reestablishment of seagrass meadows which is listed in Tier 1 of the *Wetlands Guidelines*, but all carbon sequestration of existing seagrass meadows and macroalgal beds in coastal areas where managed can be assessed.

There is about 160-170 kha of seagrass meadows and macroalgal beds in Japan recently. We treated all these ecosystems as managed and carbon sequestration from all-natural seagrass and macroalgal habitats 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 and macroalgal habitats

[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'.

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 and macroalgal habitats.

- ***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 was assessed in line with the Tier 3 methodology developed in a national research project (hereafter "MAFF research project") started in 2020[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 sequestrated organic carbon was estimated by using coefficient of long-term sequestration rate to organic carbon amount absorbed by seagrass and macroalgal established 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 were discussed regularly in a domestic committee of this research with the third-party experts (as QA process) 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)

[8] Project JPJ008722 commissioned by the Ministry of Agriculture, Forestry and Fisheries of Japan

[9] https://www.fra.go.jp/home/kenkyushokai/press/pr2023/20231101_kaisou.html

➢ ***Estimation equation***

Annual CO_2 sequestration amount through seagrass meadows and macroalgal beds was 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 were 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 was estimated by maximum amount of seagrass/macroalgal (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) were applied to deliver CO_2 removal coefficient.

$$CO_{2\ sq.} = \sum_{i,j} \left(RF_{i,j} \times Area_{i,j}/100 \right)$$

$$RF_{i,j} = RF'_{i,j} \times CF \times E \times 44/12$$

$$RF'_{i,j} = \left(\frac{P}{Bmax}\right)_{i,j} \times Bmax_{i,j} \times r2_{i,j} + \left(\frac{P}{Bmax}\right)_{i,j} \times Bmax_{i,j} \times r3_{i,j} + \left(\frac{P}{Bmax}\right)_{i,j} \times Bmax_{i,j} \times r1_{i,j} \times \left(1 - r2_{i,j} - r3_{i,j}\right) + Bmax_{i,j} \times r4_{i,j}$$

$$= Bmax_{i,j} \times \left[\left(\frac{P}{Bmax}\right)_{i,j} \times \left\{ r1_{i,j} \times \left(r2_{i,j} + r3_{i,j}\right)\left(1 - r1_{i,j}\right) \right\} + r4_{i,j} \right]$$

$CO_{2s.q.}$	: Annual CO_2 sequestration through seagrass and macroalgal [t-CO_2 yr^{-1}]
$Area_{i,j}$	: Area of sea-area *i*, type of seagrass / macroalgal *j* [ha]
$RF_{i,j}$	: CO_2 removal coefficient for sea-area *i*, type of seagrass / macroalgal *j* (annual CO_2 sequestration amount per unit of area) [g-CO_2 m^{-2} yr^{-1}]
$RF'_{i,j}$	: Organic carbon annual sequestration coefficient per unit of area for sea-area *i*, type of seagrass / macroalgal *j* [g m^{-2} yr^{-1}]
$P/Bmax_{i,j}$	: Ratio of production to maximum weight of seagrass/ macroalgal or sea-area *i*, type of seagrass / macroalgal *j* [g m^{-2} yr^{-1}/g m^{-2}]
$Bmax_{i,j}$	: Amount of maximum weight of seagrass/ macroalgal or sea-area *i*, type of seagrass / macroalgal *j* [g m^2]
$r1_{i,j}$	: Long-term sequestration rate of RPOC export for sea-area *i*, type of seagrass / macroalgal *j*. As this rate include 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 / macroalgal *j*
$r3_{i,j}$	: Long-term sequestration rate of deep sea export for sea-area *i*, type of seagrass / macroalgal *j*
$r4_{i,j}$	: Long-term sequestration rate of RDOC sequestration for sea-area *i*, type of seagrass / macroalgal *j*
CF	: Carbon fraction
E	: Ecosystem conversion factor (E=1 for national estimation)
i	: Sea-area
j	: Type of seagrass and macroalgal

➢ *Categorization of seagrass meadows and macroalgal*

There are about 15 to 20 species of seagrass and about 1,000 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 was established. These classifications were suggested by the MAFF research project.

Table 6-44 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		*Zostera marina* type	*Zostera marina, Zostera caespitosa, Zostera japonica*	x	x	x	x
		Zostera caulescens type	*Zostera caulescens*	x	x	x	x
		Phyllospadix type	*Phyllospadix iwatensis, Phyllospadix japonicus* Makino		x	x	x
		subtropical small type	*Halophila* sp., *Halodule pinifolia, Zostera japonica* (subtropica type)	x	x	x	x
		subtropical medium type	*Thalassia hemprichii, Cymodocea serrulata*	x	x	x	x
		subtropical large type	*Enhalus acoroides*	x	x	x	x
Macroalgal beds	Kelps	Kombu type	*Saccharina japonica, Laminaria religiosa. Kjellmaniella crassifolia*		x	x	x
		Long-Kombu type	*Laminaria longissima, Costaria costata, Alaria* sp.		x	x	x
	Eisenia and *Ecklonia*	*Eisenia*	*Eisenia bicyclis* (Arame), *Eisenia nipponica*		x	x	x
		Ecklonia	*Ecklonia cava* (Kajime), *Ecklonia kurome*		x	x	x
		Undaria	*Undaria pinnatifida* (Wakame), *Undaria undarioides* (Hirome)		x	x	x
	Sargassum spp.	Temperate *Sargassum* spp.	*Sargassum horneri* (Akamoku), *Sargassum fulvellum, Sargassum macrocarpum*	x	x	x	x
		Subtropical *Sargassum* spp.	*Sargassum ilicifolium, Sargassum myriocystum, Hormophysa cuneiformis*		x	x	x
	Small algae	Small green algae	*Monostroma nitidum,Ulva pertusa, Codium fragile*		x	x	x
		Small red algae	*Gelidium elegans,Chondrus ocellatus* Holmes, *Neopyropia yezoensis*		x	x	x
		Small brown algae	*Dictyota dichotoma, Fucus distichus, Dictyopteris latiuscula*		x	x	x

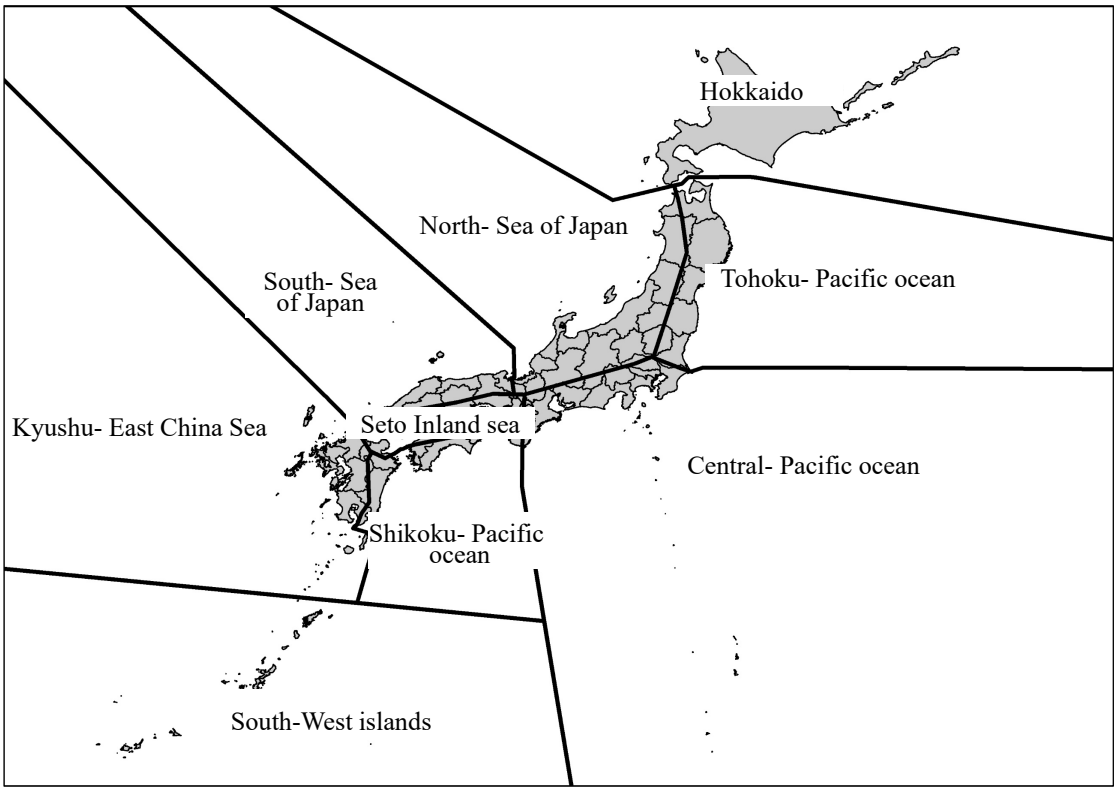

Figure 6-7 Nine sea-areas used for estimation of carbon sequestration from seagrass meadows and macroalgal beds

Reference: *Guidebook for the estimation of CO_2 sequestration by seagrass and macroalgal beds* (Japan Fisheries Research and Education Agency)

- ***Parameters***

The parameters used for the removal coefficient were determined as follows.

Maximum amount of seagrass and macroalgal habitat per area (B_{max}) were derived from the monitored data from the MAFF research project and these values were applied for all time-series. 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.

P/B_{max} was established by comprehensive literature review implemented in the MAFF research project.

"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 from the existing studies about ratio reaching deep-sea from floating macroalgal, from reaching deep-sea amount and floating macroalgal amount in sea around Japan (Abo 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, because there were no existing studies targeting long-term carbon sequestration of this process. As this value implicitly

includes the sequestrated 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. Only “r4” is directly applied to amount of seagrass and macroalgal habitat instead of NPP.

Carbon fraction was set as 30% which is a general value for seagrass meadows and macroalgal beds based on the expert judgement by the MAFF research project.

The removal coefficient integrated the parameter above is shown in the table below.

Table 6-45 Removal coefficient by sea-area and types of seagrass /macroalgal habitat [g-CO_2/m^2/yr]

Types	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
Zostera marina type	490.39	224.11	593.2	381.56	593.2	232.1	381.56	280.52	
Zostera caulescens type	847.77	212.74	847.77	847.77	847.77				
Phyllospadix type	2039.74	1780.41	713.21	713.21	535.52				
Seagrass, subtropical small type									108.79
Seagrass, subtropical medium type									305.91
Seagrass, subtropical large type									336.35
Kombu type	164.18	468.66	468.66						
Long-Kombu type	110.7								
Eisenia		274.72		127.16	423.02		162.69	127.16	
Ecklonia		61.55	15.54	151.57	49.39	126.08	25.24	20.28	
Undaria	58.48	116.28	58.48	25.7	23.71	47.49	12.23	15.83	
Temperate *Sargassum* spp.	312.03	158.86	60.5	219.24	31.56	155.21	27.33	105.5	
Subtropical *Sargassum* spp.							128.51	21.31	41.97
Small green algae	4.16	9.95	5.54	7.05	6.05	9.7	1.89	4.16	17.76
Small red algae	112.69	7.91	11.68	63.91	1.19	19.9	30.51	14.88	9.35
Small brown algae	52.38	22.9	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 area of each sea-area and seagrass and macroalgal types consistent with the removal factor were used as activity data. The areas for recent years were estimated by a spatial distribution model for seagrass meadows and macroalgal beds developed by Port and Airport Research Institute. This model used environmental data about topographic data, sea floor sediment, chlorophyll a concentration, water temperature (obtained from GCOM-C) and algorithm for distribution of seagrass meadows and macroalgal beds under the condition of 250 m special resolution and 0-50m water depth.

The time series of areas from 1990 to the recent years were constructed by using several data sources and methodologies summarized in the table below since time series data could not established by single data source and/or model. The MOE survey data for 1990 and 1999 had different categorization of sea-areas and categorization of seagrass and macroalgal types from those used for the removal coefficient mentioned above. Therefore, experts of seagrass and macroalgal in Port and Airport Research Institute implemented assessment and developed method to construct time series area estimation considering the ecosystems of seagrass and macroalgal.

Table 6-46 Data and methods used for construction area of seagrass meadows and macroalgal beds

Fiscal year	Reference
1990	Coastal Survey of the 4th National survey on Natural Environment, 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, 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
2018-2021	Spatial distribution model for seagrass meadows and macroalgal beds
2022	Extrapolation of the 2020 – 2021 trend

Table 6-47 Estimation result of the area of seagrass meadows and macroalgal beds

Types	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Zostera marina type	ha	26379	22595	20121	22893	25665	27328	27882	28437	28991	29546	30100	30203	29293	29655	30016
Zostera caulescens type	ha	10194	7599	5236	3802	2367	1507	1220	933	646	359	72	71	75	71	68
Phyllospadix type	ha	5400	4423	3818	4697	5576	6103	6279	6455	6631	6807	6982	6962	6434	6239	6044
Seagrass, subtropical small type	ha	900	806	728	714	701	692	690	687	684	682	679	672	530	566	603
Seagrass, subtropical medium type	ha	4690	4442	4194	3946	3698	3549	3499	3450	3400	3350	3301	3251	2310	2763	3216
Seagrass, subtropical large type	ha	69	65	61	58	54	52	51	51	50	49	48	48	34	41	47
Kombu type	ha	5250	13329	19270	16657	14044	12476	11953	11431	10908	10385	9863	9851	9080	8396	7712
Long-Kombu type	ha	1105	3611	5503	4934	4366	4025	3911	3797	3684	3570	3456	3530	2681	1814	947
Eisenia	ha	61593	39077	20224	16023	11822	9302	8461	7621	6781	5941	5101	5349	5595	6357	7119
Ecklonia	ha	34548	27462	21227	18399	15571	13875	13309	12743	12178	11612	11047	11460	12248	13318	14387
Undaria	ha	27477	23379	19409	15952	12495	10420	9729	9037	8346	7654	6963	6743	6900	7660	8419
Temperate *Sargassum* spp.	ha	85602	73303	61939	54314	46690	42115	40590	39065	37540	36015	34491	35217	35657	38422	41187
Subtropical *Sargassum* spp.	ha	12572	11574	10632	9919	9206	8778	8635	8493	8350	8208	8065	7969	6242	7698	9155
Small green algae	ha	10374	10277	10091	9548	9004	8678	8570	8461	8352	8244	8135	8066	6965	6955	6945
Small red algae	ha	23150	20226	17375	14811	12248	10710	10197	9685	9172	8659	8147	8032	7550	7829	8108
Small brown algae	ha	18825	15951	14050	16042	18035	19230	19628	20027	20425	20824	21222	21260	20036	21084	22132
Total	ha	328129	278120	233878	212709	191541	178840	174606	170372	166139	161905	157671	158684	151630	158868	166106

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 are assumed to be zero. 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 as 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. We also found that quite a few areas of loss of seagrass meadows or macroalgal beds have happened by change so far for a historical period. 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) Uncertainties and Time-series Consistency

- ***Uncertainty Assessment***

Uncertainties of the parameters of mangrove forests for living biomass, dead organic matter, and soil were individually assessed on the basis of the default values described in the W*etlands Guidelines* and uncertainties of the activity data were 10% for the general total inspection. Uncertainties of the parameters of seagrass meadows and macroalgal beds were 14% 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 was estimated as -16% to +16% of the total emissions from the wetlands remaining wetlands for year which emissions are calculated.

- ***Time-series Consistency***

Although some different statistics were used to estimate the area of mangrove forest, data continuity was checked and time-series consistency for this subcategory is basically ensured. For the estimation of seagrass and macroalgal, the same methodology and parameters were used for a whole time series. The reasonable time-series of area was constructed by using several data sources based on the support of experts of seagrass and macroalgal. These processes ensured time-series consistency in seagrass and macroalgal CO_2 emissions and removals estimation.

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

Carbon stock change for seagrass meadows and macroalgal beds were estimated. Accordingly, carbon stock changes in this category were recalculated for all years. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

Further improvements in carbon stock change estimation in coastal wetlands are planned.

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 FY2022 were 17 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.), this represents a decrease of 76.2% compared to FY1990 and an increase of 0.5% compared to FY2021.

With respect to living biomass, its carbon stock change (losses of living biomass in the land before conversion) as a result of land-use conversion from other land use to wetlands is estimated.

With respect to dead organic matter, and then estimated the carbon stock change in wetlands converted from forest land. Carbon stock changes in other subcategories were reported as "NA", supposing that no carbon stock change occur.

Carbon stock changes in soils in forest land converted to wetlands were reported as "NA". This was because after the areas came to be reservoirs (dams), and their soils were supposed to become anaerobic condition; hence CO_2 emissions resulting from organic matter decomposition seemed to be extremely little. 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". All carbon stock changes in mangrove, seagrass meadows and macroalgal beds were reported under wetlands remaining wetlands category.

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 (dam)***

Areas of land converted to wetlands (dam) were estimated based on the area of dam 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 dam, percentages of each land area converted to dams 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 dams. 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 dam conversion area were regarded as other land converted to wetlands.

Table 6-48 Area of land annually converted to wetlands within the past 1 year

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Land converted to Wetlands	kha	0.45	1.69	2.12	0.22	0.59	0.12	0.12	0.41	0.41	0.16	0.16	0.12	0.12	0.07	0.07
Forest land converted to Wetlands	kha	0.33	1.23	1.53	0.16	0.43	0.09	0.09	0.30	0.30	0.12	0.12	0.09	0.09	0.05	0.05
Cropland converted to Wetlands	kha	0.030	0.100	0.133	0.015	0.037	0.007	0.008	0.026	0.026	NO	0.010	0.007	0.007	0.004	0.004
Rice field	kha	0.007	0.023	0.089	0.013	0.022	0.003	0.005	0.016	0.018	NO	0.005	0.004	0.004	0.002	0.002
Upland fields	kha	0.012	0.049	0.014	0.002	0.011	0.003	0.002	0.008	0.007	NO	0.004	0.003	0.003	0.002	0.002
Orchards	kha	0.010	0.028	0.031	0.0005	0.003	0.001	0.001	0.002	0.002	NO	0.001	0.001	0.001	0.0004	0.0004
grassland converted to Wetlands	kha	0.003	0.023	0.021	0.001	0.006	0.002	0.001	0.004	0.003	NO	0.002	0.002	0.002	0.001	0.001
Settlements converted to Wetlands	kha	0.0016	0.0060	0.0075	0.0008	0.0021	0.0004	0.0004	0.0015	0.0015	0.0006	0.0006	0.0004	0.0004	0.0003	0.0003
Other land converted to Wetlands	kha	0.09	0.34	0.42	0.04	0.12	0.02	0.02	0.08	0.08	0.04	0.03	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 6-48.

Table 6-49 Area of land converted to wetlands within the past 20 years

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Land converted to Wetlands	kha	27.9	24.6	26.8	21.9	20.1	18.6	18.1	16.8	14.3	13.9	11.8	9.8	7.8	6.1	5.6
Forest land converted to Wetlands	kha	19.8	17.8	19.4	15.9	14.6	13.5	13.1	12.2	10.4	10.0	8.6	7.1	5.7	4.4	4.0
Cropland converted to Wetlands	kha	1.8	1.5	1.7	1.4	1.2	1.1	1.1	1.0	0.9	0.9	0.7	0.6	0.5	0.4	0.3
grassland converted to Wetlands	kha	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Settlements converted to Wetlands	kha	0.10	0.09	0.10	0.08	0.07	0.07	0.06	0.06	0.05	0.05	0.04	0.03	0.03	0.02	0.02
Other land converted to Wetlands	kha	5.8	4.9	5.4	4.4	4.0	3.7	3.6	3.4	2.9	2.8	2.4	2.0	1.6	1.2	1.1

c) Uncertainties 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 described 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

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

- ***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.

- ***Revision of carbon stocks of living biomass and dead organic matter (in forest land) before conversion***

Since the carbon stocks of living biomass and dead organic matter (in forest land) before conversion were revised losses in carbon stock were revised. This resulted in recalculations of carbon stock change for living biomass and dead organic matter in this category for all years.

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, but preclude forest land (4.A.), cropland (4.B.), grassland (4.C.), and wetland (4.D.). In settlements, trees existing in urban green areas such as special greenery conservation zones and urban parks, etc

absorb carbon. 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 sub-categories 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 sub-parts 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." All of urban green areas are under the active growing period (AGP), 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 has occurred is included in "other settlements."

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 the 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 sub-category is shown in Table 6-50.

In FY2022, Japan’s settlement area was about 3.90 million ha, equivalent to about 10.3% of the national land. The emissions from carbon stock changes in this category in FY2022 were 2,726 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 73.7% compared to FY1990 and an increase of 3.5% compared to FY2021.

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[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 sub-category.

[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.

Table 6-50 Each area in the subcategory of settlements

Category			Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Settlements (a)			kha	3200.0	3428.0	3594.0	3698.0	3779.0	3808.0	3827.0	3835.0	3843.0	3862.0	3870.0	3889.0	3898.0	3897.0	3897.0
	Settlements remaining Settlements (a-b)		kha	2,296.3	2,635.5	2,872.7	3,069.1	3,284.2	3,407.7	3,445.7	3,469.1	3,491.7	3,522.9	3,536.0	3,558.1	3,567.8	3,567.2	3,565.7
		Special greenery conservation zones (c)	kha	1.8	3.6	3.6	4.1	4.1	4.4	4.5	4.6	4.6	4.6	4.6	4.7	4.7	4.7	3.2
		Urban green facilities (d)	kha	82.6	106.3	123.8	134.4	136.8	131.7	127.8	124.1	121.6	119.4	116.7	112.9	109.3	106.1	101.5
		Other (a-b-c-d)	kha	2,211.8	2,525.6	2,745.3	2,930.6	3,143.3	3,271.5	3,313.5	3,340.4	3,365.4	3,398.8	3,414.7	3,440.5	3,453.9	3,456.3	3,461.0
	Land converted to Settlements (b)		kha	903.7	792.5	721.3	628.9	494.8	400.3	381.3	365.9	351.3	339.1	334.0	330.9	330.2	329.8	331.3

Table 6-51 Emissions and removals in settlements resulting from carbon stock changes

Category	Carbon pool	Unit	1990	1995	2000	2005	2010	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
4.E. Settlements	Total	kt-CO_2	10,646	8,155	6,180	4,888	4,156	3,182	3,226	3,095	3,213	3,095	2,785	2,815	2,927	2,980	2,197
	Living Biomass	kt-CO_2	1,860	832	-297	-669	-327	-601	-394	-354	-146	-135	-280	-212	3	56	-591
	Dead Wood	kt-CO_2	533	371	187	148	235	173	208	208	248	248	210	210	156	156	66
	Litter	kt-CO_2	249	166	74	53	95	65	82	82	102	102	83	83	57	57	13
	Mineral soil	kt-CO_2	7,861	6,678	6,127	5,277	4,080	3,480	3,265	3,096	2,947	2,818	2,710	2,671	2,647	2,646	2,643
	Organic soil	kt-CO_2	144	108	89	79	74	65	64	63	62	61	61	63	64	65	66
4.E.1. Settlements remaining Settlements	Total	kt-CO_2	-1,015	-1,358	-1,644	-1,815	-1,852	-1,828	-1,805	-1,776	-1,747	-1,728	-1,704	-1,667	-1,640	-1,593	-1,551
	Living Biomass	kt-CO_2	-749	-1,039	-1,273	-1,416	-1,460	-1,447	-1,432	-1,407	-1,382	-1,368	-1,351	-1,321	-1,303	-1,265	-1,230
	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	IE,NA	IE,NA	IE,NA
	Litter	kt-CO_2	-12	-15	-18	-20	-20	-20	-20	-20	-20	-20	-20	-19	-19	-19	-19
	Mineral soil	kt-CO_2	-253	-305	-354	-379	-372	-361	-353	-349	-345	-340	-334	-327	-318	-310	-302
	Organic soil	kt-CO_2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
4.E.2. Land converted to Settlements	Total	kt-CO_2	11,661	9,513	7,825	6,703	6,008	5,010	5,031	4,871	4,960	4,822	4,489	4,482	4,568	4,573	3,747
	Living Biomass	kt-CO_2	2,609	1,871	975	747	1,132	846	1,038	1,054	1,236	1,234	1,071	1,109	1,306	1,321	639
	Dead Wood	kt-CO_2	533	371	187	148	235	173	208	208	248	248	210	210	156	156	66
	Litter	kt-CO_2	261	182	92	73	115	85	102	102	121	121	103	103	76	76	32
	Mineral soil	kt-CO_2	8,114	6,982	6,481	5,656	4,453	3,841	3,619	3,445	3,292	3,158	3,044	2,998	2,966	2,955	2,944
	Organic soil	kt-CO_2	144	108	89	79	74	65	64	63	62	61	61	63	64	65	66

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 FY2022 was 1,472 kt-CO_2; this represents an increase of 45.1% compared to FY1990 and a decrease of 5.2 % compared to FY2021.

Note that "Other remaining other " in settlements includes trees growing in the yards of private residences, but based on the Tier 1 assumption that there is no change, it was reported as "NA".

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

[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.

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 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 6-52

$NT_{Sb_AGPi,j}$: 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)

j : Climate type (Hokkaido, other than Hokkaido)

- ***Parameters***

➢ ***Tier 2a: green spaces conserved by zoning***

- ***Annual living biomass growth per crown cover area***

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***

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: urban green facilities***

- ***Annual living biomass growth per individual tree***

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 6-52.

A) Urban parks

1. 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.

2. 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.

3. 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 calculated in 2 (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 in 1. The values were established separately for Hokkaido and areas other than Hokkaido.

B) Green Areas on Roads

1. 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.

2. 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.

C) 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

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 6-52 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***

➢ ***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 6-53 Activity data areas of green spaces conserved by zoning (younger than or equal to 30 years after designation)

Category		Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Green spaces conserved by zoning		kha	1.8	3.6	3.6	4.1	4.1	4.4	4.5	4.6	4.6	4.6	4.6	4.7	4.7	4.7	3.2
	Special greenery conservation zones	kha	0.6	0.9	1.2	1.8	1.9	1.9	2.0	2.1	2.1	2.1	2.1	2.2	2.2	2.2	2.1
	Suburban green space conservation zones	kha	1.2	2.7	2.4	2.2	2.3	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	1.1

[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)

➢ ***Urban Green Facilities***

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 data used are as follows.

Table 6-54 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 1960)
Green area on roads	Number of tall trees	Road Tree Planting Status Survey (conducted every year since FY2007)
	Activity area per tall tree	Basic Data Collection Survey on Tall Tree Planting on Roads (February 2007)
	Road extension and rate of greenery	Road statistics yearbook (Road extension) The Street tree of Japan (Rate of greenery)
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)

- ***Activity data area of urban green facilities***

A) 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

The area within AGP years of maintenance at the end of the fiscal year was obtained from the survey described in Table 6-54.

AGP of urban green facilities was basically set at 30 years, and 50 years for unpruned wooded areas in urban parks. For those areas prior to the year the survey was initiated were estimated by linear interpolation with statistical information.

The Activity data area of unpruned wooded areas in urban parks that are between 31 and 50 years old after maintenance was calculated by multiplying the unpruned ratio 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 was 55%, which was obtained from the results of the sample survey.

For green areas along rivers and erosion control sites, the planted land area was defined as shown in the table below.

[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.".

Table 6-55 Planting works in green areas along rivers and erosion control sites and definition of planted land area

Planting works in green areas along rivers and erosion control sites	Definition of planted land area
(1) Planting in inspection passage of excavated channel	Area of land from levee wall shoulder to private land
(2) Planting in face of riverbank of excavated channel	Area of land from levee wall shoulder to private land
(3) Planting in backslope banquette	Area of embanked land
(4) Planting in levee marginal strip (second-class and third-class)	Area of marginal strip which is subject to greening works
(5) Planting in high water channel	Area of land from low-flow channel shoulder to foot of levee slope
(6) Planting in retarding basin	Area of retarding basin
(7) Planting in lake foreshore	Area of land from low-flow channel shoulder to foot of levee slope
(8) Planting in super levee	(Same as planting in excavated channel)
(9) Greening under erosion and sediment control works	Area of land which is subject to hillside works
(10) Greening under landslide control works	Area of land which is subject to hillside works
(11) Greening under steep slope failure prevention works	Area of land which is subject to hillside works

- ***Number of tall trees per area***

The number of tall trees per area was calculated separately for Hokkaido and non-Hokkaido based on the data obtained from the sample survey as described below, and then used as a fixed time series.

A) 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 was 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.

B) Green areas at ports

The number of tall trees per area in green areas at ports was 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.

C) 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.

D) 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.

E) 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, respectively.

F) 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.

The number of tall trees per area established by the above calculations is shown in the table below.

Table 6-56 Number of tall trees per area

Item	Unit	Number of tall trees 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

B) Green areas on roads

As shown in Table 6-54, the number of tall trees planted in green areas on roads within 30 years after establishing green areas on roads is calculated by using data from the "*Road Tree Planting Status Survey*" which had been implemented in FY1987, FY1992, FY2007 and onward. Years for which data were not available were supplemented by interpolation. The activity data area of these green areas was 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 were obtained by randomly selecting road green space and dividing the area of the land by the number of tall trees planted on the land.

Using the above, the Activity data area and number of tall trees in AGP were estimated as follows.

Table 6-57 Summary of Activity data area and number of tall trees in each urban green facilities

Item	Activity data	Unit	1990	1995	2000	2005	2010	2012	2013	2014
Urban green facilities total	Activity areas	kha	82.6	106.3	123.8	134.4	136.8	133.7	131.7	127.8
Urban parks	Activity areas	kha	54.0	65.7	77.2	85.2	87.3	86.0	85.3	84.9
less than 30 years after establishing	Activity areas	kha	52.9	63.1	72.8	77.5	75.5	73.0	71.4	70.4
31-50 years after establishing(for large urban parks)	Activity areas	kha	1.1	2.6	4.3	7.7	11.7	13.0	13.9	14.5
	number of tall trees		12,604,365	15,306,142	18,029,868	19,941,056	20,476,510	20,180,954	20,015,002	19,934,189
Green area on roads	Activity areas	kha	23.7	34.1	38.3	39.9	40.2	38.6	37.6	34.1
	number of tall trees		4,979,363	8,843,605	11,623,444	13,011,342	13,499,777	13,461,867	13,265,959	12,726,010
Green areas at ports	Activity areas	kha	0.4	0.8	1.2	1.7	1.9	1.9	1.9	1.9
	number of tall trees		98,954	192,738	282,977	382,625	425,373	436,043	437,570	432,678
Green areas around sewage treatment facilities	Activity areas	kha	0.4	0.5	0.7	0.8	0.8	0.7	0.7	0.7
	number of tall trees		154,353	201,105	265,191	325,819	318,025	303,431	298,178	294,154
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	1.9
	number of tall trees		439,539	549,768	796,206	933,781	1,049,629	1,035,214	1,028,015	1,014,060
Green areas around government buildings	Activity areas	kha	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4
	number of tall trees		27,397	35,073	42,370	45,324	44,641	43,682	42,593	41,918
green areas around public rental housing	Activity areas	kha	3.1	3.9	4.6	4.7	4.3	4.1	4.0	3.9
	number of tall trees		682,118	854,794	1,022,187	1,034,293	950,245	903,489	874,187	864,466

Item	Activity data	Unit	2015	2016	2017	2018	2019	2020	2021	2022
Urban green facilities total	Activity areas	kha	124.1	121.6	119.4	116.7	112.9	109.3	106.1	101.5
Urban parks	Activity areas	kha	84.6	84.2	83.5	83.0	81.8	80.6	80.2	78.7
less than 30 years after establishing	Activity areas	kha	69.4	68.4	67.0	65.5	63.6	61.9	60.3	58.0
31-50 years after establishing(for large urban parks)	Activity areas	kha	15.1	15.8	16.5	17.5	18.1	18.7	19.9	20.7
	number of tall trees		19,844,628	19,750,642	19,584,146	19,446,332	19,154,839	18,892,804	18,788,559	18,456,130
Green area on roads	Activity areas	kha	30.8	28.8	27.3	25.2	22.9	20.7	18.3	15.5
	number of tall trees		12,170,742	11,918,033	11,669,755	11,085,378	10,943,572	10,301,861	9,607,941	8,655,924
Green areas at ports	Activity areas	kha	1.9	1.9	1.9	2.0	2.0	1.9	1.8	1.7
	number of tall trees		430,857	440,870	442,070	443,916	453,858	425,629	401,840	388,390
Green areas around sewage treatment facilities	Activity areas	kha	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.6
	number of tall trees		288,274	283,283	274,128	266,688	259,582	254,202	237,981	229,951
Green areas along river and erosion control sites	Activity areas	kha	1.8	1.8	1.8	1.7	1.7	1.6	1.6	1.6
	number of tall trees		1,000,117	984,045	974,903	954,868	916,396	902,256	893,771	890,480
Green areas around government buildings	Activity areas	kha	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3
	number of tall trees		41,004	40,048	40,065	39,047	41,093	40,113	39,450	36,581
green areas around public rental housing	Activity areas	kha	3.9	3.9	3.8	3.7	3.6	3.5	3.3	3.1
	number of tall trees		859,365	850,520	840,855	819,060	794,828	769,968	729,744	691,461

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***

➢ ***Urban green facilities (urban parks or green areas at ports)***

- ***Carbon stock changes in litter per urban park areas***

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 6-50, 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***

➢ ***Urban Green Facilities (urban park and green areas at ports)***

- ***Activity data area***

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***

➢ ***Urban Green Facilities (urban parks and green areas at ports)***

- ***Carbon stock change in mineral soils per area***

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***

➢ ***Urban Green Facilities (Urban parks and Green areas at ports)***

- ***Activity data Area***

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) Uncertainties 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 is applied according to the decision tree for activity data.

Meanwhile, 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 41%, 61%, 38%.

As a result, the uncertainty estimate was 34% 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

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

- ***Recalculation due to revision of activity data of urban green areas***

A revision was conducted on some area of urban green areas for all years. Due to this 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

- ***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 FY2022 were 4,198 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 63.1% compared to FY1990 and an increase of 0.3% compared to FY2021. 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 Volume 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 6-58 Area of land converted to settlements within the past 1 year

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Land converted to Settlements	kha	39.8	33.4	22.6	13.0	13.3	14.7	16.0	18.1	16.9	17.8	23.5	21.8	21.9	20.2	18.4
Forest land converted to Settlements	kha	14.5	10.1	5.1	4.0	6.5	5.7	5.7	6.8	6.8	5.9	5.9	5.3	5.3	3.1	3.1
Cropland converted to Settlements	kha	23.2	20.1	14.3	7.4	5.9	7.3	8.7	9.0	8.9	10.5	15.4	14.9	14.5	14.7	13.2
Rice field converted to Settlements	kha	13.0	12.1	9.5	5.6	3.5	4.2	5.0	5.1	5.3	5.7	9.1	9.0	9.2	9.0	8.3
Upland field converted to Settlements	kha	5.6	5.1	1.5	1.4	1.8	2.4	3.0	3.1	2.9	3.8	5.1	4.8	4.3	4.6	4.0
Orchard converted to Settlements	kha	4.6	2.9	3.3	0.4	0.5	0.6	0.8	0.8	0.7	0.9	1.2	1.1	1.0	1.1	0.9
Grassland converted to Settlements	kha	1.4	2.5	2.3	0.7	0.7	1.2	1.5	1.3	1.2	1.4	1.9	1.6	1.9	2.4	2.1
Wetlands converted to Settlements	kha	IE	IE	IE	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	0.2	1.1	NO	0.1	0.2	0.0	0.1	0.1	NO

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 6-58.

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 conversion shown in Table 6-14 is calculated as changing linearly to the amount of soil carbon stock after land 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 6-59).

Table 6-59 Area of land converted to settlements within the past 20 years

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Land converted to Settlements	kha	903.7	792.5	721.3	628.9	494.8	400.3	381.3	365.9	351.3	339.1	334.0	330.9	330.2	329.8	331.3
Forest land converted to Settlements	kha	275.8	281.2	259.5	218.0	148.5	115.1	110.3	106.9	105.7	104.3	103.0	102.2	102.5	100.9	101.5
Cropland converted to Settlements	kha	527.6	421.8	390.1	348.7	290.2	238.9	226.3	215.2	204.1	195.0	192.4	191.6	191.9	192.9	194.5
Grassland converted to Settlements	kha	52.3	44.5	42.0	38.0	34.1	30.4	29.7	28.5	27.2	26.2	25.6	24.9	24.5	25.5	25.5
Wetlands converted to Settlements	kha	IE	IE	IE	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	15.0	15.3	14.3	13.6	12.9	12.1	11.3	10.5	9.8

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 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) Uncertainties 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 described in the *2006 IPCC Guidelines*. The uncertainty estimate was 49% 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

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

- ***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 FY2022, Japan's other land area was about 2.69 million ha, which is equivalent to about 7.1% of the national land. The classification of other land is shown in Table 6-60 below[15].

Table 6-60 Land included in the other land category

Items		Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Other land		kha	2,518.0	2,534.7	2,525.5	2,421.1	2,458.4	2,325.4	2,375.5	2,587.0	2,723.7	2,632.1	2,612.8	2,601.1	2,599.7	2,661.3	2,691.6
	Defense facility Site	kha	139.0	140.0	140.0	140.0	140.0	140.0	139.0	139.0	135.0	135.0	135.0	135.0	135.0	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	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	503.6	503.6	503.6
	Wasteland	kha	NO	NO	NO	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	1,635.8	1,686.8	1,898.4	2,039.0	1,947.5	1,928.2	1,916.5	1,915.1	1,975.7	2,005.9

The emissions from this category in FY2022 were 401 kt-CO_2 (GHG emissions other than changes in carbon stock are not included in this value.); this represents a decrease of 82.4% compared to FY1990 value and a decrease of 6.9% compared to FY2021.

[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 6-61 Emissions and removals resulting from carbon stock changes in other land

Category	Carbon pool	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
4.F. Other land	Total	kt-CO_2	2,279	2,005	1,648	1,083	881	716	701	692	680	625	616	574	544	431	401
	Living biomass	kt-CO_2	623	507	360	85	129	99	108	117	127	109	116	108	96	24	23
	Dead wood	kt-CO_2	132	106	74	12	27	19	19	23	23	19	19	10	10	2	2
	Litter	kt-CO_2	65	52	36	6	13	10	10	11	11	10	10	5	5	1	1
	Mineral soil	kt-CO_2	1,459	1,340	1,178	980	712	589	564	541	519	487	471	451	432	404	375
	Organic soil	kt-CO_2	NO	NO	NO	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	2,279	2,005	1,648	1,083	881	716	701	692	680	625	616	574	544	431	401
	Living biomass	kt-CO_2	623	507	360	85	129	99	108	117	127	109	116	108	96	24	23
	Dead wood	kt-CO_2	132	106	74	12	27	19	19	23	23	19	19	10	10	2	2
	Litter	kt-CO_2	65	52	36	6	13	10	10	11	11	10	10	5	5	1	1
	Mineral soil	kt-CO_2	1459	1340	1178	980	712	589	564	541	519	487	471	451	432	404	375
	Organic soil	kt-CO_2	NO	NO	NO	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 6-62 Areas of other land remaining other land more than 20 years

Category	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Other land remaining Other land	kha	2,304.2	2,349.9	2,370.7	2,290.9	2,357.2	2,226.8	2,280.1	2,495.8	2,633.8	2,546.3	2,529.5	2,523.0	2,525.0	2,590.1	2,623.7

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 conversion, “the land used for soil and stone mining activities” is allocated under “Other land”.

The emissions from this subcategory in FY2022 were 401 kt-CO_2(GHG emissions other than changes in carbon stock are not included in this value.);. This represents a decrease of 82.4% compared to FY1990 and a decrease of 6.9% compared to FY2021.

With respect to living biomass, its carbon stock change as a result of land-use conversion from forest land, cropland and grassland to other land were estimated.

With respect to dead organic matter, carbon stock changes in forest land converted to other land was estimated. Carbon stock changes in dead organic matter in other subcategories (conversion from cropland and grassland) were reported as "NA", since dead organic matter pools before and after conversion were assumed to be zero, as described in section 6.5.2. b)2) and 6.6.2. b)2).

With respect to carbon stock changes in soils, carbon stock changes in soils in forest land, cropland and grassland converted to other land are estimated.

In addition, 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" (*the Move and Conversion of Cropland*) are used.

Table 6-63 Area of land converted to other land within the past 1 year

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Land converted to Other land	kha	7.1	6.2	5.2	5.3	1.9	1.7	3.8	2.0	3.5	2.0	2.4	2.3	1.8	1.0	0.9
Forest land converted to Other land	kha	3.60	2.90	2.03	0.32	0.72	0.53	0.53	0.62	0.62	0.53	0.53	0.28	0.28	0.05	0.05
Cropland converted to Other land	kha	2.4	2.1	2.0	4.1	0.8	0.8	1.9	1.2	2.7	0.5	0.9	0.8	0.9	0.8	0.7
Rice field	kha	1.2	1.3	1.6	3.9	0.5	0.3	1.3	0.8	2.2	0.3	0.4	0.4	0.5	0.5	0.4
Upland field	kha	0.6	0.5	0.1	0.1	0.2	0.3	0.5	0.3	0.4	0.2	0.4	0.4	0.3	0.2	0.2
Orchard	kha	0.5	0.3	0.3	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.0
Grassland converted to Other land	kha	0.2	0.2	0.2	0.1	0.1	0.2	0.2	0.1	0.1	0.7	0.9	1.0	0.5	0.2	0.2
Wetlands converted to Other land	kha	IE	IE	IE	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	IE	IE	IE
Non-land converted to Other land	kha	1.0	1.1	0.9	0.8	0.4	0.2	1.1	NO	0.1	0.2	0.0	0.1	0.1	NO	NO

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 6-63).

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 6-64). 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 6-64 Area of land converted to other land within the past 20 years

Subcategory	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Land converted to Other land	kha	213.8	184.8	154.8	130.2	101.2	98.6	95.4	91.2	89.8	85.8	83.3	78.0	74.7	71.2	67.9
Forest land converted to Other land	kha	102.4	97.2	85.4	65.0	42.8	33.4	30.4	28.1	26.1	23.0	20.9	18.3	16.5	14.4	12.3
Cropland converted to Other land	kha	56.8	41.6	37.1	38.0	33.3	46.5	45.9	45.0	46.5	45.8	45.5	42.7	41.7	41.1	40.5
Grassland converted to Other land	kha	5.6	5.0	4.2	4.3	3.8	3.8	3.8	3.7	3.6	4.1	4.9	5.7	6.0	6.0	5.9
Wetlands converted to Other land	kha	IE	IE	IE	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	IE	IE	IE
Non-land converted to Other land	kha	49.0	41.0	28.0	22.9	21.3	15.0	15.3	14.3	13.6	12.9	12.1	11.3	10.5	9.8	9.1

c) Uncertainties 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 described in the *2006 IPCC Guidelines*. The uncertainty was estimated as 82% 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

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

- ***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.)

Harvested Wood Products (HWP) that have been removed from forest through harvest, store carbon in the wood while HWP remain in use, including as building materials and furniture. Eventually, CO_2 are emitted when HWP are discarded through incineration or decay.

This category deals with annual carbon stock changes in the HWP pool. The production approach is applied to the estimation of HWP, and thus the carbon stock changes associated with the use or disposal of domestic HWP (such as sawnwood, wooden board, plywood, paper and paperboard) are estimated. The carbon stock changes in imported HWP are not subject to estimation. The net removals (carbon stock changes) in this category in FY2022 were 1,918 kt-CO_2; this represents an increase of 272.8% compared to FY1990 and a decrease of 10.1% compared to FY2021. The net removals in this category have been on an increasing trend since FY2014 due to an increase in the ratio of domestic wood, except for the temporal drop reflecting the impact of the Covid-19 pandemic.

In this section, the HWP pool is divided into three categories: “buildings”, “wood for other uses than buildings” and “paper and paperboard”, and reported respectively.

Table 6-65 CO_2 emissions and removals associated with carbon stock changes in the HWP pool

Category		Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Total		kt-CO_2	-515	1,269	1,599	503	-479	-353	-1,005	-1,171	-1,427	-1,659	-1,742	-1,669	-1,072	-2,133	-1,918
Buildings	Total	kt-CO_2	-215	-560	-22	-616	-1,109	-556	-1,088	-1,207	-1,226	-1,245	-1,449	-1,540	-1,521	-1,874	-1,793
	Sawnwood	kt-CO_2	-2	-238	457	-77	-492	411	-147	-235	-112	-101	-282	-157	-213	-524	-495
	Wooden board	kt-CO_2	-254	-371	-522	-459	-379	-480	-531	-507	-579	-566	-550	-671	-639	-689	-647
	Plywood	kt-CO_2	41	48	43	-80	-238	-487	-411	-465	-536	-578	-616	-713	-670	-660	-650
Wood used for other than building	Total	kt-CO_2	413	976	1,141	822	198	84	-18	-140	-226	-406	-474	-370	-146	-423	-358
	Sawnwood	kt-CO_2	843	1,137	1,289	1,292	1,235	1,078	1,024	961	955	925	845	776	881	717	770
	Wooden board	kt-CO_2	-411	-220	-240	-187	21	-11	5	30	31	46	67	220	232	239	237
	Plywood	kt-CO_2	-18	59	92	-283	-1,058	-983	-1,047	-1,130	-1,212	-1,377	-1,386	-1,366	-1,258	-1,379	-1,365
Paper and paperboard		kt-CO_2	-712	853	480	296	432	118	101	176	25	-7	180	241	595	165	233

6.10.1. Buildings

a) Category Description

This category deals with annual carbon stock changes in sawnwood, wooden board and plywood used in buildings. The net removals (carbon stock changes) in this subcategory in FY2022 were 1,793 kt-CO_2; this represents an increase of 733.3% compared to the FY1990 value and a decrease of 4.3% compared to the FY2021 value.

Note that sawnwood, wooden board and plywood used in buildings are reported in "Sawnwood", and "Wood panels" under "Solid wood" in the CRT tables, respectively.

b) Methodological Issues

- ***Estimation Method***

Since sawnwood, wooden board and plywood are mainly used for buildings and the statistics related to buildings have been compiled with a certain level of accuracy in Japan, carbon stock changes in these pools are estimated by using a country-specific stock inventory method (Tier 3). Carbon stocks in sawnwood, wooden board and plywood that are used when buildings are constructed are recorded as inflow and those released when the buildings are demolished are recorded as outflow. The net carbon stock changes are estimated by summing the inflow and outflow calculated separately. 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:

$$\Delta C_{j,i} = Inflow_{j,i} - Outflow_{j,i}$$

j	: Subcategories (sawnwood, wooden board, plywood)
i	: Year for calculation
$\Delta C_{j,i}$	: Carbon stock change in subcategory j of the building HWP pool during year i [t-C/year]
$Inflow_{j,i}$	: Inflow to subcategory j of the building HWP pool during year i [t-C/year]
$Outflow_{j,i}$	: Outflow from subcategory j of the building HWP during year i [t-C/year]

$$Inflow_{j,i} = S_{P_{st,i}} \times v_{DP_{j,st,i}} \times f_{DP_{j,i}} \times D_j \times CF_j$$

j	: Subcategory (sawnwood, wooden board, plywood)
i	: Year for calculation
st	: Use (residential or nonresidential) and structure type of buildings
$Inflow_{j,i}$	: Inflow to subcategory j of the building HWP pool during year i [t-C/year]
$S_{P\ st,i}$	: Constructed floor area by use (residential or nonresidential) and by structure type (st) during year i [m^2/year]
$v_{DP\ j,st,i}$	: 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.]

$$Outflow_{j,i} = S_{W_{st,i}} \times v_{DW_{j,st,i}} \times f_{DW_{j,i}} \times D_j \times CF_j$$

j	: Subcategory (sawnwood, wooden board, plywood)
i	: Year for calculation
st	: Use (residential or nonresidential) and structure type of buildings
$Outflow_{j,i}$	: Outflow from subcategory j of the building HWP pool 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]
$v_{DWj,st,i}$	: 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.]

- ***Parameters***

➢ ***Wood input amount per unit floor area of buildings constructed ($v_{DP\ j,st,i}$)***

- ***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 data for 2013 obtained by the Forest Agency of Japan were used for that year and the data for 1992-2012 and 2014-2020 were estimated by linear interpolation. For other years where data are missing, data were obtained in the same manner.

- ***Wooden board***

The sales and consumption quantity of wooden board by type (particle board, hardboard, medium-density fibreboard and insulating board) and use was calculated by multiplying the total sales and consumption quantity of wooden board by type obtained from the *Current Production Statistics,*

Ceramics and building materials Statistics (METI), by the ratio of the sales and consumption quantity of wooden board used for buildings, estimated from the Japan Fibreboard and Particleboard Manufacturers Association's statistics. The wood input per unit area was estimated by dividing the amount of wood calculated above, by the floor area of constructed buildings.

- ***Plywood***

The values obtained from the *Survey on Actual Demand of Construction Labor and Materials* (MLIT) were applied. As for the years where data are missing, the values were calculated by linear interpolation.

➢ ***Ratio of domestic wood for construction ($f_{DP\,j,i}$)***

- ***Sawnwood***

The ratio of domestic wood for sawnwood by conifer and non-conifer 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.

- ***Wooden board***

The sales and consumption quantity of wooden board (domestic wood) for buildings by raw material ((i) logs, (ii) wood residue in mills, (iii) wood residue in forestry practices and (iv) scrap wood) was calculated by multiplying the proportion of raw materials in particle board and fiberboard, by the ratio of domestic wood for each raw material. The ratio of domestic wood for each raw material was estimated as follows: for (i) logs, it was estimated from the production of domestic wood chips, imported wood chips, and quantity of wood used for wood chips (domestic and imported wood); for (ii) wood residue in mills, it was estimated from the shipment quantity of sawnwood (domestic and imported wood); for (iii) wood residue in forestry practices, it was estimated as 100%; and for (iv) scrap wood, the ratio of domestic wood for demolished buildings described below was applied. The ratio of domestic wood for each wooden board type was estimated by dividing the sales and consumption quantity of wooden board (domestic wood) above, by the sum of the sales and consumption quantity of wooden board for buildings.

- ***Plywood***

The ratio of domestic wood for plywood used in constructed buildings was calculated by dividing the production of plywood from domestic wood by the sum of plywood production and imports.

➢ ***The amount of wood input per unit floor area of demolished buildings ($v_{DP\,j,st,i}$) 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 ($v_{DW\,j,st,i}$) 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 ($v_{DP\,j,st,i}$) or the ratio of domestic wood for buildings ($f_{DP\,j,i}$) in subcategory j, as shown in the equations below.

$$v_{DW\,j,st,i} = \sum_n \left(\frac{S_{w\,,st,i\,(n)}}{S_{w\,st,i}} \times v_{DP\,j,s,t,i\,(n)} \right)$$

$$f_{DW\,j,i} = \sum_n \left(\frac{S_{w\,st,i\,(n)}}{S_{w\,st,i}} \times f_{DP\,j,i\,(n)} \right)$$

➢ ***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 6.11 is the oven dry mass density over air dry volume.

Table 6-66 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)		0.542	0.493

Reference: The *2019 Refinement*, Table 12.1 (excluding density for coniferous sawnwood)

Note: Country specific value is used for the density of coniferous sawnwood.

Table 6-67 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)	

Note: MIC: Ministry of Internal Affairs and Communications; 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 demolition ($S_{W\ st,\ i}$)***

The floor area of demolition was estimated by 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 ($S_{S\ st,\ i}$).

$$S_{W_{St,i}} = S_{S_{st,i-1}} + S_{P_{st,i}} - S_{S_{st,i}}$$

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.

c) Uncertainties 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***

Since wood input per unit area was obtained from the *Survey on Actual Demand of Construction Labor and Materials* by the MLIT which is implemented every two years, the data for missing years were calculated by linear interpolation. The time-series consistency for this subcategory is ensured.

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 checking the parameters for activity data and emission factors and archiving reference materials. QA/QC activities are summarized in Annex 4.

e) Category-specific Recalculations

The carbon stock changes for all years were recalculated since the amount of wood input per unit floor area of non-wooden buildings, density of coniferous sawnwood and ratio of domestic wood for construction had been updated. See Chapter 10 for the impact of recalculations on the trend.

f) Category-specific Planned Improvements

No improvements are planned.

6.10.2. Wood for other uses than buildings

a) Category Description

This category deals with carbon stock changes in sawnwood, wooden board and plywood for other uses than buildings. The net emissions from this subcategory in 1990 were 413 kt-CO_2, the net removals in FY2021 were 423 kt-CO_2, and the net removals in FY2022 were 358 kt-CO_2.

In the CRT tables, this category is reported as “Sawnwood for non-buildings”, “Wooden board for non-buildings” and “Plywood for non-buildings” under “Other (please specify)”.

b) Methodological Issues

- ***Estimation Method***

The carbon stock changes in the HWP pool of this category were estimated as the difference between the HWP pool in the reference year and prior year by 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 for other uses than buildings by the ratio of domestic wood of each subcategory (sawnwood, wooden board and plywood) and the carbon conversion factor. The estimation equations are as follows.

$$\Delta C_{j,i} = C_{j,i} - C_{j,i-1}$$

$$C_{j,i} = e^{-k_j} \times C_{j,i-1} + \left[\frac{\left(1 - e^{-k_j}\right)}{k_j}\right] \times Inflow_{j,i}$$

j : Subcategory (sawnwood, wooden board, plywood)

i : Year for calculation

$\Delta C_{j,i}$: Carbon stock change in subcategory j of the wood for other uses than buildings HWP pool during year i [t-C/year]

$C_{j,i}$: Carbon stock in subcategory j of the wood for other uses than buildings HWP pool at the end of year i [t-C]

* $C_{j,(1900)} = 0$: Carbon stock in 1900 was assumed to be zero

k_j : $k_j = \ln(2) / HLj$

HLj: half-life in subcategory j of the wood for other uses than buildings HWP pool

$Inflow_{j,i}$: Inflow to subcategory j of the wood used for other than buildings HWP pool during year i [t-C/year]

$$Inflow_{j,i} = V_{p\,j,i} \times f_{DP\,j,i} \times D_j \times CF_j$$

j : Subcategory (sawnwood, wooden board, plywood)

i : Year for calculation

$Inflow_{j,i}$: Inflow to subcategory j of the wood for other uses than buildings HWP pool during year i [t-C/year]

$VP_{j,i}$: Amount of wood in subcategory j for other uses than buildings [m^3/year]

$fDP_{j,i}$: Ratio of domestic wood in subcategory j for other uses 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.]

- ***Parameters***

➢ ***Ratio of domestic wood***

- ***Sawnwood***

The ratio of domestic wood for sawnwood for other uses than buildings was calculated by dividing the amount of shipped sawnwood produced from domestic wood by tree species, by the amount of shipment.

- ***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***

The ratio of domestic wood for plywood for other uses than buildings, was calculated by dividing the amount of input materials from domestic wood for plywood for other uses than buildings by the sum of the amount of input materials for plywood and imported veneers for plywood (in roundwood-equivalent volume).

➢ ***Default half-lives***

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***

The same values as for the "Buildings" category were used (section 6.10.1.) (See Table 6-66 for the details).

Table 6-68 Data used for parameters (wood for other uses than buildings)

	Variable	Reference	Note
	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)	

METI: Ministry of Economy, Trade and Industry; MOF: Ministry of Finance

● ***Activity Data***

Activity data used were the shipment of sawnwood, sales and consumption quantity of wooden board, and production of plywood. The shipment of sawnwood was estimated by subtracting the shipment quantity of sawnwood for buildings from the total shipment quantity of sawnwood in *the Report on Supply and Demand of Lumber* (MAFF). 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) in 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) . The

amount of production of plywood was estimated by subtracting the amount of production of plywood of domestic wood for buildings from the amount of production of total plywood of domestic wood obtained from the *Report on Supply and Demand of Lumber* (MAFF). 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 for other wood use [kt-C/year]
t : Year (1900-1961)
V_{1961} : Annual production for other wood use for the year 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) Uncertainties and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainties of carbon stock changes of wood for other uses 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 for other uses 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 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

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

e) Category-specific Recalculations

The carbon stock changes for all years were recalculated since the density of coniferous sawnwood, the method of tracing production of wooden board and plywood back to 1900 and the wood input for plywood were updated. See Chapter 10 for the impact of recalculations on the trend.

f) Category-specific Planned Improvements

Wood used mainly in the form of roundwood in the civil engineering and construction field is not included in the HWP estimation at present.

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 FY2021 were 165 kt-CO_2, and the net emissions in FY2022 were 233 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 uses than buildings" category by 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 of paper products HWP pool during year *i* [t-C/year]
C_i	: Carbon stock in paper products HWP pool at the end of year *i* [t-C]
	*$C_{(1900)}$=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***

The ratio of domestic wood for paper and paperboard was estimated by dividing the sum of consumption of paper pulp, waste paper and waste paper pulp originated from domestic wood by the total consumption of paper pulp, waste paper, waste paper 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 waste paper and waste 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 waste paper and waste paper pulp in the *Trade Statistics of Japan* (MOF) from the total consumption and then multiplying it by the ratio of domestic wood for waste paper and waste paper pulp. The ratio of domestic wood for waste paper and waste paper 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 6-69 Data used for parameters (Paper and paperboard)

	Variable	Reference	Note
1	Paper pulp, waste paper, waste paper 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 waste paper and waste paper 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)	

METI: Ministry of Economy, Trade and Industry; MOF: Ministry of Finance

➢ ***Half-life***

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***

The default parameters (C conversion factor: 0.386 t-C/t) for paper and paperboard described in the *2019 Refinement* (Tables 12.1) were 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) Uncertainties 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

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

e) Category-specific Recalculations

The carbon stock changes for all years were recalculated since the method for tracing paper and paperboard back to 1900 and the method for estimating the ratio of domestic wood were updated. See Chapter 10 for the impact of recalculations on the trend.

f) Category-specific Planned Improvements

No improvements are planned.

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 FY2022 is 5.9 t-CO_2. For more details, see section 4.9.5.3. in Chapter 4.

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 FY2022 were 0.76 kt-CO_2 eq. This represents a decrease of 38.7% compared to FY1990.

Table 6-70 Direct /Indirect N_2O emissions from N fertilization

Category	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
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	0.003	0.003	0.003
	kt-CO_2 eq.	1.24	1.07	0.99	0.96	0.83	0.83	0.80	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
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	0.003	0.003	0.003
Forest land remaining 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	0.003	0.003	0.003
Land converted to Forest land	kt-N_2O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Wetlands	kt-N_2O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Wetllands remaining Wetllands	kt-N_2O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Land converted to Wetllands	kt-N_2O	IE	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	IE
Settlements land remaining Settlements	kt-N_2O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Land converted to Settlements	kt-N_2O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Other	kt-N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

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 emission factor (0.62% [kg-N_2O-N/kg-N[16]]), 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)* 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 volatilization] (Vol.4、Table 11.3, disaggregated, wet climate)

[16] Akiyama et al. (2006)

- ***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-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 fertilizer] (Table 11.3 in Vol.4, aggregated)

- ***Emission factor (N leaching and runoff)***

0.011 [kg N_2O-N/(kg N leaching/runoff)] (Table 11.3 in Vol.4, aggregated)

- ***Activity Data***

Amount of N fertilizer applied to forest land as mentioned above.

c) Uncertainties and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainty estimates of N_2O emissions from N fertilization were 31% 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 -92% to +276%.

- ***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

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

Due to the reclassification of categories, not only N_2O direct emissions but also N_2O indirect emissions were calculated within this category, therefore, recalculations were conducted for all years.

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 FY2022 were 46.7 kt-CO_2 eq. This represents a decrease of 29.5% compared to FY1990, and a decrease of 0.6 % compared to FY2021.

Table 6-71 CH_4 and N_2O emissions from drainage of organic soils

Category		Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Total		kt-CO_2 eq.	66.2	57.9	53.4	51.5	49.8	47.2	47.2	47.0	45.9	45.8	46.2	46.4	46.6	47.0	46.7
CH_4 Total		kt-CH_4	2.27	2.00	1.85	1.79	1.73	1.64	1.64	1.64	1.60	1.59	1.61	1.61	1.62	1.63	1.62
		kt-CO_2 eq.	63.6	55.9	51.8	50.0	48.4	46.0	46.0	45.8	44.7	44.7	45.0	45.2	45.3	45.7	45.4
	Forest land	kt-CH_4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Cropland	kt-CH_4	0.96	0.97	0.99	0.99	0.98	0.97	0.96	0.96	0.96	0.95	0.95	0.95	0.95	0.95	0.95
	Grassland	kt-CH_4	0.08	0.09	0.09	0.09	0.08	0.10	0.11	0.12	0.09	0.09	0.09	0.09	0.09	0.09	0.09
	Wetlands	kt-CH_4	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA
		Peat land	kt-CH_4	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		Flooded land	kt-CH_4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Other wetlands	kt-CH_4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Settlements	kt-CH_4	1.23	0.94	0.77	0.71	0.67	0.58	0.57	0.56	0.55	0.55	0.57	0.57	0.58	0.60	0.59
N_2O Total		kt-N_2O	0.010	0.008	0.006	0.006	0.005	0.005	0.005	0.004	0.004	0.004	0.005	0.005	0.005	0.005	0.005
		kt-CO_2 eq.	2.62	1.99	1.64	1.51	1.42	1.23	1.20	1.18	1.17	1.17	1.20	1.21	1.23	1.27	1.25
	Forest land	kt-N_2O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Wetlands	kt-N_2O	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA
		Peat land	kt-N_2O	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
		Flooded land	kt-N_2O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Other wetlands	kt-N_2O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Settlements	kt-N_2O	0.010	0.008	0.006	0.006	0.005	0.005	0.005	0.004	0.004	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 6-72 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	$kgN_2O\text{-}N/ha/yr$	Country specific data (Actual measurement in rice field in Hokkaido)

Table 6-73 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*, Table2.3)

- ***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) Uncertainties and Time-series Consistency

- ***Uncertainty Assessment***

The uncertainties for parameters were assessed on the basis of default values described in the *Wetlands Guidelines.* As a result, the uncertainty estimates for the CH_4 emissions from drained inland organic soils were 65%.

- ***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

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 area of organic soil were revised, 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 FY2022 were 386.8 kt-CO_2 eq. This represents a decrease of 54.4% compared to FY1990, and an increase of 0.7 % compared to FY2021.

Table 6-74 Direct /Indirect N_2O emissions from N mineralization

Category	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Total	kt-N_2O	3.20	2.81	2.59	2.30	1.89	1.63	1.58	1.53	1.49	1.45	1.44	1.44	1.44	1.45	1.46
	kt-CO_2 eq.	847.3	744.5	686.0	610.6	500.8	432.4	417.7	404.6	393.9	384.0	380.8	380.6	381.2	383.9	386.8
Forest land	kt-N_2O	0.39	0.39	0.39	0.40	0.40	0.40	0.40	0.40	0.40	0.41	0.41	0.42	0.42	0.43	0.44
Forest land remaining Forest land	kt-N_2O	0.39	0.39	0.39	0.40	0.40	0.40	0.40	0.40	0.40	0.41	0.41	0.42	0.42	0.43	0.44
Land converted to Forest land	kt-N_2O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Cropland	kt-N_2O	0.13	0.08	0.05	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.05
Land converted to Cropland	kt-N_2O	0.13	0.08	0.05	0.03	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.05
Graassland	kt-N_2O	0.0056	0.0034	0.0020	0.0012	0.0006	0.0011	0.0008	0.0007	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
Land converted to Graassland	kt-N_2O	0.0056	0.0034	0.0020	0.0012	0.0006	0.0011	0.0008	0.0007	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
Wetlands	kt-N_2O	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA	NE,NA
Wetlands remaining Wetlands	kt-N_2O	NA	NA	NA	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	NE	NE	NE
Settlements	kt-N_2O	2.29	1.98	1.84	1.61	1.28	1.04	1.00	0.95	0.91	0.88	0.86	0.85	0.85	0.86	0.86
Settlements remaining Settlements	kt-N_2O	NA	NA	NA	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	1.04	1.00	0.95	0.91	0.88	0.86	0.85	0.85	0.86	0.86
Other land	kt-N_2O	0.39	0.35	0.31	0.26	0.19	0.16	0.16	0.15	0.14	0.14	0.13	0.13	0.12	0.11	0.11
Land converted to Other land	kt-N_2O	0.39	0.35	0.31	0.26	0.19	0.16	0.16	0.15	0.14	0.14	0.13	0.13	0.12	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.

$$N_2O = N_2O - N_{direct_N_{mineral,i}} \times 44/28$$

$$N_2O\text{-}N_{direct\text{-}N_{Minerarl_i}} = F_{SOM_i} \times EF1_i \quad \text{(Equation 11.1, Vol.4 of the } \textit{2006 IPCC Guidelines}\text{)}$$

$$F_{SOM_i} = \sum_k \left(\Delta C_{Mineral_{i,k}} \times \frac{1}{R_{i,k}}\right) \quad \text{(Equation 11.8, Vol.4 of the } \textit{2006 IPCC Guidelines}\text{)}$$

$N_2O\text{-}N_{direct\text{-}NMineral}$	: 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
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 cropland and grassland, the equations above were summarized as follows and set as the N_2O-N direct emission factor per unit area ($EF_{N2O\text{-}Ni,j}$) [kg-N_2O-N/ha].

$$N_2O\text{-}N_{direct\text{-}N_{Mineral_{i,j}}} = c_{ms-loss_{i,j,k}} \times A_{i,j,k} \times \frac{1}{R_{i,k}} \times EF1_{i,j}$$

$$= \left\{EF_i \times \sum_k \left(c_{ms-loss_{i,j,k}} \times \frac{1}{R_{i,k}}\right)\right\} \times \sum_k \left(A_{i,j,k}\right)$$

$$= EF_{N2O\text{-}N_{i,j}} \times A_{i,j}$$

$C_{ms\text{-}loss}$	: Soil carbon loss per unit area due to loss of organic matter in mineral soil [kg-C/ha]
A	: Area of mineral soil with loss of soil carbon due to loss of soil organic matter [ha]
i	: Land use/type of land (rice field, upland fields, orchards (fruit orchards, tea gardens), grasslands (pastures))
j	: Regions (Hokkaido, Tohoku, Kanto, Hokuriku, Tokai/Kinki, Chugoku/Shikoku, Kyushu/Okinawa)
k	: Soil type (based on classification by Yagasaki and Shirato (2014))

- ***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] described 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 and for the whole area (Table 6-75) obtained from the soil survey by Matsui et al. (2021) was applied.

Table 6-75 C/N ratio for soil by land use [kg-C/kg-N]

Land use	C/N ratio	Reference
Forest	15.0	*2006 IPCC Guidelines*, Vol.4, chp.11, p11-16
Average of Cropland and Grassland	12.0	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).
Rice fields	11.5	
Paddy fields	12.3	
Orchards	11.6	
Pasture land	13.1	

➢ ***Parameters used for cropland (converted from other land use) and grassland***

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).

- ***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 cropland were used. The soil types were organized into three groups, and the results of the mean values for each land type are shown in Table 6-76.

Table 6-76 C/N ratio by soil type for each type of land use in cropland and grassland

Soil type	Rice fields	Upland fields	Orchards and tea plantations	Pasture land
Lowland soils	10.9	11.4	11.0	11.6
Andosols	13.5	12.8	13.0	13.9
Other soils	10.8	10.3	10.5	11.4

- ***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 1 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 6-77.

Table 6-77 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

- ***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) Uncertainties 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 described in the *2006 IPCC Guidelines* were used. The uncertainty of emissions/removals 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 in the N_2O emissions from N mineralization associated with loss of soil organic matter were assessed at -54% to +145%. The uncertainty of indirect N_2O emissions from N mineralization associated with loss of soil organic matter was 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

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

Other land converted to settlements from N mineralization were estimated, and the revision of C/N ratio, emission of N_2O per amount of N mineralization and the area of mineral soils are recalculated in cropland and grassland, N_2O emissions in forest land, cropland, grassland and other land 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. For the emissions of CO and NO_X, see Annex 5.

For forest land, the emissions resulting from wildfires in forest land remaining forest land and land converted to forest land are reported in a lump for wildfires in forest land remaining forest land, because the data in the statistics for forest fires include the wildfires occurred in both of the categories. Moreover, controlled burning activities in forests and land conversion from land-use categories other than forest land to forest land are not implemented in Japan because the activities are stringently restricted by the "Waste Management and Public Cleansing Act" and "Fire Service Act". Hence, the emissions resulting from controlled burning in forest land do not occur and are reported as "NO".

CH_4 and N_2O emissions from controlled burning in cropland are estimated for woody biomass burning of pruned branches from orchard. One of the characteristics of Japan's cropland is intensive management. Under this management style, the occurrences of wildfire are regarded as negligible. CH_4 and N_2O emissions from wildfires in cropland are reported as "NO". In addition, CH_4 and N_2O

emissions from controlled burning in grassland are estimated. CH_4 and N_2O emissions from wildfires in grassland are reported as "NO" for the same reasons as cropland.

CH_4 and N_2O emissions from wildfires in land other than forest land, cropland and grassland are reported as "NE" because information on wildfires is not enough. CH_4 and N_2O emissions from biomass burning in Wetlands are reported as "NE" because it can be considered insignificant.

CO_2 emission is not included in this category because it was included in estimation of carbon stock changes.

The emissions by this subcategory in FY2022 were 51.1 kt-CO_2 eq. This represents a decrease of 29.8% compared to FY1990 and a decrease of 12.2% compared to FY2021. These fluctuations are due to less amount of woody biomass burning of pruned branches from orchard over the long run, while, in the short run, inconsistencies of wildfire occurrences also effect it.

Table 6-78 Non-CO_2 emissions from biomass burning

Category		Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Total		kt-CO_2 eq.	72.8	70.0	65.8	65.9	57.0	54.9	77.0	56.7	50.7	76.5	51.2	54.0	50.5	58.3	51.1
CH_4 Total		kt-CH_4	1.9	1.8	1.7	1.7	1.4	1.3	2.1	1.4	1.2	2.1	1.2	1.3	1.2	1.5	1.2
		kt-CO_2 eq.	53.1	50.8	47.3	47.7	39.5	37.7	58.5	39.5	33.9	58.2	34.4	37.1	34.0	41.3	34.6
	Forest land	kt-CH_4	0.4	0.4	0.4	0.4	0.2	0.2	0.9	0.2	0.1	0.9	0.1	0.2	0.1	0.4	0.2
	Cropland	kt-CH_4	1.0	0.9	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.6	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	0.5	0.5	0.5
	Wetlands	kt-CH_4	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO
	Settlements	kt-CH_4	NO	NO	NO	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	NO	NO	NO
	Other	kt-CH_4	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
N_2O Total		kt-N_2O	0.07	0.07	0.07	0.07	0.07	0.06	0.07	0.06	0.06	0.07	0.06	0.06	0.06	0.06	0.06
		kt-CO_2 eq.	19.7	19.1	18.5	18.2	17.5	17.2	18.5	17.2	16.8	18.3	16.7	16.8	16.6	17.0	16.5
	Forest land	kt-N_2O	0.003	0.003	0.003	0.003	0.001	0.001	0.006	0.002	0.000	0.006	0.001	0.001	0.001	0.003	0.001
	Cropland	kt-N_2O	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	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	0.05	0.05	0.05
	Wetlands	kt-N_2O	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO
	Settlements	kt-N_2O	NO	NO	NO	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	NO	NO	NO
	Other	kt-N_2O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

b) Methodological Issues

1) CH_4 and N_2O emissions from forest fires

- ***Estimation Method***

For CH_4, and N_2O emissions due to biomass burning from forest fires, the Tier 1 method is used in *GPG-LULUCF*.

➢ ***Forest land***

- ***CH_4***

$$bbGHG_f = L_{forest\ fires} \times ER$$

- ***N_2O***

$$bbGHG_f = L_{forest\ fires} \times ER \times NC_{ratio}$$

$bbGHG_f$: GHG emissions due to forest biomass burning
$L_{forest\ fires}$: Carbon released due to forest fires [t-C/yr]
ER : Emission ratio (CH_4 : 0.012, N_2O : 0.007)

NC_{ratio} : Nitrogen Carbon ratio of the biomass

- ***Parameters***

➢ ***Emission ratio***

The following values are applied to emission ratios for non-CO_2 gases due to biomass burning.

CH_4: 0.012, N_2O: 0.007 (Default value stated in the *GPG-LULUCF*, Table 3A.1.15)

➢ ***NC ratio***

The following values are applied to NC ratio.

NC ratio: 0.01 (default value stated in the *GPG-LULUCF* p.3.50)

- ***Activity Data***

➢ ***Forest land***

As activity data in forest land, carbon stock loss due to forest fire is used. Carbon stock loss due to forest fire is estimated by the Tier 3 method in the *2006 IPCC Guidelines*. For each of the national forest land and private forest land, carbon stock loss are calculated from the fire-damaged timber volume multiplied by wood density, the biomass expansion factor and the carbon fraction of dry matter.

$$L_{forest\ fires} = \Delta C_n + \Delta C_p$$

$L_{forest\ fires}$: carbon stock loss due to forest fire [t-C/yr]
ΔC_n : carbon stock loss due to fire in national forests [t-C/yr]
ΔC_P : carbon stock loss due to fire in private forests [t-C/yr]

Fire-damaged timber volume is separately estimated for national forests and private forests. With regard to national forests, the timber volume of standing trees damaged due to fires in national forests in the *Handbook of Forestry Statistics* is used. With regard to private forests, the damaged timber volume due to fires is estimated by using the actual damaged area and damaged timber volume by age class (inquiry survey by Forestry Agency). Damaged timber volume for age classes equal to or under 4 is calculated 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 (ratio of damaged timber volume to stand volume) of damaged timber volumes whose age classes equal to or over 5 in private forests. The loss ratio is assumed to be constant regardless of age classes.

- ***National forest, Private forest***

$$\Delta C_{n,p} = Vf_{n,p} \times D_{n,p} \times BEF_{n,p} \times CF_{n,p}$$

The values for wood density and biomass expansion factors for national and private forest land are

$\Delta C_{n,p}$: Carbon loss due to fire in national forests and private forest [t-C/yr]
$Vf_{n,p}$: Damaged timber volume due to fire in national forests and private forest [m^3/yr]
$D_{n,p}$: Wood density in national forests and private forest [t-d.m./m^3]
$BEF_{n,p}$: Biomass expansion factor for national forests and private forest
$CF_{n,p}$: Carbon fraction of dry matter [t-C/t-d.m.]

determined as weighted averages using the ratios of intensively managed forests and semi-natural forests.

Table 6-79 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 6-80 Damaged timber volume due to wildfire

Category		Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Damaged timber volume due to disturbance in national forest		m^3	3,688	1,014	1,599	359	16,091	279	5,326	2,472	916	75	112	49	275	498	734
Damaged timber volume due to disturbance in private forest		m^3	64,918	69,180	60,640	73,348	15,810	26,620	147,989	38,571	8,151	157,051	16,309	34,245	17,235	62,745	24,479
≧5	Actual damaged area	kha	0.29	0.94	0.48	0.35	0.07	0.18	0.53	0.22	0.04	0.35	0.09	0.15	0.07	0.30	0.05
	Damaged timber volume	m^3	47,390	58,129	54,487	59,235	12,780	25,204	137,078	36,693	7,370	153,412	15,148	33,276	15,914	61,583	18,048
≦4	Actual damaged area	kha	0.27	0.51	0.16	0.27	0.06	0.04	0.18	0.05	0.02	0.04	0.03	0.02	0.03	0.03	0.08
	Damaged timber volume	m^3	17,528	11,051	6,153	14,113	3,030	1,416	10,911	1,878	781	3,639	1,161	969	1,321	1,163	6,430

Reference: Based on *Handbook of Forestry Statistics* for national forest, and Forestry Agency data for private forest

- ***Note***

In Japan, emissions due to biomass burning are estimated separately for national forests and for private forests, because of different reporting procedures in regard to forest fire information. However, forest fires in Japan are covered by a set of data for both national forests and private forests, and the emissions are thus appropriately estimated.

2) CH_4 and N_2O emissions from burning of pruned branches from orchard trees

- ***Estimation Method***

For CH_4 and N_2O 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* was applied. The estimation equation is as follows:

$$L_{fire} = W_B \times C_f \times G_{ef} \times 10^{-6}$$

L_{fire} : Amount of greenhouse gas emission from fire [kt- GHG]
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 value of 0.9 which has been used generally in field burning of crop residues in agriculture in Japan is applied. For emission factor, the default emission factors of "Agricultural residue" provided in the *2006 IPCC Guidelines* are used.

Table 6-81 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 (Amount burned)***

The amount burned data was calculated by multiplying the same the cultivation area of the orchard trees as used in the calculation of carbon stock change in 4.B., by the MAFF by dry matter residue weight per unit area (400kg/10a) from the domestic field survey conducted by the National Institute of

Resources (1982), and ratio of burning of pruned branches in field (25%) from the result of monitoring survey of soils in 2008.

$$W_B = \sum_i (A_i \times E \times 10) \times R$$

W_B : Amount of burning pruned branches from orchard trees [kg-d.m.]
A : Cultivation area of orchard trees [ha]
E : Dry matter residue weight per unit area [kg-d.m./10a]
R : Combustion ratio of pruned branches from orchard trees
i : Type of orchard tree

3) CH_4 and N_2O from biomass burning in Grassland

- ***Estimation method***

For CH_4 and N_2O emissions due to biomass burning from grassland, the estimation method (Equation 2.27, p2.42, Vol.4) described in the *2006 IPCC Guidelines* was applied. The estimation equation is as follows:

$$L_{fire} = A \times M_B \times C_f \times G_{ef} \times 10^{-6}$$

L_{fire} : Amount of greenhouse gas emission from fire [kt-GHG]
A : Area burnt [ha]
M_B : 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 6-82 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***

The total mass of fuel available for combustion in grassland is calculated by multiplying area burnt of grassland, by the average amount of dry mass per unit area. There is no comprehensive statistical information or official data relating to burnt area of grassland. However, the area of controlled large-scale burning events on grassland which may affect national GHG emissions is limited in Japan. The area burnt 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 burnt per area unit, value of 10 t-d.m./ha is applied according to expert judgment that considering survey data on burning of grassland 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) Uncertainties 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 described 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 described 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 71% for CH_4 and 46% 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 2022. 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

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 cultivation area of orchard trees from 2017 were revised, CH_4 and N_2O emissions from burning of pruned branches from orchard trees after FY2017 were recalculated. The CH_4 and N_2O emissions from forest fires for the period of FY1990 - FY2005 were recalculated, since the 2021 Yield Tables were applied and the forest stock volume data was updated.

See Chapter 10 for impact on 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.

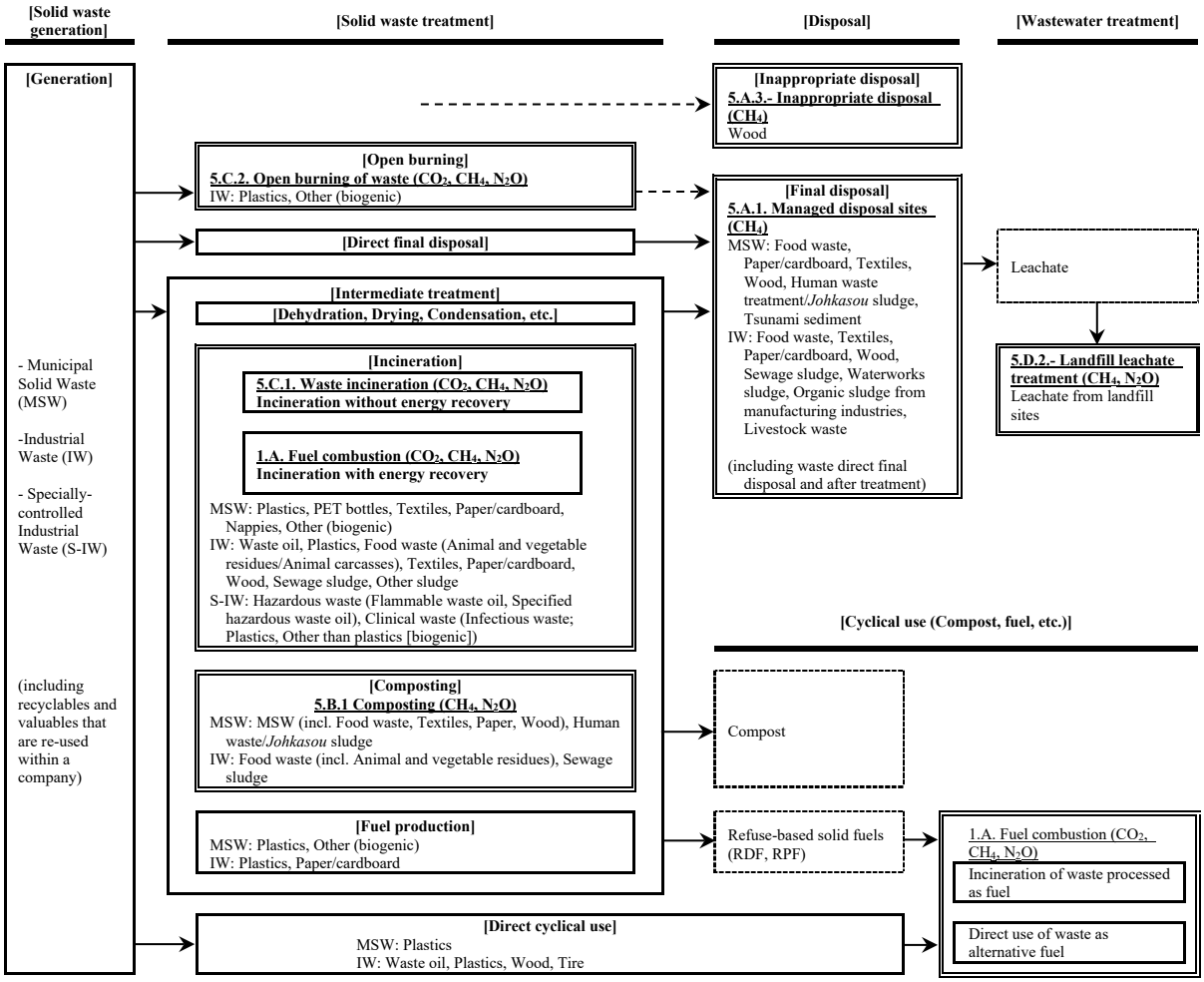

Figure 7-1 Flow chart of solid waste managements and the estimation categories

[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 Gases Emissions Estimation Methods* (https://www.env.go.jp/earth/ondanka/ghg-mrv/committee/).

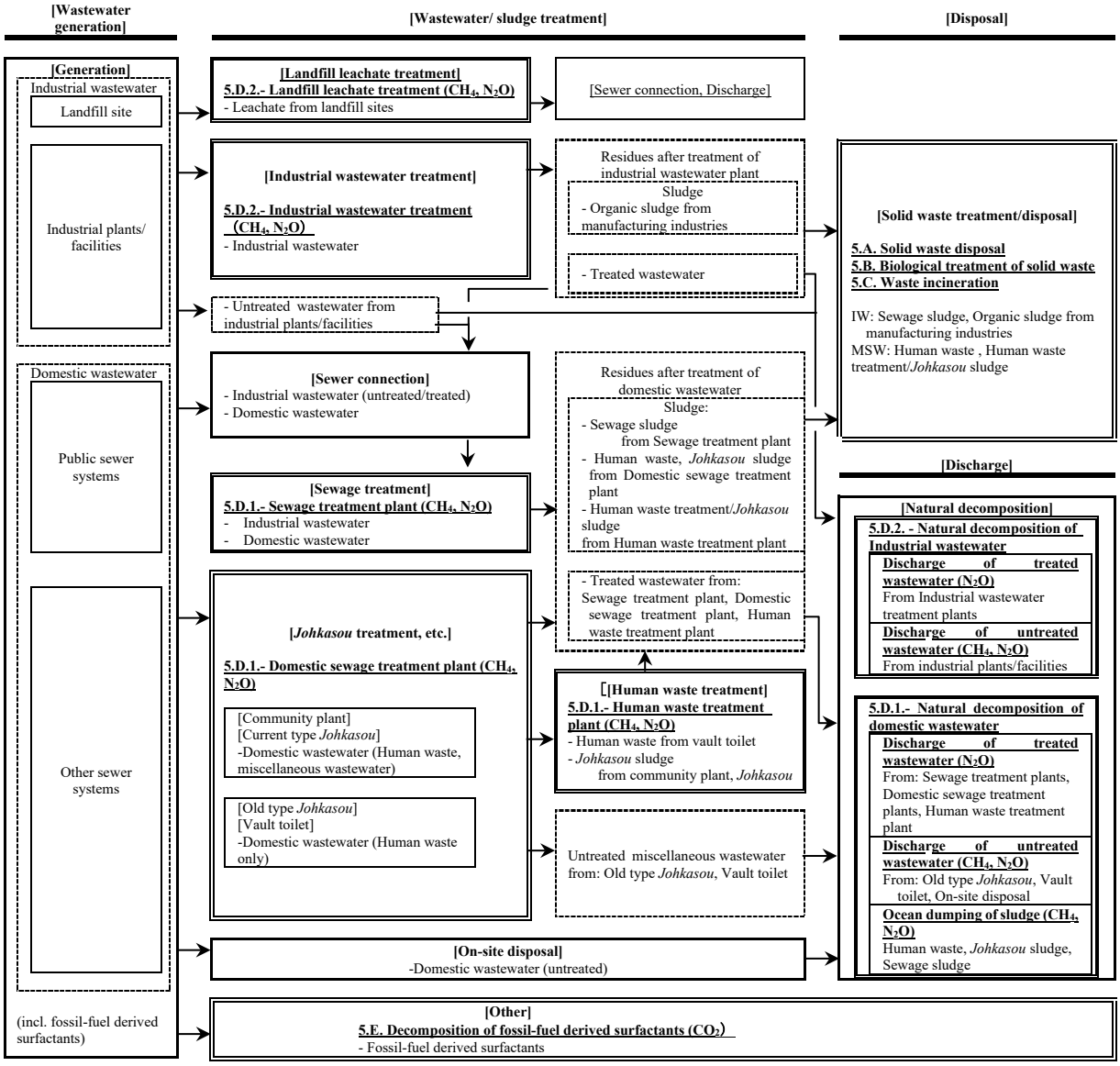

Figure 7-2 Flow chart of wastewater/sludge treatments and the GHG estimation categories

"Waste" to be covered in this sector is the waste as defined in the *2006 IPCC Guidelines*. In the case of Japan, the waste does not only include municipal waste and industrial waste as defined by the Waste Management and Public Cleansing Act, but also include recyclables and valuables that are re-used within a company, and are reported in category "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 municipal waste and industrial waste in Japan, estimation methodologies for many of emission sources in the waste sector are discussed respectively for municipal waste and industrial waste. 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 on Waste Sector

In FY2022, emissions from the Waste sector resulted in 17,524 kt-CO_2 eq. and accounted for 1.5% of Japan's total GHG emissions (excluding LULUCF). Total emissions had decreased by 43.6% compared to those of FY1990 and decreased by 4.5% compared to those of FY2021. Breakdown of FY2022

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 on the energy sector) accounting for 65.2% (a decrease by 16.2% from FY1990) followed by the Wastewater Treatment and Discharge (5.D.) accounting for 20.0% (a decrease by 35.4% compared to FY1990), Solid Waste Disposal (5.A.) accounting for 9.3% (a decrease by 85.2% from FY1990), Other (5.E.) accounting for 3.7% (a decrease by 6.9% from FY1990) , and Biological Treatment of Solid Waste (5.B.) accounting for 1.8% (an increase by 41.1% 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 plastic and waste oil accounting for 58.4%, followed by N_2O emissions from wastewater treatment and discharge accounting for 10.1%, CH_4 emissions from wastewater treatment and discharge accounting for 9.9%.

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 FY2020 (15.9%) in comparison with FY1990 (7.4%), the total disposal amount has reduced in FY2020 (13 Mt) in comparison with FY1990 (109 Mt) (Ministry of the Environment: MOE, 2023). 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 72.4% 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, T1: IPCC Tier 1, T2: IPCC Tier 2, T3: IPCC Tier 3, CS: country specific method or EF

- ***Activity Data***

As activity data in the methodologies on the waste sector, the *Report of the Research on the State of Wide-range Movement and Cyclical Use of Wastes – 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 on 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 Uncertainty on the Waste Sector

The uncertainty of GHG emissions on 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) Uncertainties and Time-series Consistency*" in each category's section.

- ***Emission Factors***

The uncertainties in emission factors are assessed by using the 95% confidence interval obtained from actual measurement, 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 error 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 in industrial waste 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 evaluated at 5% based on expert judgment.
Water works	-5%	+10%	Sampling error in the statistics is evaluated at 5% based on expert judgment as well as sewage statistics. However, water works statistics target only water company and supplier 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 error propagation equation.

7.1.5. 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 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 research on 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 on 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 Gases 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 datils 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 municipal waste and industrial waste 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. (7.2.1)	Municipal solid waste	Food waste			Managed disposal sites	a. Anaerobic	○
		Paper/cardboard					○
		Wood					○
		Textiles	Natural fiber [1]				○
		Sludge	Human waste treatment/*Johkasou* sludge				○
			Tsunami sediment [2]				○[2]
	Industrial waste	Food waste [3]	Animal and vegetable residues, Animal carcasses				○
		Paper/cardboard				b. Semi-aerobic - Managed well	○
		Wood					○
		Textiles	Natural fiber [1]			- Managed poorly	○
		Sludge	Sewage sludge	Digested sewage sludge [4]			○
				Other sewage sludge			○
			Waterworks sludge				○
			Organic sludge from manufacturing industries				○
			Livestock waste [5]				○
	–					c. Active-aeration	NO
5.A.2. (7.2.2)	–				Unmanaged disposal sites		NO
5.A.3. (7.2.3)	Industrial waste	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 industrial waste 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
CH_4	5.A.1. Managed waste disposal saites	a. Anaerobic landfill	MSW	kt-CH_4	220.9	184.5	136.8	98.6	66.1	51.9	48.1	44.1	40.4	37.4	34.5	31.8	29.2	26.9	24.5
			IW	kt-CH_4	152.9	139.2	107.7	70.6	40.7	30.5	27.4	25.0	22.9	21.0	19.4	17.9	16.6	15.5	14.7
		b. Semi-aerobic landfill	MSW	kt-CH_4	17.7	25.9	28.7	30.6	24.9	21.7	20.3	19.4	18.0	17.0	15.9	14.9	13.9	12.8	11.9
			IW	kt-CH_4	4.6	8.2	12.2	13.7	10.6	9.9	9.3	8.7	8.2	7.8	7.5	7.3	7.3	7.2	7.0
		c. Active-aeration		kt-CH_4	NO	NO	NO	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	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	0.4	0.4	0.4	0.4	0.4	0.3
	Total			kt-CH_4	396.2	358.0	286.0	214.0	142.7	114.5	105.6	97.6	89.9	83.7	77.6	72.3	67.3	62.8	58.5
				kt-CO_2 eq.	11,092	10,024	8,007	5,992	3,996	3,205	2,956	2,734	2,519	2,344	2,173	2,025	1,885	1,757	1,637

Estimated GHG emissions from solid waste disposal on land are shown in Table 7-4. In FY2022, GHG emissions from this source category are 1,637 kt-CO_2 eq. and accounted for 0.1% of the national total emissions (excluding LULUCF). Emissions from this category decreased by 85.2% 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 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 Disposal Sites (5.A.1.)

a) Category Description

In Japan, part of food waste, paper/cardboard, textiles, wood, and sludge in municipal solid waste (MSW) and industrial waste (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 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 (dry basis) that is damped into a landfill site j without incineration [kg-CH_4/t]
$A_{i,j}$	: Amount of a biodegradable waste i (dry basis) that is dumped into a landfill site j without incineration and is biodegraded within an inventory year) [t]
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 below.

Table 7-5 Carbon content of waste disposed of in managed landfill sites (dry basis)

Item		Carbon Content	Reference
Municipal solid waste	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 carbon contents of MSW obtained from actual measurements 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 %	Substituted the value for "Other sewage sludge"
	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 substituted for tsunami sediment by expert judgment
Industrial waste	Food waste	43.4 %	Substituted the carbon content of MSW for that of IW 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 researches (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 substituted 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 %	Substituted the value for "Other sewage sludge"

➢ ***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
Municipal solid waste	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	
Industrial waste	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)]
Municipal solid waste	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
Industrial waste	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 MSW 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: dry basis) [t (dry)]
$W_{i,j}(T)$: Amount of waste i remaining in site j in year T (dry basis) [t (dry)]
$w_{i,j}(T)$: Amount of waste i landfilled into site j in year T (dry basis) [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 (wet basis) [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 site 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 these inappropriate management conditions of the leachate collection system at landfill sites, a country-specific parameter is defined as "percentage of open outflow port of leachate collection system" and used for the estimation of activity data of "Managed well – semi-aerobic landfill sites" and "Managed poorly – semi-aerobic landfill sites" for municipal solid waste disposal sites and industrial waste 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: dry basis) [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: dry basis) [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: dry basis) [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 municipal solid waste: t, for industrial waste: m^3]
W : Disposal amount in a reporting year at whole semi-aerobic landfill sites [for municipal solid waste: t, for industrial waste: 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
MSW																
Food waste	kt (dry)	424	272	196	78	30	21	18	16	13	13	13	10	9	7	7
Paper/ cardboad	kt (dry)	1,140	859	698	492	311	226	182	142	125	97	102	63	58	54	55
Textiles (natural fiber)	kt (dry)	59	46	34	67	3	3	3	3	2	1	1	1	1	1	1
Wood	kt (dry)	363	200	155	81	40	65	27	22	21	18	19	13	10	9	9
Human waste treatment/ *Johkasou* sludge	kt (dry)	78	51	46	47	20	10	8	7	8	9	12	12	11	13	12
Ttsunami sediment[1)]	kt (dry)	NO	NO	NO	NO	NO	29	NO	NO	NO	NO	NO	NO	NO	NO	NO
IW																
Food waste	kt (dry)	65	177	109	45	22	11	15	12	13	14	14	18	18	14	14
Paper/ cardboad	kt (dry)	102	125	137	89	31	16	17	12	15	11	29	24	28	28	27
Textiles (natural fiber)	kt (dry)	4	16	15	17	7	6	10	11	11	9	7	10	10	11	11
Wood	kt (dry)	465	490	235	230	145	111	116	124	110	129	129	126	125	100	97
Digested sewage sludge	kt (dry)	59	50	31	11	3	4	5	3	3	3	4	3	4	3	3
Other sewage sludge	kt (dry)	219	185	114	42	17	11	12	12	12	10	10	7	5	7	6
Waterworks sludge	kt (dry)	199	166	146	66	67	67	67	67	67	67	67	67	67	67	67
Organic sludge from manufacturing industry	kt (dry)	339	156	69	48	31	17	14	13	10	12	12	11	11	13	13
Livestock waste	kt (dry)	12	12	11	11	11	12	13	13	13	12	13	13	13	13	13

Note:
1) 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
Municipal solid waste	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, - Substituted FY1980 value 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)	Substituted FY1978 value 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
Industrial waste	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 industrial waste are considered to consist of natural fiber due to the Waste Management and Public Cleansing Act	- Estimated by interpolation for some fiscal years, - Substituted FY1980 value 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 - Substituted FY1985 value 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	Substituted FY1980 value 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	Substituted FY1989 value 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 on the Environment* (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) - Substituted FY1990 value for the years prior to FY1990
		Food manufacturing industry			
	Livestock waste		Survey conducted by MOE	–	Substituted FY1980 value 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
Municipal solid waste	Food waste		Untreated	75%	Water percentage of food waste in the *Cyclical Use of Waste Report* (MOE)
			Treated	30%	Specified by considering material flow
	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%	Substituted the value for wood by expert judgment
Industrial solid waste	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 MSW Landfill Sites by Site Structure Type***

Among the Japan's MSW 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 actual 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 actual 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 actual 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
MSW																
Anaerobic landfill	%	74.2	64.2	54.4	43.5	36.1	39.9	28.4	28.8	29.1	35.4	30.6	31.8	30.0	28.1	28.1
Semi-aerobic landfill	%	25.8	35.8	45.6	56.5	63.9	60.1	71.6	71.2	70.9	64.6	69.4	68.2	70.0	71.9	71.9
IW																
Anaerobic landfill	%	90.2	81.1	66.4	48.3	47.0	30.0	35.0	37.7	33.4	30.4	25.3	24.1	27.2	29.1	31.8
Semi-aerobic landfill	%	9.8	18.9	33.6	51.7	53.0	70.0	65.0	62.3	66.6	69.6	74.7	75.9	72.8	70.9	68.2

- ***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 actual measurements at the Central Breakwater Landfill Site in metropolitan Tokyo, the largest managed landfill for MSW in Japan at the time, Ito (1992) obtained a set of half-lives. Assuming this research was on a representative managed 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 have 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 municipal solid waste, 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 industrial waste, 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 municipal solid waste and industrial waste

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Municipal solid waste	%	64.7	64.7	64.7	64.7	69.1	69.7	71.9	70.3	73.2	71.2	70.5	71.8	71.2	72.7	72.7
Industrial waste	%	84.3	84.3	84.3	84.3	88.2	85.6	85.6	85.6	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 making it possible to set a delay time specific to Japan, the default value (6 months) given in the *2006 IPCC Guidelines* is used.

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	2014	2015	2016	2017	2018	2019	2020	2021	2022
a. Anaerobic landfill	Mumicipal solid waste	Food waste	kt (dry)	358	278	172	99	44	27	23	19	16	14	12	10	9	7	6
		Paper/cardboard	kt (dry)	1,042	913	724	545	393	319	297	274	252	232	213	196	179	164	150
		Textiles (natural fiber)	kt (dry)	54	48	38	31	23	18	16	15	13	12	11	10	9	8	7
		Wood	kt (dry)	186	186	179	167	155	147	144	142	139	137	134	132	129	127	124
		Human waste treatment/ *Johkasou* sludge	kt (dry)	96	66	44	29	17	12	11	10	8	7	7	6	6	5	5
		Ttsunami sediment	kt (dry)	NO	NO	NO	NO	NO	0.4	1	1	1	1	1	1	1	1	1
	Industrial waste	Food waste	kt (dry)	69	102	117	74	32	21	17	15	12	11	9	8	7	7	6
		Paper/cardboard	kt (dry)	137	138	121	99	74	58	53	49	44	41	37	34	32	29	27
		Textiles (natural fiber)	kt (dry)	22	16	15	12	10	8	7	7	7	6	6	6	5	5	5
		Wood	kt (dry)	224	261	258	247	232	221	218	214	211	208	205	201	198	195	192
		Digested sewage sludge	kt (dry)	59	52	38	22	10	7	6	5	4	4	3	3	3	2	2
		Other sewage sludge	kt (dry)	221	196	144	83	39	26	22	19	17	15	13	11	9	8	7
		Waterworks sludge	kt (dry)	180	165	127	85	51	40	36	34	33	31	29	27	25	24	23
		Organic sludge from manufacturing industry	kt (dry)	336	260	153	87	43	30	25	22	19	16	14	12	11	9	8
		Livestock waste	kt (dry)	11	11	9	7	6	5	5	5	5	5	4	4	4	4	4
b. Semiaerobic landfill (Managed well)	Mumicipal solid waste	Food waste	kt (dry)	45	61	58	53	31	21	19	17	16	13	12	11	10	9	8
		Paper/cardboard	kt (dry)	77	124	150	170	171	161	160	150	149	137	127	122	112	107	99
		Textiles (natural fiber)	kt (dry)	4	7	8	11	11	9	8	8	7	6	6	5	5	5	4
		Woods	kt (dry)	6	10	14	16	18	18	19	19	19	18	18	18	18	18	18
		Human waste treatment/ *Johkasou* sludge	kt (dry)	9	12	13	14	12	10	9	8	8	7	6	6	6	6	6
		Ttsunami sediment [2)]	kt (dry)	NO	NO	NO	NO	NO	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	Industrial waste	Food waste	kt (dry)	4	13	30	33	20	17	15	13	12	11	11	10	11	11	10
		Paper/cardboard	kt (dry)	5	10	17	26	31	27	25	24	22	21	19	19	19	19	19
		Textiles (natural fiber)	kt (dry)	1	1	2	3	4	4	4	4	4	5	5	5	5	5	5
		Wood	kt (dry)	5	12	17	23	30	31	32	33	33	34	35	36	36	37	38
		Digested sewage sludge	kt (dry)	3	5	7	7	5	4	3	3	3	3	3	3	3	3	2
		Other sewage sludge	kt (dry)	11	19	27	27	18	16	14	13	12	11	10	9	9	8	7
		Waterworks sludge	kt (dry)	10	17	25	30	32	34	35	35	35	36	37	38	39	39	40
		Organic sludge from manufacturing industry	kt (dry)	17	24	24	26	20	18	17	15	14	13	12	11	10	10	9
		Livestock waste	kt (dry)	1	1	2	3	5	5	5	6	6	6	6	7	7	7	7
b. Semiaerobic landfill (Managed poorly)	Mumicipal solid waste	Food waste	kt (dry)	25	33	32	29	14	9	8	7	6	5	5	4	4	3	3
		Paper/cardboard	kt (dry)	42	68	82	93	77	70	62	63	54	55	53	48	45	40	37
		Textiles (natural fiber)	kt (dry)	2	4	4	6	5	4	3	3	3	3	2	2	2	2	2
		Woods	kt (dry)	3	6	7	9	8	8	7	8	7	7	8	7	7	7	7
		Human waste treatment/ *Johkasou* sludge	kt (dry)	5	6	7	8	5	4	4	3	3	3	3	2	3	2	2
		Ttsunami sediment [2)]	kt (dry)	NO	NO	NO	NO	NO	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	Industrial waste	Food waste	kt (dry)	1	2	6	6	3	3	2	2	2	2	2	2	2	2	2
		Paper/cardboard	kt (dry)	1	2	3	5	4	4	4	4	4	3	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	1	1	1
		Wood	kt (dry)	1	2	3	4	4	5	5	5	6	6	6	6	6	6	6
		Digested sewage sludge	kt (dry)	1	1	1	1	1	1	1	1	1	0.5	0.5	0.4	0.4	0.4	0.4
		Other sewage sludge	kt (dry)	2	4	5	5	2	3	2	2	2	2	2	2	1	1	1
		Waterworks sludge	kt (dry)	2	3	5	6	4	6	6	6	6	6	6	6	7	7	7
		Organic sludge from manufacturing industry	kt (dry)	3	4	4	5	3	3	3	3	2	2	2	2	2	2	2
		Livestock waste	kt (dry)	0.1	0.2	0.4	1	1	1	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 MSW for the purpose of electric power generation implemented at the Tokyo Metropolitan Inner Landfill Site for the Central Breakwater Landfill Site is the sole practice example 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 landfill sites in Japan

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Amount of landfill gas use	km^3 N	1,985	2,375	2,372	140	1,266	1,734	1,612	1,565	1,488	NO	NO	NO	NO	32	508
CH_4 ratio	%	53.3	42.2	40.0	48.5	43.8	44.9	41.0	39.2	40.2	NA	NA	NA	NA	68.8	69.7
Amount of CH_4 use	km^3 N	1,059	1,003	949	68	555	779	661	613	598	NO	NO	NO	NO	22	354
CH_4 unit conversion	Gg-CH_4	0.76	0.72	0.68	0.05	0.40	0.56	0.47	0.44	0.43	NO	NO	NO	NO	0.02	0.25

Note: The trend of landfill gas use significantly depends on the operation of the only power plant at the Central Breakwater Landfill Site.

- ***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 MSW 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) Uncertainties and Time-series Consistency

- ***Uncertainties***

The uncertainties in emission factors for municipal solid waste and industrial waste on the category 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 obtained from actual measurement, or by expert judgment.

Regarding the uncertainty for activity data for this sector, due to the lack of information on statistical error 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 on the category "managed disposal sites (5.A.1.)"

Item		GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
			(-)	(+)	(-)	(+)	(-)	(+)			
Municipal waste	Food waste	CH_4	-47%	+47%	-10%	+10%	-48%	+48%	The uncertainties in emission factors are evaluated by combining the 95% confidence interval of actual measurement data of carbon content, the uncertainty in fraction of degradable organic carbon dissimilated and proportion of methane in generated gas based on expert judgment, and the uncertainty in default value of MCF and oxidation factor provided by the *2006 IPCC Guidelines*, by using the formula for propagation of errors. (Method 1)	The uncertainty in municipal waste statistics based on expert judgment is applied.	Combined by using the formula for propagation of errors.
	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 in emission factor for wood is substituted, since the substance of tsunami sediment for estimation is assumed to be wood.		
Industrial waste	Food waste	CH_4	-47%	+47%	-30%	+30%	-56%	+56%	The uncertainty is evaluated by using method 1.	The uncertainty in industrial waste statistics based on expert judgment is applied.	Combined by using the formula for propagation of errors.
	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 in emission factor is evaluated by using method 1. The uncertainty of carbon content in the method is evaluated based on expert judgment.	The uncertainty in sewage statistics based on expert judgment is applied.	
	Waterworks sludge	CH_4	-51%	+51%	-5%	+10%	-51%	+52%	The uncertainty is evaluated by using method 1.	The uncertainty in the waterworks statistics based on expert judgment is applied.	
	Organic sludge from manufacturing industries	CH_4	-58%	+58%	-30%	+30%	-65%	+65%	The uncertainty in emission factor is evaluated by using method 1. The uncertainty of carbon content in the method is evaluated by expert judgment.	The uncertainty in industrial waste statistics based on expert judgment is applied.	
	Livestock waste	CH_4	-51%	+51%	-30%	+30%	-59%	+59%	The uncertainty in emission factors is evaluated 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 evaluated based on expert judgment.	The uncertainty in municipal waste statistics based on expert judgment is applied.	Combined by using the formula for propagation of errors.

- ***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

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

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 comparing to the one of appropriate waste disposal. Although these inappropriate disposal lands or areas generally satisfy the conditions of managed 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 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 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Wood	kt (dry)	48.8	51.9	144.9	21.1	19.0	5.1	4.8	26.1	6.9	6.7	4.9	2.8	5.3	6.2	3.5

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 industrial waste wood disposed of in managed 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 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Wood	kt (dry)	2.6	5.8	16.6	17.4	16.1	15.3	14.4	14.1	14.2	13.9	13.7	13.5	13.3	12.2	10.0

- ***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 by 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) Uncertainties and Time-series Consistency

- ***Uncertainties***

The uncertainties in emission factor and activity data are evaluated by using the same methods that are used for "Managed Disposal Sites (5.A.1.)". Details of the uncertainty assessment on this category are shown in the Table 7-20.

Table 7-20 Uncertainty assessment on the category "inappropriate disposal sites (5.A.3.-)"

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Inappropriately disposed waste	CH_4	-42%	+41%	-60%	+60%	-74%	+73%	The uncertainty in emission factor for wood is substituted, since the source for estimation is assumed to be wood.	The twofold higher uncertainty than the value in industrial waste statistics is applied based on expert judgment.	Combined by using the formula for propagation of errors.

- ***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

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

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. (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. (7.3.2)	–		Anaerobic digestion	NE	NO

Estimated GHG emissions from this category are shown in Table 7-22. I n FY2022, emissions from this source category are 312 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 41.1% 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 are 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
CH_4	5.B.1. Composting	Municipal solid waste	kt-CH_4	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.1	0.1	0.1
		Human waste/ *Jokasou* sludge	kt-CH_4	NO	NO	NO	0.004	0.02	0.02	0.02	0.03	0.03	0.02	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	3.8	3.9	3.9	3.4	3.4	3.1	2.8	2.9	2.9
	5.B.2. Anaerobic digestion at biogas facilities		kt-CH_4	NE	NE	NE	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	4.0	4.1	4.1	3.6	3.6	3.3	3.0	3.1	3.1
			kt-CO_2 eq.	60	60	61	107	104	112	112	114	115	100	100	92	83	86	86
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	0.04	0.04	0.04	0.04	0.03	0.03	0.03
		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	0.01	0.01	0.01	0.01
		Industrial waste	kt-N_2O	0.59	0.59	0.59	1.05	1.00	1.09	1.08	1.10	1.11	0.96	0.95	0.88	0.79	0.82	0.82
	5.B.2. Anaerobic digestion at biogas facilities		kt-N_2O	NO	NO	NO	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	1.12	1.14	1.15	1.00	0.99	0.92	0.83	0.85	0.85
			kt-CO_2 eq.	161	159	161	284	275	298	296	302	305	265	263	244	220	226	226
Total			kt-CO_2 eq.	221	219	222	391	379	410	408	416	421	366	362	336	303	312	312

7.3.1. Composting (5.B.1)

a) Category Description

Part of the MSW and industrial waste 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 “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 (wet basis) [kg-CH_4/t], [kg-N_2O/t]

A_i : Amount of composted organic waste i (wet basis) [t]

- ***Emission Factor***

Country-specific emission factors obtained from actual measurements at 9 facilities in summer and winter 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]	N_2O emission factor [kg-N_2O/t]	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 actual measurement was 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 of 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 actual measurement, 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 industrial waste in the Waste Management and Public Cleansing Act, it is included in industrial waste 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
MSW	Food waste	kt (wet)	35	20	29	66	117	121	115	122	134	141	133	131	122	110	104
	Paper/cardboard	kt (wet)	28	16	23	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Textiles	kt (wet)	3	2	2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Wood	kt (wet)	8	5	4	33	48	45	60	60	85	84	83	75	73	74	70
	Total	kt (wet)	74	42	58	99	165	166	175	182	219	225	216	206	195	184	174
Human waste/*Johkasou* sludge		kt (wet)	NO	NO	NO	4	17	19	25	35	30	21	21	23	22	23	23
IW	Food waste	kt (wet)	2,063	2,063	2,063	3,747	3,564	3,883	3,861	3,923	3,973	3,439	3,417	3,164	2,849	2,950	2,933
	Sewage sludge	kt (wet)	118	126	135	147	144	136	139	140	129	105	103	84	77	77	104
	Total	kt (wet)	2,180	2,189	2,198	3,894	3,708	4,019	4,000	4,063	4,102	3,543	3,520	3,249	2,925	3,027	3,036

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

The uncertainties in emission factors are evaluated according to the survey for EFs (MOE, 2018a). As for the uncertainty in 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 on this category are indicated in the Table 7-26.

Table 7-26 Uncertainty assessment on the category "composting (5.B.1.)"

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Composting	CH_4	-79%	+79%	-30%	+30%	-84%	+84%	The uncertainty is evaluated according to the survey for the EFs (MOE, 2018a)	The uncertainty in valuables based on expert judgment is applied since AD mostly consists of valuables.	Combined by using the formula for propagation of errors.
	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

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

By updating the statistical data, CH_4 and N_2O emissions in FY2021 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 municipal waste, and biogas facilities for industrial waste 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 views 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 "7.5.1.1. Sewage Treatment Plant (5.D.1.-)".

- ***Biogas Facilities for Municipal Waste***

MOE (2008) states that fermentation equipment at biogas facilities for municipal waste 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 industrial waste are not controlled by the guidelines such as for these for municipal waste, operators ought to keep airtight at the facilities in their installations as a safety measure.

- ***Emission Estimates***

Biogas facilities in Japan for municipal waste and industrial waste 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 "7.4.1. Waste Incineration (without Energy Recovery) (5.C.1.)" and "7.4.2. Open Burning of Waste (5.C.2.)" are reported under this category.

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 (7.4.1)	Municipal solid waste (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; Gasification melting furnace	○	○[2]	○[2]
			Biomass-based plastics	5.C.1.a.i. Municipal solid waste		NA[1]		
		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	Fossil-fuel derived fraction	5.C.1.b.i. Municipal solid waste		○		
			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 (7.4.1.2)	Waste oil	Fossil-fuel derived oil	5.C.1.b.ii.5. Fossil liquid waste	Incinerator	○	○	○
			Animal and vegetable 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]
		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	-		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]	○	○
			Other than sewage sludge	5.C.1.a.ii.5. Other (Sludge)	Incinerator	NA[1]	○	○
	Specially-controlled industrial waste (7.4.1.3)	Hazardous waste (Waste oil)	Flammable waste oil	5.C.1.b.ii.2. Hazardous waste		○	○	○
			Specified hazardous industrial waste oil	5.C.1.b.ii.2. Hazardous waste		○	○	○
		Infectious waste	Plastics (Fossil-fuel derived)	5.C.1.b.ii.3. Clinical waste		○	○	○
			Other (except plastics)	5.C.1.a.ii.3. Clinical waste		NA[1]	○	○
5.C.2 (7.4.2)	Municipal solid waste (7.4.2.1)			-	Open burning	NO	NO	NO
	Industrial waste (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[6]	IE[6]

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 municipal solid waste 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) 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.)".

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 (Category 1) as "7.4.3. Waste Incineration and Energy Use (Reported on Energy Sector) (1.A.)". For details of reporting category on 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.

Table 7-28 Waste types whose emissions are estimated for waste incineration and energy use (reported on energy sector) (1.A.)

Category	Waste type			Fuel type on energy sector	Treatment type		CO_2	CH_4	N_2O
1.A.4. (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]		
		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	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 oil	Other fossil fuels		Incinerator	○	○	○
			Animal and vegetable oil	Biomass			NA[1]	○	○
		Plastics	Fossil-fuel derived plastics	Other fossil fuels			○	○	○
			Biomass-based plastics	Biomass[8]			NA[1]	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	–			IE[5]	IE[5]	IE[5]
			Natural fiber	Biomass			NA[1]	○	○
		Sludge	Sewage sludge	–			NO	NO	NO
			Other than sewage sludge	Biomass			NA[1]	○	○
	Specially-controlled industrial waste			–			IE[5]	IE[5]	IE[5]
1.A.1./ 1.A.2./ 1.A.4. (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		–			NO	NO	NO
	IW	Waste oil	Fossil-fuel derived oil	Other fossil fuels			○	○	○
			Animal and vegetable oil	Biomass			NA[1]	○	○
		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. (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 CRT tables.
2) CH_4 and N_2O emissions from incineration of municipal solid waste in bulk are estimated by each incineration type and reported as “Other fossil fuels” in the CRT tables.
3) Included in fossil-fuel derived plastics in ISW
4) Included in biogenic fraction of paper/cardboard
5) Included in “Specially-controlled industrial waste” 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 are 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 on the energy sector) (1.A.)

Treatment type	Waste type		Application breakdown	Major application	Reporting category on 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	○	○	○
	Industrial waste					○	○	○
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]
	Industrial waste	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	Refuse-derived fuel (RDF)		(Unclassified)	Fuel use (including power generation)	1.A.2.g. Other [1]	○	○	○
	Refuse Paper and Plastic fuel (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 tables. For detail, see Table 7-28 .
3) Blast furnace gas generated from 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 coke oven is normally at least 1,000 degree 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.

Estimated GHG emissions from waste incineration (category 5.C.) are shown in Table 7-30. In FY2022, emissions from waste incineration are 11,422 kt-CO_2 eq. and accounted for 1.0% of the national total emissions (excluding LULUCF). The emissions from this source category decreased by 16.2% 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 is now allocated to the energy sector, CO_2 emission estimates from the waste sector decreased. The trend in the IEFs of CO_2 for this category is basically stable and range from

2.59 to 2.70 [t-CO_2/t-waste (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.

Table 7-30 GHG emissions from waste incineration and open burning (5.C.)

Gas	Category			Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
CO_2	5.C.1. Waste incineration	Munisipal solid waste	Plastics[1)]	kt-CO_2	3,981	3,973	4,067	2,385	1,636	2,122	1,751	1,927	1,282	1,267	1,550	1,608	1,684	1,815	1,793
			PET bottles[1)]	kt-CO_2	289	289	366	202	131	161	178	184	118	116	178	192	194	171	162
			Paper/cardboard[1)]	kt-CO_2	590	610	588	488	426	451	420	436	287	253	320	311	336	341	336
			Nappies[1)]	kt-CO_2	153	180	162	171	195	211	206	224	153	145	185	181	189	194	196
			Synthetic textiles[1)]	kt-CO_2	540	568	440	446	591	451	410	521	319	307	331	350	351	379	371
		Industrial waste	Waste oil[1)]	kt-CO_2	3,670	4,366	4,799	4,270	4,128	3,652	3,990	3,324	3,856	3,699	3,740	3,400	3,224	3,353	2,866
			Plastics[1)]	kt-CO_2	2,131	4,539	4,380	4,332	3,785	3,942	3,391	3,770	3,708	3,884	3,960	3,755	2,994	3,276	3,178
			Paper/cardboard[1)]	kt-CO_2	41	86	87	39	34	17	14	12	12	13	12	1	2	2	2
		Specially-controlled industrial waste	Flammable waste oil[1)]	kt-CO_2	698	1,036	1,526	1,402	1,143	796	782	692	816	652	772	930	912	771	818
			Specified hazardous industrial waste oil[1)]	kt-CO_2	19	28	41	38	42	55	124	149	131	95	101	102	77	78	78
			Infectious waste (plastics)[1)]	kt-CO_2	199	328	428	435	395	341	452	426	411	395	480	531	467	449	426
	5.C.2. Open burning (Industrial waste plastics)[1)]			kt-CO_2	6.3	6.3	1.7	0.4	0.2	0.1	0.1	0.0	0.1	0.1	0.2	0.1	0.1	0.0	0.0
	Total			kt-CO_2	12,319	16,010	16,884	14,209	12,506	12,200	11,719	11,666	11,095	10,827	11,629	11,361	10,431	10,829	10,226
CH_4	5.C.1. Waste incineration	Munisipal solid waste[2)]		kt-CH_4	0.5	0.4	0.4	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Industrial waste	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	0.0	0.0	0.0
			Plastics[2)]	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	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	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	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	0.3	0.3	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	0.0	0.0	0.0
			Sludge (sewage sludge/ other)[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	0.0	0.0	0.0
		Specially-controlled industrial waste	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	0.0	0.0	0.0
			Specified hazardous industrial 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	0.0	0.0	0.0
			Infectious waste (plastics)[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	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	0.0	0.0	0.0
	5.C.2. Open burning (Industrial waste)[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	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	0.4	0.4	0.4	0.4	0.4	0.3	0.3
				kt-CO_2 eq.	31	33	23	20	13	13	12	11	10	11	12	11	10	9	9
N_2O	5.C.1. Waste incineration	Munisipal solid waste[2)]		kt-N_2O	1.03	1.05	0.98	0.52	0.46	0.47	0.43	0.47	0.30	0.28	0.34	0.34	0.34	0.34	0.33
		Industrial waste	Waste oil[2)]	kt-N_2O	0.02	0.02	0.02	0.10	0.09	0.08	0.09	0.08	0.09	0.08	0.09	0.08	0.07	0.08	0.07
			Plastics[2)]	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	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	0.02	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	0.01	0.01	0.01	0.01	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	0.08	0.07	0.09	0.09	0.08	0.07	0.07	0.06
			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	0.00	0.00	0.00
			Sewage sludge[3)]	kt-N_2O	2.68	3.66	4.16	5.49	4.69	4.95	4.37	4.37	3.89	4.28	4.32	4.45	4.18	4.04	3.80
			Other sludge[3)]	kt-N_2O	0.89	0.92	0.94	0.22	0.19	0.18	0.17	0.16	0.16	0.18	0.17	0.17	0.15	0.15	0.15
		Specially-controlled industrial waste	Flammable waste oil[1)]	kt-N_2O	0.00	0.00	0.01	0.03	0.02	0.02	0.02	0.01	0.02	0.01	0.02	0.02	0.02	0.02	0.02
			Specified hazardous industrial waste oil[1)]	kt-N_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00
			Infectious waste (plastics)[1)]	kt-N_2O	0.01	0.02	0.03	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	0.01	0.01	0.01
	5.C.2. Open burning (Industrial waste)[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	0.00	0.00	0.00
	Total			kt-N_2O	4.86	6.12	6.54	6.60	5.62	5.86	5.22	5.23	4.60	4.98	5.09	5.19	4.89	4.74	4.48
				kt-CO_2 eq.	1,287	1,621	1,733	1,749	1,489	1,553	1,384	1,386	1,219	1,320	1,348	1,376	1,296	1,255	1,187
Total				kt-CO_2 eq.	13,637	17,664	18,640	15,977	14,008	13,766	13,115	13,063	12,324	12,158	12,989	12,748	11,737	12,094	11,422

Note:
1) Include fossil-fuel derived component only.
2) Include both fossil-fuel derived component and biogenic component.
3) Include biogenic 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 "Biogenic (5.C.a)" in Table 5.C of the CRT.

For reference, the GHG emissions from waste incineration for energy purpose and with energy recovery are shown in Table 7-31. In FY2022, the emissions from waste incineration including these sources are 30,581 kt-CO_2, and it accounts for 2.7% of Japan's total GHG emissions (excluding LULUCF). The emissions from this source's category had increased by 23.6% compared to those in FY1990.

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	2014	2015	2016	2017	2018	2019	2020	2021	2022
CO_2	5.C. Waste Incineration and open burning (without energy recovery)[1]				kt-CO_2	12,319	16,010	16,884	14,209	12,506	12,200	11,719	11,666	11,095	10,827	11,629	11,361	10,431	10,829	10,226
	1.A. Fuel combustion	Waste Incineration with Energy Recovery	MSW	Plastics[1]	kt-CO_2	4,625	4,982	6,376	5,151	3,309	4,202	3,685	3,575	4,196	4,565	4,148	4,501	4,412	4,626	4,571
				PET bottles[1]	kt-CO_2	336	363	573	436	264	318	375	342	386	418	476	537	509	437	413
				Paper/cardboard[1]	kt-CO_2	686	765	922	1,055	861	893	885	808	939	911	857	870	880	870	857
				Nappy[1]	kt-CO_2	178	226	253	369	395	417	434	415	502	522	494	507	496	496	500
				Synthetic textiles[1]	kt-CO_2	627	713	689	964	1,196	894	862	967	1,045	1,106	887	981	920	966	945
			IW	Waste oil[1]	kt-CO_2	21	30	28	109	176	152	175	169	176	117	123	134	133	77	144
				Plastics[1]	kt-CO_2	31	66	188	307	581	607	677	898	837	830	817	983	1,042	892	793
				Paper/cardboard[1]	kt-CO_2	0.1	0.7	1.0	0.6	2.1	1.6	1.7	1.4	1.3	1.2	1.0	0.0	0.2	0.2	0.2
		Direct Use of Waste as Alternative Fuel	MSW	Plastics[1]	kt-CO_2	NO	NO	94	522	464	239	232	270	259	273	224	228	220	208	217
			IW	Waste oil[1]	kt-CO_2	3,592	4,193	4,150	5,215	4,778	4,796	4,592	5,015	4,678	4,680	5,079	5,328	4,996	5,144	4,835
				Plastics[1]	kt-CO_2	55	59	450	1,238	1,835	1,890	2,180	2,094	2,240	2,366	2,485	2,571	2,519	2,660	2,711
			Waste Tire[1]		kt-CO_2	527	845	1,044	869	1,008	958	1,014	1,037	997	1,036	1,064	973	946	940	980
		Incineration of Waste Processed as Fuel	RDF[1]		kt-CO_2	34	40	151	423	387	393	394	366	365	364	368	322	313	299	300
			RPF[1]		kt-CO_2	NO	11	46	684	1,171	1,342	1,317	1,354	1,445	1,461	1,478	1,451	1,410	1,502	1,450
	Total				kt-CO_2	23,031	28,304	31,850	31,550	28,933	29,303	28,545	28,978	29,160	29,478	30,131	30,748	29,228	29,947	28,940
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	0.4	0.4	0.4	0.4	0.4	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	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	0.0	0.0	0.0
				Plastics[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	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	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	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	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	0.0	0.0	0.0
				Sludge other than 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	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	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	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	0.2	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	5.2	5.0	4.9	5.2	5.0	5.5	5.4	5.4	5.3
			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	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	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	0.0	0.0	0.0
	Total				kt-CH_4	3.5	3.6	3.8	4.0	5.0	5.6	6.1	5.8	5.7	6.1	5.9	6.4	6.2	6.2	6.2
					kt-CO_2 eq.	97	100	106	111	141	158	171	163	160	170	167	178	174	174	173
N_2O	5.C. Waste Incineration and open burning (without energy recovery)[2]				kt-N_2O	4.86	6.12	6.54	6.60	5.62	5.86	5.22	5.23	4.60	4.98	5.09	5.19	4.89	4.74	4.48
	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	0.91	0.86	0.99	1.00	0.92	0.94	0.89	0.86	0.85
			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	0.00	0.00	0.00	0.00	0.00
				Plastics[2]	kt-N_2O	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.00
				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	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	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	0.01	0.01	0.01	0.01	0.01
				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	0.00	0.00	0.00
				Sludge other than sewage sludge[3]	kt-N_2O	0.01	0.01	0.01	0.00	0.00	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.01
		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	NO	NO	NO
			IW	Waste oil[2]	kt-N_2O	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.01	0.02	0.01
				Plastics[2]	kt-N_2O	0.03	0.02	0.03	0.02	0.05	0.04	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06
				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	0.06	0.06	0.06	0.06	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	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	0.01	0.01	0.01	0.01	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	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03
	Total				kt-N_2O	6.13	7.51	8.18	7.85	6.72	6.98	6.35	6.30	5.80	6.20	6.23	6.36	6.01	5.83	5.54
					kt-CO_2 eq.	1,624	1,990	2,167	2,080	1,781	1,850	1,682	1,670	1,537	1,643	1,651	1,685	1,593	1,544	1,468
Total					kt-CO_2 eq.	24,752	30,394	34,123	33,741	30,855	31,311	30,398	30,810	30,857	31,291	31,948	32,611	30,995	31,664	30,581

Note:
1) Include fossil-fuel derived component only.
2) Include both fossil-fuel derived component and biogenic component.
3) Include biogenic component only.

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 municipal solid waste 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 volume of waste incinerated (dry basis) and the percentage of municipal waste 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"), synthetic textiles, paper/cardboard and nappies in municipal solid waste are estimated.

$$E = \sum_i EF_i \times A_i \times (1 - R)$$

E : CO_2 Emissions from the incineration of municipal solid waste type i [kg-CO_2]
EF_i : Emission factor for the incineration of waste type i (dry basis) [kg-CO_2/t]
A_i : Volume of waste type i incinerated (dry basis) [t]
R : Percentage of municipal solid waste incinerated at facilities with energy recovery

- ***Emission Factor***

➢ ***Equation***

In accordance with the *2006 IPCC Guidelines*, the emission factor is 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 (dry basis) [kg-CO_2/t]
CF_i : Carbon content in waste type i (dry basis) [%]
FCF_i : Fossil-fuel derived fraction in carbon in waste type i [%]
OF : Oxidation factor [%]

[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.

➢ ***Carbon Content (CF)***

The carbon contents in MSW by waste type are shown in the following table.

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 each of domestic 14 cities (MOE, 2020b)
PET bottles	62.1 %	Averaged value of the data obtained from actual measurements 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 data obtained from actual measurements at domestic 14 cities (MOE, 2020b)
Nappies	56.0 %	Estimated based on an interview survey of *Japan Hygiene Products Industry Association* (MOE, 2021)

➢ ***Fossil-fuel Derived Fraction in Carbon in Waste (FCF)***

- ***Synthetic Textiles, Paper/Cardboard, Nappies***

The fossil-fuel derived fractions in carbon in synthetic textiles, paper/cardboard and nappies in MSW are shown in the following table.

Table 7-33 Fossil-fuel derived fraction in carbon in synthetic textiles, paper/cardboard and nappies in MSW (*FCF*)

Item	Fossil-fuel derived fraction in carbon	Reference
Synthetic textiles	100%	Assumed that all is fossil-fuel derived by expert judgement
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)

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, IW plastics) in FY *T* [%]

$BPW_i(T)$: Amount of biogenic fraction in plastic *i* (MSW plastics, MSW PET bottles, IW plastics) in FY *T* [t (dry)]

$PW_i(T)$: Amount of plastic *i* (MSW plastics, MSW PET bottles, IW plastics) generation in FY *T*, excluding impurities [t (dry)]

Amount of MSW plastics, MSW PET bottles and IW plastics generation in *FY T* ($PW_{msw}(T)$) are obtained from the *Cyclical Use of Wastes 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.

$$BP_i(T) = \sum_t^T \sum_j (BP_{j,t} \times DP_{j,t} \times B_j \times W_{i,j,t}(T) \times DW_i(T))$$

$BP_{j,t}$: 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, IW plastics) in FY T after use [%]

$DW_i(T)$: Fraction of plastic i (MSW plastics, MSW PET plastic, IW plastics) 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 a circumstance, 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 are 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 are 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Plastics in MSW	%	100	100	100	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	57.1	52.0	54.4	59.6	61.7	62.8	69.0	74.6	81.1
Plastics in IW	%	100	100	100	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.

Table 7-35 Fossil-fuel derived fraction in waste plastics (*FCF*)

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Plastics in MSW	%	100.0	100.0	100.0	99.6	99.3	99.3	99.1	99.1	99.0	99.1	99.1	98.8	98.5	98.4	98.4
PET bottle in MSW	%	100.0	100.0	100.0	100.0	100.0	99.8	99.8	99.8	99.7	99.7	99.7	99.7	99.6	99.5	99.4
Plastics in IW	%	100.0	100.0	100.0	100.0	99.9	99.7	99.6	99.6	99.6	99.8	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 (dry basis)

Item	Unit	Emission factor	Note
Plastics	kg-CO_2/t	2,816	In case of *FCF*=1
PET bottles	kg-CO_2/t	2,277	
Synthetic textiles	kg-CO_2/t	2,310	–
Paper/cardboard	kg-CO_2/t	144	–
Nappies	kg-CO_2/t	1,220	–

● ***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 Wastes Report*. Note the reported amounts of plastic including PET bottles potentially include biomass-based plastics. 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 (dry basis) [t (dry)]
MSW_i : Amount of plastics or PET bottles in MSW incinerated (wet basis) [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)

➢ *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 (dry basis) [t (dry)]
$MSW_{textiles}$: Amount of textiles incinerated (wet basis) [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 the 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 (dry basis) [t (dry)]
$C_{semisynthetic}$: Amount of domestic final consumption of semisynthetic textiles (dry basis) [t (dry)]
$C_{total\ fiber}$: Amount of domestic final consumption of total textiles (dry basis) [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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Fraction of synthetic textile	%	52.2	52.9	55.3	54.4	59.4	62.2	62.9	65.3	63.9	65.6	64.5	63.6	61.3	61.4	60.5

➢ *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 Wastes Report* includes nappies, for activity data, activity data of nappies incinerated are subtracted from the amount of paper/cardboard incinerated.

$$A_{paper} = MSW_{paper} \times (1 - u_{paper}) - A_{nappy}$$

A_{paper} : Activity data for incineration of paper/cardboard (MSW) incinerated (dry basis) [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 nappies incinerated (dry basis) [t (dry)]

➢ *Nappies*

Although nappies in Japan's municipal waste is generally classified into paper or textiles, the incinerated amount is not clearly distinguished from these categories.

- *Prior to FY2004*

Based on expert judgement, the amount of domestic production of nappies is applied as the activity data for nappy incinerated prior to FY2004.

The amount of domestic production of nappies is derived from the reported amount of nappies for adult and infant (dry basis) on the *JHPIA news* published by Japan Hygiene Products Industry Association.

- *FY 2005 Onward*

The amount of nappies incinerated for FY2005 onward are estimated by following equation based on MOE (2020a), as the amount of nappy consumption.

$$A_{nappy} = \sum_i WT_i \times N_i \times PN_i \times 365/10^6$$

A_{nappy} : Activity data of nappies incinerated (amount of nappy consumption: dry basis) [t (dry)]
WT_i : Weight of nappy *i* (for adult or child) per piece (dry basis) [t (dry)]
N_i : Number of nappy *i* (for adult or child) consumed per person and day [piece/person/day]
PN_i : Number of nappy *i* (for adult or child) users [person]

Properties of each parameter in the estimation are as shown in following table.

Table 7-40 Parameters in estimation of amount of nappy consumption

Item	User	Volume	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_{0-3} : Population in age from 0 to 3	

Note: MIC: Ministry of Internal Affairs and Communications, MHLW: Ministry of Health, Labour and Welfare

➢ *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 (dry basis)

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Plastics	kt (dry)	3,056	3,180	3,708	2,686	1,769	2,261	1,949	1,971	1,964	2,091	2,042	2,197	2,198	2,325	2,296
PET bottles	kt (dry)	275	286	412	280	173	211	244	232	222	236	288	321	310	268	254
Synthetic textile	kt (dry)	505	555	489	610	774	582	551	644	591	612	528	576	550	582	570
Paper/cardboad	kt (dry)	8,885	9,583	10,523	10,751	8,964	9,366	9,092	8,662	8,541	8,106	8,204	8,224	8,471	8,440	8,310
Nappy	kt (dry)	272	333	340	442	483	515	525	524	537	546	556	564	562	566	570

- ***Percentage of Municipal Waste Incinerated at Municipal Incineration Facilities for Energy Recovery***

Percentage of municipal waste 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 municipal solid waste incinerated at incineration facilities with energy recovery

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
With off-field power generation or heat utilization	%	53.7	55.6	61.1	68.4	66.9	66.4	67.8	65.0	76.6	78.3	72.8	73.7	72.4	71.8	71.8
Without off-field power generation or heat utilization	%	46.3	44.4	38.9	31.6	33.1	33.6	32.2	35.0	23.4	21.7	27.2	26.3	27.6	28.2	28.2

2) CH_4

- ***Estimation Method***

CH_4 emissions from incinerator are estimated by multiplying the amount of MSW (wet basis) by incinerator method by each emission factor. CH_4 emissions from gasification melting furnace 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 allocated to the waste sector.

$$E = \sum_i (EF_i \times A_i) \times (1 - R)$$

E : CH_4 emission from the incineration of MSW [kg-CH_4]
EF_i : Emission factor for incineration method i (or furnace type i) (wet basis) [kg-CH_4/t]
A_i : Amount of incinerated MSW by incineration method i (or furnace type i) (wet basis) [t]
R : Percentage of MSW incinerated at facilities with energy recovery

- ***Emission Factor***

➢ ***Incinerator***

In order to implement countermeasures against dioxins, 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 for incinerator 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 actual measurement survey.

In order to apply activity data based on the amount of incineration by incineration method, emission factors are established by incineration method (continuous incinerator, semi-continuous incinerator, and batch type incinerator) using the weighted average of fraction of the amount of incineration by incinerator type for each fiscal year. The Correction taking into account CH_4 concentrations in the atmosphere is not made to these emission factors.

➢ ***Gasification Melting Furnace***

Different emission factor is used for each furnace type (shaft furnace, fluidized bed, and rotary kiln) (MOE, 2010). Also, in order to apply activity data based on the total amount of incineration, emission factors are determined by taking the weighted average of the amount of incineration by gasification melting furnace type for each year.

Table 7-43 CH_4 emission factors by type of incineration method (MSW)

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Continuous incinerator	g-CH_4/t	8.2	8.2	8.3	2.6	2.7	2.7	2.7	2.7	2.7	2.7	2.6	2.6	2.6	2.5	2.5
Semi-continuous incinerator	g-CH_4/t	69.6	69.6	75.1	19.9	20.9	20.9	21.1	20.7	20.4	20.5	20.9	20.5	20.9	21.1	21.1
Batch type incinerator	g-CH_4/t	80.5	80.5	84.1	13.2	11.6	11.7	11.7	11.8	11.8	10.9	10.9	11.0	11.0	11.0	11.0
Gasification melting furnace	g-CH_4/t	NA	NA	5.6	6.9	7.0	6.9	6.9	6.9	6.9	6.9	6.9	6.9	6.8	6.9	6.9

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 for CH_4 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 incineration by incineration method of incinerator or gasification meting furnace provided by the *Waste Treatment in Japan* (MOE).

Table 7-44 Amount of incineration of MSW by incineration method (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Continuous incinerator	kt (wet)	26,215	29,716	32,749	32,246	27,603	28,246	27,360	27,364	26,961	26,883	26,877	27,266	26,344	25,998	25,645
Semi-continuous incinerator	kt (wet)	4,810	5,455	5,882	4,047	2,968	2,827	2,524	2,349	2,164	2,072	1,894	1,849	1,760	1,580	1,559
Batch type incinerator	kt (wet)	5,643	4,328	3,131	1,562	1,078	970	867	842	744	693	660	625	589	562	554
Gasification melting furnace	kt (wet)	NO	NO	370	2,397	3,605	4,098	4,161	4,328	4,423	4,599	4,739	4,889	4,875	4,902	4,835

3) N_2O

● ***Estimation Method***

N_2O emissions from incinerator are estimated by multiplying the amount of MSW (wet basis) by incinerator method by each emission factor. N_2O emissions from gasification melting furnace 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 allocated to the waste sector.

$$E = \sum_i (EF_i \times A_i) \times (1 - R)$$

E : N_2O emission from the incineration of MSW [kg-N_2O]

EF_i : Emission factor for incineration method i (or furnace type i) (wet basis) [kg-N_2O /t]

A_i : Amount of incinerated MSW by incineration method i (or furnace type i) (wet basis) [t]

R : Percentage of MSW incinerated at facilities with energy recovery

- ***Emission Factor***

➢ ***Incinerator***

Same as for CH_4 emissions estimation, for the N_2O emission factors for incinerator by type and by incineration method, different values are used for the period FY2001 and before (MOE, 2006b), and from FY2002 onward (MOE, 2010), respectively. In order to apply activity data based on the amount of incineration by incineration method, emission factors are established by incineration method (continuous incinerator, semi-continuous incinerator, and batch type incinerator) using the weighted average of fraction of the amount of incineration by incinerator type for each fiscal year calculated based on the *Waste Treatment in Japan* (MOE).

➢ ***Gasification Melting Furnace***

Different emission factor is used for each furnace type (shaft furnace, fluidized bed, and rotary kiln) (MOE, 2010). In order to apply the activity data based on the total amount of incineration, emission factors are established by taking the weighted average of the amount of incineration by gasification melting furnace type for each year calculated based on the *Waste Treatment in Japan* (MOE).

Table 7-45 N_2O emission factors by incineration types (MSW)

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Continuous incinerator	g-N_2O/t	58.8	58.8	59.1	37.9	38.0	38.0	38.1	38.1	38.1	37.9	37.8	37.9	37.9	37.7	37.7
Semi-continuous incinerator	g-N_2O/t	56.8	56.8	57.3	71.5	73.2	73.1	73.5	72.8	72.3	72.5	73.2	72.5	73.2	73.6	73.6
Batch type incinerator	g-N_2O/t	71.4	71.4	74.8	76.0	76.2	76.2	76.2	76.2	76.2	76.3	76.3	76.3	76.3	76.3	76.3
Gasification melting furnace	g-N_2O/t	NA	NA	16.9	12.0	11.5	11.7	12.0	12.2	12.5	12.1	12.4	12.3	12.7	12.7	12.7

Reference: MOE (2006b), MOE (2010), *Waste Treatment in Japan* (MOE), Ishikawa Prefecture et al. (1991-1997), JSAE (1996), Ueno et al. (1992)

- ***Activity Data***

The activity data for CH_4 emissions from incinerators and gasification melting furnaces are also applied for the activity data for N_2O emission from them.

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

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 in the actual measurement on the surveys for emissions factors. As for the uncertainties in activity data, the uncertainties in municipal solid waste data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-46 and Table 7-47.

Table 7-46 Uncertainty assessment for municipal solid waste on the category "waste incineration (5.C.1.-)" (CO_2)

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Plastics	CO_2	-1%	+1%	-10%	+10%	-10%	+10%	Quoted from MOE (2020b), a reference of emission factors.	The uncertainty in municipal waste statistics based on expert judgment is applied.	Combined by using the formula for propagation of errors.
PET bottles	CO_2	-0.4%	+0.4%	-10%	+10%	-10%	+10%	Quoted from MOE (2020b), a reference of emission factors.		
Synthetic textiles	CO_2	-2%	+2%	-10%	+10%	-10%	+10%	It is evaluated at the 95% confidence interval in actual measurement data of carbon content in synthetic textiles.		
Paper/ cardboard	CO_2	-13%	+13%	-10%	+10%	-16%	+16%	It is evaluated by combining the 95% confidence interval in actual measurement data of carbon content with that of fossil-derived carbon.		
Nappies	CO_2	-13%	+13%	-10%	+10%	-16%	+16%	Due to lack of information for the uncertainty of the emission factor, the uncertainty of Paper/ cardboard is substituted based on expert judgment.		

Table 7-47 Uncertainty assessment for municipal solid waste on the category "waste incineration (5.C.1.-)" (CH_4 and N_2O)

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Continuous incineration /Stoker furnace	CH_4	-39%	+39%	-10%	+10%	-40%	+40%	The uncertainty is quoted from MOE (2010), a reference of emission factors.	The uncertainty based on expert judgment in municipal waste statistics is applied.	Combined by using the formula for propagation of errors.
	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

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

By revising biomass-based plastic products data, CO_2 emissions from FY2005 onward were recalculated. By updating the statistical data, CO_2 emissions from FY2019 onwards and CH_4 and N_2O emissions in FY2021 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 industrial waste 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 volume of fossil-fuel derived waste oil, plastics, and paper/cardboard incinerated, Japan's country-specific emission factors, and the percentage of incinerated industrial waste with energy recovery at industrial waste incineration facilities in accordance. Note that since it is difficult to estimate percentages of water content in waste oil and plastic in industrial waste, the emission factors for these sources are identified as wet basis. Also, since industrial textiles does not include synthetic textiles under the regulation of the Waste Management and Public Cleansing Act, the industrial textiles is 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.

$$E_i = EF_i \times A_i \times (1 - R_i)$$

E_i : CO_2 Emissions from incineration of waste type i [kg-CO_2]
EF_i : Emission factor for incineration of waste type i [kg-CO_2/t]
(wet basis for waste oil and plastic; dry basis for paper/cardboard)
A_i : Amount of incinerated waste type i [t]
(wet basis for waste oil and plastic; dry basis for paper/cardboard)
R_i : Percentage of industrial waste 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.

$$EF_i = CF_i \times FCF_i \times OF \times 44/12$$

EF_i : Emission factor for industrial waste *i* [kg-CO_2/t]
CF_i : Carbon content in industrial waste *i* [%]
FCF_i : Fossil-fuel derived fraction in industrial waste *i* [%]
OF : Oxidation factor [%]

➢ ***Carbon Content (CF)***

Carbon contents in industrial waste are shown the table below.

Table 7-48 Carbon contents of industrial waste (*CF*)

Item	Carbon contents	Note	References
Fossil-fuel derived waste oil	80%	wet basis	Environmental Agency (1992)
Plastics	70%	wet basis	Environmental Agency (1992)
Paper/cardboard	40.8%	dry basis	Substituted the carbon content of MSW (MOE, 2020b) for that of IW because its properties are similar to those of MSW

➢ ***Fossil-Fuel Derived Fraction in Carbon in Paper/Cardboard in Industrial Waste (FCF)***

For the fossil-fuel derived fractions in carbon in industrial waste are shown following table.

Table 7-49 Fossil-fuel derived fractions in carbon in fossil-fuel derived industrial waste (*FCF*)

Item	Fossil-fuel derived fraction	Reference
Fossil-fuel derived waste oil	100%	Expert judgement
Plastics	Variable	See Table 7-35
Paper/cardboard	9.6%	Substituted the fossil-fuel derived fraction of MSW (MOE, 2020b) for that of IW because its properties are similar to those of MSW

➢ ***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 7-50.

Table 7-50 Emission factors for fossil-fuel derived fraction of waste oil, plastics and paper/cardboard in industrial waste (*EF*)

Item	Unit	Emission factor	Note
Fossil-fuel derived waste oil	kg-CO_2/t (wet)	2,933	–
Plastics	kg-CO_2/t (wet)	2,567	In case of *FCF*=1
Paper/cardboard	kg-CO_2/t (dry)	144	–

- ***Activity Data***

For the activity data for CO_2 emissions from the incineration of waste oil, plastics and paper/cardboard in industrial waste, the amount of incineration provided by the *Cyclical Use of Waste Report* (MOE) is used. Note that the statistical data for industrial waste from this report includes but does not distinguish specially-controlled industrial waste. To avoid double counting in the activity data estimation, the

amount of specially-controlled industrial waste incinerated is subtracted from the statistical data (see also the section"7.4.1.3. Specially-controlled Industrial Waste (5.C.1.-)". Details of methodologies to estimate activity data are shown below.

$$A_{oil} = IW_{oil} \times (1 - F_{bio}) - SIW_{oil}$$

A_{oil} : Activity data for the incineration of waste fossil-fuel derived oil (wet basis) [t (wet)]

IW_{oil} : Amount of waste oil incinerated in industrial waste (wet basis) [t (wet)]

SIW_{oil} : Amount of waste oil incinerated in specially-controlled industrial waste[1)] (wet basis) [t (wet)]

F_{bio} : Fraction of waste oil from animal and vegetable origin[2)] [%]

Note:
1) All the waste oil in specially-controlled industrial waste to be estimated for emissions are waste fossil-fuel derived oil.
2) From the survey conducted by the MOE

Table 7-51 Fraction of waste oil from animal and vegetable origin

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
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	6.0	6.0	6.0

$$A_{plastics} = IW_{plastics} - A_{inf.\,plastics}$$

$A_{plastics}$: Activity data for the incineration of plastics (wet basis) [t (wet)]

$IW_{plastics}$: Amount of plastics incinerated in industrial waste (wet basis) [t (wet)]

$A_{inf.\,plastics}$: Amount of infectious plastics incinerated in specially-controlled industrial waste (wet basis) [t (wet)]

Note: Fossil-fuel derived fraction of plastics in industrial waste 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.

$$A_{paper} = (IW_{paper} - A_{inf.exc.\ plastics}) \times (1 - u_{paper})$$

A_{paper} : Activity data for the incineration of paper/cardboard (dry basis) [t (dry)]

IW_{paper} : Amount of paper/cardboard incinerated in industrial waste (wet basis) [t (wet)]

$A_{inf.\,exc.\,plastics}$: Amount of infectious waste incinerated in specially-controlled industrial waste except plastics (wet basis) [t (wet)]

u_{paper} : Percentage of waste content in paper or cardboard in industrial waste [%]

Note: Of the specially-controlled industrial waste, infectious waste (except plastics) is assumed to be paper/cardboard. Percentage of water content in paper/cardboard in industrial waste is given the value 15% (see Table 7-11).

For more detail of activity data estimated, see Table 7-54.

- ***Percentage of Industrial Waste Incinerated at Industrial Incineration Facilities for Energy Recovery (by Type)***

Percentage of industrial waste 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 municipal waste 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 industrial waste 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Waste oil [1)]	%	0.6	0.7	0.6	2.5	4.1	4.0	4.2	4.8	4.4	3.1	3.2	3.8	4.0	2.2	4.8
Plastics	%	1.4	1.4	4.1	6.6	13.3	13.3	16.7	19.2	18.4	17.6	17.1	20.8	25.8	21.4	20.0
Wood [2)]	%	0.2	0.8	1.1	1.5	5.9	8.5	10.5	10.2	9.7	8.5	7.6	7.9	9.5	11.1	11.0
Sludge [3)]	%	0.9	0.8	1.0	1.1	2.2	8.3	12.5	12.2	12.0	10.6	11.5	11.2	14.5	12.0	9.0
Other [4)]	%	0.2	0.8	1.1	1.5	1.5	1.9	2.6	4.2	5.0	3.3	3.6	3.3	11.4	10.4	4.4

Note:
1) "Waste oil" includes fossil-fuel derived/animal and vegetable oil.
2) "Wood" includes paper/cardboard and wood.
3) Not applicable for "sewage sludge".
4) "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 volume of industrial waste incinerated by Japan's country specific emission factor and by percentage of industrial waste incinerated at incineration facilities with energy recovery.

$$E = \sum_j \{EF_j \times A_j \times (1 - R_j)\}$$

E : Emission of methane from the incineration of industrial waste [kg-CH_4]
EF_j : Emission factor for waste type j (wet basis) [kg-CH_4/t]
A_j : Incinerated amount of waste type j (wet basis) [t]
Rj : Percentage of industrial waste j incinerated at 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 actual measurement survey. The correction taking into account CH_4 concentrations in the atmosphere is not made to these emission factors. The emission factor for paper/cardboard or wood in MOE (2006b) and MOE (2010) is substituted for the emission factor for textiles (natural fiber), and animal and vegetable residues/animal carcasses.

Table 7-53 CH_4 emission factors for industrial waste by waste type

Item	Unit	FY1990-2001	FY2002-
Waste oil (fossil-fuel derived/animal and vegetable)	g-CH_4 /t	4.8	4.0
Plastics	g-CH_4 /t	30	8.0
Paper/cardboard	g-CH_4 /t	22	225
Wood	g-CH_4 /t	22	225
Textiles (natural fiber)	g-CH_4 /t	22	225
Animal and vegetable residues/animal carcasses	g-CH_4 /t	22	225
Sludge	g-CH_4 /t	14	1.5
Other than sewage sludge	g-CH_4 /t	14	1.5

Reference: Environmental Agency (2000), MOE (2006b), MOE (2010), Ishikawa Pref. et al. (1991-1999), JSAE (1996)

- ***Activity Data***

The volume of waste incinerated (wet basis) by waste type is used as the activity data for CH_4 emissions from the incineration of industrial waste.

➢ ***Paper/Cardboard, Wood, Textiles (natural fiber) and Animal and Plant Residues/Animal Carcasses:***

The volume 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.

➢ ***Sludge***

Activity data is taken as the aggregate of the values obtained from the "Volume of Other Incinerated Organic Sludge" section in the *Cyclical Use of Waste Report* (MOE), and the "Volume of Incinerated Sewage Sludge" reported in a survey by the Ministry of Lands, Infrastructure, Transport and Tourism (MLIT).

➢ ***Waste Oil (Fossil-fuel derived/Animal and Vegetable) 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 specially-controlled industrial waste 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 oil and animal and vegetable oil are included in waste oil for the activity data for CH_4 emission estimates. Note that activity data for plastics includes biomass-based plastics.

Table 7-54 Incinerated industrial waste by waste types (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Waste fossil-fuel derived oil	kt (wet)	1,258	1,498	1,646	1,493	1,467	1,297	1,420	1,191	1,375	1,301	1,317	1,205	1,145	1,169	1,026
Waste animal and vegetable oil	kt (wet)	40	69	103	115	121	103	115	100	113	103	107	103	97	96	88
Plastics	kt (wet)	842	1,794	1,780	1,808	1,703	1,778	1,591	1,826	1,777	1,840	1,864	1,848	1,574	1,626	1,549
Paper/cardboad	kt (wet)	335	712	718	323	292	152	130	114	109	116	103	5	18	16	15
Wood	kt (wet)	2,679	4,744	3,114	1,865	1,101	1,388	1,137	1,120	1,062	1,263	1,247	1,161	1,055	958	927
Textiles (natural fiber)	kt (wet)	31	49	50	43	24	35	39	27	36	29	21	23	30	28	27
Animal and vegetable residues/animal carcasses	kt (wet)	77	125	272	167	190	151	153	168	154	133	159	204	170	198	197
Sewage sludge	kt (wet)	3,214	3,829	4,300	5,174	5,187	5,078	5,014	5,046	4,964	5,188	5,198	5,236	5,023	4,938	4,529
Sludge other than sewage sludge	kt (wet)	1,972	2,023	2,071	2,288	2,010	1,954	2,021	1,880	1,884	2,003	1,938	1,962	1,790	1,690	1,651

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 industrial waste other than sewage sludge are estimated by multiplying the volume 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 industrial waste incinerated at the industrial waste 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 industrial waste [kg-N_2O]

EF_j : Emission factor for waste type j (wet basis) [kg-N_2O /t]

A_j : Incinerated amount of waste type j (wet basis) [t]

R_j : Percentage of industrial waste 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 volume of sewage sludge incinerated at the facilities conducted by MLIT. Since emission factors are different depending on the types of flocculants, incinerators, and furnace temperatures, they are established for each category as given in Table 7-55.

Table 7-55 N_2O emission factors for sewage sludge incineration (wet basis)

Type of flocculant	Type of incinerator	Combustion Temperature	Emission factor[1)] [g-N_2O/t]
High-molecular weight flocculant	Fluidized bed incinerator	Normal temperature combustion (around 800˚C)	1,508
	Fluidized bed incinerator[2)]	High temperature combustion (around 850˚C)	645
	Multiple hearth	–	882
Lime Sludge	–	–	294
–	- Multiple hearth air injection incineration method fluidized bed incinerator - Two-stage incineration method circulating fluidized bed incinerator - Stoker furnace	High temperature combustion (around 850˚C)	263
–	Carbonization furnace for solid fuel production	–	31.2

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. (1996), MOE (2006b), MOE (2013b), MOE (2015)
Note:
1) The same emission factors are used for all the reporting years.
2) Excludes multiple hearth air injection incineration method fluidized bed incinerator and two-stage incineration method circulating fluidized bed incinerator.

➢ ***Waste Other than Sewage Sludge***

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 actual measurement survey. The correction 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 industrial waste by type (wet basis)

Item	Unit	FY1990-2001	FY2002-
Waste oil (fossil-fuel derived/animal and vegetable)	g-N_2O /t	12	62
Plastics	g-N_2O /t	180	15
Paper/cardboard	g-N_2O /t	21	77
Wood	g-N_2O /t	21	77
Textiles (natural fiber)	g-N_2O /t	21	77
Animal and vegetable residues/animal carcasses	g-N_2O /t	21	77
Sludge (excluding sewage sludge)	g-N_2O /t	457	99

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 "volume of incinerated sewage sludge, by flocculants and by incinerator types" reported in a survey by MLIT are used as activity data (wet basis).

Table 7-57 Amount of sewage sludge incinerated (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
High-molecular-weight flocculant/ fluidized bed incinerator (nomal temp.)	kt (wet)	971	1,541	1,721	2,792	1,916	2,219	1,690	1,730	1,243	1,581	1,609	1,763	1,630	1,549	1,512
High-molecular-weight flocculant/ fluidized bed incinerator (high temp.)	kt (wet)	474	886	1,491	1,524	2,369	2,212	2,547	2,401	2,793	2,573	2,594	2,420	2,327	2,271	2,032
High-molecular-weight flocculant/multiple hearth	kt (wet)	679	611	504	109	61	40	NO	NO	NO	NO	NO	NO	NO	NO	NO
Lime sludge	kt (wet)	877	529	319	284	108	22	1	NO	NO	NO	NO	NO	NO	NO	NO
- Multiple hearth air injection/blowing incineration method fluidized bed incinerator, - Two-stage incineration method circulating fluidized bed incinerator, - Stoker furnace	kt (wet)	213	262	266	463	726	518	654	781	800	876	817	832	818	881	752
Carbonization furnace for solid fuel production	kt (wet)	NO	NO	NO	2	6	68	122	133	129	157	178	221	248	238	232

➢ ***Industrial Waste Other than Sewage Sludge***

Activity data (wet basis) is determined in the same manner as for the CH_4 emissions from industrial waste, with the exception that the "volume of other incinerated organic sludge" is used as activity data for the sludge (excluding sewage sludge).

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

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 in the actual measurement on the surveys for emissions factors. As for the uncertainties in activity data, the uncertainties in industrial waste data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-58.

Table 7-58 Uncertainty assessment for industrial waste on the category "waste incineration (5.C.1.-)"

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Waste oil	CO_2	-2%	+2%	-30%	+30%	-30%	+30%	Due to the lack of information for the uncertainty of the emission factor, twice as much as the uncertainty in municipal waste plastics is substituted based on expert judgment.	The uncertainty based on expert judgment in industrial waste statistics is applied.	Combined by using the formula for propagation of errors.
	CH_4	-100%	+181%	-30%	+30%	-104%	+184%	The uncertainty is quoted from MOE (2010), a reference of emission factors.		
	N_2O	-76%	+76%	-30%	+30%	-81%	+81%			
Plastics	CO_2	-2%	+2%	-30%	+30%	-30%	+30%	Due to the lack of information for the uncertainty of the emission factor, twice as much as the uncertainty in municipal waste plastics is substituted based on expert judgment.		Combined by using the formula for propagation of errors.
	CH_4	-100%	+216%	-30%	+30%	-104%	+218%	The uncertainties are quoted from MOE (2010), a reference of emission factors.		
	N_2O	-44%	+44%	-30%	+30%	-53%	+53%			
Paper/ cardboard	CO_2	-13%	+13%	-30%	+30%	-104%	+401%	It is evaluated by combining the 95% confidence interval in actual measurement data of carbon content with that of fossil-derived fraction in the carbon.		Combined by using the formula for propagation of errors.
Paper/ cardboard or wood	CH_4	-100%	+412%	-30%	+30%	-104%	+413%	The uncertainty is quoted from MOE (2010), a reference of emission factors.		Combined by using the formula for propagation of errors.
	N_2O	-64%	+64%	-30%	+30%	-71%	+71%			
Sludge	CH_4	-100%	+201%	-30%	+30%	-104%	+203%			Combined by using the formula for propagation of errors.
	N_2O	-84%	+84%	-30%	+30%	-89%	+89%			
Textiles (Natural fiber)	CH_4	-100%	+412%	-30%	+30%	-104%	+413%	Due to the lack of information for the uncertainty of the emission factor, the uncertainty in paper/cardboard or wood is substituted based on expert judgment.		Combined by using the formula for propagation of errors.
	N_2O	-64%	+64%	-30%	+30%	-71%	+71%			
Animal and vegetable residues/ animal carcasses	CH_4	-100%	+412%	-30%	+30%	-104%	+413%			Combined by using the formula for propagation of errors.
	N_2O	-64%	+64%	-30%	+30%	-71%	+71%			

- ***Time-series Consistency***

  Emissions are calculated in a consistent manner.

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

By re-examining the amount of sewage sludge incinerated data, CH_4 and N_2O emissions for the whole time series were recalculated. By revising biomass-based plastic products data, CO_2 emissions from

FY2010 onward were recalculated. By updating the statistical data, CO_2, CH_4 and N_2O emissions in FY2021 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 specially-controlled industrial waste 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 specially-controlled industrial waste

Waste type	Substance
Flammable waste oil	Gasoline, Kerosene, Gas oil or diesel oil
Specified hazardous industrial waste 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 plastics	Plastics
Infectious waste (except plastic)	Glasses, Textile, Paper

In this category, CO_2, CH_4, and N_2O emissions from incineration of specially-controlled industrial waste 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 specially-controlled industrial waste is not sufficiently understood, the emissions from specially-controlled industrial waste 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 industrial waste oil and infectious waste plastic contained in specially-controlled industrial waste 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 volume of waste incinerated.

- ***Emission Factor***

- ***Flammable Waste Oil***

Emission factors for waste oil in industrial waste is used for flammable waste oil in specially-controlled industrial waste, since the difference of carbon contents and oxidation factor in the two source categories is considered to be small.

- ***Specified Hazardous Industrial Waste Oil***

In accordance with the approach taken by the *2006 IPCC Guidelines,* emission factor for specified hazardous industrial waste oil is estimated as follows.

$$EF = CF \times FCF \times OF \times (1 - u) \times 44/12$$

EF : Emission factor for the incineration of specified hazardous industrial waste oil [kg-CO_2/t]
CF : Carbon content in specified hazardous industrial waste oil (dry basis) [%]
FCF : Fossil-fuel derived fraction in specified hazardous industrial waste oil [%]
OF : Oxidation factor [%]
u : Percentage of water content in specified hazardous industrial waste oil [%]

Average carbon content in specified hazardous industrial waste oil (dry basis) is estimated using weighted average of carbon content in chemical formula of substances shown in Table 7-59 for incinerated substances based on MOE (2010-2011). For the fossil-fuel derived fraction in specified hazardous industrial waste oil, the default value of 100% indicated in the *2006 IPCC Guidelines* is used. For the oxidation factor, the default value of 100% indicated in the *2006 IPCC Guidelines* is used. The percentage of water content in specified hazardous industrial waste oil is determined to be 5% by expert judgment.

- ***Infectious Plastic***

For infectious plastic, the emission factors for incineration of plastics in industrial waste are substituted since the difference in terms of carbon contents and oxidation factor in the two source categories is considered to be small.

Table 7-60 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 industrial waste oil	kg-CO_2/t (wet)	1,024
Infectious plastics	kg-CO_2/t (wet)	2,567

- ***Activity Data***

Generally, the amount of specially-controlled industrial waste incinerated obtained from the *Cyclical Use of Waste Report* (MOE) is used as the activity data in and after FY2008. As for the past activity data which the survey data is not available, output volume 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 volume of waste oil and infectious plastic waste contained in specially-controlled industrial waste is incinerated. Details are shown below.

- ***Flammable Waste Oil***

The amount of specially-controlled industrial waste oil incinerated from the *Cyclical Use of Waste Report* (MOE) is used as the activity data. Since the data includes both of incinerated amounts of flammable waste oil and specified hazardous industrial waste oil, the amounts of flammable waste oil are estimated by following equation. All the waste oil in specially-controlled industrial waste to be estimated for emissions is waste fossil-fuel derived oil.

$$A_{flam.oil} = SIW_{oil} - A_{s-hazard.oil}$$

$A_{flam.\ oil}$: Amount of flammable waste oil incinerated (wet basis) [t]
SIW_{oil} : Total amount of specially-controlled industrial waste oil incinerated (wet basis) [t]

$A_{s\text{-}hazard.\ oil}$: Amount of specified hazardous industrial waste oil incinerated (wet basis) [t]

- ***Specified Hazardous Industrial Waste Oil***

The activity data is obtained from following equation using the amount of specified hazardous industrial waste 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 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 industrial waste oil incinerated (wet basis) [t]
$R_{s\text{-}hazard.\ oil}$: Amount of specified hazardous industrial waste oil reduced in incineration (wet basis) [t]
r : Residual fraction of incinerated waste oil [%]

- ***Infectious Plastic***

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 from Japan Society of Waste Management Experts: JSWME (1997). All of Infectious plastics are considered to be fossil-fuel derived.

$$A_{inf.plastics} = ISW_{inf.} \times C_{inf.plastics}$$

$A_{inf.\ plastics}$: Amount of infectious plastics incinerated (wet basis) [t]
$ISW_{inf.}$: Total amount of infectious waste incinerated (wet basis) [t]
$C_{inf.\ plastics}$: Percentage of plastic content in infectious waste [%]

2) CH_4

- ***Estimation Method***

Emissions of CH_4 from the incineration of waste oil and infectious waste included in the specially-controlled industrial waste are calculated by multiplying the volume of incinerated waste by type (wet basis) by Japan's country-specific emission factor.

- ***Emission Factor***

Because actual measurement data are not available, the emission factors for the incineration of industrial waste are used as substitutes for the emission factor for the specially-controlled industrial waste by type. Specifically, the substitute emission factors used are: the waste fossil-fuel derived oil in industrial waste for the flammable waste oil and specified hazardous waste oil; the plastic in industrial waste for the infectious plastic; and the paper/cardboard and wood in industrial waste for the other infectious waste (biogenic).

- ***Activity Data***

- ***Flammable Waste Oil***

Activity data is the same as those used for CO_2 emission.

- ***Specified Hazardous Industrial Waste Oil***

Activity data is the same as those used for CO_2 emission.

- ***Infectious Plastics***

Activity data is the same as those used for CO_2 emission.

- ***Infectious Waste except Plastics***

The activity data is obtained from similar equation to Infectious plastics, as follows.

$$A_{inf.exc.\ plastics} = ISW_{inf.} \times \left(1 - C_{inf.plastics}\right)$$

$A_{inf.\ exc.\ plastics}$: Amount of infectious waste except plastics incinerated (wet basis) [t]

$ISW_{inf.}$: Total amount of infectious waste incinerated (wet basis) [t]

$C_{inf.\ plastics}$: Percentage of plastic content in infectious waste [%]

3) N_2O

- ***Estimation Method***

Emissions of N_2O from the incineration of waste oil and infectious waste in specially-controlled industrial waste are calculated by multiplying the incinerated volume of each type of waste (wet basis) by Japan's country-specific emission factor.

- ***Emission Factor***

Because actual measurement data are not available, the N_2O emission factors for the incineration of industrial waste are used as substitutes for determining the emission factor for each type of specially-controlled industrial waste. Specifically, the substitute emission factors used are: the waste oil in industrial waste for the flammable waste oil and specified hazardous industrial waste oil; the plastics in industrial waste for the infectious plastics; and the paper/cardboard and wood in industrial waste for the waste other than infectious plastics.

- ***Activity Data***

The same activity data used for CH_4 emissions is used.

Table 7-61 Amount of incineration of specially-controlled industrial waste (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Flammable waste oil	kt (wet)	238	353	520	478	390	271	266	236	278	222	263	317	311	263	279
Specified hazardous industrial waste oil	kt (wet)	18	27	40	37	41	54	122	145	128	93	99	100	75	76	76
Infectious waste (plastics)	kt (wet)	78	128	167	169	154	133	176	166	160	154	187	207	182	175	166
Infectious waste (except plastics)	kt (wet)	105	172	225	228	106	92	121	114	110	106	129	142	125	121	115

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

The uncertainty assessment is conducted as well as the assessment for the industrial waste incineration. As for the uncertainties in activity data, the uncertainties in specially-controlled industrial waste data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in Table 7-62.

Table 7-62 Uncertainty assessment for specially-controlled industrial waste on the category "waste incineration (5.C.1.-)"

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission/removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Specially-controlled industrial waste	CO_2	-2%	+2%	-60%	+60%	-60%	+60%	Due to the lack of information for the uncertainty of the emission factor, the uncertainty in municipal waste plastics is substituted based on expert judgment.	The uncertainty in specially-controlled industrial waste based on expert judgment is used.	Combined by using the formula for propagation of errors.
	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

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

By updating the statistical data, CO_2, CH_4 and N_2O emissions in FY2021 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 municipal solid waste 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 industrial waste (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 industrial waste 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 volume 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 industrial waste plastics (wet basis) [kg-CO_2/t]
CF : Carbon content in industrial waste plastics (wet basis) [%]
FCF : Fossil-fuel derived fraction in industrial waste plastics [%]
OF : Oxidation factor [%]

Table 7-63 CO_2 emission factors and relevant parameters of open burning of industrial waste plastics

Item	Value	Reference	Note
EF	1,822 kg-CO_2/t (wet)	–	Country-specific
CF	70 %	Environmental Agency (1992)	See also "7.4.1.2. Industrial Waste (5.C.1.-)".
FCF	100%	*2006 IPCC Guidelines*	Default value
OF	71 %	*2019 Refinement*	Default value

- ***Activity Data***

The amount of plastics as industrial waste burned in the open air obtained from the *Report on Survey of Organizations in Industrial Waste Administration* (MOE) is used as the activity data in and after FY1996. 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 way to estimate before 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 7-64 The amount of fossil-fuel derived industrial waste burned in the open air (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Plastics	kt (wet)	3.4	3.4	0.9	0.2	0.1	0.1	0.1	0.02	0.05	0.1	0.1	0.1	0.03	0.02	0.02

2) CH_4, N_2O

- ***Estimation Method***

Emissions of CH_4 and N_2O from the open burning of industrial waste 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 volume 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 7-65 CH_4 and N_2O emission factors for open burning of industrial waste

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 industrial waste 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 way to estimate.

Table 7-66 The amount of industrial waste burned in the open air (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Total wet weight amount	kt (wet)	72.2	72.2	28.9	3.5	1.3	1.3	0.6	1.0	0.5	0.7	0.8	0.8	0.4	0.6	0.6
Total dry weight amount	kt (dry)	62.4	62.4	25.5	3.1	1.1	1.2	0.5	0.8	0.5	0.6	0.7	0.7	0.4	0.5	0.5

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

Details of the uncertainty assessment on this category are indicated in Table 7-67.

Table 7-67 Uncertainty assessment on the category “open burning of waste (5.C.2.-)”

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission/removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Plastics	CO_2	-2%	+2%	-30%	+30%	-30%	+30%	Due to the lack of information for the uncertainty of the emission factor, the uncertainty in municipal waste plastics is substituted based on expert judgment.	The uncertainty in specially-controlled industrial waste based on expert judgment is used.	Combined by using the formula for propagation of errors.
Industrial waste	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 only for and after FY1996, 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

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

By updating the statistical data, CO_2, CH_4 and N_2O emissions in FY2020 and FY2021 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

7.4.3. Waste Incineration and Energy Use (Reported on 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 industrial waste 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 "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***

$$E = EF \times A \times R$$

E : Emission of CO_2 from waste incineration [kg-CO_2]
EF : Emission factor for incineration (dry basis) [kg-CO_2/t]
A : Amount of waste incinerated (dry basis) [t]
R : Percentage of municipal solid waste incinerated at incineration facilities with energy recovery

➢ ***Industrial Waste***

$$E = EF \times A \times R$$

E : Emission of CO_2 from waste incineration [kg-CO_2]
EF : Emission factor for waste incineration (wet basis) [kg-CO_2/t]
A : Amount of waste incinerated (wet basis) [t]
R : Fraction of industrial waste incinerated at industrial waste 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 : Emissions of CH_4 or N_2O from incineration of municipal solid waste [kg-CH_4], [kg-N_2O]
EFi : Emission factor for municipal solid waste incinerator type *i* (wet basis) [kg-CH_4/t], [kg-N_2O/t]
Ai : Amount of municipal solid waste incinerated for incinerator type *i* (wet basis) [t]
R : Percentage of municipal solid waste incinerated at facilities with energy recovery

➢ ***Industrial Waste***

$$E = \sum_j \left(EF_j \times A_j \times R_j\right)$$

E : Emissions of CH_4 or N_2O from incineration of industrial waste [kg-CH_4], [kg-N_2O]
EF_j : Emission factor for industrial waste type *j* (wet basis) [kg-CH_4/t], [kg-N_2O/t]
A_j : Amount of industrial waste type *j* incinerated (wet basis) [t]
R_j : Fraction of industrial waste type *j* incinerated at industrial waste incineration facilities with energy recovery

- ***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 basis)]
GCV : Gross calorific value of MSW [MJ/kg]
R : Fraction of MSW incinerated at MSW incineration facility with energy recovery

Based on the actual measurement results obtained at municipality, the calorific value 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 industrial waste [TJ]
Aj : Amount of industrial waste type *j* incinerated [kg (wet basis)]
GCVj : Gross calorific value of industrial waste type *j* [MJ/kg]
R : Fraction of industrial waste type *j* incinerated at industrial waste incineration facility with energy recovery

Calorific value of industrial waste is indicated in Table 7-72 (as referred to hereinafter).

c) Uncertainties and Time-series Consistency

Methodologies similar to the ones used in "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

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

Same recalculations as the category waste incineration (without energy recovery) were conducted. For details, see the paragraphs for category-specific recalculations on "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 volume 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 waste fossil-fuel derived oil in industrial waste, and waste tires.

- ***Emission Factor***

Emission factors are established for the plastics from MSW that are used as chemical raw material in coke ovens and waste tires. For the remaining emission sources, the emission factors for "7.4.1. Waste Incineration (without Energy Recovery) (5.C.1.)" are applied.

Table 7-68 CO_2 Emission factors specially defined for this category

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
MSW-coke oven	kg-CO_2/t (dry)	1,467	1,467	1,467	1,467	1,467	1,467	1,467	1,467	1,467	1,467	1,467	1,467	1,467	1,467	1,467
Waste tire	kg-CO_2/t (dry)	1,867	1,794	1,799	1,746	1,759	1,744	1,736	1,698	1,677	1,673	1,661	1,645	1,641	1,562	1,562

- ***Activity Data***

For details of the amount of waste used as raw materials or fuels, see the7.4.3.2.a-7.4.3.2.c.

Table 7-69 Amount of direct use of waste as alternative fuel (Activity data: wet basis)

Waste type		Application brakedown	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
MSW	Plastics	Liquefaction	kt (wet)	NO	NO	3	7	1	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		Blast furnace reducing agent	kt (wet)	NO	NO	25	37	27	30	27	31	29	28	28	28	29	31	28
		Coke oven chemical feedstock	kt (wet)	NO	NO	11	175	177	NO	17	29	25	32	17	25	24	24	23
		Gasification	kt (wet)	NO	NO	1	59	53	58	51	55	55	57	46	45	42	35	41
Industrial waste	Waste oil	(Unclassified)	kt (wet)	1,243	1,461	1,452	1,848	1,701	1,707	1,633	1,786	1,664	1,664	1,809	1,900	1,780	1,833	1,721
	Plastics	Blast furnace reducing agent	kt (wet)	NO	NO	57	160	134	107	149	144	156	168	132	148	115	147	183
		Chemical industry	kt (wet)	5	4	5	2	1	1	0.4	0.4	0.2	3	3	4	5	5	0
		Paper industry	kt (wet)	NO	NO	3	3	18	14	18	16	17	18	18	18	17	19	18
		Cement burning	kt (wet)	NO	9	102	302	445	518	595	576	623	643	718	746	746	774	784
		Automobile manufacturere	kt (wet)	16	10	8	4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		Liquefaction	kt (wet)	NO	NO	1	1	1	1	1	1	0.1	NO	1	1	1	1	1
		Gasification	kt (wet)	NO	NO	NO	11	117	97	90	81	79	91	97	86	99	92	71
	Wood	(Unclassified)	kt (wet)	1,635	1,635	2,061	2,683	3,900	4,425	4,878	4,628	4,555	4,832	4,690	5,097	4,996	4,986	4,958
Waste tire		Cement burning	kt (wet)	111	275	361	181	95	62	53	59	63	70	64	70	69	73	81
		Boiler	kt (wet)	119	126	75	12	8	6	2	2	5	3	3	2	2	3	5
		Iron manufacture	kt (wet)	NO	NO	57	51	30	27	27	20	19	17	14	18	16	17	NO
		Gasification	kt (wet)	NO	NO	NO	27	49	44	50	49	51	58	61	56	10	1	2
		Metal refining	kt (wet)	67	37	30	10	1	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		Tire manufacture	kt (wet)	NO	32	39	24	23	27	22	23	23	21	20	9	2	2	3
		Paper manufacture	kt (wet)	NO	26	42	210	388	372	415	439	407	436	446	402	412	425	433
		Power generation	kt (wet)	NO	NO	7	9	9	40	46	51	58	47	66	66	96	112	136
Refuse-derived fuel		(Unclassified)	kt (wet)	34	39	148	415	380	386	388	361	360	359	362	318	310	297	297
Refuse paper and plastic fuel (RPF)		Petroleum product manufacturer	kt (wet)	NO	NO	0.4	5	4	3	4	4	3	4	0.2	0.1	0.4	NO	NO
		Chemical industry	kt (wet)	NO	NO	7	15	22	26	20	22	19	18	17	17	9	3	1
		Paper industry	kt (wet)	NO	8	25	465	803	926	912	940	1,014	1,022	1,036	1,013	992	1,070	1,031
		Cement manufacturer	kt (wet)	NO	NO	0.2	8	15	16	17	14	11	13	15	18	16	12	15

Note:

- The amount of biogenic fraction such as biomass-based plastics, waste animal and vegetable 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 except for waste oils and plastics in industrial waste, the figures in the above table are converted into dry basis amount by subtracting water contents.
- Waste oil includes “used lubricant” and “used solvent”.

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 wastes 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 7-70 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 7-70 Data used for the calculation of CH_4 and N_2O emission factors for direct use of wastes 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
Industrial waste	Waste oil	(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			
Refuse-derived fuel (RDF)		(Unclassified)	Boilers (wood, charcoal, and other solid fuel)	Boilers (other than fluidized-bed) (solid fuel)	Calorific value of RDF
Refuse-derived fuel (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 7-71 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 (gas 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 fuel)	0.83	1.8
Other industrial furnaces (solid fuel)	13.1	1.1
Other industrial furnaces (gaseous fuel)	2.3	1.2

Reference: MOE (2006a)

Table 7-72 Calorific Value of waste incinerated and used as raw material or fuel

Item		Unit	GCV	Reference
Waste oil (including reclaimed oil)		TJ/L	40.2	*General Energy Statistics* (ANRE); estimated with 0.9[kg/L] (JSWME, 1997)
Plastics		MJ/kg	29.3	*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	2004 and before	MJ/kg	20.9	*General Energy Statistics* (ANRE)
	2005 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)

- ***Activity Data***

➢ ***Amount of Waste Used as Raw Material or Fuel***

Activity data are determined for each category using the wet-basis values (Table 7-69). 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) Uncertainties and Time-series Consistency

See the respective section.

d) Category-specific QA/QC and Verification

See the respective section.

e) Category-specific Recalculations

See the respective section.

f) Category-specific Planned Improvements

See the respective section.

7.4.3.2.a. Municipal Waste (Plastic) Used as Alternative Fuel (1.A.1 and 1.A.2)

a) Category Description

This category covers the emissions from municipal waste (plastic) used as alternative fuels. Plastics in MSW collected under the Containers and Packaging Recycling Law are processed into petrochemical, blast furnace reducing agent, chemical raw material in coke oven, and gasification to be used as alternative fuel or raw material. Note that PET bottles are not included in municipal waste in this source.

b) Methodological Issues

1) CO_2

- ***Estimation Method***

Emissions are calculated by multiplying the amount of fossil-fuel derived plastic in MSW by each usage (petrochemical, blast furnace reducing agent, chemical raw material in coke oven, and gasification) by Japan's country-specific emission factor.

- ***Emission Factor***

For the emission factors for plastics in MSW in the usage of petrochemical, blast furnace reducing agent, and gasification, the same values applied in "7.4.1.1. Municipal Solid Waste (5.C.1.-) are applied. The emission factor for plastics used as chemical raw material in coke ovens is set as the volume 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 municipal solid waste (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 [%]

- ***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 (wet basis)[1] [t (wet)]
P_{JCPRA} : Amount of plastics (wet basis) 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 percentage for designated legal bodies is substituted 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 Japan Containers and Packaging Recycling Association (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) Uncertainties and Time-series Consistency

● ***Uncertainties***

The uncertainty assessment is conducted as well as assessment in the category of the municipal waste incineration. Details of the uncertainty assessment on this category are shown in the Table 7-73.

Table 7-73 Uncertainty assessment for municipal waste plastics used as alternative fuels (1.A.1 and 1.A.2)

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Plastics	CO_2	-1%	+1%	-10%	+10%	-10%	+10%	The equivalent assessment of the uncertainty in municipal waste plastics in "5.C Incineration" is used.	The uncertainty in municipal waste statistics based on expert judgment is used.	Combined by using the formula for propagation of errors.
	CH_4	-39%	+39%	-10%	+10%	-40%	+40%	The equivalent assessment of the uncertainty in municipal waste in "5.C Incineration" is used.		
	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

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

By revising biomass-based plastic products data, CO_2 emissions from FY2005 onward were recalculated. By updating the statistical data, CO_2 emissions in FY2021 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 industrial waste (plastics, waste oil, and wood) used as raw material or fuels.

b) Methodological Issues

1) CO_2

- ***Estimation Method and Emission Factor***

Emissions are estimated by multiplying the amount of plastics and fossil-fuel derived waste oil used as raw material or fuels by emission factor used for incineration of industrial waste (See "7.4.1.2. Industrial Waste (5.C.1.-) ").

- ***Activity Data***

➢ ***Plastics***

Estimated activity data are the amounts of plastics (wet basis) in industrial waste 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 industrial waste 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 fluid 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.

➢ ***Waste Oil (Fossil-fuel Derived)***

The activity data for waste oil is mainly obtained from the *Cyclical Use of Waste Report* (MOE). The valuables, which are not included in the *Cyclical Use of Waste Report* (MOE), is additionally obtained from the other sources as "Used lubricant" and "Used solvent".

- ***Waste Oil***

The amount of waste oil indicated as "Fuel Usage" of "Direct Recycle Usage" and "Recycle Usage after Treatment" of industrial waste is used as the activity data of the waste oil that includes biogenic fraction. Hence in the estimation method for CO_2 emissions, the amount of biogenic "waste animal and vegetable oil" 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 of the amount of incinerated industrial waste oil.

- ***Used Lubricants***

The amount of recycled heavy oil products derived from used lubricant, indicated in the *Lubricant Recycle Handbook,* Japan Lubricating Oil Society is also used as activity data of fossil fuel-derived waste oil. All used lubricants are assumed to be fossil-fuel derived. The data for FY2001 and before are estimated by using the trend of the amount of incinerated industrial waste oil.

- ***Used Solvents***

The data of the amount of used solvents to be used as alternative fuel (valuables-origin), surveyed by the Japan Solvent Recycling Industry Association is also used as activity data for fossil fuel-derived waste oil. All used solvents 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 used for CO_2 emission estimates from this source is also used for CH_4 and N_2O emission estimates. 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 / Animal and Vegetable)***

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, waste animal and vegetable oil are also included for the estimation of activity data from this source.

➢ ***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). The values before FY1997 are estimated by using the average value in the period of FY1998-2002.

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

The uncertainty assessment is conducted as well as assessment in the category of the industrial waste incineration. Details of the uncertainty assessment on this category are shown in the Table 7-74.

Table 7-74 Uncertainty assessment for industrial waste plastics used as alternative fuels (1.A.2)

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Plastics	CO_2	-2%	+2%	-30%	+30%	-30%	+30%	The equivalent assessment of the uncertainty in industrial waste plastics in "5.C Incineration" is used.	The uncertainty based on expert judgment in industrial waste statistics is applied.	Combined by using the formula for propagation of errors.
	CH_4	-100%	+216%	-30%	+30%	-104%	+218%			
	N_2O	-44%	+44%	-30%	+30%	-53%	+53%			
Waste oil	CO_2	-2%	+2%	-30%	+30%	-30%	+30%	The equivalent assessment of the uncertainty in industrial waste oil in "5.C Incineration" is used.		Combined by using the formula for propagation of errors.
	CH_4	-100%	+181%	-30%	+30%	-104%	+184%			
	N_2O	-76%	+76%	-30%	+30%	-81%	+81%			
Wood	CH_4	-100%	+412%	-30%	+30%	-104%	+413%	The equivalent assessment of the uncertainty in industrial waste paper/cardboard or wood in "5.C Incineration" is used.		Combined by using the formula for propagation of errors.
	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

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

By revising biomass-based plastic products data, CO_2 emissions from FY2010 onward were recalculated. By updating the statistical data, CO_2 emissions in FY2021 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 volume of the fossil fuel-derived carbon in the waste tires is calculated by the material contents of new tires. 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 (dry basis) [kg-CO_2/t]
CF : Fossil fuel-derived carbon content in waste tires
OF : Oxidation factor of waste tires

- ***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* (Japan Automobile Tire Manufacturers Association).

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 volume 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 volume 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) Uncertainties and Time-series Consistency

- ***Uncertainties***

The uncertainty assessment is conducted as well as assessment in the category of the industrial waste incineration. Details of the uncertainty assessment on this category are shown in the Table 7-75.

Table 7-75 Uncertainty assessment for waste tire used as alternative fuels (1.A.1 and 1.A.2)

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Waste tire	CO_2	-2%	+2%	-30%	+30%	-30%	+30%	Due to the lack of information for the uncertainty of the emission factor, the uncertainty in industrial waste plastic is substituted based on expert judgment.	The uncertainty based on expert judgment in industrial waste statistics is applied.	Combined by using the formula for propagation of errors.
	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

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

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 (dry basis) [kg-CO_2/t]
AD_{RDF} : Activity data for RDF use (dry basis) [t]

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

E_{RPF} : CO_2 Emissions from RPF use [kg-CO_2]
EF_{RPF} : Emission factor for RPF use (dry basis) [kg-CO_2/t]
AD_{RPF} : Activity data for RPF use (dry basis) [t]

- ***Emission Factor***

Emission factor associated with the use of the refuse-derived solid fuels (RDF and RPF) is calculated for RDF and RPF respectively by the equation 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 "7.2.1. Managed Disposal Sites (5.A.1.)" and "7.4.1.2. Industrial 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 municipal solid waste, the fractions of carbon content in each waste type used in "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 municipal solid waste, fossil-fuel derived fractions of each waste type used in "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

$$EF_{RPF,coal} = 1000 \times P_{RPF,coal} \times C \times OF_{RPF} \times 44/12 \times FCF_{plastics}$$
$$= 1000 \times 0.528 \times 0.737 \times 1.0 \times 44/12 \times FCF_{plastics}$$
$$= 1426\ [\text{kg-}CO_2/\text{t}] \times FCF_{plastics}$$

Coke-equivalent product

$$EF_{RPF,coke} = 1000 \times P_{RPF,coke} \times C \times OF_{RPF} \times 44 / 12 \times FCF_{plastics}$$
$$= 1000 \times 0.910 \times 0.737 \times 1.0 \times 44 / 12 \times FCF_{plastics}$$
$$= 2457\ [\text{kg-}CO_2/\text{t}] \times FCF_{plastics}$$

$EF_{RPF,coal}$: Emission factor for the use of coal-equivalent product RPF (dry basis) [kg-CO_2/t]
$EF_{RPF,coke}$: Emission factor for the use of coke-equivalent product RPF (dry basis) [kg-CO_2/t]
$P_{RPF,coal}$: 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 waste plastic-derived content contained in RPF in dry basis is calculated with the fraction of water content of RDF, to which the average water content of industrial waste 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)***

Due to the fact that most of plastic contained in RDF is industrial waste-derive (Seki, 2004), the fraction of carbon content contained in plastic in dry basis (73.7%) is calculated by using the fraction of carbon content contained in industrial waste plastic applied in "7.4.1.2. Industrial Waste (5.C.1.-), CO_2" (70%) and the fraction of water content of industrial waste plastic (5%).

- ***Oxidation Factor for RPF at RPF Fuel Facilities (OF_{RPF})***

As applied in "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 Plastic in RPF ($FCF_{plastics}$)***

The same values for industrial waste 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 is 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) (dry basis) [kg-CO_2/t]
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 plastic in RPF

Table 7-76 CO_2 emission factors for the emissions from the use of refused-derived fuel (RDF) or refuse paper and plastic fuel (RPF)

Item	Emission Factor [kg-CO_2/t (dry)]
RDF	1,081
RPF (coal-equivalent products)	1,426
RPF (coke-equivalent products)	2,457
RPF (weighted average values)	1,636

Note: Each emission factor indicated in the table 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*. For the fiscal years that the data are unavailable, emission estimates are conducted substituting the values of the refuse processing capacity.

$$A_{RDF} = a_{RDF} \times (1 - u_{RDF})$$

A_{RDF} : Activity data for RDF use (dry basis)
a_{RDF} : Amount for RDF production at RDF production facilities (wet basis) [t]
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 7-69). 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 "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 products manufacturer 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) Uncertainties and Time-series Consistency

- ***Uncertainties***

The uncertainty assessment is conducted as well as the assessment for the municipal waste or industrial waste incineration. Details of the uncertainty assessment on this category are indicated in the Table 7-77.

Table 7-77 Uncertainty assessment for incineration of waste refuse-based solid fuels (1.A.1 and 1.A.2)

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
RDF	CO_2	-1%	+1%	-10%	+10%	-10%	+10%	Due to the lack of information for the uncertainty of the emission factor, the uncertainty in municipal waste plastics is substituted based on expert judgment.	The uncertainty in municipal waste statistics based on expert judgment is used.	Combined by using the formula for propagation of errors.
	CH_4	-39%	+39%	-10%	+10%	-40%	+40%			
	N_2O	-34%	+34%	-10%	+10%	-35%	+35%			
RPF	CO_2	-2%	+2%	-30%	+30%	-30%	+30%	Due to the lack of information for the uncertainty of the emission factor, the uncertainty in municipal waste plastics is substituted based on expert judgment.	The uncertainty based on expert judgment in industrial waste statistics is applied.	Combined by using the formula for propagation of errors.
	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

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

By revising biomass-based plastic products data, CO_2 emissions from FY2005 onward were recalculated. By updating the statistical data, CO_2, CH_4 and N_2O emissions in FY2021 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 and industrial wastewater treatment and discharge are reported under the category "Wastewater Treatment and Discharge (5.D.)". The target categories are shown in Table 7-78. 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 type of sources, it is difficult to analyze the trend in the IEFs.

Table 7-78 Categories overview for wastewater treatment and discharge (5.D.)

Category	Wastewater type					Treatment type			CH_4	N_2O
5.D.1. (7.5.1)	Domestic wastewater	Plant	Public sewer system	Sewage		Sewage treatment plants (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	Miscellaneous wastewater		Domestic sewage treatment plants (mainly *Johkasou*) (7.5.1.2)	Community plant		○	○
							Current type *Johkasou*	Advanced type	TN removal type	○	○
									TN and TP removal type		
									BOD removal type		
								Other advanced type		○	○
								Standard type		○	○
				Human waste			Old type *Johkasou*			○	○
							Vault toilet			○	○
				Collected human waste	Human waste and *Johkasou* sludge (from domestic sewage treatment plants)	Human waste treatment plants (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 (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. (7.5.2)	Industrial wastewater	Plant	Manufacture of food			Industrial wastewater treatment (7.5.2.1)	(Industrial wastewater treatment plants)			○	○
			Manufacture of pulp, paper and paper products							○	○
			Manufacture of chemical and allied product							○	○
			Manufacture of iron and steel							○	○
			Manufacture of beverages, tobacco and feed							○	○
			Manufacture of textile products								
			Manufacture of petroleum and coal products								
			Manufacture of plastic products								
			Manufacture of rubber products								
			Manufacture of leather tanning, leather products and fur skins								
		Effluent	Wastewater		Untreated wastewater	Natural decomposition of Industrial wastewater (7.5.2.2)	Discharge of untreated wastewater	(from industrial plants/facilities)		○	○[2]
					Treated wastewater		Discharge of treated wastewater	(from industrial wastewater treatment plants)		NA	○[2]
	Landfill leachate (plant)					Landfill leachate treatment (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 7-79. In FY2022, emissions from this source category are 3,499 kt-CO_2 eq. and accounted for 0.3% of the national total emissions (excluding LULUCF). The emissions from this source category decreased by 35.4% 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. Due to the same reason, the N_2O emissions from the subcategory of "Sewage Treatment Plants (5.D.1.-)" for FY1995 through FY1998 increased.

Table 7-79 GHG emissions from wastewater treatment and discharge (5.D.)

Gas	Category		Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
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	12.6	12.4	12.6	12.1	12.5	13.1	12.9	12.9	12.9
		Domestic sewage treatment plant	kt-CH_4	30.4	35.0	38.8	38.3	36.8	35.3	34.7	34.3	33.8	32.9	32.4	31.3	30.8	31.5	31.5
		Human-waste treatment plant	kt-CH_4	5.2	3.2	1.8	1.0	0.6	0.5	0.5	0.4	0.4	0.3	0.3	0.3	0.3	0.2	0.2
		Natural decomposition of domestic wastewater	kt-CH_4	61.7	50.8	39.5	28.7	21.1	18.1	17.2	16.4	15.8	15.0	14.3	13.7	13.1	11.8	11.8
	5.D.2. Industrial wastewater	Industrial wastewater 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	1.7	1.7	1.7
		Natural decomposition of industrial wastewater	kt-CH_4	8.2	7.8	7.9	8.3	4.9	4.1	4.3	4.6	4.1	3.7	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	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	Total		kt-CH_4	117.7	110.0	102.2	91.2	78.1	72.5	71.2	70.0	68.6	65.9	65.1	64.0	62.6	61.9	61.9
			kt-CO_2 eq.	3,295	3,080	2,863	2,553	2,188	2,029	1,993	1,959	1,920	1,846	1,824	1,793	1,753	1,733	1,733
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	1.59	1.55	1.55	1.45	1.49	1.53	1.47	1.47	1.47
		Domestic sewage treatment plant	kt-N_2O	1.52	1.65	1.70	1.57	1.53	1.56	1.56	1.55	1.56	1.56	1.55	1.57	1.56	1.60	1.60
		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	0.01	0.01	0.01
		Natural decomposition of domestic wastewater	kt-N_2O	2.79	2.72	2.49	2.29	2.11	2.08	2.01	2.02	2.00	1.98	1.94	2.03	1.91	1.89	1.89
	5.D.2. Industrial wastewater	Industrial wastewater 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	1.13	1.13	1.13
		Natural decomposition of industrial wastewater	kt-N_2O	1.06	1.02	1.02	0.97	0.66	0.59	0.56	0.54	0.55	0.55	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	0.01	0.005	0.005	0.005	0.004	0.004	0.003	0.003
	Total		kt-N_2O	8.01	8.18	7.72	7.65	7.10	6.99	6.86	6.80	6.80	6.69	6.68	6.82	6.64	6.66	6.66
			kt-CO_2 eq.	2,123	2,169	2,046	2,028	1,881	1,851	1,819	1,803	1,803	1,772	1,769	1,807	1,760	1,766	1,766
Total			kt-CO_2 eq.	5,417	5,249	4,909	4,581	4,069	3,880	3,812	3,762	3,723	3,618	3,593	3,601	3,512	3,499	3,499

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 77.6% of the population at the end of FY2022.

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 FY2022, *Johkasou* (including rural sewerage and other facilities) is used by 18.4% 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 7-80 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: persons]	
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 domestic wastewater discharged [Unit: kg-BOD]	Amount of nitrogen in domestic wastewater discharged [Unit: kg-N]

7.5.1.1. Sewage Treatment Plant (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 factor for wastewater treatment processes (528.7 [mg-CH_4/m^3])
EF_{SSTT} : Average of emission factor 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 the country (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 7-81.)
EF_{SSTT} : Average of emission factor for sludge treatment process (0.6 [mg-N_2O/m^3])

Table 7-81 N_2O Emission factor by wastewater treatment process at sewage treatment plant

Wastewater treatment process	N_2O EF for wastewater treatment process[3)] [mg-N_2O/m^3]	N_2O EF for sludge treatment process [mg-N_2O/m^3]
Standard activated sludge process[1)]	142	0.6
Anaerobic-aerobic activated sludge process	29.2	0.6
Anaerobic-anoxic-oxic process and recycled nitrification; denitrification process[2)]	11.7	0.6
Recycled nitrification-denitrification membrane bioreactor	0.5	0.6

Note:
1) Includes all the wastewater treatment processes other than indicated above.
2) Includes all the wastewater treatment processes which remove nitrogen 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 amount of wastewater treated used for N_2O emission estimates are also used for the activity data for CH_4 emission estimates.

Table 7-82 Activity data for wastewater treated at sewage treatment plant

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Standard activated sludge process	10^6 m^3	9,761	10,780	10,686	11,405	11,358	10,736	10,699	10,401	10,394	9,648	9,908	10,124	9,733	9,733	9,733
Anaerobic-aerobic activated sludge process	10^6 m^3	73	446	1,523	1,039	909	931	938	933	962	1,107	1,248	1,497	1,456	1,456	1,456
Anaerobic-anoxic-oxic process and recycled nitrification; denitrification process	10^6 m^3	23	89	487	1,374	2,181	2,629	2,684	2,819	3,033	2,998	3,132	3,361	3,480	3,480	3,480
Recycled nitrification-denitrification membrane bioreactor	10^6 m^3	NO	NO	NO	0.1	2.0	14.9	0.1	0.2	4.8	0.4	6.3	5.8	6.2	6.2	6.2
Total	10^6 m^3	9,857	11,316	12,696	13,818	14,450	14,311	14,320	14,153	14,393	13,754	14,293	14,989	14,674	14,674	14,674

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

The uncertainties in emission factors for CH_4 and N_2O in sewage treatment plant are evaluated by using the 95% confidence intervals of actual measurement 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 on this category are indicated in Table 7-83.

Table 7-83 Uncertainty assessment for sewage treatment plant on the category "Domestic wastewater (5.D.1.-)"

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Sewage treatment plant	CH_4	-31%	+31%	-5%	+5%	-31%	+31%	The uncertainty is assessed by using the 95% interval confidence of actual measurement data in MOE (2006b).	The uncertainty in sewage statistics based on expert judgment is used.	Combined by using the formula for propagation of errors.
	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

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

No recalculations are conducted.

f) Category-specific Planned Improvements

No improvements are planned.

7.5.1.2. Domestic Sewage Treatment Plant (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 vaults. The *Johkasou* means decentralized wastewater treatment facilities installed at an individual home.

Table 7-84 Type of sewage and sewage treatment

Plant type				Sewage type	Description	
Community plants				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 type certified in performance under the amended Building Standards Act in effect FY2001
			TN and TP removal type			
			BOD removal type			
			Other advanced type			
		Standard type				Standard type under former the 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
Vaults 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 "Human waste treatment plant (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 (i.e. household *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 7-85.

Table 7-85 Emission factors for CH_4 and N_2O from domestic wastewater 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 performance 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 values of the upper limit and the lower limit of actual 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 J*ohkasou* 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 7-86 Annual treatment population by type of domestic sewage treatment plant (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Community plant	1000 person	493	398	414	552	293	304	302	294	286	320	336	306	259	193	193
Current type *Johkasou* (Sub tatal)	1000 person	6,274	8,515	10,806	12,792	14,082	14,492	14,564	14,600	14,630	14,557	14,506	14,381	14,421	15,206	15,206
Advanced type																
TN removal type	1000 person	NO	NO	NO	263	1,433	2,612	2,948	3,105	3,447	3,862	3,954	4,507	4,772	5,315	5,315
TN and TP removal type	1000 person	NO	NO	NO	3	14	35	37	39	40	42	43	56	51	58	58
BOD removal type	1000 person	NO	NO	NO	34	33	25	22	19	18	20	29	54	58	35	35
Other advanced type	1000 person	NO	NO	NO	4,501	6,132	6,123	6,098	6,153	6,022	5,666	5,691	5,345	5,110	5,273	5,273
Standard type	1000 person	6,274	8,515	10,806	7,991	6,471	5,697	5,459	5,284	5,103	4,968	4,788	4,419	4,429	4,524	4,524
Old type *Johkasou*	1000 person	26,828	26,105	23,289	18,303	13,948	12,383	11,822	11,415	11,018	10,543	10,151	9,875	9,319	8,317	8,317
Vault toilet	1000 person	38,920	29,409	20,358	13,920	9,984	8,242	7,727	7,197	6,871	6,528	6,086	5,745	5,481	5,097	5,097
Total	1000 person	72,515	64,427	54,867	45,567	38,307	35,421	34,415	33,506	32,805	31,948	31,079	30,307	29,480	28,813	28,813

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

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 actual measurement 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 substituted. As for the uncertainties in activity data, the uncertainties in domestic wastewater data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-87.

Table 7-87 Uncertainty assessment for domestic sewage treatment plant on the category "Domestic wastewater (5.D.1.-)"

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Community Plant	CH_4	-32%	+32%	-10%	+10%	-33%	+33%	The uncertainty is assessed based on expert judgment. (The uncertainty in current type *Johkasou* is substituted).	The uncertainty in municipal waste statistics based on expert judgment is used.	Combined by using the formula for propagation of errors.
	N_2O	-45%	+45%	-10%	+10%	-46%	+46%			
Current type *Johkasou*	CH_4	-32%	+32%	-10%	+10%	-33%	+33%	Quoted from MOE (2013c).		Combined by using the formula for propagation of errors.
	N_2O	-45%	+45%	-10%	+10%	-46%	+46%			
Old type *Johkasou*	CH_4	-84%	+84%	-10%	+10%	-84%	+84%			Combined by using the formula for propagation of errors.
	N_2O	-87%	+87%	-10%	+10%	-88%	+88%			
Vault toilet	CH_4	-49%	+49%	-10%	+10%	-50%	+50%			Combined by using the formula for propagation of errors.
	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

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

By updating the statistical data, CH_4 and N_2O emissions in FY2021 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 Plant (5.D.1.-)

a) Category Description

This category covers emissions of CH_4 and N_2O emissions from treatment of vault toilet human waste and *Johkasou* sludge collected 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 domestic wastewater 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 7-88 CH_4 emission factors by each treatment process

Treatment method	CH_4 Emission factor [kg-CH_4/m^3]	Reference
Anaerobic treatment	0.543	Estimated by multiplying the actual methane emissions given in Japan Environmental Sanitation Center (1990) by the value of 1 – CH_4 recovery rate (90%).
Aerobic treatment	0.00545	Simple average value of standard de-nitrification and high-load de-nitrification since actual data on emissions is not available.
Standard de-nitrification treatment	0.0059	Tanaka et al. (1995)
High load de-nitrification treatment	0.005	Tanaka et al. (1995)
Membrane separation	0.00545	Because the current status of its emissions is not identified, substituted the emission factor for aerobic treatment.
Other	0.00545	Because the current status of its emissions is not identified, substituted the emission factor for aerobic treatment.

- ***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 7-91), 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 7-89) by the capacity of each treatment process (Table 7-90).

$$A_i = W_H \times C_i / C_T$$

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 7-89 Volume of human waste and *Johkasou* sludge treated at their treatment plants

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Human waste from vault toilet	1000 kL	20,406	18,049	14,673	10,400	7,917	6,771	6,375	6,153	5,890	5,627	5,415	5,191	4,974	4,781	4,781
Johkasou sludge	1000 kL	9,224	11,545	13,234	13,790	13,760	13,726	13,562	13,537	13,648	13,536	13,534	13,415	13,372	13,260	13,260
Total	1000 kL	29,630	29,594	27,907	24,190	21,677	20,497	19,937	19,690	19,538	19,163	18,949	18,606	18,346	18,041	18,041

Table 7-90 Trends in treatment capacity by treatment process

Unit	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Anaerobic treatment	kL/day	34,580	19,869	10,996	6,476	3,891	3,059	2,779	2,245	2,155	1,799	1,574	1,527	1,330	898	898
Aerobic treatment	kL/day	26,654	19,716	12,166	8,465	6,753	6,001	5,899	5,979	5,600	4,743	4,468	3,760	3,666	4,967	4,967
Standard denitrification	kL/day	25,196	30,157	31,908	29,655	26,173	25,153	24,663	24,023	22,812	21,544	21,113	21,599	21,322	20,416	20,416
High-intensity denitrification	kL/day	8,158	13,817	16,498	17,493	16,104	14,529	14,336	13,831	13,651	13,838	13,289	13,153	12,601	12,330	12,330
Membrane separation	kL/day	NO	1,616	2,375	3,055	3,684	4,074	2,204	3,373	3,184	2,853	2,404	2,458	2,410	2,240	2,240
Other	kL/day	13,777	20,028	25,917	30,277	34,577	33,975	34,983	33,940	36,074	37,430	40,223	40,137	40,882	40,906	40,906

Table 7-91 Activity Data for human waste by treatment types

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Anaerobic treatment	1000 kL	9,455	5,589	3,073	1,642	925	722	653	530	504	419	359	344	297	198	198
Aerobic treatment	1000 kL	7,288	5,546	3,400	2,146	1,605	1,417	1,386	1,412	1,311	1,106	1,019	847	818	1,096	1,096
Standard denitrification	1000 kL	6,889	8,483	8,917	7,518	6,222	5,940	5,794	5,672	5,339	5,022	4,816	4,863	4,758	4,505	4,505
High-intensity denitrification	1000 kL	2,231	3,887	4,611	4,435	3,828	3,431	3,368	3,266	3,195	3,226	3,031	2,962	2,812	2,721	2,721
Membrane separation	1000 kL	NO	455	664	774	876	962	518	796	745	665	548	553	538	494	494
Other	1000 kL	3,767	5,634	7,243	7,676	8,220	8,024	8,219	8,014	8,443	8,725	9,175	9,037	9,123	9,026	9,026
Total	1000 kL	29,630	29,594	27,907	24,190	21,677	20,497	19,937	19,690	19,538	19,163	18,949	18,606	18,346	18,041	18,041

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 nitrous oxide 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 study on the emission factors for human waste treatment facilities conducted in FY1994 (Tanaka et al., 1997) and FY2003 (Ohmura et al., 2004) in Japan, because of the advancement of the structure of human waste treatment facilities and the technology of operation and maintenance, actual measurement results show the improvement in the emission factors for high load de-nitrification treatment and membrane separation; therefore, different emission factors are used for FY1994 or before and from FY2003 onwards.

Table 7-92 N_2O emission factors by each treatment process

Treatment method	N_2O emission factors [kg-N_2O/kg-N]		
	FY1990-1994	FY1995-2002	From 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) Use median value of actual measurements at 13 plants given in Tanaka et al. (1998)
2) Use median value of actual measurements at 13 plants given 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 7-89).

- ***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 7-90).

- ***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 value of FY2000 is substituted for the values from FY2001 onward. (See Table 7-93).

Table 7-93 Concentration of nitrogen contained in collected human waste and *Johkasou* sludge

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Human waste from vault toilet	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	2,700	2,700	2,700
Johkasou sludge	mg-N/L	1,060	300	580	580	580	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	1,258	1,242	1,219	1,203	1,186	1,171	1,155	1,142	1,142

Table 7-94 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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Anaerobic treatment	kt-N	28.8	11.2	5.2	2.4	1.3	0.9	0.8	0.7	0.6	0.5	0.4	0.4	0.3	0.2	0.2
Aerobic treatment	kt-N	22.2	11.1	5.8	3.2	2.2	1.8	1.7	1.8	1.6	1.3	1.2	1.0	0.9	1.3	1.3
Standard denitrification	kt-N	21.0	17.0	15.1	11.2	8.4	7.6	7.3	7.0	6.5	6.0	5.7	5.7	5.5	5.1	5.1
High-intensity denitrification	kt-N	6.8	7.8	7.8	6.6	5.2	4.4	4.2	4.1	3.9	3.9	3.6	3.5	3.2	3.1	3.1
Membrane separation	kt-N	NO	0.9	1.1	1.2	1.2	1.2	0.7	1.0	0.9	0.8	0.7	0.6	0.6	0.6	0.6
Other	kt-N	11.5	11.3	12.3	11.4	11.1	10.3	10.3	10.0	10.3	10.5	10.9	10.6	10.5	10.3	10.3
Total	kt-N	90.2	59.4	47.3	36.1	29.4	26.2	25.1	24.5	23.8	23.0	22.5	21.8	21.2	20.6	20.6

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

As for the uncertainties in emission factors for CH_4 and N_2O in human waste treatment plant, the uncertainties in similar emission sources are substituted. As for the uncertainties in activity data, the uncertainties in domestic wastewater data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-95.

Table 7-95 Uncertainty assessment for human waste treatment plant on the category "Domestic wastewater (5.D.1.-)"

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Human waste treatment plant	CH_4	-84%	+84%	-10%	+10%	-84%	+84%	The uncertainty is assessed based on expert judgment. (The uncertainty in Old type *Johkasou* is substituted).	The uncertainty in municipal waste statistics based on expert judgment is used.	Combined by using the formula for propagation of errors.
	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 actual measurement data by using the methods described in Table 7-92. 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

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

No recalculations are conducted.

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 domestic wastewater 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 7-96.

Table 7-96 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 toilet
	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 domestic wastewater that is discharged into public waters by the emission factor. The N_2O emission is calculated 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 domestic wastewater [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 domestic wastewater

- ***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 value of 0.005 kg N_2O-N/kg N after conversion of the units.

$$EF_{N2O} = 0.005 \text{ [kg-N}_2\text{O-N/kg-N]} \times 44/28$$
$$= 0.0079 \text{ [kg-N}_2\text{O/kg-N]}$$

- ***Activity Data***

➢ ***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 emission from this is already included in the "Direct soil emission (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 equations:

$$A = A_{sp} + A_{dp} + A_{hp}$$

A : Total nitrogen in treated domestic wastewater (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 are obtained from the equation below:

$$A_{sp} = \sum_i (W_i \times D_i) \times 10^{-6}$$

W_i : Amount of treated wastewater in sewage treatment plant i [m^3]
D_i : Nitrogen concentration in treated wastewater from sewage treatment plant i [mg-N/L]

References:
1) *Sewage Statistics* (JSWA) for both parameters

- ***Domestic Sewage Treatment Plant***

Total nitrogen in treated wastewater from domestic sewage treatment plants (community plant, 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 7-97)
P_i : User population of domestic sewage treatment plant type i [person] (see Table 7-86)
R_i : Fraction of nitrogen removal in domestic sewage plant type i [%] (see Table 7-98)
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 7-97 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 7-98 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 Plant***

Total nitrogen in treated wastewater from human waste treatment plant are 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 plant[1)] [m^3]
D : Nitrogen concentration in treated wastewater from human waste treatment plant [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 7-99) weighted by treatment capacities by treatment process (Table 7-90).

Table 7-99 Nitrogen concentrations in discharged wastewater from each human waste treatment method

Treatment method	Nitrogen concentration [mg-N/l]	Reference
Anaerobic treatment	98.0	Okazaki et al. (2001)
Aerobic treatment	32.5	
Standard de-nitrification treatment	5.5	
High load de-nitrification treatment	19.0	
Membrane separation	10.0	

➢ ***Sludge***

Activity data for CH_4 and N_2O emissions from sludge dumped into 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/*Jokasou* sludge dumped into ocean [g-BOD], [g-N]
V_H : Human waste dumped in ocean [1)] [kL]
D_H : BOD/Nitrogen concentration in human waste[2)] [mg-BOD/L], [mg-N/L]
V_J : *Jokasou* sludge dumped in ocean [1)] [kL]
D_J : BOD/Nitrogen concentration in *Jokasou* 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 ocean [g-BOD], [g-N]
V : Sewage sludge dumped into 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 substituted by Expert judgement based on Okazaki et al. (2001).

Estimated activity data are shown in Table 7-100.

Table 7-100 Amount of organic material and nitrogen in untreated domestic wastewater and discharged into public water zone (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Organic mater in:																
Untreated wastewater (from old type *Johkasou*)	kt-BOD	392	381	341	267	204	181	173	167	161	154	148	144	136	121	121
Untreated wastewater (from Vault toilet)	kt-BOD	568	429	298	203	146	120	113	105	101	95	89	84	80	74	74
Untreated wastewater (from On-site disposal)	kt-BOD	46	21	9	4	2	1	1	1	1	1	1	1	1	1	1
Human waste, *Johkasou* sludge (Ocean dumping)	kt-BOD	22	14	9	4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sewege sludge (Ocean dumping)	kt-BOD	1	1	0.05	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total	kt-BOD	1,029	846	658	478	351	302	287	273	263	250	238	229	218	197	197
Nitrogen in:																
Untreated wastewater (from old type *Johkasou*)	kt-N	19.6	19.1	17.0	13.4	10.2	9.0	8.6	8.3	8.1	7.7	7.4	7.2	6.8	6.1	6.1
Untreated wastewater (from Vault toilet)	kt-N	28.4	21.5	14.9	10.2	7.3	6.0	5.6	5.3	5.0	4.8	4.4	4.2	4.0	3.7	3.7
Untreated wastewater (from on-site disposal)	kt-N	2.3	1.1	0.5	0.2	0.1	0.1	0.1	0.1	0.05	0.05	0.1	0.1	0.04	0.04	0.04
Treated wastewater	kt-N	297.0	301.2	281.8	267.0	251.6	250.0	241.3	243.0	241.9	239.2	235.2	246.8	231.8	230.6	230.6
Human waste, *Johkasou* sludge (Ocean dumping)	kt-N	7.2	3.2	2.2	0.8	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Sewege sludge (Ocean dumping)	kt-N	0.1	0.1	0.01	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total	kt-N	354.6	346.0	316.4	291.5	269.1	265.1	255.6	256.7	255.0	251.7	247.2	258.2	242.7	240.5	240.5

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

As for the uncertainties in emission factors for CH_4 and N_2O in this category, the uncertainties in similar emission sources are substituted. As for the uncertainties in activity data, the uncertainties in domestic wastewater data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-101.

Table 7-101 Uncertainty assessment for natural decomposition of domestic wastewater on the category "Domestic wastewater (5.D.1.-)"

Item	GHGs	Emission/ removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
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 municipal waste statistics based on expert judgment is used.	Combined by using the formula for propagation of errors.
	N_2O	-58%	+58%	-10%	+10%	-59%	+59%	Due to the lack of information for the uncertainty of the emission factor, the uncertainty in CH_4 is substituted based on expert judgment.		

- ***Time-series Consistency***

The emissions are calculated in a consistent manner.

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

By updating the statistical data, N_2O emissions in FY2016 and FY2021 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 industrial wastewater 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 industrial wastewater 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 industrial wastewater [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 industrial wastewater [kg-BOD], [kg-N]

- ***Emission Factor***

Country-specific emission factors obtained from a set of actual measurement at 8 plants in summer and winter (MOE, 2018 a) are adopted (MOE, 2018 b).

Table 7-102 Emission Factors for industrial wastewater treatment facilities

Category of Manufacturing	CH_4 Emission factor [g-CH_4/kg-BOD]	N_2O Emission factor [g-N_2O/kg-N]
Manufacture of food	1.2	0.47
Manufacture of pulp, paper and paper products	2.5	0.014
Manufacture of chemical and allied product	0.92	17
Manufacture of iron and steel	7.3	4.0
Other manufactures (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 emission are estimated based on the amount of organic matter contained in wastewater using BOD concentrations. The emission estimates are conducted for the industries which generate large amount of CH4 emissions with high BOD concentrations from the treatment of wastewater referring to the industry types provided in the *Revised 1996 IPCC Guidelines* (Table 7-103). The amount of organic matter is obtained by sorting and aggregating by industry type according to the middle industrial classification provided by JSWA (2009).

The use of COD concentrations is required to report activity data on CRT; however, activity data are reported as "NE" because country-specific methodology is used for this source.

$$A_{CH4,i} = W_i \times BOD_i / 1000$$

Where,

$$W_i = I_i \times F_{CH4,i} \times F_{onsite,i}$$

$A_{CH4,i}$: Amount of BOD in industrial wastewater from industry type *i* (Activity data) [kg-BOD]
W_i : Amount of industrial wastewater 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 industrial wastewater from industry type *i* used for product processing and/or washing [m^3]
$F_{CH4,i}$: Percentage of industrial wastewater from industry type *i* treated at treatment facilities emitting CH_4 [%]
$F_{onsite,i}$: Percentage of industrial wastewater from industry type *i* treated on-site [%]

The activity data for N_2O emissions are obtained based on the amount of nitrogen contained in industrial wastewater 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,

$$W_i = I_i \times F_{N2O,i} \times F_{onsite,i}$$

$A_{N2O,i}$: Amount of nitrogen in industrial wastewater from industry type *i* (Activity data) [kg-N]
W_i : Amount of industrial wastewater 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 industrial wastewater from industry type *i* used for product processing and/or washing [m^3]
$F_{N2O,i}$: Percentage of industrial wastewater from industry type *i* treated at treatment facilities emitting N_2O [%]
$F_{onsite,i}$: Percentage of industrial wastewater from industry type *i* treated on-site [%]

- ***Amount of Industrial Wastewater Inflowed 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 industrial wastewater treated at wastewater treatment facilities.

- ***Percentage of Industrial Wastewater Treated at Facilities Generating CH_4***

Emissions of CH_4 from industrial wastewater treatment are believed to be generated from the treatment of wastewater with the activated sludge method and from the anaerobic treatment. Industrial wastewater 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 industrial wastewater treatment are believed to be generated mainly from biological treatment processes such as denitrification. Data on the fraction of industrial wastewater treated at facilities generating CH_4 is also used for N_2O emission estimates.

- ***Percentage of Industrial Wastewater Treated On-site***

Percentage of industrial wastewater 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 7-103 BOD and nitrogen concentrations by industry type used for emission estimates

Industry code	Category of Manufacturing	mg-BOD/L	mg-N/L
9	Manufacture of food	1,470	62
10	Manufacture of beverages, tobacco and feed	1,138	77
11	Manufacture of textile products	386	36
14	Manufacture of pulp, paper and paper products	556	37
16	Manufacture of chemical and allied product	1,093	191
17	Manufacture of petroleum and coal products	975	289
18	Manufacture of plastic products	268	11
19	Manufacture of rubber products	112	32
20	Manufacture of leather tanning, leather products and fur skins	1,810	60
22	Manufacture of iron and steel	246	310

Table 7-104 BOD load and TN load of industrial wastewater (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
BOD load																
Manufacture of 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	348.4	348.4	348.4
Manufacture of 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	62.0	62.0	62.0
Manufacture of 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	36.4	36.4	36.4
Manufacture of 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	324.0	324.0	324.0
Manufacture of 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	146.1	146.1	146.1
Manufacture of 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	0.3	0.3	0.3
Manufacture of 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	6.2	6.2	6.2
Manufacture of 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	0.1	0.1	0.1
Manufacture of 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	0.2	0.2	0.2
Manufacture of 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	1.4	1.4	1.4
TN load																
Manufacture of 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	17.4	17.4	17.4
Manufacture of 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	3.3	3.3	3.3
Manufacture of 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	4.1	4.1	4.1
Manufacture of 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	12.0	12.0	12.0
Manufacture of 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	49.8	49.8	49.8
Manufacture of 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	0.04	0.04	0.04
Manufacture of 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	0.4	0.4	0.4
Manufacture of 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	0.02	0.02	0.02
Manufacture of 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	0.01	0.01	0.01
Manufacture of 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	57.5	57.5	57.5

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

The uncertainties in emission factors are evaluated according to the survey for EFs (MOE, 2018a). As for the uncertainties in activity data, the uncertainties in industrial wastewater data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-105.

Table 7-105 Uncertainty assessment for industrial wastewater treatment on the category "Industrial wastewater (5.D.2.-)"

Item	GHGs	Emission/ removal factor uncertainty [%]		Activity data uncertainty [%]		Emission/ removal uncertainty [%]		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Industrial wastewater treatment	CH_4	-60%	+60%	-30%	+30%	-67%	+67%	The uncertainty is evaluated according to the survey for EFs (MOE, 2018a).	The uncertainty in industrial waste statistics based on expert judgment is used.	Combined by using the formula for propagation of errors.
	N_2O	-95%	+95%	-30%	+30%	-100%	+100%			

- ***Time-series Consistency***

Data on the percentage of industrial wastewater 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. The emissions are calculated in a consistent manner.

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

No recalculations are conducted.

f) Category-specific Planned Improvements

No improvements are planned.

7.5.2.2. Natural Decomposition of Industrial Wastewater (5.D.2.-)

a) Category Description

Although most of the industrial wastewater in Japan generated in industrial plants and facilities is processed at industrial wastewater treatment plants, treated wastewater which is discharged into public waters contains residual nitrogen. Also, some industrial wastewater is discharged into public waters without any treatment. The CH_4 and N_2O emissions from untreated wastewater decomposing 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 industrial wastewater discharged into public waters are estimated in accordance with the method in the *2006 IPCC Guidelines*, as shown below.

$$E = EF \times A$$

E : Emission of methane or nitrous oxide from the natural decomposition of industrial wastewater [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 industrial wastewater

- ***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 the category "7.5.1.4. Natural Decomposition of Domestic Wastewater (5.D.1.-)".

Table 7-106 CH_4 and N_2O emission factors for the category natural decomposition of industrial wastewater

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 7-103 of "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 industrial wastewater discharged into public waters from industrial plant/facility i [m^3]

Q_i : BOD or TN concentration of untreated industrial wastewater discharged from industrial plant/facility i [g-BOD/L], [g-N/L]

Table 7-107 BOD and TN loadings in untreated wastewater discharged into public waters (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
BOD load																
Manufacture of food	kt-BOD	8.0	8.5	9.0	16.3	6.2	4.3	4.6	5.0	5.3	5.5	5.5	5.5	5.5	5.5	5.5
Manufacture of beverages, tobacco and feed	kt-BOD	0.6	0.6	0.6	0.6	0.3	0.3	0.2	0.2	0.3	0.4	0.4	0.4	0.4	0.4	0.4
Manufacture of textile products	kt-BOD	3.4	2.9	2.2	2.2	4.4	5.1	3.8	2.5	2.9	3.3	3.3	3.3	3.3	3.3	3.3
Manufacture of pulp, paper and paper products	kt-BOD	9.4	8.9	8.9	8.4	3.6	6.9	5.2	3.4	3.7	4.1	4.1	4.1	4.1	4.1	4.1
Manufacture of chemical and allied product	kt-BOD	49.5	50.6	44.9	46.7	28.3	23.4	25.3	27.2	24.0	20.8	20.8	20.8	20.8	20.8	20.8
Manufacture of petroleum and coal products	kt-BOD	25.4	20.8	24.6	26.9	11.3	8.5	9.8	11.2	10.2	9.1	9.1	9.1	9.1	9.1	9.1
Manufacture of plastic products	kt-BOD	0.6	0.6	0.6	0.8	0.7	0.5	0.6	0.6	0.4	0.1	0.1	0.1	0.1	0.1	0.1
Manufacture of rubber products	kt-BOD	0.2	0.1	0.1	0.1	0.1	0.04	0.1	0.1	0.1	0.04	0.04	0.04	0.04	0.04	0.04
Manufacture of leather tanning, leather products and fur skins	kt-BOD	0.3	0.3	0.2	0.1	0.001	0.001	0.001	0.002	0.001	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002
Manufacture of iron and steel	kt-BOD	39.7	37.3	40.3	36.5	26.1	19.1	22.5	26.0	22.2	18.5	18.5	18.5	18.5	18.5	18.5
TN load																
Manufacture of food	kt-N	5.0	5.3	5.6	5.3	3.2	3.3	2.9	2.6	2.5	2.4	2.4	2.4	2.4	2.4	2.4
Manufacture of beverages, tobacco and feed	kt-N	0.6	0.6	0.6	0.4	0.3	0.3	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3
Manufacture of textile products	kt-N	0.8	0.7	0.5	0.4	1.7	1.8	1.7	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
Manufacture of 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	0.5	0.5	0.5
Manufacture of chemical and allied product	kt-N	31.4	32.2	28.5	28.2	21.3	16.1	15.8	15.5	15.9	16.2	16.2	16.2	16.2	16.2	16.2
Manufacture of petroleum and coal products	kt-N	19.6	16.0	18.9	8.8	7.6	7.2	7.0	6.7	6.5	6.3	6.3	6.3	6.3	6.3	6.3
Manufacture of plastic products	kt-N	0.3	0.3	0.3	0.4	0.3	0.3	0.3	0.4	0.2	0.1	0.1	0.1	0.1	0.1	0.1
Manufacture of rubber products	kt-N	0.3	0.3	0.2	0.3	0.1	0.1	0.1	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Manufacture of 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	0.001	0.001	0.001
Manufacture of iron and steel	kt-N	33.3	31.2	33.7	41.8	17.6	14.9	14.6	14.2	14.7	15.2	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 industrial wastewater discharged into public water from industrial plant/facility i [m^3]

TN_i : TN concentration in treated industrial wastewater discharged from industrial plant/facility i [g-N/L]

Table 7-108 TN loadings in treated industrial wastewater discharged into public waters (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Manufacture of food	kt-N	5.8	6.2	6.5	7.0	4.0	7.9	6.6	5.3	5.3	5.4	5.4	5.4	5.4	5.4	5.4
Manufacture of beverages, tobacco and feed	kt-N	1.1	1.1	1.1	0.7	0.6	0.5	0.4	0.4	0.7	1.1	1.1	1.1	1.1	1.1	1.1
Manufacture of textile products	kt-N	2.5	2.1	1.6	2.1	1.7	1.5	1.3	1.1	1.2	1.4	1.4	1.4	1.4	1.4	1.4
Manufacture of pulp, paper and paper products	kt-N	8.4	8.0	8.0	8.0	5.4	3.8	4.1	4.4	5.6	6.8	6.8	6.8	6.8	6.8	6.8
Manufacture of chemical and allied product	kt-N	17.0	17.4	15.5	14.2	15.9	13.7	13.2	12.7	11.2	9.7	9.7	9.7	9.7	9.7	9.7
Manufacture of 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	0.5	0.5	0.5
Manufacture of 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	0.1	0.1	0.1
Manufacture of 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	0.1	0.1	0.1
Manufacture of leather tanning, leather products and fur skins	kt-N	0.28	0.23	0.18	0.09	0.04	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Manufacture of iron and steel	kt-N	5.3	5.0	5.4	4.1	3.1	2.1	2.4	2.7	2.8	2.9	2.9	2.9	2.9	2.9	2.9

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

As for the uncertainties in emission factors for CH_4 and N_2O in this category, the uncertainties in similar emission sources are substituted. As for the uncertainties in activity data, the uncertainties in industrial wastewater data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-109.

Table 7-109 Uncertainty assessment for natural decomposition of industrial wastewater on the category "Industrial wastewater (5.D.2.-)"

Item	GHGs	Emission/ removal factor uncertainty		Activity data uncertainty		Emission/ removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
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 industrial waste statistics based on expert judgment is used.	Combined by using the formula for propagation of errors.
	N_2O	-58%	+58%	-30%	+30%	-66%	+66%	Due to the lack of information for the uncertainty of the emission factor, the uncertainty in CH_4 is substituted based on expert judgment.		

- ***Time-series Consistency***

The emissions are calculated in a consistent manner.

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

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 MSW 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 thorough organic waste disposed of in MSW and IW landfill sites are applied for its activity data, and the methodology for the natural decomposition of domestic wastewater 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
EF : CH_4 and N_2O emission factor
L_i : Potential BOD load [kg-BOD] and TN load [kg-N] to be remained in leachate percolated thorough organic waste disposed of in MSW and IW landfill sites

- ***Emission Factors***

Emission factors for CH_4 and N_2O are determined in accordance with the methodology for the natural decomposition of domestic wastewater 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 maximum CH_4 generation potential (B_0) is determined to be 0.6 kg-CH_4/kg-BOD which is a default value for "Domestic waste water" 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*.

$$\begin{aligned} EF_{CH4} &= B_0 \times MCF \\ &= 0.6 \quad [\text{kg-CH}_4/\text{kg-BOD}] \quad \times 0.8 \\ &= 0.48 \quad [\text{kg-CH}_4/\text{kg-BOD}] \end{aligned}$$

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 MSW 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 thorough organic waste disposed of in MSW 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 thorough organic waste disposed of in MSW 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 7-110 BOD load and TN load of landfill leachate (Activity data)

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
BOD load	kt-BOD	2.6	2.5	2.2	1.6	0.8	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.3	0.3
TN load	kt-N	3.5	3.3	3.0	2.2	1.1	0.8	0.7	0.7	0.6	0.6	0.6	0.5	0.5	0.4	0.4

c) Uncertainties and Time-series Consistency

- ***Uncertainties***

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 substituted. As for the uncertainties in activity data, the uncertainties in industrial wastewater data indicated in Table 7-2 are applied. Details of the uncertainty assessment on this category are indicated in the Table 7-111.

Table 7-111 Uncertainty assessment for landfill leachate treatment on the category "Industrial wastewater (5.D.2.-)"

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Landfill leachate treatment	CH_4	-39%	+39%	-100%	+100%	-107%	+107%	The uncertainty is quoted from MOE (2010), a reference of emission factors.	Due to the lack of information for the uncertainty of the activity data, the uncertainty is assessed by expert judgment.	Combined by using the formula for propagation of errors.
	N_2O	-39%	+39%	-100%	+100%	-107%	+107%	Due to the lack of information for the uncertainty of the emission factor, the uncertainty in the EF of CH4 in this category is substituted 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

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

By updating the statistical data, CH_4 and N_2O emissions from FY2017 onward 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 7-113.

Table 7-112 Categories whose emissions are estimated for other (5.E.)

Category	Waste type	Treatment type	CO_2	CH_4	N_2O
5.E.1. (7.6.1)	Fossil-fuel Derived Surfactants	Decomposition at wastewater treatment facilities and/or the environment	○	NA	NA

In FY2022, emissions from this source category are 654 kt-CO_2 eq. and accounted for 0.06% of the national total emissions (excluding LULUCF). The emissions from this source category had decreased by 6.9% compared to those in FY1990. This emission decrease is primarily due to the decrease in CO_2 emissions from the use of alkylbenzenes by introduction of the Pollutant Release and Transfer Register (PRTR).

Table 7-113 GHG emissions from category other (5.E.)

Gas	Category	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
CO_2	5.E. Other (Decomposition of fossil-fuel derived surfactants)	kt-CO_2	703	668	656	507	527	605	617	625	619	637	673	582	597	679	654

7.6.1. Decomposition of Fossil-fuel Derived Surfactants (5.E.-)

a) Category Description

Surfactants are used for various cleaning activities at home and factories in Japan. Fossil-fuel derived surfactants discharged into wastewater treatment facilities and into the environment, and emit CO_2. As this emission source did not correspond to any of the existing waste categories (5.A. to 5.D.), it is included in the "Other (5.E.)" section. Because "CH_4 and N_2O emissions from wastewater treatment" and "CO_2 emissions from the decomposition of fossil-fuel derived surfactants" concern different types of gas, they are unrelated to each other and pose no duplicate inventory issues.

b) Methodological Issues

- ***Estimation Method***

As neither the *2006 IPCC Guidelines* specified a method for determining CO_2 emissions, a method specifically established in Japan is applied to the calculation. Because carbon contained in surfactants that emitted into wastewater treatment facilities and into the environment is eventually oxidized to CO_2 and emitted into the atmosphere as a result of surfactants decomposition, CO_2 emissions are estimated based on the amount of carbon contained in surfactants that emitted into wastewater treatment facilities and into the environment.

Based on the facts stated above, the CO_2 emissions are calculated by multiplying the volume of the fossil-fuel derived surfactant for each type of raw material by the carbon content of each of the materials. The calculation covered 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 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 7-114 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 volume of raw materials used in the surfactants obtained from the statistical data for surfactant use by an import/export adjustment factor.

➢ ***Volume of Surfactants Used***

The volumes of the use of surfactant by material are obtained from the consumption of raw materials for surfactants indicated in the *Current Production Statistics - Chemical Industry*. As there is no compilation of usage since FY2002, the volume of use is estimated using the simple averages (k value) of ratio of consumption and production in the period from FY1990 to FY2001.

➢ ***Export/import Correction Factor***

Correction factor is calculated from the export/import statistics in *International Trade Statistics* by the Ministry of Finance (MOF) for categories of anionic surfactants, cationic surfactants, non-ionic surfactants, and other organic surfactants and the volume of surfactants used. As some of the materials for surfactants are used in several types of surfactants, an average of the export/import correction factor is weighted by surfactant production volume 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 7-115 Activity data associated with decomposition of fossil-fuel derived surfactants

Item	Unit	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Synthetic alcohol	t	29,239	16,253	28,285	31,609	33,750	43,324	42,947	44,299	45,551	45,601	47,840	43,762	48,057	53,151	51,216
Alkyl benzene	t	105,432	102,794	80,832	47,349	50,519	44,980	47,494	44,044	39,485	42,769	44,565	31,291	25,309	26,984	27,720
Alkyl phenol	t	10,141	8,798	7,454	3,448	2,054	4,318	4,885	4,873	4,638	5,661	6,211	4,711	3,677	4,363	4,076
Ethylene oxide	t	124,984	132,175	146,509	127,150	131,148	161,969	163,777	171,380	174,243	176,247	187,729	171,687	184,127	214,129	203,761

c) Uncertainties and Time-series Consistency

- ***Uncertainty***

The uncertainty in emission factor for CO_2 is evaluated by using molecular weight which is used for calculation of emission factors, based on expert judgment. As for activity data, the same assessment as municipal waste statistics is applied based on expert judgment since information on the uncertainty is not available.

Table 7-116 Uncertainty assessment for decomposition of fossil-fuel derived surfactants on the category "Other (5.E.-)"

Item	GHGs	Emission /removal factor uncertainty		Activity data uncertainty		Emission /removal uncertainty		The method of evaluating uncertainty in emission factor	The method of evaluating uncertainty in activity data	The method of evaluating uncertainty in emissions/ removals
		(-)	(+)	(-)	(+)	(-)	(+)			
Decomposition of fossil-fuel derived surfactants	CO_2	-1%	+1%	-10%	+10%	-10%	+10%	The uncertainty is assessed by using molecular weight data based on expert judgment.	Due to the lack of information for the uncertainty of the activity data, the uncertainty in municipal waste statistics is substituted by expert judgment.	Combined by using the formula for propagation of errors.

- ***Time-series Consistency***

Consistent methodology is used in the estimation. However, data on the amount of raw materials consumed for surfactants have become not available since FY2002 and activity data are estimated from the production amount of the surfactants.

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

No recalculations are conducted.

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*;

[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.

$$E_{CO2} = E_{CH4} \times \frac{44}{16}$$

$$E_{CO2} = E_{NMVOC} \times C \times \frac{44}{12}$$

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).

$$E = N_{Volatilization} \times EF \times 44/28$$

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 and Time-series Consistency

- ***Uncertainty***

Refer to 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 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.

In addition, in accordance with the *MPGs*, the values for the inventory submitted in 2024 are based on the GWP values as described in the IPCC Fifth Assessment Report (AR5). In the previous submission, the calculations were based on the GWP of AR4 in accordance with the *UNFCCC Inventory Reporting Guidelines*. Therefore, a recalculation was necessary due to the change in GWP.

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 (energy; industrial processes and product use; agriculture; land use, land-use change and forestry; and waste) are described separately under sections named as “Category-specific Recalculations” in Chapters 3 to 7. However, recalculations due to changes in GWP are in principle not described.

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 FY 2021 have been recalculated in many categories.

10.2. Implications for Emission and Removal Levels

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”.

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) increased by 0.01%, and the total emissions in year FY 2021 decreased by 0.50% (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 2023 and 2024

[Mt-CO_2 eq.]

		1990	1991	1992	1993	1994	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021
CO_2	JNGI 2023	1,092.9	1,095.8	1,101.9	1,091.6	1,146.9	1,159.6	1,178.8	1,200.5	1,143.2	1,250.0	1,201.8	1,166.5	1,149.7	1,130.0	1,085.4	1,053.4	987.7	1,010.0
with LULUCF	JNGI 2024	1,083.7	1,089.8	1,095.8	1,085.6	1,140.7	1,153.4	1,175.5	1,198.7	1,135.5	1,241.4	1,193.5	1,158.8	1,142.7	1,123.5	1,079.2	1,047.7	981.7	1,003.1
(excl. Indirect CO_2)	*difference*	*-0.84%*	*-0.54%*	*-0.55%*	*-0.55%*	*-0.54%*	*-0.53%*	*-0.28%*	*-0.15%*	*-0.68%*	*-0.69%*	*-0.69%*	*-0.66%*	*-0.61%*	*-0.58%*	*-0.57%*	*-0.54%*	*-0.61%*	*-0.68%*
CO_2	JNGI 2023	1,157.2	1,168.9	1,178.7	1,171.7	1,226.7	1,239.0	1,263.8	1,290.1	1,214.7	1,315.2	1,264.1	1,223.2	1,202.5	1,186.8	1,141.7	1,104.5	1,039.8	1,062.1
without LULUCF	JNGI 2024	1,157.4	1,169.1	1,178.9	1,171.9	1,226.9	1,239.2	1,264.0	1,290.3	1,214.8	1,315.3	1,263.8	1,223.2	1,203.2	1,187.5	1,142.5	1,105.5	1,040.5	1,061.9
(excl. Indirect CO_2)	*difference*	*0.02%*	*0.01%*	*0.02%*	*0.01%*	*0.02%*	*0.01%*	*0.02%*	*0.01%*	*0.01%*	*0.01%*	*-0.02%*	*0.00%*	*0.06%*	*0.06%*	*0.07%*	*0.08%*	*0.07%*	*-0.03%*
CH_4	JNGI 2023	44.6	44.0	43.9	43.0	43.1	41.9	37.4	34.1	31.2	29.2	28.7	28.3	28.3	28.1	27.7	27.6	27.4	27.4
with LULUCF	JNGI 2024	49.9	49.2	49.1	48.1	48.2	46.8	41.8	38.2	34.9	32.7	32.2	31.8	31.7	31.5	31.0	30.7	30.5	30.5
	difference	*11.84%*	*11.86%*	*11.88%*	*11.89%*	*11.90%*	*11.90%*	*11.94%*	*12.03%*	*12.10%*	*12.07%*	*12.06%*	*12.06%*	*12.06%*	*12.09%*	*11.81%*	*11.49%*	*11.05%*	*11.03%*
	(from GWP change)	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*
CH_4	JNGI 2023	44.5	43.9	43.8	42.9	42.9	41.8	37.3	34.1	31.1	29.1	28.6	28.3	28.2	28.0	27.7	27.5	27.4	27.4
without LULUCF	JNGI 2024	49.8	49.1	49.0	48.0	48.1	46.7	41.7	38.2	34.8	32.7	32.1	31.7	31.6	31.4	30.9	30.6	30.4	30.4
	difference	*11.84%*	*11.86%*	*11.88%*	*11.89%*	*11.90%*	*11.90%*	*11.94%*	*12.03%*	*12.09%*	*12.07%*	*12.06%*	*12.06%*	*12.06%*	*12.09%*	*11.81%*	*11.48%*	*11.05%*	*11.02%*
	(from GWP change)	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*
N_2O	JNGI 2023	33.2	32.8	33.0	32.8	34.0	34.3	31.0	26.0	23.3	22.4	21.9	21.6	21.1	21.3	20.8	20.4	20.1	19.9
with LULUCF	JNGI 2024	29.7	29.4	29.5	29.4	30.4	30.7	27.6	23.3	21.1	20.3	19.9	19.6	19.1	19.4	18.9	18.4	18.1	18.0
	difference	*-10.35%*	*-10.38%*	*-10.49%*	*-10.42%*	*-10.63%*	*-10.60%*	*-10.89%*	*-10.31%*	*-9.41%*	*-9.06%*	*-9.24%*	*-9.25%*	*-9.21%*	*-9.15%*	*-9.37%*	*-9.74%*	*-9.93%*	*-9.42%*
	(from GWP change)	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*
N_2O	JNGI 2023	32.2	31.9	32.1	32.0	33.2	33.5	30.2	25.3	22.7	21.9	21.5	21.2	20.6	20.9	20.4	20.0	19.7	19.5
without LULUCF	JNGI 2024	28.9	28.6	28.7	28.6	29.6	29.9	26.9	22.7	20.6	19.9	19.5	19.2	18.7	19.0	18.5	18.0	17.7	17.6
	difference	*-10.37%*	*-10.41%*	*-10.53%*	*-10.47%*	*-10.68%*	*-10.65%*	*-10.95%*	*-10.39%*	*-9.49%*	*-9.15%*	*-9.34%*	*-9.36%*	*-9.33%*	*-9.27%*	*-9.50%*	*-9.89%*	*-10.10%*	*-9.60%*
	(from GWP change)	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*
HFCs	JNGI 2023	15.9	17.4	17.8	18.1	21.1	25.2	22.9	12.8	23.3	32.1	35.8	39.3	42.6	45.0	47.1	50.0	52.2	53.6
	JNGI 2024	13.4	14.6	15.0	15.4	18.0	21.6	19.8	11.8	22.0	30.3	33.8	37.1	39.5	41.0	42.3	44.5	46.1	46.9
	difference	*-15.87%*	*-15.85%*	*-15.77%*	*-15.15%*	*-14.74%*	*-14.50%*	*-13.20%*	*-7.28%*	*-5.86%*	*-5.58%*	*-5.48%*	*-5.50%*	*-7.41%*	*-8.91%*	*-10.09%*	*-11.01%*	*-11.62%*	*-12.44%*
PFCs	JNGI 2023	6.6	7.5	7.6	11.0	13.5	17.7	11.9	8.6	4.3	3.3	3.4	3.3	3.4	3.5	3.5	3.4	3.5	3.2
	JNGI 2024	6.2	7.0	7.1	10.1	12.4	16.2	10.5	7.8	3.8	3.0	3.1	3.0	3.1	3.2	3.2	3.2	3.2	2.9
	difference	*-5.99%*	*-6.53%*	*-6.77%*	*-7.49%*	*-7.78%*	*-8.37%*	*-11.95%*	*-9.79%*	*-9.96%*	*-9.34%*	*-9.00%*	*-8.98%*	*-9.04%*	*-9.36%*	*-8.59%*	*-8.35%*	*-8.19%*	*-7.94%*
SF_6	JNGI 2023	12.9	14.2	15.6	15.7	15.0	16.4	7.0	5.0	2.4	2.1	2.0	2.1	2.2	2.1	2.1	2.0	2.0	2.0
	JNGI 2024	13.8	15.2	16.8	16.8	16.1	17.6	8.2	5.8	2.8	2.3	2.3	2.4	2.4	2.3	2.3	2.2	2.2	2.2
	difference	*7.11%*	*7.15%*	*7.17%*	*7.15%*	*7.14%*	*7.16%*	*16.49%*	*15.92%*	*15.89%*	*13.04%*	*12.22%*	*14.01%*	*11.54%*	*12.22%*	*10.57%*	*10.05%*	*10.74%*	*9.31%*
	(from GWP change)	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*
NF_3	JNGI 2023	0.03	0.03	0.03	0.04	0.08	0.20	0.29	1.47	1.54	1.62	1.12	0.57	0.63	0.45	0.31	0.29	0.34	0.38
	JNGI 2024	0.03	0.03	0.03	0.04	0.07	0.17	0.26	1.36	1.42	1.50	1.04	0.52	0.58	0.41	0.28	0.26	0.29	0.33
	difference	*-14.23%*	*-14.23%*	*-14.23%*	*-14.23%*	*-14.23%*	*-14.23%*	*-9.66%*	*-7.42%*	*-7.55%*	*-6.98%*	*-7.22%*	*-8.16%*	*-8.34%*	*-9.54%*	*-11.60%*	*-12.82%*	*-13.11%*	*-12.78%*
	(from GWP change)	*-6.40%*	*-6.40%*	*-6.40%*	*-6.40%*	*-6.40%*	*-6.40%*	*-6.40%*	*-6.40%*	*-6.40%*	*-6.40%*	*-6.40%*	*-6.40%*	*-6.40%*	*-6.40%*	*-6.40%*	*-6.40%*	*-6.40%*	*-6.40%*
Indirect CO_2	JNGI 2023	5.5	5.3	5.0	4.8	4.8	4.7	4.2	3.2	2.4	2.3	2.2	2.2	2.1	2.1	2.1	2.0	1.9	1.9
	JNGI 2024	5.5	5.3	5.0	4.8	4.8	4.7	4.2	3.3	2.4	2.3	2.2	2.2	2.2	2.1	2.1	2.0	1.9	1.8
	difference	*0.15%*	*0.18%*	*0.19%*	*0.20%*	*0.20%*	*0.21%*	*0.22%*	*0.33%*	*0.47%*	*0.44%*	*0.43%*	*0.43%*	*0.45%*	*0.48%*	*0.46%*	*0.45%*	*0.45%*	*-1.48%*
Total	JNGI 2023	1,269.3	1,283.8	1,295.6	1,291.4	1,352.4	1,373.8	1,373.3	1,377.5	1,300.0	1,405.4	1,356.5	1,317.8	1,300.1	1,286.7	1,242.7	1,207.7	1,144.9	1,168.1
without LULUCF	JNGI 2024	1,269.4	1,283.6	1,295.4	1,290.9	1,351.1	1,371.4	1,371.3	1,378.0	1,300.2	1,405.0	1,355.6	1,317.1	1,299.1	1,284.8	1,240.0	1,204.2	1,140.5	1,162.2
excl. Indirect CO_2	*difference*	*0.01%*	*-0.01%*	*-0.02%*	*-0.04%*	*-0.10%*	*-0.18%*	*-0.14%*	*0.04%*	*0.01%*	*-0.02%*	*-0.07%*	*-0.06%*	*-0.08%*	*-0.15%*	*-0.22%*	*-0.29%*	*-0.39%*	*-0.50%*
Total	JNGI 2023	1,206.1	1,211.7	1,219.8	1,212.4	1,273.6	1,295.3	1,289.2	1,288.6	1,229.2	1,340.7	1,294.8	1,261.7	1,247.9	1,230.5	1,186.9	1,157.0	1,093.3	1,116.4
with LULUCF	JNGI 2024	1,196.7	1,205.3	1,213.3	1,205.6	1,265.8	1,286.4	1,283.7	1,287.2	1,221.5	1,331.7	1,285.8	1,253.2	1,239.1	1,221.3	1,177.2	1,147.0	1,082.2	1,103.9
excl. Indirect CO_2	*difference*	*-0.77%*	*-0.53%*	*-0.53%*	*-0.56%*	*-0.61%*	*-0.68%*	*-0.43%*	*-0.11%*	*-0.63%*	*-0.67%*	*-0.69%*	*-0.67%*	*-0.70%*	*-0.75%*	*-0.82%*	*-0.87%*	*-1.02%*	*-1.12%*
Total	JNGI 2023	1,274.8	1,289.1	1,300.6	1,296.2	1,357.2	1,378.5	1,377.5	1,380.7	1,302.5	1,407.6	1,358.7	1,320.0	1,302.3	1,288.8	1,244.8	1,209.7	1,146.8	1,170.0
without LULUCF	JNGI 2024	1,274.9	1,288.9	1,300.4	1,295.7	1,355.9	1,376.1	1,375.6	1,381.3	1,302.6	1,407.3	1,357.8	1,319.3	1,301.2	1,286.9	1,242.1	1,206.2	1,142.3	1,164.0
incl. Indirect CO_2	*difference*	*0.01%*	*-0.01%*	*-0.01%*	*-0.04%*	*-0.10%*	*-0.17%*	*-0.14%*	*0.04%*	*0.01%*	*-0.02%*	*-0.07%*	*-0.06%*	*-0.08%*	*-0.15%*	*-0.22%*	*-0.29%*	*-0.39%*	*-0.51%*
Total	JNGI 2023	1,211.5	1,217.0	1,224.9	1,217.1	1,278.4	1,299.9	1,293.5	1,291.9	1,231.6	1,343.0	1,297.0	1,263.9	1,250.0	1,232.6	1,189.0	1,159.0	1,095.2	1,118.3
with LULUCF	JNGI 2024	1,202.2	1,210.7	1,218.4	1,210.4	1,270.6	1,291.1	1,287.9	1,290.4	1,223.9	1,334.0	1,288.1	1,255.4	1,241.2	1,223.4	1,179.2	1,149.0	1,084.0	1,105.8
incl. Indirect CO_2	*difference*	*-0.77%*	*-0.52%*	*-0.53%*	*-0.56%*	*-0.60%*	*-0.68%*	*-0.43%*	*-0.11%*	*-0.63%*	*-0.67%*	*-0.69%*	*-0.67%*	*-0.70%*	*-0.75%*	*-0.82%*	*-0.87%*	*-1.02%*	*-1.12%*

Table 10-2 Comparison of emissions and removals in the inventories submitted in 2023 and 2024 (Energy sector)

1. Energy [Mt-CO_2 eq.]

Category	Gas		1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021
A. Fuel Combustion	CO_2	JNGI 2023	368.5	378.9	395.5	449.7	473.8	583.5	553.4	527.3	521.5	507.7	470.2	447.7	436.0	444.3
1. Energy Industries		JNGI 2024	368.2	378.5	395.0	449.1	473.3	582.9	552.3	526.8	521.5	507.8	470.3	447.7	436.1	442.7
		difference	*-0.10%*	*-0.11%*	*-0.12%*	*-0.12%*	*-0.12%*	*-0.09%*	*-0.18%*	*-0.10%*	*0.01%*	*0.01%*	*0.02%*	*0.02%*	*0.03%*	*-0.37%*
	CH_4	JNGI 2023	0.5	0.4	0.3	0.2	0.3	0.2	0.2	0.3	0.4	0.4	0.4	0.4	0.4	0.4
		JNGI 2024	0.5	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.3	0.2	0.2
		difference	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*11.99%*	*12.00%*	*12.01%*	*12.12%*	*-2.59%*	*-18.21%*	*-42.68%*	*-42.98%*
	N_2O	JNGI 2023	0.9	1.4	1.6	2.1	2.1	2.4	2.3	2.4	2.3	2.4	2.3	1.9	1.9	1.9
		JNGI 2024	0.8	1.2	1.4	1.9	1.8	2.1	2.1	2.1	2.0	2.2	2.0	1.7	1.6	1.7
		difference	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.13%*	*-11.07%*	*-11.01%*	*-11.01%*	*-11.43%*	*-12.05%*	*-12.53%*	*-12.78%*
A. Fuel Combustion	CO_2	JNGI 2023	349.8	357.7	346.9	334.6	301.1	304.9	297.3	288.1	274.3	269.9	267.4	260.0	233.7	249.5
2. Manufacturing Industries		JNGI 2024	349.7	357.6	346.9	334.5	301.0	304.8	297.3	288.0	274.2	270.3	267.6	260.3	233.2	250.4
and Construction		*difference*	*-0.02%*	*-0.03%*	*-0.02%*	*-0.02%*	*-0.02%*	*-0.01%*	*0.00%*	*-0.03%*	*-0.01%*	*0.13%*	*0.06%*	*0.11%*	*-0.23%*	*0.34%*
	CH_4	JNGI 2023	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.6	0.6	0.6	0.5	0.5
		JNGI 2024	0.4	0.4	0.4	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.5
		difference	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.01%*	*11.98%*	*12.00%*	*12.13%*	*7.69%*	*2.65%*	*-0.72%*	*0.06%*
	N_2O	JNGI 2023	1.3	1.7	1.9	1.9	1.7	1.8	1.7	1.7	1.7	1.7	1.6	1.6	1.5	1.5
		JNGI 2024	1.1	1.5	1.7	1.7	1.5	1.6	1.5	1.5	1.5	1.5	1.5	1.4	1.3	1.3
		difference	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.08%*	*-11.08%*	*-11.07%*	*-11.08%*	*-11.07%*	*-11.02%*	*-11.34%*	*-11.71%*	*-11.98%*	*-11.85%*
A. Fuel Combustion	CO_2	JNGI 2023	202.1	242.8	253.1	238.1	222.0	215.1	210.1	208.9	207.1	205.3	203.0	199.0	176.6	177.9
3. Transport		JNGI 2024	202.1	242.8	253.1	238.1	222.0	215.1	210.1	208.9	207.1	205.3	203.0	199.0	176.6	177.9
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-0.01%*
	CH_4	JNGI 2023	0.3	0.3	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		JNGI 2024	0.3	0.3	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		difference	*2.24%*	*2.11%*	*2.05%*	*1.11%*	*-0.88%*	*-2.65%*	*-3.41%*	*-3.73%*	*-4.33%*	*-4.81%*	*-5.33%*	*-5.90%*	*-7.32%*	*-8.37%*
	N_2O	JNGI 2023	3.7	4.1	4.0	2.8	2.1	1.8	1.7	1.7	1.6	1.6	1.6	1.6	1.4	1.4
		JNGI 2024	3.4	3.8	3.7	2.6	1.9	1.7	1.6	1.6	1.5	1.5	1.5	1.5	1.3	1.3
		difference	*-8.50%*	*-8.56%*	*-8.45%*	*-7.85%*	*-7.40%*	*-6.91%*	*-6.77%*	*-6.77%*	*-6.66%*	*-6.66%*	*-6.54%*	*-6.27%*	*-5.72%*	*-5.63%*
A. Fuel Combustion	CO_2	JNGI 2023	158.2	175.4	190.3	196.0	156.9	149.3	141.9	139.2	140.9	144.7	141.8	140.7	140.2	135.5
4. Other Sectors		JNGI 2024	158.2	175.4	190.3	196.0	156.9	149.3	142.0	139.2	140.9	144.3	141.6	140.5	140.5	134.8
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-0.03%*	*-0.01%*	*0.01%*	*-0.04%*	*0.00%*	*-0.27%*	*-0.18%*	*-0.18%*	*0.21%*	*-0.47%*
	CH_4	JNGI 2023	0.2	0.3	0.3	0.5	0.5	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
		JNGI 2024	0.3	0.3	0.4	0.6	0.5	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2
		difference	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.14%*	*12.21%*	*12.15%*	*12.07%*	*11.93%*	*17.73%*	*23.75%*	*29.47%*	*24.69%*
	N_2O	JNGI 2023	0.7	0.8	0.8	0.7	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.6
		JNGI 2024	0.6	0.7	0.7	0.7	0.6	0.5	0.5	0.5	0.6	0.6	0.6	0.5	0.5	0.5
		difference	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.08%*	*-10.94%*	*-10.89%*	*-10.91%*	*-10.93%*	*-10.99%*	*-16.48%*	*-22.19%*	*-26.80%*	*-27.34%*
B. Fugitive Emissions	CO_2	JNGI 2023	0.006	0.004	0.003	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
1. Solid Fuels		JNGI 2024	0.006	0.004	0.003	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.39%*
	CH_4	JNGI 2023	4.9	2.5	1.6	0.7	0.6	0.6	0.6	0.5	0.5	0.6	0.5	0.5	0.5	0.5
		JNGI 2024	5.5	2.8	1.8	0.8	0.7	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.5	0.5
		difference	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*15.35%*
	N_2O	JNGI 2023	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000
		JNGI 2024	0.002	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000	0.000
		difference	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-12.38%*
B. Fugitive Emissions	CO_2	JNGI 2023	0.2	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.5	0.4	0.4	0.4	0.4	0.4
2. Oil and Natural Gas		JNGI 2024	0.2	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.5	0.5	0.4	0.4	0.4	0.4
		difference	*5.68%*	*0.74%*	*2.76%*	*4.46%*	*4.99%*	*4.74%*	*4.19%*	*4.42%*	*4.30%*	*4.69%*	*4.41%*	*4.05%*	*3.81%*	*4.16%*
	CH_4	JNGI 2023	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2
		JNGI 2024	0.3	0.4	0.4	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3
		difference	*41.68%*	*42.77%*	*39.80%*	*40.53%*	*43.94%*	*43.86%*	*43.56%*	*43.28%*	*42.23%*	*44.46%*	*43.21%*	*43.70%*	*44.42%*	*43.91%*
	N_2O	JNGI 2023	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		JNGI 2024	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		difference	*15.70%*	*-12.49%*	*27.50%*	*54.24%*	*65.86%*	*64.48%*	*59.06%*	*63.05%*	*70.04%*	*73.27%*	*73.43%*	*50.42%*	*48.42%*	*53.77%*
1. Total	GHG	JNGI 2023	1,091.9	1,167.4	1,197.8	1,228.8	1,163.1	1,261.7	1,211.5	1,172.3	1,152.5	1,136.6	1,091.1	1,055.5	994.1	1,015.0
		JNGI 2024	1,091.6	1,166.7	1,196.9	1,227.8	1,162.2	1,260.8	1,210.2	1,171.3	1,152.2	1,136.3	1,090.7	1,055.1	993.4	1,012.9
		difference	*-0.02%*	*-0.06%*	*-0.08%*	*-0.08%*	*-0.08%*	*-0.07%*	*-0.11%*	*-0.08%*	*-0.02%*	*-0.03%*	*-0.04%*	*-0.04%*	*-0.07%*	*-0.20%*

*Excluding Indirect CO_2

Table 10-3 Comparison of emissions and removals in the inventories submitted in 2023 and 2024 (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	2014	2015	2016	2017	2018	2019	2020	2021
A. Mineral Industry	CO_2	JNGI 2023	48.7	50.7	43.5	41.1	32.7	34.9	34.7	33.5	33.4	33.9	33.6	32.2	30.7	31.1
		JNGI 2024	48.7	50.7	43.5	41.1	32.7	34.9	34.7	33.5	33.4	33.9	33.6	32.2	30.7	31.1
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-0.17%*
B. Chemical Industry	CO_2	JNGI 2023	6.5	6.5	6.3	5.5	5.1	4.5	4.4	4.3	4.0	4.2	3.9	4.0	3.4	4.1
		JNGI 2024	6.1	6.1	6.0	5.2	4.9	4.2	4.1	4.0	3.7	3.9	3.6	3.8	3.1	3.8
		difference	*-6.03%*	*-6.23%*	*-5.00%*	*-4.87%*	*-5.56%*	*-6.63%*	*-6.82%*	*-7.58%*	*-8.25%*	*-7.67%*	*-7.79%*	*-7.19%*	*-8.10%*	*-6.45%*
	CH_4	JNGI 2023	0.04	0.04	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.03
		JNGI 2024	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03
		difference	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*
	N_2O	JNGI 2023	9.6	9.7	6.3	2.6	1.8	1.3	1.0	0.8	0.7	0.6	0.5	0.6	0.7	0.4
		JNGI 2024	8.6	8.6	5.6	2.3	1.6	1.1	0.9	0.7	0.6	0.5	0.4	0.5	0.6	0.4
		difference	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*
	HFCs	JNGI 2023	15.9	22.0	16.0	1.0	0.2	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.2	0.3
		JNGI 2024	13.3	18.5	13.4	0.9	0.2	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.2	0.2
		difference	*-16.22%*	*-16.06%*	*-16.11%*	*-13.25%*	*-11.88%*	*-10.35%*	*-10.98%*	*-11.33%*	*-9.40%*	*-11.28%*	*-9.83%*	*-9.83%*	*-13.54%*	*-12.64%*
	PFCs	JNGI 2023	0.3	0.9	1.7	1.0	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		JNGI 2024	0.3	0.8	1.5	1.0	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		difference	*-8.18%*	*-8.18%*	*-9.79%*	*-8.26%*	*-8.57%*	*-9.32%*	*-9.67%*	*-9.48%*	*-9.44%*	*-9.46%*	*-9.26%*	*-9.16%*	*-8.98%*	*-9.14%*
	SF_6	JNGI 2023	3.5	4.5	0.8	0.9	0.2	0.1	0.1	0.1	0.1	0.04	0.05	0.04	0.05	0.05
		JNGI 2024	3.6	4.6	0.8	1.0	0.2	0.1	0.1	0.1	0.1	0.04	0.05	0.04	0.05	0.05
		difference	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*
	NF_3	JNGI 2023	0.003	0.02	0.1	1.2	1.3	1.5	1.0	0.4	0.4	0.2	0.06	0.02	0.02	0.02
		JNGI 2024	0.003	0.02	0.1	1.2	1.2	1.4	0.9	0.4	0.4	0.2	0.05	0.02	0.01	0.02
		difference	*-6.40%*	*-6.40%*	*-6.40%*	*-6.40%*	*-6.40%*	*-6.40%*	*-6.40%*	*-6.40%*	*-6.40%*	*-6.40%*	*-6.40%*	*-6.40%*	*-6.40%*	*-6.40%*
C. Metal Industry	CO_2	JNGI 2023	7.3	6.9	6.8	6.6	6.3	6.4	6.3	6.1	6.0	5.9	5.8	5.4	5.0	5.5
		JNGI 2024	7.3	6.9	6.9	6.7	6.4	6.4	6.3	6.1	6.0	5.9	5.8	5.5	5.1	5.4
		difference	*0.36%*	*0.43%*	*0.40%*	*0.63%*	*0.65%*	*0.63%*	*0.61%*	*0.64%*	*0.69%*	*0.66%*	*0.68%*	*0.80%*	*0.66%*	*-0.58%*
	CH_4	JNGI 2023	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.02
		JNGI 2024	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		difference	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*
	HFCs	JNGI 2023	NO	NO	NO	NO	NO	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.002
		JNGI 2024	NO	NO	NO	NO	NO	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.001	0.002
		difference	*NA*	*NA*	*NA*	*NA*	*NA*	*-9.09%*	*-9.09%*	*-9.09%*	*-9.09%*	*-9.09%*	*-9.09%*	*-9.09%*	*-9.09%*	*-9.09%*
	PFCs	JNGI 2023	0.20	0.17	0.04	0.04	0.03	0.02	0.00	NO	NO	NO	NO	NO	NO	NO
		JNGI 2024	0.30	0.15	0.04	0.03	0.02	0.01	0.00	NO	NO	NO	NO	NO	NO	NO
		difference	*48.03%*	*-10.14%*	*-10.14%*	*-10.14%*	*-10.14%*	*-10.14%*	*-10.14%*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*	*NA*
	SF_6	JNGI 2023	0.1	0.1	1.0	1.1	0.3	0.2	0.2	0.2	0.3	0.2	0.3	0.3	0.3	0.3
		JNGI 2024	0.2	0.1	1.0	1.1	0.3	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3
		difference	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*	*3.07%*
D. Non-energy Products from Fuels and Solvent Use	CO_2	JNGI 2023	2.0	2.4	2.7	2.9	2.8	2.7	2.5	2.5	2.6	2.7	2.7	2.6	2.3	2.3
		JNGI 2024	2.2	2.6	2.8	3.0	2.9	2.8	2.7	2.6	2.7	2.8	2.9	2.8	2.5	2.5
		difference	*8.21%*	*7.32%*	*6.85%*	*5.80%*	*5.37%*	*4.77%*	*4.92%*	*4.62%*	*4.19%*	*4.05%*	*7.67%*	*7.82%*	*8.09%*	*8.81%*

*Excluding Indirect CO_2

Table 10-3 Comparison of emissions and removals in the inventories submitted in 2023 and 2024 (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	2014	2015	2016	2017	2018	2019	2020	2021
E. Electronic Industry	N_2O	JNGI 2023														
		JNGI 2024	0.01	0.03	0.04	0.1	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4
		difference	0.01	0.03	0.04	0.1	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4
	HFCs	JNGI 2023	0.001	0.3	0.3	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		JNGI 2024	0.1	0.4	0.4	0.3	0.2	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.2	0.1
		difference	*7442.42%*	*53.44%*	*52.40%*	*38.58%*	*30.94%*	*17.64%*	*13.97%*	*9.43%*	*19.61%*	*22.71%*	*25.18%*	*31.50%*	*37.83%*	*3.55%*
	PFCs	JNGI 2023	1.5	4.0	7.0	4.7	2.3	1.6	1.7	1.7	1.8	1.9	1.9	1.8	1.9	1.6
		JNGI 2024	1.3	3.5	6.1	4.3	2.0	1.5	1.5	1.5	1.6	1.7	1.7	1.6	1.7	1.5
		difference	*-9.65%*	*-12.41%*	*-12.72%*	*-10.17%*	*-10.89%*	*-10.44%*	*-9.65%*	*-9.71%*	*-9.92%*	*-10.37%*	*-8.86%*	*-8.19%*	*-8.23%*	*-8.01%*
	SF_6	JNGI 2023	0.4	0.5	1.5	1.3	0.5	0.4	0.4	0.4	0.3	0.4	0.3	0.3	0.3	0.3
		JNGI 2024	1.0	1.2	2.5	1.9	0.8	0.5	0.5	0.6	0.5	0.6	0.5	0.5	0.5	0.4
		difference	*127.06%*	*127.06%*	*65.74%*	*52.34%*	*52.00%*	*51.15%*	*44.37%*	*47.60%*	*54.59%*	*54.50%*	*46.36%*	*45.64%*	*49.94%*	*44.54%*
	NF_3	JNGI 2023	0.03	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4
		JNGI 2024	0.03	0.2	0.1	0.2	0.2	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3
		difference	*-14.96%*	*-14.96%*	*-12.03%*	*-12.90%*	*-14.62%*	*-13.66%*	*-12.24%*	*-12.44%*	*-12.48%*	*-12.96%*	*-12.79%*	*-13.27%*	*-13.43%*	*-13.21%*
F. Product Uses as Substitutes for ODS	HFCs	JNGI 2023	0.001	2.9	6.6	11.5	23.0	31.9	35.6	39.1	42.3	44.7	46.9	49.7	51.9	53.2
		JNGI 2024	0.001	2.7	6.0	10.6	21.6	30.1	33.6	36.9	39.2	40.7	42.1	44.2	45.8	46.6
		difference	*-9.02%*	*-9.09%*	*-8.95%*	*-7.64%*	*-6.08%*	*-5.64%*	*-5.52%*	*-5.53%*	*-7.48%*	*-8.99%*	*-10.18%*	*-11.10%*	*-11.72%*	*-12.47%*
	PFCs	JNGI 2023	4.5	12.6	3.2	2.8	1.7	1.5	1.5	1.5	1.5	1.5	1.5	1.6	1.5	1.4
		JNGI 2024	4.2	11.7	2.8	2.5	1.6	1.4	1.4	1.4	1.3	1.4	1.4	1.4	1.3	1.3
		difference	*-7.07%*	*-7.07%*	*-11.45%*	*-9.70%*	*-8.92%*	*-8.11%*	*-8.19%*	*-8.11%*	*-7.86%*	*-7.95%*	*-8.05%*	*-8.29%*	*-7.82%*	*-7.44%*
G. Other Product Manufacture and Use	N_2O	JNGI 2023	0.3	0.4	0.4	0.4	0.3	0.4	0.6	0.4	0.4	0.4	0.4	0.4	0.4	0.6
		JNGI 2024	0.2	0.4	0.3	0.2	0.1	0.1	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		difference	*-15.63%*	*-16.68%*	*-21.49%*	*-38.09%*	*-69.23%*	*-81.34%*	*-53.03%*	*-85.55%*	*-86.46%*	*-85.21%*	*-84.83%*	*-81.94%*	*-82.29%*	*-84.99%*
	HFCs	JNGI 2023	0.008	0.006	0.008	0.005	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.006	0.006	0.007
		JNGI 2024	0.006	0.005	0.006	0.004	0.003	0.002	0.002	0.002	0.003	0.002	0.002	0.005	0.005	0.006
		difference	*-16.22%*	*-16.22%*	*-16.22%*	*-16.22%*	*-16.22%*	*-16.22%*	*-16.22%*	*-16.22%*	*-16.22%*	*-16.22%*	*-16.22%*	*-16.22%*	*-16.22%*	*-16.22%*
	PFCs	JNGI 2023	0.02	0.01	0.02	0.01	0.01	0.02	0.02	0.01	0.03	0.03	0.05	0.06	0.07	0.08
		JNGI 2024	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.04	0.05	0.06	0.07
		difference	*-9.62%*	*-9.62%*	*-9.62%*	*-10%*	*-11.5%*	*-13.04%*	*-12.79%*	*-12.63%*	*-13.71%*	*-13.74%*	*-14.22%*	*-13.87%*	*-13.93%*	*-14.05%*
	SF_6	JNGI 2023	8.8	11.3	3.7	1.7	1.4	1.5	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
		JNGI 2024	9.1	11.6	3.8	1.8	1.5	1.6	1.5	1.5	1.5	1.5	1.4	1.4	1.4	1.4
		difference	*3.07%*	*3.07%*	*3.07%*	*4.76%*	*7.70%*	*5.65%*	*5.55%*	*7.29%*	*3.28%*	*3.28%*	*3.28%*	*3.28%*	*3.34%*	*3.33%*
H. Other	CO_2	JNGI 2023	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		JNGI 2024	0.9	1.0	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	1.0	0.9	0.9	0.9
		difference	*1251.93%*	*1228.14%*	*976.16%*	*946.07%*	*1046.27%*	*866.48%*	*891.64%*	*886.47%*	*809.16%*	*787.36%*	*810.53%*	*846.35%*	*918.70%*	*1004.68%*
2. Total	GHG	JNGI 2023	109.9	136.3	108.3	87.1	80.6	89.4	92.0	93.0	96.1	98.9	99.9	101.1	100.7	103.3
		JNGI 2024	107.4	131.8	105.0	86.5	79.6	87.9	90.4	91.3	93.4	95.4	95.7	96.2	95.2	97.0
		difference	*-2.27%*	*-3.25%*	*-3.05%*	*-0.70%*	*-1.30%*	*-1.61%*	*-1.74%*	*-1.78%*	*-2.81%*	*-3.57%*	*-4.17%*	*-4.87%*	*-5.51%*	*-6.02%*

*Excluding Indirect CO_2

Table 10-4 Comparison of emissions and removals in the inventories submitted in 2023 and 2024 (Agriculture sector)

3. Agriculture [Mt-CO_2 eq.]

Category	Gas		1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021
A. Enteric Fermentation	CH_4	JNGI 2023	9.4	9.3	9.0	8.7	8.2	7.7	7.5	7.5	7.5	7.5	7.5	7.6	7.6	7.7
		JNGI 2024	10.6	10.4	10.0	9.7	9.2	8.7	8.4	8.4	8.4	8.4	8.4	8.5	8.5	8.6
		difference	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*11.98%*
B. Manure Management	CH_4	JNGI 2023	3.4	3.2	3.0	2.8	2.6	2.5	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.5
		JNGI 2024	3.8	3.6	3.4	3.2	2.9	2.8	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
		difference	*11.92%*	*11.92%*	*11.91%*	*11.88%*	*11.85%*	*11.85%*	*11.85%*	*11.86%*	*11.86%*	*11.85%*	*11.86%*	*11.86%*	*11.87%*	*11.85%*
	N_2O	JNGI 2023	4.3	4.1	4.0	4.2	4.4	4.1	4.0	3.9	3.9	4.0	3.9	3.9	3.9	3.9
		JNGI 2024	3.9	3.6	3.5	3.7	3.9	3.6	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5
		difference	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.09%*	*-11.13%*	*-11.15%*	*-11.14%*	*-11.15%*	*-11.17%*	*-11.18%*	*-11.20%*	*-11.20%*	*-11.21%*
C. Rice Cultivation	CH_4	JNGI 2023	12.1	13.1	12.2	12.2	12.2	12.1	12.1	11.9	12.1	12.1	12.0	11.9	12.0	11.9
		JNGI 2024	13.6	14.7	13.6	13.7	13.6	13.5	13.6	13.4	13.6	13.5	13.4	13.3	13.4	13.4
		difference	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.01%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*11.83%*	*11.83%*	*11.84%*
D. Agricultural Soils	N_2O	JNGI 2023	7.3	6.8	6.5	6.1	5.8	5.7	5.7	5.7	5.7	5.7	5.7	5.6	5.6	5.6
		JNGI 2024	6.7	6.1	5.9	5.5	5.3	5.3	5.2	5.3	5.3	5.4	5.3	5.2	5.2	5.2
		difference	*-9.24%*	*-9.25%*	*-9.13%*	*-9.62%*	*-8.42%*	*-8.10%*	*-7.70%*	*-6.75%*	*-6.76%*	*-6.53%*	*-6.58%*	*-7.24%*	*-7.15%*	*-7.39%*
F. Field Burning of Agricultural Residues	CH_4	JNGI 2023	0.13	0.11	0.10	0.09	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06
		JNGI 2024	0.08	0.07	0.06	0.05	0.03	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
		difference	*-38.65%*	*-37.74%*	*-41.39%*	*-42.56%*	*-53.39%*	*-50.09%*	*-50.77%*	*-51.59%*	*-54.68%*	*-54.53%*	*-56.19%*	*-52.16%*	*-52.80%*	*-50.13%*
	N_2O	JNGI 2023	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		JNGI 2024	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		difference	*-42.07%*	*-39.54%*	*-44.83%*	*-47.19%*	*-57.34%*	*-54.16%*	*-55.08%*	*-56.57%*	*-58.96%*	*-59.56%*	*-60.33%*	*-57.29%*	*-57.80%*	*-55.91%*
G. Liming	CO_2	JNGI 2023	0.6	0.3	0.3	0.2	0.2	0.4	0.4	0.3	0.3	0.3	0.2	0.2	0.2	0.2
		JNGI 2024	0.6	0.3	0.3	0.2	0.2	0.4	0.4	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%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
H. Urea Application	CO_2	JNGI 2023	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
		JNGI 2024	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	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%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
3. Total	GHG	JNGI 2023	37.5	37.1	35.2	34.5	33.7	32.8	32.4	32.1	32.1	32.3	32.0	32.0	32.1	32.2
		JNGI 2024	39.3	39.0	37.0	36.3	35.4	34.5	34.1	33.9	33.9	34.0	33.8	33.7	33.8	33.9
		difference	*4.70%*	*5.22%*	*5.14%*	*5.05%*	*5.13%*	*5.20%*	*5.30%*	*5.46%*	*5.49%*	*5.48%*	*5.49%*	*5.36%*	*5.39%*	*5.38%*

Table 10-5 Comparison of emissions and removals in the inventories submitted in 2023 and 2024 (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	2014	2015	2016	2017	2018	2019	2020	2021
A. Forest Land	CO_2	JNGI 2023	-86.3	-95.4	-98.0	-99.8	-82.6	-76.3	-73.4	-66.9	-62.3	-64.4	-62.9	-58.7	-60.4	-58.3
		JNGI 2024	-94.3	-100.8	-100.8	-101.2	-89.5	-83.6	-80.5	-73.8	-69.0	-70.8	-69.0	-64.5	-65.9	-63.6
		difference	*9.30%*	*5.61%*	*2.89%*	*1.38%*	*8.34%*	*9.56%*	*9.74%*	*10.33%*	*10.68%*	*9.93%*	*9.69%*	*9.84%*	*9.10%*	*9.00%*
	CH_4	JNGI 2023	0.01	0.01	0.01	0.01	0.00	0.00	0.02	0.01	0.00	0.02	0.00	0.01	0.00	0.01
		JNGI 2024	0.01	0.01	0.01	0.01	0.01	0.00	0.03	0.01	0.00	0.03	0.00	0.01	0.00	0.01
		difference	*14.18%*	*13.32%*	*12.75%*	*13.19%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*11.97%*
	N_2O	JNGI 2023	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		JNGI 2024	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		difference	*90.07%*	*90.13%*	*90.33%*	*90.13%*	*91.06%*	*91.20%*	*86.15%*	*87.04%*	*86.88%*	*83.29%*	*84.52%*	*86.01%*	*88.43%*	*91.06%*
B. Cropland	CO_2	JNGI 2023	8.3	3.8	4.0	3.9	5.8	5.5	6.2	5.7	5.4	4.6	4.0	4.7	4.6	4.7
		JNGI 2024	8.0	3.8	4.0	3.9	5.8	5.5	6.2	5.7	5.4	4.6	3.8	4.3	4.2	4.0
		difference	*-3.72%*	*-1.42%*	*-0.49%*	*-0.09%*	*0.00%*	*-0.15%*	*-0.18%*	*0.00%*	*-0.03%*	*0.26%*	*-4.21%*	*-7.90%*	*-9.68%*	*-13.75%*
	CH_4	JNGI 2023	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
		JNGI 2024	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04
		difference	*11.11%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.52%*	*12.87%*	*13.14%*	*13.54%*	*13.56%*	*13.56%*	*13.56%*	*13.55%*	*13.66%*
	N_2O	JNGI 2023	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		JNGI 2024	0.04	0.03	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02
		difference	*44.40%*	*37.95%*	*19.50%*	*30.57%*	*31.96%*	*34.08%*	*35.48%*	*36.85%*	*40.23%*	*40.49%*	*41.26%*	*41.67%*	*41.39%*	*41.82%*
C. Grassland	CO_2	JNGI 2023	0.9	0.1	-0.9	-0.3	0.1	1.1	1.7	1.3	1.1	0.8	0.6	0.7	0.6	0.5
		JNGI 2024	1.0	0.1	-0.9	-0.3	0.1	1.1	1.7	1.3	1.1	0.8	0.5	0.6	0.4	0.2
		difference	*12.72%*	*-22.37%*	*3.28%*	*9.26%*	*-0.68%*	*0.00%*	*0.00%*	*-0.21%*	*-0.33%*	*-0.07%*	*-7.17%*	*-11.85%*	*-24.65%*	*-56.21%*
	CH_4	JNGI 2023	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01
		JNGI 2024	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		difference	*11.84%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.01%*	*12.01%*	*12.01%*	*12.01%*	*12.01%*	*12.02%*	*12.02%*
	N_2O	JNGI 2023	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		JNGI 2024	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		difference	*-10.39%*	*-14.33%*	*-16.60%*	*-17.94%*	*-18.78%*	*-22.10%*	*-22.00%*	*-21.94%*	*-18.90%*	*-18.89%*	*-18.88%*	*-18.89%*	*-18.88%*	*-18.87%*
D. Wetlands	CO_2	JNGI 2023	0.07	0.28	0.33	0.03	0.09	0.02	0.02	0.06	0.06	0.02	0.02	0.02	0.02	0.04
		JNGI 2024	-0.5	-0.2	-0.1	-0.4	-0.3	-0.4	-0.4	-0.3	-0.3	-0.4	-0.3	-0.3	-0.3	-0.3
		difference	*-870.80%*	*-177.90%*	*-117.23%*	*-1159.98%*	*-409.31%*	*-2096.70%*	*-2070.25%*	*-597.03%*	*-598.53%*	*-1538.95%*	*-1564.48%*	*-1575.01%*	*-1471.10%*	*-1056.48%*
E. Settlements	CO_2	JNGI 2023	10.6	8.2	6.2	4.9	4.2	3.2	3.1	3.2	3.1	2.8	2.8	2.9	3.0	2.2
		JNGI 2024	10.4	8.0	6.1	4.8	4.1	3.2	3.1	3.2	3.1	2.8	2.8	3.2	3.3	2.6
		difference	*-2.55%*	*-1.44%*	*-1.77%*	*-1.86%*	*-1.71%*	*-1.56%*	*-1.31%*	*-1.12%*	*-1.05%*	*-0.16%*	*-0.13%*	*10.65%*	*10.74%*	*19.92%*
	CH_4	JNGI 2023	0.03	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		JNGI 2024	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
		difference	*12.04%*	*13.06%*	*13.23%*	*17.26%*	*17.86%*	*18.19%*	*17.81%*	*17.61%*	*17.53%*	*17.73%*	*17.76%*	*17.39%*	*16.99%*	*17.20%*
	N_2O	JNGI 2023	0.5	0.4	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
		JNGI 2024	0.6	0.5	0.5	0.4	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2
		difference	*22.81%*	*24.51%*	*24.49%*	*24.67%*	*24.29%*	*24.73%*	*24.97%*	*25.05%*	*25.14%*	*25.22%*	*25.21%*	*25.40%*	*25.65%*	*26.46%*
F. Other Land	CO_2	JNGI 2023	2.3	2.0	1.7	1.1	0.9	0.7	0.7	0.6	0.6	0.6	0.6	0.5	0.5	0.4
		JNGI 2024	2.3	2.0	1.6	1.1	0.9	0.7	0.7	0.7	0.7	0.6	0.6	0.6	0.5	0.4
		difference	*-0.33%*	*-0.80%*	*-0.63%*	*2.55%*	*3.30%*	*4.33%*	*7.02%*	*8.40%*	*9.02%*	*10.25%*	*10.98%*	*13.52%*	*14.25%*	*15.11%*
	N_2O	JNGI 2023	0.08	0.07	0.06	0.05	0.04	0.03	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.02
		JNGI 2024	0.10	0.09	0.08	0.07	0.05	0.04	0.04	0.04	0.04	0.04	0.03	0.03	0.03	0.03
		difference	*27.11%*	*26.41%*	*26.47%*	*30.51%*	*33.07%*	*35.63%*	*39.71%*	*43.72%*	*45.87%*	*47.84%*	*49.31%*	*51.50%*	*52.21%*	*52.13%*
G. Harvested Wood Products	CO_2	JNGI 2023	-0.3	1.6	1.7	0.6	0.0	0.6	-0.6	-0.7	-0.7	-1.1	-1.3	-1.3	-0.4	-1.6
		JNGI 2024	-0.5	1.3	1.6	0.5	-0.5	-0.4	-1.0	-1.2	-1.4	-1.7	-1.7	-1.7	-1.1	-2.1
		difference	*94.76%*	*-20.55%*	*-7.70%*	*-19.20%*	*-1241.95%*	*-155.3%*	*78.54%*	*61.51%*	*98.41%*	*50.98%*	*30.35%*	*25.76%*	*167.96%*	*33.65%*
H. Other	CO_2	JNGI 2023	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		JNGI 2024	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*0.00%*
4. Total	GHG	JNGI 2023	-63.3	-78.6	-84.1	-88.8	-70.9	-64.7	-61.7	-56.1	-52.3	-56.2	-55.8	-50.7	-51.6	-51.7
		JNGI 2024	-72.7	-85.0	-87.7	-90.9	-78.7	-73.4	-69.7	-63.9	-60.0	-63.5	-62.8	-57.3	-58.3	-58.3
		difference	*14.91%*	*8.20%*	*4.25%*	*2.28%*	*11.10%*	*13.47%*	*12.92%*	*13.76%*	*14.77%*	*12.92%*	*12.59%*	*12.94%*	*13.01%*	*12.72%*

Table 10-6 Comparison of emissions and removals in the inventories submitted in 2023 and 2024 (Waste sector)

5. Waste		[Mt-CO_2 eq.]														
Category	Gas		1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021
A. Solid Waste Disposal	CH_4	JNGI 2023	9.9	9.0	7.2	5.4	3.6	2.9	2.6	2.4	2.2	2.1	1.9	1.8	1.7	1.6
		JNGI 2024	11.1	10.0	8.0	6.0	4.0	3.2	3.0	2.7	2.5	2.3	2.2	2.0	1.9	1.8
		difference	*11.60%*	*11.67%*	*11.83%*	*11.92%*	*11.98%*	*12.01%*	*12.02%*	*12.03%*	*12.02%*	*12.03%*	*12.04%*	*12.05%*	*12.07%*	*11.98%*
B. Biological Treatment of Solid Waste	CH_4	JNGI 2023	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		JNGI 2024	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
		difference	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*16.10%*
	N_2O	JNGI 2023	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2
		JNGI 2024	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2
		difference	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-7.85%*
C. Incineration and Open Burning of Waste	CO_2	JNGI 2023	12.3	16.0	16.9	14.2	12.5	12.2	11.7	11.7	11.1	10.8	11.6	11.4	10.4	10.4
		JNGI 2024	12.3	16.0	16.9	14.2	12.5	12.2	11.7	11.7	11.1	10.8	11.6	11.4	10.4	10.8
		difference	*0.00%*	*0.00%*	*0.00%*	*0.00%*	*-0.02%*	*0.00%*	*-0.02%*	*0.00%*	*0.00%*	*0.01%*	*0.01%*	*0.02%*	*0.06%*	*4.55%*
	CH_4	JNGI 2023	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		JNGI 2024	0.03	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		difference	*12.22%*	*12.00%*	*12.00%*	*12.04%*	*12.18%*	*12.05%*	*12.11%*	*12.20%*	*12.23%*	*12.21%*	*12.19%*	*12.27%*	*11.58%*	*9.08%*
	N_2O	JNGI 2023	1.4	1.9	2.2	2.0	1.5	1.5	1.4	1.5	1.3	1.4	1.5	1.5	1.4	1.2
		JNGI 2024	1.3	1.6	1.7	1.7	1.5	1.6	1.4	1.4	1.2	1.3	1.3	1.4	1.3	1.3
		difference	*-10.48%*	*-15.03%*	*-19.63%*	*-10.93%*	*-1.67%*	*1.14%*	*-2.71%*	*-7.48%*	*-7.08%*	*-7.25%*	*-7.21%*	*-6.59%*	*-7.07%*	*1.29%*
D. Wastewater Treatment and Discharge	CH_4	JNGI 2023	2.9	2.8	2.6	2.3	2.0	1.8	1.8	1.7	1.7	1.6	1.6	1.6	1.6	1.6
		JNGI 2024	3.3	3.1	2.9	2.6	2.2	2.0	2.0	2.0	1.9	1.8	1.8	1.8	1.8	1.7
		difference	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*12.00%*	*11.42%*
	N_2O	JNGI 2023	2.4	2.4	2.3	2.3	2.1	2.1	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0
		JNGI 2024	2.1	2.2	2.0	2.0	1.9	1.9	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
		difference	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-11.07%*	*-10.91%*
E. Other	CO_2	JNGI 2023	0.7	0.7	0.7	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.7	0.6	0.6	0.7
		JNGI 2024	0.7	0.7	0.7	0.5	0.5	0.6	0.6	0.6	0.6	0.6	0.7	0.6	0.6	0.7
		difference	*0.00%*	*0.00%*	*0.00%*	*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 2023	30.0	33.0	32.0	27.0	22.6	21.5	20.7	20.5	19.5	19.0	19.7	19.2	18.0	17.7
		JNGI 2024	31.1	33.8	32.4	27.4	23.0	21.9	20.9	20.6	19.6	19.1	19.8	19.3	18.0	18.3
		difference	*3.60%*	*2.46%*	*1.45%*	*1.57%*	*1.67%*	*1.50%*	*1.16%*	*0.70%*	*0.69%*	*0.55%*	*0.43%*	*0.37%*	*0.35%*	*3.55%*

10.3. Implication for Emission and Removal Trends, including Time-series Consistency

Table 10-7 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 2023 submission and the 2024 submission is made through the comparison of changes between FY1990 and FY2021.

The change between FY1990 and FY2021 total emissions (excluding the LULUCF sector and including indirect CO_2) in the 2024 submission decreased by approximately 6.0 million tonnes (in CO_2 equivalents) and decreased by 0.47 percentage points, compared to the data reported in the previous submission.

Table 10-7 Comparison of change between 1990 and 2021 total emissions (excluding the LULUCF sector, and including indirect CO_2) between the inventories submitted in 2023 and 2024

	Emissions (2021) - Emissions (1990) [Mt-CO_2 eq.]			Emissions (2021) / Emissions (1990) - 1 [%]		
	JNGI 2023	JNGI 2024	Difference	JNGI 2023	JNGI 2024	Difference
CO_2	-95.1	-95.5	-0.5	-8.2%	-8.3%	-0.04%
CH_4	-17.2	-19.4	-2.3	-38.6%	-39.0%	-0.45%
N_2O	-12.8	-11.3	1.5	-39.6%	-39.1%	0.52%
HFCs	37.6	33.5	-4.1	236.0%	249.7%	13.70%
PFCs	-3.4	-3.3	0.1	-51.9%	-52.9%	-1.00%
SF_6	-10.8	-11.5	-0.7	-84.1%	-83.7%	0.33%
NF_3	0.3	0.3	-0.04	1065.6%	1085.3%	19.66%
Indirect CO_2	-3.6	-3.6	-0.04	-65.9%	-66.4%	-0.56%
Total	-104.8	-110.9	-6.0	-8.22%	-8.70%	-0.47%

10.4. Areas of improvement and planned improvements

10.4.1. Improvements after submission of the inventory

The major improvements carried out after the submission of the 2023 inventory are listed below.

Table 10-8 Changes in estimation methods

Sector and category		Changes in estimation methods
1.A.3.d	Domestic navigation	Emission factors of CH_4 and N_2O were changed from the default values in the *2006 IPCC Guidelines* to the default values multiplied by correction factors.
1.B.2.a.i	Oil exploration	For leaks, the notation key was changed from "IE" to "NA".
1.B.2.a.ii	Oil production and upgrading	For leaks, venting and flaring, the emission factors for CH_4, CO_2 and N_2O were revised to the default values of the *2019 Refinement*.
1.B.2.a.iv	Oil refining and storage	The notation key for N_2O was changed from "NA" to "IE".
1.B.2.a.v	Distribution of oil products	The notation key for CH_4 and CO_2 was changed from "NE" to "NA".
1.B.2.a.vi	Other (abandoned oil wells, etc.)	Fugitive emissions due to accident is reported as "NE".
1.B.2.b.i	Natural gas exploration	The notation key for leaks was changed from "IE" to "NA". For flaring, the emission factors for CH_4, CO_2 and N_2O were revised to the default values of the *2019 Refinement*, and the

Sector and category		Changes in estimation methods
		activity data were changed to the number of onshore explorative wells.
1.B.2.b.ii	Natural gas production and gathering	For leaks and flaring, the emission factors were revised to the default values of the *2019 Refinement*.
1.B.2.b.iii	Natural gas processing	For leaks, venting and flaring, the emission factors were revised to the default values of the *2019 Refinement*.
1.B.2.c.ii.3	Flaring (combined)	This category is reported as "IE", since the emissions from flaring associated with exploratory drilling and testing of oil and natural gas are reported together in "Flaring (Gas) (1.B.2.c.ii.2)" in this submission.
1.A.1.b. 1.A.2.a. 2.B.1. 2.B.8.d.	Petroleum refining, Iron and steel, Ammonia production, Ethylene oxide	CO_2 recoveries for liquefied CO_2 and for dry ice are newly estimated and subtracted from the CO_2 emissions of the source category where the CO_2 recovered from. (see section 4.9.1.)
2.B.10.b.- 2.C.1.f.- 2.H.3.-	Utilization of Carbonated Gas	CO_2 recoveries subtracted from the CO_2 emissions of 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.) were allocated under the category in which the CO_2 was utilized, without omission, based on the thinking of the *2006 IPCC Guidelines*.
2.H.2.	Food and Beverages Industry	
2.H.3.-	Environmentally friendly concrete	The amount of CO_2 fixation by environmentally friendly concrete were newly estimated.
1.A.2.c. 1.A.2.d. 1.A.2.f. 2.H.3.- 4.H.	Chemicals, Pulp, paper, and print, Non-metallic minerals, Other Other	The amount of CO_2 fixation by environmentally friendly concrete were subtracted from the emissions from the category where the CO_2 was recovered for the manufacturing of concrete.
2.E.1.	Semiconductor	The methodology was revised based on the Tier 2a of the *2019 Refinement*.
2.F.1.a.	Commercial refrigeration	Emission factors for 2016 onward used for the estimation of emissions from leaks during operation were revised.
2.F.3.	Fire protection	Emissions from disposal were newly estimated.
2.F.4.b.-	Other - Aerosols	Emissions of HFC-43-10mee and HFC-227ea were newly estimated.
3.B.4. 3.D.a.2. 3.D.b.1. 3.D.b.2.	Manure Management –Poultry Agricultural Soils - Direct N_2O Emissions - Organic Fertilizer Agricultural Soils - Indirect N_2O Emissions – Atmospheric Deposition, N mineralization associated with loss of soil organic matter	The emission factors for "Carbonization" and "Composting" were separately established using country specific values and default values in the *2019 Refinement*.
3.D.a.2.	Agricultural Soils - Direct N_2O Emissions - Organic Fertilizer	The emission factors by type of organic N fertilizers were established.
3.D.a.4.	Agricultural Soils - Direct N_2O Emissions - Crop Residues	Combustion factor was revised to that in the *2019 Refinement*.
3.D.a.5.	Agricultural Soils - Direct N_2O Emissions - Mineralization/Immobilization Associated with Loss/Gain of Soil Organic Matter	The emissions from Grassland were included in the reporting of Agriculture sector.
3.F.	Field Burning of Agricultural Residues	The emission factor of rice straw was revised and combustion factor of other crops removed from field and burned in field was updated.

Sector and category		Changes in estimation methods
4.A.1	Forest land remaining forest land	CENTURY-jfos model which calculates carbon stock changes of dead wood, litter and mineral soils was revised. However, it was applied for the years from FY2008 onwards.
4.A.1 4.(IV)	Forest land remaining forest land	The yield tables for the intensively managed forests in the private forests, which are used to estimate volume per unit area, were revised.
4.B.1 4.C.1	Cropland remaining cropland Grassland remaining Grassland	The input data used in the Roth C model calculation was modified.
4.D.1	Wetlands remaining wetlands	Carbon stock changes for seagrass meadows and macroalgal beds were estimated.
4.G	Buildings	The amount of wood input per unit floor area of non-wooden buildings, density of coniferous sawnwood and ratio of domestic wood for construction was updated.
4.G	Wood for other uses than buildings	Density of coniferous wood and the method of tracing production of wooden board and plywood, and wood input for plywood was updated.
4.G	Paper and paperboard	The method of tracing paper and paperboard was updated and the method for estimating the ratio of domestic wood was updated.

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 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 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 FY2022 (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, 48 and 41 sources and sinks were identified as the key categories for FY2022 and FY1990, respectively (Table A1-1 and Table A1-2). On the other hand, in the case of excluding the LULUCF sector, 38 and 36 sources were identified as the key categories for FY2022 and FY1990, respectively (Table A1-3 and Table A1-4).

Table A1-1 Japan's key categories (FY2022, 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		#11	
#3	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	#3	#7	#2	#7
#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	#5	#25	#22
#6	4.A.	Forest Land	1. Forest Land Remaining Forest Land	CO_2	#6	#8	#3	#4
#7	1.A.1.	Energy Industries	Liquid Fuels	CO_2	#7	#2	#31	#15
#8	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	#8	#3	#32	#19
#9	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	#9	#9	#29	
#10	2.F.	Product Uses as Substitutes for ODS	1. Refrigeration and Air Conditioning Equipment	HFCs	#10	#6	#6	#6
#11	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	#11	#10		
#12	2.A.	Mineral Industry	1. Cement Production	CO_2	#12	#11	#24	#25
#13	3.C.	Rice Cultivation		CH_4	#13		#27	
#14	1.A.3.	Transport	d. Domestic Navigation	CO_2	#14			
#15	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	#15	#16	#10	#16
#16	5.C.	Incineration and Open Burning of Waste		CO_2	#16		#15	
#17	1.A.3.	Transport	a. Domestic Aviation	CO_2	#17	#21		
#18	3.A.	Enteric Fermentation		CH_4	#18		#7	
#19	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	#19		#14	#26
#20	1.A.4.	Other Sectors	Solid Fuels	CO_2	#20	#18		
#21	2.C.	Metal Industry	1. Iron and Steel Production	CO_2	#21			
#22	2.A.	Mineral Industry	2. Lime Production	CO_2	#22			
#23	4.B.	Cropland	1. Cropland Remaining Cropland	CO_2			#22	#24
#24	4.E.	Settlements	2. Land Converted to Settlements	CO_2		#17	#12	#5
#25	3.B.	Manure Management		N_2O			#5	
#26	3.D.	Agricultural Soils	1. Direct Emissions	N_2O			#13	
#27	2.F.	Product Uses as Substitutes for ODS	2. Foam Blowing Agents	HFCs		#24	#17	#14
#28	2.B.	Chemical Industry	Other Products Except Anmonia	CO_2			#16	#28
#29	2.D.	Non-energy Products from Fuels and Solvent Use		CO_2			#20	
#30	3.D.	Agricultural Soils		N_2O			#4	#20
#31	4.G.	Harvested Wood Products		CO_2			#33	#29
#32	5.D.	Wastewater Treatment and Discharge		N_2O			#28	
#33	5.A.	Solid Waste Disposal		CH_4		#14		#9
#34	2.E.	Electronics Industry		PFCs			#19	
#35	2.G.	Other Product Manufacture and Use		SF_6		#15	#9	#2
#36		Indirect CO_2	from IPPU Sector	Ind CO_2		#23	#26	#11
#37	5.C.	Incineration and Open Burning of Waste		N_2O			#23	
#38	1.A.3.	Transport	b. Road Transportation	N_2O			#21	#10
#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		#20		#3
#41	2.E.	Electronics Industry		SF_6			#18	#13
#42	4.F.	Other Land	2. Land Converted to Other Land	CO_2				#12
#43	4.(III)	N_2O Emissions from N Mineralization/Immobilization		N_2O			#30	#21
#44	2.B.	Chemical Industry	2. Nitric Acid Production	N_2O				#27
#45	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O				#8
#46	2.B.	Chemical Industry	9. Fluorochemical Production	HFCs		#12		
#47	2.B.	Chemical Industry	9. Fluorochemical Production	SF_6		#22		
#48	2.B.	Chemical Industry	3. Adipic Acid Production	N_2O		#19		#23

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			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	#16
#3	1.A.1.	Energy Industries	Liquid Fuels	CO_2	#3	#17
#4	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	#4	#23
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	#5	#24
#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	#26
#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	5.C.	Incineration and Open Burning of Waste		CO_2	#14	#20
#15	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	#15	
#16	4.E.	Settlements	2. Land Converted to Settlements	CO_2	#16	#7
#17	5.A.	Solid Waste Disposal		CH_4	#17	#13
#18	3.A.	Enteric Fermentation		CH_4	#18	#10
#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	4.B.	Cropland	1. Cropland Remaining Cropland	CO_2	#21	#21
#22	2.C.	Metal Industry	1. Iron and Steel Production	CO_2	#22	
#23	1.A.3.	Transport	a. Domestic Aviation	CO_2	#23	
#24	2.A.	Mineral Industry	2. Lime Production	CO_2	#24	
#25	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	#25	#27
#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	#12
#29	3.D.	Agricultural Soils	1. Direct Emissions	N_2O		#15
#30	3.B.	Manure Management		N_2O		#6
#31	2.B.	Chemical Industry	Other Products Except Anmonia	CO_2		#18
#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		#19
#35	2.D.	Non-energy Products from Fuels and Solvent Use		CO_2		#28
#36	5.D.	Wastewater Treatment and Discharge		N_2O		#31
#37	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O		#14
#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		#11
#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 (FY2022, 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	#18	#10	
#3	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	#3	#7	#2	#5
#4	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	#4	#4	#7	#14
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	#5	#5	#22	#17
#6	1.A.1.	Energy Industries	Liquid Fuels	CO_2	#6	#2	#27	#12
#7	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	#7	#3	#28	#15
#8	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	#8	#8	#26	
#9	2.F.	Product Uses as Substitutes for ODS	1. Refrigeration and Air Conditioning Equipment	HFCs	#9	#6	#5	#4
#10	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	#10	#9		
#11	2.A.	Mineral Industry	1. Cement Production	CO_2	#11	#10	#21	#20
#12	3.C.	Rice Cultivation		CH_4	#12		#24	
#13	1.A.3.	Transport	d. Domestic Navigation	CO_2	#13			
#14	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	#14	#14	#9	#13
#15	5.C.	Incineration and Open Burning of Waste		CO_2	#15		#13	
#16	1.A.3.	Transport	a. Domestic Aviation	CO_2	#16	#19		
#17	3.A.	Enteric Fermentation		CH_4	#17		#6	
#18	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	#18		#12	#19
#19	1.A.4.	Other Sectors	Solid Fuels	CO_2		#15		#23
#20	3.B.	Manure Management		N_2O			#4	
#21	3.D.	Agricultural Soils	1. Direct Emissions	N_2O			#11	
#22	2.F.	Product Uses as Substitutes for ODS	2. Foam Blowing Agents	HFCs			#15	#10
#23	2.B.	Chemical Industry	Other Products Except Anmonia	CO_2			#14	#22
#24	2.D.	Non-energy Products from Fuels and Solvent Use		CO_2			#18	
#25	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O			#3	#16
#26	5.D.	Wastewater Treatment and Discharge		N_2O			#25	
#27	5.A.	Solid Waste Disposal		CH_4		#12		#7
#28	2.E.	Electronics Industry		PFCs			#17	
#29	2.G.	Other Product Manufacture and Use		SF_6		#13	#8	#2
#30		Indirect CO_2	from IPPU Sector	Ind CO_2			#23	#9
#31	5.C.	Incineration and Open Burning of Waste		N_2O			#20	
#32	1.A.3.	Transport	b. Road Transportation	N_2O			#19	#8
#33	1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	CH_4		#17		#3
#34	2.E.	Electronics Industry		SF_6			#16	#11
#35	2.B.	Chemical Industry	2. Nitric Acid Production	N_2O				#21
#36	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O				#6
#37	2.B.	Chemical Industry	9. Fluorochemical Production	HFCs		#11		
#38	2.B.	Chemical Industry	3. Adipic Acid Production	N_2O		#16		#18

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	#16
#3	1.A.1.	Energy Industries	Liquid Fuels	CO_2	#3	#17
#4	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	#4	#19
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	#5	#20
#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	#18
#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	5.C.	Incineration and Open Burning of Waste		CO_2	#13	#15
#14	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	#14	
#15	5.A.	Solid Waste Disposal		CH_4	#15	#9
#16	3.A.	Enteric Fermentation		CH_4	#16	#8
#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	#22
#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		#13
#25	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2		#28
#26	3.D.	Agricultural Soils	1. Direct Emissions	N_2O		#14
#27	3.B.	Manure Management		N_2O		#5
#28	2.B.	Chemical Industry	Other Products Except Anmonia	CO_2		#12
#29	1.A.3.	Transport	b. Road Transportation	N_2O		#11
#30	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O		#4
#31	2.D.	Non-energy Products from Fuels and Solvent Use		CO_2		#23
#32	5.D.	Wastewater Treatment and Discharge		N_2O		#27
#33	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O		#10
#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		#7

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 emissions and removals. 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 FY2022 gives the following 22 sub-categories as the key categories and that of excluding LULUCF gives the following 18 subcategories 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 (FY2022)

	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	255,511.44	0.211	21.1%	21.1%
#2	1.A.3.	Transport	b. Road Transportation	CO_2	164,512.63	0.136	13.6%	34.7%
#3	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	142,039.86	0.117	11.7%	46.5%
#4	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	127,301.36	0.105	10.5%	57.0%
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	69,644.68	0.058	5.8%	62.8%
#6	4.A.	Forest Land	1. Forest Land Remaining Forest Land	CO_2	-59,107.17	0.049	4.9%	67.7%
#7	1.A.1.	Energy Industries	Liquid Fuels	CO_2	52,205.97	0.043	4.3%	72.0%
#8	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	51,658.34	0.043	4.3%	76.2%
#9	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	43,256.59	0.036	3.6%	79.8%
#10	2.F.	Product Uses as Substitutes for ODS	1. Refrigeration and Air Conditioning Equipment	HFCs	42,810.33	0.035	3.5%	83.4%
#11	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	30,643.82	0.025	2.5%	85.9%
#12	2.A.	Mineral Industry	1. Cement Production	CO_2	22,479.16	0.019	1.9%	87.8%
#13	3.C.	Rice Cultivation		CH_4	13,067.90	0.011	1.1%	88.8%
#14	1.A.3.	Transport	d. Domestic Navigation	CO_2	10,373.42	0.009	0.9%	89.7%
#15	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	10,257.93	0.008	0.8%	90.5%
#16	5.C.	Incineration and Open Burning of Waste		CO_2	10,225.83	0.008	0.8%	91.4%
#17	1.A.3.	Transport	a. Domestic Aviation	CO_2	9,704.87	0.008	0.8%	92.2%
#18	3.A.	Enteric Fermentation		CH_4	8,660.61	0.007	0.7%	92.9%
#19	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	8,424.38	0.007	0.7%	93.6%
#20	1.A.4.	Other Sectors	Solid Fuels	CO_2	6,320.81	0.005	0.5%	94.1%
#21	2.C.	Metal Industry	1. Iron and Steel Production	CO_2	5,208.35	0.004	0.4%	94.6%
#22	2.A.	Mineral Industry	2. Lime Production	CO_2	4,650.45	0.004	0.4%	94.9%
	Excluding LULUCF							
#1	1.A.1.	Energy Industries	Solid Fuels	CO_2	255,511.44	0.225	22.50%	22.5%
#2	1.A.3.	Transport	b. Road Transportation	CO_2	164,512.63	0.145	14.49%	37.0%
#3	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	142,039.86	0.125	12.51%	49.5%
#4	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	127,301.36	0.112	11.21%	60.7%
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	69,644.68	0.061	6.13%	66.8%
#6	1.A.1.	Energy Industries	Liquid Fuels	CO_2	52,205.97	0.046	4.60%	71.4%
#7	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	51,658.34	0.045	4.55%	76.0%
#8	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	43,256.59	0.038	3.81%	79.8%
#9	2.F.	Product Uses as Substitutes for ODS	1. Refrigeration and Air Conditioning Equipment	HFCs	42,810.33	0.038	3.77%	83.6%
#10	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	30,643.82	0.027	2.70%	86.3%
#11	2.A.	Mineral Industry	1. Cement Production	CO_2	22,479.16	0.020	1.98%	88.3%
#12	3.C.	Rice Cultivation		CH_4	13,067.90	0.012	1.15%	89.4%
#13	1.A.3.	Transport	d. Domestic Navigation	CO_2	10,373.42	0.009	0.91%	90.3%
#14	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	10,257.93	0.009	0.90%	91.2%
#15	5.C.	Incineration and Open Burning of Waste		CO_2	10,225.83	0.009	0.90%	92.1%
#16	1.A.3.	Transport	a. Domestic Aviation	CO_2	9,704.87	0.009	0.85%	93.0%
#17	3.A.	Enteric Fermentation		CH_4	8,660.61	0.008	0.76%	93.7%
#18	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	8,424.38	0.007	0.74%	94.5%

Table A1-6 Results of Approach 2 level assessment (FY2022)

	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	255,511.44	6%	18.7%	18.7%
#2	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	142,039.86	6%	10.4%	29.2%
#3	4.A.	Forest Land	1. Forest Land Remaining Forest Land	CO_2	-59,107.17	9%	6.0%	35.2%
#4	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O	2,072.23	246%	6.0%	41.2%
#5	3.B.	Manure Management		N_2O	3,418.80	132%	5.3%	46.5%
#6	2.F.	Product Uses as Substitutes for ODS	1. Refrigeration and Air Conditioning Equipment	HFCs	42,810.33	6%	3.0%	49.5%
#7	3.A.	Enteric Fermentation		CH_4	8,660.61	30%	3.0%	52.5%
#8	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	127,301.36	2%	2.4%	54.9%
#9	2.G.	Other Product Manufacture and Use		SF_6	1,397.09	143%	2.3%	57.2%
#10	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	10,257.93	19%	2.3%	59.5%
#11	1.A.3.	Transport	b. Road Transportation	CO_2	164,512.63	1%	2.3%	61.8%
#12	4.E.	Settlements	2. Land Converted to Settlements	CO_2	4,198.27	44%	2.2%	64.0%
#13	3.D.	Agricultural Soils	1. Direct Emissions	N_2O	3,131.16	59%	2.2%	66.1%
#14	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	8,424.38	19%	1.9%	68.0%
#15	5.C.	Incineration and Open Burning of Waste		CO_2	10,225.83	15%	1.8%	69.8%
#16	2.B.	Chemical Industry	Other Products Except Anmonia	CO_2	2,548.65	55%	1.6%	71.4%
#17	2.F.	Product Uses as Substitutes for ODS	2. Foam Blowing Agents	HFCs	2,591.42	50%	1.5%	73.0%
#18	2.E.	Electronics Industry		SF_6	423.13	300%	1.5%	74.4%
#19	2.E.	Electronics Industry		PFCs	1,503.07	81%	1.4%	75.9%
#20	2.D.	Non-energy Products from Fuels and Solvent Use		CO_2	2,328.25	51%	1.4%	77.3%
#21	1.A.3.	Transport	b. Road Transportation	N_2O	1,107.48	107%	1.4%	78.7%
#22	4.B.	Cropland	1. Cropland Remaining Cropland	CO_2	4,447.06	24%	1.2%	79.9%
#23	5.C.	Incineration and Open Burning of Waste		N_2O	1,186.55	78%	1.1%	81.0%
#24	2.A.	Mineral Industry	1. Cement Production	CO_2	22,479.16	4%	1.1%	82.1%
#25	1.A.4.	Other Sectors	Liquid Fuels	CO_2	69,644.68	1%	1.0%	83.0%
#26		Indirect CO_2	from IPPU Sector	Ind CO_2	1,364.67	59%	0.9%	84.0%
#27	3.C.	Rice Cultivation		CH_4	13,067.90	6%	0.9%	84.9%
#28	5.D.	Wastewater Treatment and Discharge		N_2O	1,765.73	42%	0.9%	85.8%
#29	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	43,256.59	2%	0.8%	86.6%
#30	4.(III)	N_2O Emissions from N Mineralization/Immobilization		N_2O	386.76	159%	0.7%	87.3%
#31	1.A.1.	Energy Industries	Liquid Fuels	CO_2	52,205.97	1%	0.7%	88.0%
#32	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	51,658.34	1%	0.7%	88.7%
#33	4.G.	Harvested Wood Products		CO_2	-1,918.02	30%	0.7%	89.4%
Excluding LULUCF								
#1	1.A.1.	Energy Industries	Solid Fuels	CO_2	255,511.44	6%	21.37%	21.4%
#2	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	142,039.86	6%	11.88%	33.3%
#3	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O	2,072.23	246%	6.81%	40.1%
#4	3.B.	Manure Management		N_2O	3,418.80	132%	6.05%	46.1%
#5	2.F.	Product Uses as Substitutes for ODS	1. Refrigeration and Air Conditioning Equipment	HFCs	42,810.33	6%	3.47%	49.6%
#6	3.A.	Enteric Fermentation		CH_4	8,660.61	30%	3.43%	53.0%
#7	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	127,301.36	2%	2.72%	55.7%
#8	2.G.	Other Product Manufacture and Use		SF_6	1,397.09	143%	2.68%	58.4%
#9	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	10,257.93	19%	2.60%	61.0%
#10	1.A.3.	Transport	b. Road Transportation	CO_2	164,512.63	1%	2.57%	63.6%
#11	3.D.	Agricultural Soils	1. Direct Emissions	N_2O	3,131.16	59%	2.47%	66.1%
#12	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	8,424.38	19%	2.13%	68.2%
#13	5.C.	Incineration and Open Burning of Waste		CO_2	10,225.83	15%	2.04%	70.2%
#14	2.B.	Chemical Industry	Other Products Except Anmonia	CO_2	2,548.65	55%	1.87%	72.1%
#15	2.F.	Product Uses as Substitutes for ODS	2. Foam Blowing Agents	HFCs	2,591.42	50%	1.73%	73.8%
#16	2.E.	Electronics Industry		SF_6	423.13	300%	1.70%	75.5%
#17	2.E.	Electronics Industry		PFCs	1,503.07	81%	1.62%	77.1%
#18	2.D.	Non-energy Products from Fuels and Solvent Use		CO_2	2,328.25	51%	1.59%	78.7%
#19	1.A.3.	Transport	b. Road Transportation	N_2O	1,107.48	107%	1.58%	80.3%
#20	5.C.	Incineration and Open Burning of Waste		N_2O	1,186.55	78%	1.24%	81.6%
#21	2.A.	Mineral Industry	1. Cement Production	CO_2	22,479.16	4%	1.24%	82.8%
#22	1.A.4.	Other Sectors	Liquid Fuels	CO_2	69,644.68	1%	1.09%	83.9%
#23		Indirect CO_2	from IPPU Sector	Ind CO_2	1,364.67	59%	1.08%	85.0%
#24	3.C.	Rice Cultivation		CH_4	13,067.90	6%	1.06%	86.0%
#25	5.D.	Wastewater Treatment and Discharge		N_2O	1,765.73	42%	0.98%	87.0%
#26	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	43,256.59	2%	0.92%	87.9%
#27	1.A.1.	Energy Industries	Liquid Fuels	CO_2	52,205.97	1%	0.82%	88.8%
#28	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	51,658.34	1%	0.81%	89.6%

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 23 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 28 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	199,518.60	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	178,587.22	0.128	12.8%	40.0%
#4	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	134,126.79	0.096	9.6%	49.6%
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	129,077.78	0.093	9.3%	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	-84,713.44	0.061	6.1%	72.8%
#8	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	80,030.95	0.057	5.7%	78.6%
#9	2.A.	Mineral Industry	1. Cement Production	CO_2	38,701.10	0.028	2.8%	81.3%
#10	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	22,241.56	0.016	1.6%	82.9%
#11	1.A.3.	Transport	d. Domestic Navigation	CO_2	13,674.88	0.010	1.0%	83.9%
#12	3.C.	Rice Cultivation		CH_4	13,584.76	0.010	1.0%	84.9%
#13	2.B.	Chemical Industry	9. Fluorochemical Production	HFCs	13,347.05	0.010	1.0%	85.8%
#14	5.C.	Incineration and Open Burning of Waste		CO_2	12,318.70	0.009	0.9%	86.7%
#15	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	11,894.05	0.009	0.9%	87.6%
#16	4.E.	Settlements	2. Land Converted to Settlements	CO_2	11,389.02	0.008	0.8%	88.4%
#17	5.A.	Solid Waste Disposal		CH_4	11,092.46	0.008	0.8%	89.2%
#18	3.A.	Enteric Fermentation		CH_4	10,553.65	0.008	0.8%	89.9%
#19	4.A.	Forest Land	2. Land Converted to Forest Land	CO_2	-9,577.97	0.007	0.7%	90.6%
#20	2.G.	Other Product Manufacture and Use		SF_6	9,084.65	0.007	0.7%	91.3%
#21	4.B.	Cropland	1. Cropland Remaining Cropland	CO_2	7,371.57	0.005	0.5%	91.8%
#22	2.C.	Metal Industry	1. Iron and Steel Production	CO_2	7,233.65	0.005	0.5%	92.3%
#23	1.A.3.	Transport	a. Domestic Aviation	CO_2	7,162.41	0.005	0.5%	92.8%
#24	2.A.	Mineral Industry	2. Lime Production	CO_2	6,674.45	0.005	0.5%	93.3%
#25	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	6,504.76	0.005	0.5%	93.8%
#26	2.B.	Chemical Industry	3. Adipic Acid Production	N_2O	6,412.36	0.005	0.5%	94.2%
#27	1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	CH_4	5,482.08	0.004	0.4%	94.6%
#28		Indirect CO_2	from IPPU Sector	Ind CO_2	4,448.96	0.003	0.3%	95.0%
	Excluding LULUCF							
#1	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	199,518.60	0.156	15.6%	15.6%
#2	1.A.3.	Transport	b. Road Transportation	CO_2	180,367.42	0.141	14.1%	29.8%
#3	1.A.1.	Energy Industries	Liquid Fuels	CO_2	178,587.22	0.140	14.0%	43.8%
#4	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	134,126.79	0.105	10.5%	54.3%
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	129,077.78	0.101	10.1%	64.4%
#6	1.A.1.	Energy Industries	Solid Fuels	CO_2	109,537.93	0.086	8.6%	73.0%
#7	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	80,030.95	0.063	6.3%	79.3%
#8	2.A.	Mineral Industry	1. Cement Production	CO_2	38,701.10	0.030	3.0%	82.4%
#9	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	22,241.56	0.017	1.7%	84.1%
#10	1.A.3.	Transport	d. Domestic Navigation	CO_2	13,674.88	0.011	1.1%	85.2%
#11	3.C.	Rice Cultivation		CH_4	13,584.76	0.011	1.1%	86.2%
#12	2.B.	Chemical Industry	9. Fluorochemical Production	HFCs	13,347.05	0.010	1.0%	87.3%
#13	5.C.	Incineration and Open Burning of Waste		CO_2	12,318.70	0.010	1.0%	88.2%
#14	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	11,894.05	0.009	0.9%	89.2%
#15	5.A.	Solid Waste Disposal		CH_4	11,092.46	0.009	0.9%	90.1%
#16	3.A.	Enteric Fermentation		CH_4	10,553.65	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	7,233.65	0.006	0.6%	92.2%
#19	1.A.3.	Transport	a. Domestic Aviation	CO_2	7,162.41	0.006	0.6%	92.7%
#20	2.A.	Mineral Industry	2. Lime Production	CO_2	6,674.45	0.005	0.5%	93.2%
#21	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	6,504.76	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%

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%	11.1%	11.1%
#2	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	199,518.60	6%	10.6%	21.7%
#3	4.A.	Forest Land	1. Forest Land Remaining Forest Land	CO_2	-84,713.44	9%	6.3%	28.0%
#4	1.A.1.	Energy Industries	Solid Fuels	CO_2	109,537.93	6%	5.8%	33.8%
#5	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O	2,655.70	246%	5.6%	39.4%
#6	3.B.	Manure Management		N_2O	3,865.02	132%	4.4%	43.7%
#7	4.E.	Settlements	2. Land Converted to Settlements	CO_2	11,389.02	44%	4.3%	48.0%
#8	1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	CH_4	5,482.08	84%	3.9%	52.0%
#9	1.A.3.	Transport	b. Road Transportation	N_2O	3,074.39	107%	2.8%	54.8%
#10	3.A.	Enteric Fermentation		CH_4	10,553.65	30%	2.7%	57.4%
#11	2.E.	Electronics Industry		SF_6	950.73	300%	2.4%	59.9%
#12		Indirect CO_2	from IPPU Sector	Ind CO_2	4,448.96	59%	2.2%	62.1%
#13	5.A.	Solid Waste Disposal		CH_4	11,092.46	23%	2.2%	64.3%
#14	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O	1,487.61	162%	2.1%	66.3%
#15	3.D.	Agricultural Soils	1. Direct Emissions	N_2O	4,002.69	59%	2.0%	68.3%
#16	1.A.3.	Transport	b. Road Transportation	CO_2	180,367.42	1%	1.8%	70.1%
#17	1.A.1.	Energy Industries	Liquid Fuels	CO_2	178,587.22	1%	1.8%	71.9%
#18	2.B.	Chemical Industry	Other Products Except Anmonia	CO_2	3,661.61	55%	1.7%	73.6%
#19	4.F.	Other Land	2. Land Converted to Other Land	CO_2	2,279.16	84%	1.6%	75.2%
#20	5.C.	Incineration and Open Burning of Waste		CO_2	12,318.70	15%	1.6%	76.8%
#21	4.B.	Cropland	1. Cropland Remaining Cropland	CO_2	7,371.57	24%	1.5%	78.3%
#22	2.A.	Mineral Industry	1. Cement Production	CO_2	38,701.10	4%	1%	80%
#23	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	134,126.79	1%	1%	81%
#24	1.A.4.	Other Sectors	Liquid Fuels	CO_2	129,077.78	1%	1%	82%
#25	4.(III)	N_2O Emissions from N Mineralization/Immobilization		N_2O	847.31	159%	1%	83%
#26	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	80,030.95	2%	1%	85%
#27	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	6,504.76	19%	1%	86%
#28	2.D.	Non-energy Products from Fuels and Solvent Use		CO_2	2,207.26	51%	1%	87%
#29	2.E.	Electronics Industry		PFCs	1,314.38	81%	1%	87%
#30	5.C.	Incineration and Open Burning of Waste		N_2O	1,287.27	78%	1%	88%
#31	5.D.	Wastewater Treatment and Discharge		N_2O	2,122.77	42%	1%	89%
#32	4.A.	Forest Land	2. Land Converted to Forest Land	CO_2	-9,577.97	9%	1%	90%
	Excluding LULUCF							
#1	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	199,518.60	5%	13.1%	13.1%
#2	2.G.	Other Product Manufacture and Use		SF_6	9,084.65	83%	9.4%	22.5%
#3	1.A.1.	Energy Industries	Solid Fuels	CO_2	109,537.93	5%	7.2%	29.7%
#4	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O	2,655.70	164%	5.4%	35.1%
#5	3.B.	Manure Management		N_2O	3,865.02	89%	4.3%	39.4%
#6	1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	CH_4	5,482.08	63%	4.3%	43.7%
#7	2.E.	Electronics Industry		SF_6	950.73	300%	3.6%	47.2%
#8	3.A.	Enteric Fermentation		CH_4	10,553.65	27%	3.5%	50.8%
#9	5.A.	Solid Waste Disposal		CH_4	11,092.46	23%	3.2%	53.9%
#10	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O	1,487.61	162%	3.0%	57.0%
#11	1.A.3.	Transport	b. Road Transportation	N_2O	3,074.39	72%	2.8%	59.7%
#12	2.B.	Chemical Industry	Other Products Except Anmonia	CO_2	3,661.61	55%	2.5%	62.2%
#13		Indirect CO_2	from IPPU Sector	Ind CO_2	4,448.96	45%	2.5%	64.7%
#14	3.D.	Agricultural Soils	1. Direct Emissions	N_2O	4,002.69	50%	2.5%	67.2%
#15	5.C.	Incineration and Open Burning of Waste		CO_2	12,318.70	15%	2.3%	69.5%
#16	1.A.3.	Transport	b. Road Transportation	CO_2	180,367.42	1%	2.2%	71.7%
#17	1.A.1.	Energy Industries	Liquid Fuels	CO_2	178,587.22	1%	2.2%	73.9%
#18	2.A.	Mineral Industry	1. Cement Production	CO_2	38,701.10	4%	2.0%	75.9%
#19	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	134,126.79	1%	1.6%	77.5%
#20	1.A.4.	Other Sectors	Liquid Fuels	CO_2	129,077.78	1%	1.6%	79.1%
#21	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	80,030.95	2%	1.5%	80.7%
#22	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	6,504.76	19%	1.5%	82.2%
#23	2.D.	Non-energy Products from Fuels and Solvent Use		CO_2	2,207.26	51%	1.4%	83.6%
#24	2.E.	Electronics Industry		PFCs	1,314.38	81%	1.3%	84.9%
#25	5.C.	Incineration and Open Burning of Waste		N_2O	1,287.27	78%	1.3%	86.2%
#26	3.C.	Rice Cultivation		CH_4	13,584.76	6%	1.0%	87.2%
#27	5.D.	Wastewater Treatment and Discharge		N_2O	2,122.77	38%	1.0%	88.2%
#28	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	4,207.45	19%	1.0%	89.2%

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 emissions and removals is calculated. The trend assessment is calculated by multiplying this value by the ratio of contribution of the relevant category to total emissions and removals. 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 FY2022 gives the following 24 sub-categories as the key categories and that of excluding LULUCF gives the following 19 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 23 sub-categories as the key categories (Table A1-10).

Table A1-9 Results of Approach 1 trend assessment (FY2022)

	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	255511.44	0.112	21.8%	21.8%
#2	1.A.1.	Energy Industries	Liquid Fuels	CO_2	178587.22	52205.97	0.078	15.1%	36.8%
#3	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	134126.79	51658.34	0.050	9.6%	46.4%
#4	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	80030.95	127301.36	0.040	7.7%	54.1%
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	129077.78	69644.68	0.033	6.5%	60.5%
#6	2.F.	Product Uses as Substitutes for ODS	1. Refrigeration and Air Conditioning Equipment	HFCs	NO	42810.33	0.031	5.9%	66.5%
#7	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	199518.60	142039.86	0.027	5.2%	71.7%
#8	4.A.	Forest Land	1. Forest Land Remaining Forest Land	CO_2	-84713.44	-59107.17	0.024	4.7%	76.4%
#9	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	22241.56	43256.59	0.017	3.2%	79.6%
#10	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	11894.05	30643.82	0.014	2.8%	82.4%
#11	2.A.	Mineral Industry	1. Cement Production	CO_2	38701.10	22479.16	0.009	1.7%	84.1%
#12	2.B.	Chemical Industry	9. Fluorochemical Production	HFCs	13347.05	66.24	0.009	1.7%	85.8%
#13	4.A.	Forest Land	2. Land Converted to Forest Land	CO_2	-9577.97	-656.28	0.007	1.4%	87.1%
#14	5.A.	Solid Waste Disposal		CH_4	11092.46	1636.76	0.006	1.2%	88.3%
#15	2.G.	Other Product Manufacture and Use		SF_6	9084.65	1397.09	0.005	0.9%	89.2%
#16	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	4207.45	10257.93	0.005	0.9%	90.1%
#17	4.E.	Settlements	2. Land Converted to Settlements	CO_2	11389.02	4198.27	0.004	0.8%	91.0%
#18	1.A.4.	Other Sectors	Solid Fuels	CO_2	353.86	6320.81	0.004	0.8%	91.8%
#19	2.B.	Chemical Industry	3. Adipic Acid Production	N_2O	6412.36	18.95	0.004	0.8%	92.6%
#20	1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	CH_4	5482.08	510.34	0.003	0.6%	93.2%
#21	1.A.3.	Transport	a. Domestic Aviation	CO_2	7162.41	9704.87	0.002	0.5%	93.7%
#22	2.B.	Chemical Industry	9. Fluorochemical Production	SF_6	3577.34	33.74	0.002	0.4%	94.1%
#23		Indirect CO_2	from IPPU Sector	Ind CO_2	4448.96	1364.67	0.002	0.4%	94.5%
#24	2.F.	Product Uses as Substitutes for ODS	2. Foam Blowing Agents	HFCs	1.22	2591.42	0.0018568	0.4%	94.8%
	Excluding LULUCF								
#1	1.A.1.	Energy Industries	Solid Fuels	CO_2	109,537.93	255,511.44	0.1239	23.9%	23.9%
#2	1.A.1.	Energy Industries	Liquid Fuels	CO_2	178,587.22	52,205.97	0.0838	16.2%	40.1%
#3	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	134,126.79	51,658.34	0.0532	10.3%	50.4%
#4	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	80,030.95	127,301.36	0.0439	8.5%	58.9%
#5	1.A.4.	Other Sectors	Liquid Fuels	CO_2	129,077.78	69,644.68	0.0355	6.9%	65.7%
#6	2.F.	Product Uses as Substitutes for ODS	1. Refrigeration and Air Conditioning Equipment	HFCs	NO	42,810.33	0.0336	6.5%	72.2%
#7	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	199,518.60	142,039.86	0.0280	5.4%	77.6%
#8	1.A.4.	Other Sectors	Gaseous Fuels	CO_2	22,241.56	43,256.59	0.0184	3.6%	81.1%
#9	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	11,894.05	30,643.82	0.0157	3.0%	84.2%
#10	2.A.	Mineral Industry	1. Cement Production	CO_2	38,701.10	22,479.16	0.0094	1.8%	86.0%
#11	2.B.	Chemical Industry	9. Fluorochemical Production	HFCs	13,347.05	66.24	0.0093	1.8%	87.8%
#12	5.A.	Solid Waste Disposal		CH_4	11,092.46	1,636.76	0.0065	1.2%	89.0%
#13	2.G.	Other Product Manufacture and Use		SF_6	9,084.65	1,397.09	0.0053	1.0%	90.1%
#14	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	4,207.45	10,257.93	0.0051	1.0%	91.0%
#15	1.A.4.	Other Sectors	Solid Fuels	CO_2	353.86	6,320.81	0.0047	0.9%	91.9%
#16	2.B.	Chemical Industry	3. Adipic Acid Production	N_2O	6,412.36	18.95	0.0045	0.9%	92.8%
#17	1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	CH_4	5,482.08	510.34	0.0034	0.7%	93.5%
#18	1.A.3.	Transport	b. Road Transportation	CO_2	180,367.42	164,512.63	0.0030	0.6%	94.1%
#19	1.A.3.	Transport	a. Domestic Aviation	CO_2	7,162.41	9,704.87	0.0026	0.5%	94.6%

Table A1-10 Results of Approach 2 trend assessment (FY2022)

	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	255,511.44	6%	7.04	15.9%	15.9%
#2	2.G.	Other Product Manufacture and Use		SF_6	9,084.65	1,397.09	143%	6.97	15.8%	31.7%
#3	1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	CH_4	5,482.08	510.34	84%	2.68	6.1%	37.8%
#4	4.A.	Forest Land	1. Forest Land Remaining Forest Land	CO_2	-84,713.44	-59,107.17	9%	2.12	4.8%	42.6%
#5	4.E.	Settlements	2. Land Converted to Settlements	CO_2	11,389.02	4,198.27	44%	1.93	4.4%	47.0%
#6	2.F.	Product Uses as Substitutes for ODS	1. Refrigeration and Air Conditioning Equipment	HFCs	NO	42,810.33	6%	1.86	4.2%	51.2%
#7	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	199,518.60	142,039.86	6%	1.69	3.8%	55.0%
#8	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O	1,487.61	96.88	162%	1.44	3.3%	58.3%
#9	5.A.	Solid Waste Disposal		CH_4	11,092.46	1,636.76	23%	1.38	3.1%	61.4%
#10	1.A.3.	Transport	b. Road Transportation	N_2O	3,074.39	1,107.48	107%	1.27	2.9%	64.3%
#11		Indirect CO_2	from IPPU Sector	Ind CO_2	4,448.96	1,364.67	59%	1.12	2.5%	66.8%
#12	4.F.	Other Land	2. Land Converted to Other Land	CO_2	2,279.16	400.91	84%	0.99	2.2%	69.0%
#13	2.E.	Electronics Industry		SF_6	950.73	423.13	300%	0.93	2.1%	71.2%
#14	2.F.	Product Uses as Substitutes for ODS	2. Foam Blowing Agents	HFCs	1.22	2,591.42	50%	0.93	2.1%	73.3%
#15	1.A.1.	Energy Industries	Liquid Fuels	CO_2	178,587.22	52,205.97	1%	0.91	2.1%	75.3%
#16	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	4,207.45	10,257.93	19%	0.88	2.0%	77.3%
#17	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	80,030.95	127,301.36	2%	0.63	1.4%	78.7%
#18	4.A.	Forest Land	2. Land Converted to Forest Land	CO_2	-9,577.97	-656.28	9%	0.62	1.4%	80.1%
#19	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	134,126.79	51,658.34	1%	0.58	1.3%	81.5%
#20	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O	2,655.70	2,072.23	246%	0.56	1.3%	82.7%
#21	4.(III)	N_2O Emissions from N Mineralization/Immobilization		N_2O	847.31	386.76	159%	0.43	1.0%	83.7%
#22	1.A.4.	Other Sectors	Liquid Fuels	CO_2	129,077.78	69,644.68	1%	0.39	0.9%	84.6%
#23	2.B.	Chemical Industry	3. Adipic Acid Production	N_2O	6,412.36	18.95	9%	0.38	0.9%	85.4%
#24	4.B.	Cropland	1. Cropland Remaining Cropland	CO_2	7,371.57	4,447.06	24%	0.37	0.8%	86.3%
#25	2.A.	Mineral Industry	1. Cement Production	CO_2	38,701.10	22,479.16	4%	0.37	0.8%	87.1%
#26	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	6,504.76	8,424.38	19%	0.35	0.8%	87.9%
#27	2.B.	Chemical Industry	2. Nitric Acid Production	N_2O	654.55	185.61	112%	0.32	0.7%	88.6%
#28	2.B.	Chemical Industry	Other Products Except Ammonia	CO_2	3,661.61	2,548.65	55%	0.29	0.7%	89.3%
#29	4.G.	Harvested Wood Products		CO_2	-514.50	-1,918.02	30%	0.29	0.7%	90.0%
Excluding LULUCF										
#1	1.A.1.	Energy Industries	Solid Fuels	CO_2	109,537.93	255,511.44	6%	7.76	19.3%	19.3%
#2	2.G.	Other Product Manufacture and Use		SF_6	9,084.65	1,397.09	143%	7.53	18.7%	38.0%
#3	1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	CH_4	5,482.08	510.34	84%	2.90	7.2%	45.2%
#4	2.F.	Product Uses as Substitutes for ODS	1. Refrigeration and Air Conditioning Equipment	HFCs	NO	42,810.33	6%	2.04	5.1%	50.3%
#5	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	199,518.60	142,039.86	6%	1.75	4.4%	54.6%
#6	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N_2O	1,487.61	96.88	162%	1.56	3.9%	58.5%
#7	5.A.	Solid Waste Disposal		CH_4	11,092.46	1,636.76	23%	1.49	3.7%	62.2%
#8	1.A.3.	Transport	b. Road Transportation	N_2O	3,074.39	1,107.48	107%	1.37	3.4%	65.6%
#9		Indirect CO_2	from IPPU Sector	Ind CO_2	4,448.96	1,364.67	59%	1.20	3.0%	68.6%
#10	2.F.	Product Uses as Substitutes for ODS	2. Foam Blowing Agents	HFCs	1.22	2,591.42	50%	1.02	2.5%	71.1%
#11	2.E.	Electronics Industry		SF_6	950.73	423.13	300%	1.00	2.5%	73.6%
#12	1.A.1.	Energy Industries	Liquid Fuels	CO_2	178,587.22	52,205.97	1%	0.98	2.4%	76.1%
#13	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	4,207.45	10,257.93	19%	0.97	2.4%	78.5%
#14	1.A.1.	Energy Industries	Gaseous Fuels	CO_2	80,030.95	127,301.36	2%	0.70	1.7%	80.2%
#15	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	134,126.79	51,658.34	1%	0.62	1.5%	81.8%
#16	3.D.	Agricultural Soils	2. Indirect Emissions	N_2O	2,655.70	2,072.23	246%	0.56	1.4%	83.2%
#17	1.A.4.	Other Sectors	Liquid Fuels	CO_2	129,077.78	69,644.68	1%	0.42	1.0%	84.2%
#18	2.B.	Chemical Industry	3. Adipic Acid Production	N_2O	6,412.36	18.95	9%	0.41	1.0%	85.2%
#19	1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	6,504.76	8,424.38	19%	0.39	1.0%	86.2%
#20	2.A.	Mineral Industry	1. Cement Production	CO_2	38,701.10	22,479.16	4%	0.39	1.0%	87.2%
#21	2.B.	Chemical Industry	2. Nitric Acid Production	N_2O	654.55	185.61	112%	0.35	0.9%	88.0%
#22	2.B.	Chemical Industry	Other Products Except Ammonia	CO_2	3,661.61	2,548.65	55%	0.31	0.8%	88.8%
#23	1.A.4.	Other Sectors	Solid Fuels	CO_2	353.86	6,320.81	6%	0.29	0.7%	89.5%

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 (FY2022)

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	178,587.22	52,205.97	0.043	4.3%	0.0778	15.1%	1%	0.007	0.7%	0.91	2.1%
1.A.1.	Energy Industries	Solid Fuels	CO_2	109,537.93	255,511.44	0.211	21.1%	0.1125	21.8%	6%	0.187	18.7%	7.04	15.9%
1.A.1.	Energy Industries	Gaseous Fuels	CO_2	80,030.95	127,301.36	0.105	10.5%	0.0396	7.7%	2%	0.024	2.4%	0.63	1.4%
1.A.1.	Energy Industries	Other Fossil Fuels	CO_2	0.00	32.05	0.000	0.0%	0.0000	0.0%	19%	0.000	0.0%	0.00	0.0%
1.A.1.	Energy Industries		CH_4	514.47	218.35	0.000	0.0%	0.0002	0.0%	64%	0.002	0.2%	0.11	0.3%
1.A.1.	Energy Industries		N_2O	790.98	1,638.03	0.001	0.1%	0.0007	0.1%	30%	0.006	0.6%	0.20	0.4%
1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO_2	134,126.79	51,658.34	0.043	4.3%	0.0495	9.6%	1%	0.007	0.7%	0.58	1.3%
1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	199,518.60	142,039.86	0.117	11.7%	0.0269	5.2%	6%	0.104	10.4%	1.69	3.8%
1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO_2	11,894.05	30,643.82	0.025	2.5%	0.0143	2.8%	2%	0.006	0.6%	0.23	0.5%
1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO_2	4,207.45	10,257.93	0.008	0.8%	0.0046	0.9%	19%	0.023	2.3%	0.88	2.0%
1.A.2.	Manufacturing Industries and Construction		CH_4	402.93	525.79	0.000	0.0%	0.0001	0.0%	64%	0.004	0.4%	0.08	0.2%
1.A.2.	Manufacturing Industries and Construction		N_2O	1,120.30	1,152.23	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	9,704.87	0.008	0.8%	0.0023	0.5%	1%	0.001	0.1%	0.03	0.1%
1.A.3.	Transport	a. Domestic Aviation	CH_4	6.31	2.18	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	75.65	0.000	0.0%	0.0000	0.0%	141%	0.001	0.1%	0.02	0.1%
1.A.3.	Transport	b. Road Transportation	CO_2	180,367.42	164,512.63	0.136	13.6%	0.0015	0.3%	1%	0.023	2.3%	0.02	0.0%
1.A.3.	Transport	b. Road Transportation	CH_4	282.90	91.42	0.000	0.0%	0.0001	0.0%	104%	0.001	0.1%	0.12	0.3%
1.A.3.	Transport	b. Road Transportation	N_2O	3,074.39	1,107.48	0.001	0.1%	0.0012	0.2%	107%	0.014	1.4%	1.27	2.9%
1.A.3.	Transport	c. Railways	CO_2	935.40	448.71	0.000	0.0%	0.0003	0.1%	1%	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	46.28	0.000	0.0%	0.0000	0.0%	200%	0.001	0.1%	0.06	0.1%
1.A.3.	Transport	d. Domestic Navigation	CO_2	13,674.88	10,373.42	0.009	0.9%	0.0014	0.3%	1%	0.001	0.1%	0.02	0.0%
1.A.3.	Transport	d. Domestic Navigation	CH_4	7.11	5.22	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	141.07	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	129,077.78	69,644.68	0.058	5.8%	0.0334	6.5%	1%	0.010	1.0%	0.39	0.9%
1.A.4.	Other Sectors	Solid Fuels	CO_2	353.86	6,320.81	0.005	0.5%	0.0043	0.8%	6%	0.005	0.5%	0.27	0.6%
1.A.4.	Other Sectors	Gaseous Fuels	CO_2	22,241.56	43,256.59	0.036	3.6%	0.0167	3.2%	2%	0.008	0.8%	0.27	0.6%
1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	6,504.76	8,424.38	0.007	0.7%	0.0018	0.4%	19%	0.019	1.9%	0.35	0.8%
1.A.4.	Other Sectors		CH_4	267.29	230.53	0.000	0.0%	0.0000	0.0%	64%	0.002	0.2%	0.00	0.0%
1.A.4.	Other Sectors		N_2O	613.07	441.39	0.000	0.0%	0.0001	0.0%	30%	0.002	0.2%	0.02	0.1%
1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	CO_2	5.90	0.41	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	510.34	0.000	0.0%	0.0032	0.6%	84%	0.005	0.5%	2.68	6.1%
1.B.	Fugitive Emissions from Fuels	1. Solid Fuels	N_2O	1.76	0.36	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	14.19	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	0.85	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	237.51	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	155.13	0.000	0.0%	0.0001	0.0%	13%	0.000	0.0%	0.01	0.0%
1.B.	Fugitive Emissions from Fuels	2.c. Venting & Flaring	CH_4	59.50	44.18	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	0.10	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	22,479.16	0.019	1.9%	0.0089	1.7%	4%	0.011	1.1%	0.37	0.8%
2.A.	Mineral Industry	2. Lime Production	CO_2	6,674.45	4,650.45	0.004	0.4%	0.0010	0.2%	4%	0.002	0.2%	0.04	0.1%
2.A.	Mineral Industry	3. Glass Production	CO_2	312.93	148.26	0.000	0.0%	0.0001	0.0%	6%	0.000	0.0%	0.01	0.0%
2.A.	Mineral Industry	4. Other Process Uses of Carbonates	CO_2	3,025.31	1,726.84	0.001	0.1%	0.0007	0.1%	6%	0.001	0.1%	0.04	0.1%
2.B.	Chemical Industry	1. Ammonia Production	CO_2	2,448.52	909.44	0.001	0.1%	0.0009	0.2%	2%	0.000	0.0%	0.02	0.0%
2.B.	Chemical Industry	Other Products Except Ammonia	CO_2	3,661.61	2,548.65	0.002	0.2%	0.0005	0.1%	55%	0.016	1.6%	0.29	0.7%
2.B.	Chemical Industry	2. Nitric Acid Production	N_2O	654.55	185.61	0.000	0.0%	0.0003	0.1%	112%	0.002	0.2%	0.32	0.7%
2.B.	Chemical Industry	3. Adipic Acid Production	N_2O	6,412.36	18.95	0.000	0.0%	0.0041	0.8%	9%	0.000	0.0%	0.38	0.9%
2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid	N_2O	1,487.61	96.88	0.000	0.0%	0.0009	0.2%	162%	0.002	0.2%	1.44	3.3%
2.B.	Chemical Industry	9. Fluorochemical Production	HFCs	13,347.05	66.24	0.000	0.0%	0.0086	1.7%	2%	0.000	0.0%	0.17	0.4%
2.B.	Chemical Industry	9. Fluorochemical Production	PFCs	303.84	66.67	0.000	0.0%	0.0001	0.0%	2%	0.000	0.0%	0.00	0.0%
2.B.	Chemical Industry	9. Fluorochemical Production	SF_6	3,577.34	33.74	0.000	0.0%	0.0023	0.4%	2%	0.000	0.0%	0.05	0.1%
2.B.	Chemical Industry	9. Fluorochemical Production	NF_3	2.61	19.16	0.000	0.0%	0.0000	0.0%	47%	0.000	0.0%	0.01	0.0%
2.B.	Chemical Industry	Whole of Chemical Industries	CH_4	41.99	26.30	0.000	0.0%	0.0000	0.0%	58%	0.000	0.0%	0.00	0.0%
2.C.	Metal Industry	1. Iron and Steel Production	CO_2	7,233.65	5,208.35	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	15.05	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	2.12	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	1.17	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	282.00	0.000	0.0%	0.0001	0.0%	100%	0.003	0.3%	0.11	0.2%
2.D.	Non-energy Products from Fuels and Solvent Use		CO_2	2,207.26	2,328.25	0.002	0.2%	0.0002	0.0%	51%	0.014	1.4%	0.13	0.3%
2.E.	Electronics Industry		N_2O	13.25	447.51	0.000	0.0%	0.0003	0.1%	5%	0.000	0.0%	0.02	0.0%
2.E.	Electronics Industry		HFCs	55.22	97.42	0.000	0.0%	0.0000	0.0%	100%	0.001	0.1%	0.03	0.1%
2.E.	Electronics Industry		PFCs	1,314.38	1,503.07	0.001	0.1%	0.0002	0.0%	81%	0.014	1.4%	0.18	0.4%
2.E.	Electronics Industry		SF_6	950.73	423.13	0.000	0.0%	0.0003	0.1%	300%	0.015	1.5%	0.93	2.1%
2.E.	Electronics Industry		NF_3	25.36	317.14	0.000	0.0%	0.0002	0.0%	71%	0.003	0.3%	0.15	0.3%
2.F.	Product Uses as Substitutes for ODS	1. Refrigeration and Air Conditioning Equipment	HFCs	0.00	42,810.33	0.035	3.5%	0.0307	5.9%	6%	0.030	3.0%	1.86	4.2%
2.F.	Product Uses as Substitutes for ODS	2. Foam Blowing Agents	HFCs	1.22	2,591.42	0.002	0.2%	0.0019	0.4%	50%	0.015	1.5%	0.93	2.1%
2.F.	Product Uses as Substitutes for ODS	3. Fire Protection	HFCs	0.00	9.21	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	425.73	0.000	0.0%	0.0003	0.1%	10%	0.000	0.0%	0.03	0.1%
2.F.	Product Uses as Substitutes for ODS	5. Solvents	HFCs	0.00	129.35	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	1,406.29	0.001	0.1%	0.0017	0.3%	10%	0.002	0.2%	0.17	0.4%
2.G.	Other Product Manufacture and Use		N_2O	245.40	91.54	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	5.74	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	72.50	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	1,397.09	0.001	0.1%	0.0049	0.9%	143%	0.023	2.3%	6.97	15.8%
2.H.	Other		CO_2	873.52	885.03	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	8,660.61	0.007	0.7%	0.0006	0.1%	30%	0.030	3.0%	0.18	0.4%
3.B.	Manure Management		CH_4	3,786.09	2,708.85	0.002	0.2%	0.0005	0.1%	17%	0.005	0.5%	0.08	0.2%
3.B.	Manure Management		N_2O	3,865.02	3,418.80	0.003	0.3%	0.0000	0.0%	132%	0.053	5.3%	0.06	0.1%
3.C.	Rice Cultivation		CH_4	13,584.76	13,067.90	0.011	1.1%	0.0006	0.1%	6%	0.009	0.9%	0.04	0.1%
3.D.	Agricultural Soils	1. Direct Emissions	N_2O	4,002.69	3,131.16	0.003	0.3%	0.0003	0.1%	59%	0.022	2.2%	0.20	0.5%
3.D.	Agricultural Soils	2. Indirect Emissions	N_2O	2,655.70	2,072.23	0.002	0.2%	0.0002	0.0%	246%	0.060	6.0%	0.56	1.3%
3.F.	Field Burning of Agricultural Residues		CH_4	77.94	30.34	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	8.33	0.000	0.0%	0.0000	0.0%	300%	0.000	0.0%	0.03	0.1%
3.G.	Liming		CO_2	550.24	203.11	0.000	0.0%	0.0002	0.0%	50%	0.001	0.1%	0.10	0.2%
3.H.	Urea Application		CO_2	181.77	208.19	0.000	0.0%	0.0000	0.0%	50%	0.001	0.1%	0.02	0.0%

Table A1-11 Data used for the key category analysis (FY2022) (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.A.	Forest Land	1. Forest Land Remaining Forest Land	CO_2	84,713.44	59,107.17	0.049	4.9%	0.0244	4.7%	9%	0.060	6.0%	2.12	4.8%
4.A.	Forest Land	2. Land Converted to Forest Land	CO_2	9,577.97	656.28	0.001	0.1%	0.0071	1.4%	9%	0.001	0.1%	0.62	1.4%
4.B.	Cropland	1. Cropland Remaining Cropland	CO_2	7,371.57	4,447.06	0.004	0.4%	0.0016	0.3%	24%	0.012	1.2%	0.37	0.8%
4.B.	Cropland	2. Land Converted to Cropland	CO_2	649.51	371.57	0.000	0.0%	0.0002	0.0%	19%	0.001	0.1%	0.03	0.1%
4.C.	Grassland	1. Grassland Remaining Grassland	CO_2	478.26	285.94	0.000	0.0%	0.0001	0.0%	9%	0.000	0.0%	0.01	0.0%
4.C.	Grassland	2. Land Converted to Grassland	CO_2	485.42	128.64	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	601.21	356.57	0.000	0.0%	0.0002	0.0%	16%	0.001	0.1%	0.04	0.1%
4.D.	Wetlands	2. Land Converted to Wetlands	CO_2	73.37	17.48	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	1,014.70	1,471.98	0.001	0.1%	0.0003	0.0%	39%	0.007	0.7%	0.10	0.2%
4.E.	Settlements	2. Land Converted to Settlements	CO_2	11,389.02	4,198.27	0.003	0.3%	0.0043	0.8%	44%	0.022	2.2%	1.93	4.4%
4.F.	Other Land	2. Land Converted to Other Land	CO_2	2,279.16	400.91	0.000	0.0%	0.0012	0.2%	84%	0.004	0.4%	0.99	2.2%
4.G.	Harvested Wood Products		CO_2	514.50	1,918.02	0.002	0.2%	0.0010	0.2%	30%	0.007	0.7%	0.29	0.7%
4.H.	Other		CO_2	0.00	0.01	0.000	0.0%	0.0000	0.0%	6%	0.000	0.0%	0.00	0.0%
4.(I)	N_2O Emissions from N Inputs to Managed Soils		N_2O	1.24	0.76	0.000	0.0%	0.0000	0.0%	31%	0.000	0.0%	0.00	0.0%
4.(II)	CH_4 Emissions from Drainage of Organic Soils		CH_4	63.63	45.44	0.000	0.0%	0.0000	0.0%	66%	0.000	0.0%	0.01	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%	200%	0.000	0.0%	0.00	0.0%
4.(III)	N_2O Emissions from N Mineralization/Immobilization		N_2O	847.31	386.76	0.000	0.0%	0.0003	0.1%	159%	0.007	0.7%	0.43	1.0%
4.(IV)	Biomass Burning		CH_4	53.09	34.64	0.000	0.0%	0.0000	0.0%	141%	0.001	0.1%	0.01	0.0%
4.(IV)	Biomass Burning		N_2O	19.71	16.49	0.000	0.0%	0.0000	0.0%	86%	0.000	0.0%	0.00	0.0%
5.A.	Solid Waste Disposal		CH_4	11,092.46	1,636.76	0.001	0.1%	0.0060	1.2%	23%	0.004	0.4%	1.38	3.1%
5.B.	Biological Treatment of Solid Waste		CH_4	60.47	85.72	0.000	0.0%	0.0000	0.0%	84%	0.001	0.1%	0.02	0.0%
5.B.	Biological Treatment of Solid Waste		N_2O	160.75	226.37	0.000	0.0%	0.0001	0.0%	170%	0.005	0.5%	0.10	0.2%
5.C.	Incineration and Open Burning of Waste		CO_2	12,318.70	10,225.83	0.008	0.8%	0.0006	0.1%	15%	0.018	1.8%	0.09	0.2%
5.C.	Incineration and Open Burning of Waste		CH_4	31.18	9.26	0.000	0.0%	0.0000	0.0%	249%	0.000	0.0%	0.03	0.1%
5.C.	Incineration and Open Burning of Waste		N_2O	1,287.27	1,186.55	0.001	0.1%	0.0000	0.0%	78%	0.011	1.1%	0.02	0.0%
5.D.	Wastewater Treatment and Discharge		CH_4	3,294.53	1,732.96	0.001	0.1%	0.0009	0.2%	21%	0.004	0.4%	0.18	0.4%
5.D.	Wastewater Treatment and Discharge		N_2O	2,122.77	1,765.73	0.001	0.1%	0.0001	0.0%	42%	0.009	0.9%	0.04	0.1%
5.E.	Other		CO_2	702.83	654.38	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	1,040.93	455.96	0.000	0.0%	0.0003	0.1%	39%	0.002	0.2%	0.13	0.3%
	Indirect CO_2	from IPPU Sector	Ind CO_2	4,448.96	1,364.67	0.001	0.1%	0.0019	0.4%	59%	0.009	0.9%	1.12	2.5%
Absolute Figure Total (including LULUCF)				1,395,056.26	1,209,303.57	1.000	100.0%	0.5168	100.0%		1.000	100.0%	44.18	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	178,587.22	0.128	12.8%	1%	0.018	1.8%
1.A.1.	Energy Industries	Solid Fuels	CO_2	109,537.93	0.079	7.9%	6%	0.058	5.8%
1.A.1.	Energy Industries	Gaseous Fuels	CO_2	80,030.95	0.057	5.7%	2%	0.011	1.1%
1.A.1.	Energy Industries	Other Fossil Fuels	CO_2	0.00	0.000	0.0%	19%	0.000	0.0%
1.A.1.	Energy Industries		CH_4	514.47	0.000	0.0%	64%	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	134,126.79	0.096	9.6%	1%	0.013	1.3%
1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO_2	199,518.60	0.143	14.3%	6%	0.106	10.6%
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	4,207.45	0.003	0.3%	19%	0.007	0.7%
1.A.2.	Manufacturing Industries and Construction		CH_4	402.93	0.000	0.0%	64%	0.002	0.2%
1.A.2.	Manufacturing Industries and Construction		N_2O	1,120.30	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%	1%	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%	1%	0.018	1.8%
1.A.3.	Transport	b. Road Transportation	CH_4	282.90	0.000	0.0%	104%	0.003	0.3%
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%	1%	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%	1%	0.001	0.1%
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	129,077.78	0.093	9.3%	1%	0.013	1.3%
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%	0.003	0.3%
1.A.4.	Other Sectors	Other Fossil Fuels	CO_2	6,504.76	0.005	0.5%	19%	0.010	1.0%
1.A.4.	Other Sectors		CH_4	267.29	0.000	0.0%	64%	0.001	0.1%
1.A.4.	Other Sectors		N_2O	613.07	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	59.50	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%

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.A.	Mineral Industry	1. Cement Production	CO_2	38,701.10	0.028	2.8%	4%	0.014	1.4%
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%	0.002	0.2%
2.B.	Chemical Industry	1. Ammonia Production	CO_2	2,448.52	0.002	0.2%	2%	0.000	0.0%
2.B.	Chemical Industry	Other Products Except Anmonia	CO_2	3,661.61	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%	0.021	2.1%
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%
2.C.	Metal Industry	1. Iron and Steel Production	CO_2	7,233.65	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	2,207.26	0.002	0.2%	51%	0.010	1.0%
2.E.	Electronics Industry		N_2O	13.25	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%	0.111	11.1%
2.H.	Other		CO_2	873.52	0.001	0.1%	2%	0.000	0.0%
3.A.	Enteric Fermentation		CH_4	10,553.65	0.008	0.8%	30%	0.027	2.7%
3.B.	Manure Management		CH_4	3,786.09	0.003	0.3%	17%	0.005	0.5%
3.B.	Manure Management		N_2O	3,865.02	0.003	0.3%	132%	0.044	4.4%
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	4,002.69	0.003	0.3%	59%	0.020	2.0%
3.D.	Agricultural Soils	2. Indirect Emissions	N_2O	2,655.70	0.002	0.2%	246%	0.056	5.6%
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	84,713.44	0.061	6.1%	9%	0.063	6.3%
4.A.	Forest Land	2. Land Converted to Forest Land	CO_2	9,577.97	0.007	0.7%	9%	0.007	0.7%
4.B.	Cropland	1. Cropland Remaining Cropland	CO_2	7,371.57	0.005	0.5%	24%	0.015	1.5%
4.B.	Cropland	2. Land Converted to Cropland	CO_2	649.51	0.000	0.0%	19%	0.001	0.1%
4.C.	Grassland	1. Grassland Remaining Grassland	CO_2	478.26	0.000	0.0%	9%	0.000	0.0%
4.C.	Grassland	2. Land Converted to Grassland	CO_2	485.42	0.000	0.0%	21%	0.001	0.1%
4.D.	Wetlands	1. Wetlands Remaining Wetlands	CO_2	601.21	0.000	0.0%	16%	0.001	0.1%
4.D.	Wetlands	2. Land Converted to Wetlands	CO_2	73.37	0.000	0.0%	23%	0.000	0.0%
4.E.	Settlements	1. Settlements Remaining Settlements	CO_2	1,014.70	0.001	0.1%	39%	0.003	0.3%
4.E.	Settlements	2. Land Converted to Settlements	CO_2	11,389.02	0.008	0.8%	44%	0.043	4.3%
4.F.	Other Land	2. Land Converted to Other Land	CO_2	2,279.16	0.002	0.2%	84%	0.016	1.6%
4.G.	Harvested Wood Products		CO_2	514.50	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%	31%	0.000	0.0%
4.(II)	CH_4 Emissions from Drainage of Organic Soils		CH_4	63.63	0.000	0.0%	66%	0.000	0.0%
4.(II)	N_2O Emissions from Drainage of Organic Soils		N_2O	2.62	0.000	0.0%	200%	0.000	0.0%
4.(III)	N_2O Emissions from N Mineralization/Immobilization		N_2O	847.31	0.001	0.1%	159%	0.011	1.1%
4.(IV)	Biomass Burning		CH_4	53.09	0.000	0.0%	141%	0.001	0.1%
4.(IV)	Biomass Burning		N_2O	19.71	0.000	0.0%	86%	0.000	0.0%
5.A.	Solid Waste Disposal		CH_4	11,092.46	0.008	0.8%	23%	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	12,318.70	0.009	0.9%	15%	0.016	1.6%
5.C.	Incineration and Open Burning of Waste		CH_4	31.18	0.000	0.0%	249%	0.001	0.1%
5.C.	Incineration and Open Burning of Waste		N_2O	1,287.27	0.001	0.1%	78%	0.009	0.9%
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%	0.008	0.8%
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	1,040.93	0.001	0.1%	39%	0.003	0.3%
	Indirect CO_2	from IPPU Sector	Ind CO_2	4,448.96	0.003	0.3%	59%	0.022	2.2%
Total (including LULUCF)				1,395,056.26	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 FY2022, total net emissions in Japan were approximately 1,082 million tons (carbon dioxide equivalents). Uncertainty of total net emissions in FY2022 has been assessed at -3% to +2% and uncertainty introduced into the trend in total net emissions has been 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 91% of the net emissions.

Table A2-1 Uncertainty of Japan's total net emissions

A	B	C	D	G-1990		G-2022		I	J	
Category	GHGs	FY1990 emissions / removals	FY2022 emissions / removals	Combined uncertainty in FY1990		Combined uncertainty in FY2022		Inventory trend in national emissions for FY2022 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	1,078,221	982,337	-2%	+1%	-3%	+2%	-8.9%	-3.1%	+2.1%
1A. Fuel Combustion (Stationary:CH_4,N_2O)	CH_4, N_2O	3,709	4,206	-22%	+29%	-24%	+27%	13.4%	0.0%	+0.0%
1A. Fuel Combustion (Transport:CH_4,N_2O)	CH_4, N_2O	3,719	1,470	-30%	+89%	-28%	+83%	-60.5%	0.0%	+0.0%
1B. Fugitive Emissions from Fuels	CO_2, CH_4, N_2O	5,988	1,166	-37%	+77%	-18%	+38%	-80.5%	0.0%	+0.0%
2. IPPU (CO_2,CH_4,N_2O)	CO_2, CH_4, N_2O	74,077	41,768	-5%	+5%	-5%	+5%	-43.6%	-0.1%	+0.1%
2. IPPU (HFCs,PFCs,SF_6,NF_3)	HFCs, PFCs, SF_6, NF_3	33,364	51,657	-11%	+40%	-7%	+8%	54.8%	-0.5%	+0.5%
3. Agriculture	CO_2, CH_4, N_2O	39,281	33,510	-11%	+25%	-10%	+23%	-14.7%	-0.1%	+0.1%
4. LULUCF	CO_2, CH_4, N_2O	-72,708	-53,175	-13%	13%	-11%	+11%	-26.9%	-0.4%	+0.4%
5. Waste	CO_2, CH_4, N_2O	31,071	17,524	-11%	+11%	-11%	+12%	-43.6%	-0.2%	+0.2%
Indirect CO_2	Ind CO_2	5,490	1,821	-26%	+48%	-24%	+45%	-66.8%	0.0%	+0.0%
Total Net Emissions		1,202,213	1,082,284	-2.0%	+2.1%	-2.5%	+2.0%	-10.0%	-3.1%	+2.2%

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-2022		T	I	J	K		L		M	
Category		GHG	FY1990 emissions / removals	FY2022 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 FY2022		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.	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	%	%	%	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %
Total			1,202,213	1,082,284							-2.0%	+2.1%	-2.5%	+2.0%	-10.0%							-3.1%	+2.2%
1.A. Fuel Combustion	Liquid Fuels	CO_2	643,860	358,484	-1%	+1%	-	-	-1%	+1%	-0.6%	0.4%	-0.4%	0.3%	-44.3%	0.2%	29.8%	0.0%	0.0%	-0.5%	0.3%	0.5%	0.3%
1.A. Fuel Combustion	Solid Fuels	CO_2	309,482	403,895	-6%	+4%	-	-	-6%	+4%	-1.6%	1.1%	-2.3%	1.6%	30.5%	0.1%	33.6%	0.0%	0.0%	-3.0%	2.0%	3.0%	2.0%
1.A. Fuel Combustion	Gaseous Fuels	CO_2	114,167	201,244	-1%	+1%	-	-	-1%	+2%	-0.1%	0.2%	-0.3%	0.3%	76.3%	0.1%	16.7%	0.0%	0.0%	-0.3%	0.3%	0.3%	0.3%
1.A. Fuel Combustion	Other Fossil Fuels	CO_2	10,712	18,714	-	-	-	-	-19%	+19%	-0.2%	0.2%	-0.3%	0.3%	74.7%	0.0%	1.6%	0.0%	0.0%	-0.4%	0.4%	0.4%	0.4%
1.A. Stationary Combustion		CH_4	1,185	975	-	-	-	-	-29%	+64%	0.0%	0.1%	0.0%	0.1%	-17.7%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
1.A. Stationary Combustion		N_2O	2,524	3,232	-	-	-	-	-30%	+30%	-0.1%	0.1%	-0.1%	0.1%	28.0%	0.0%	0.3%	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%	-65.5%	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	76	-5%	+5%	-70%	+150%	-70%	+150%	0.0%	0.0%	0.0%	0.0%	32.9%	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	91	-	-	-	-	-36%	+104%	0.0%	0.0%	0.0%	0.0%	-67.7%	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	1,107	-	-	-	-	-37%	+107%	-0.1%	0.3%	0.0%	0.1%	-64.0%	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%	-52.7%	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%	-26.6%	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	141	-13%	+13%	-41%	+140%	-43%	+141%	0.0%	0.0%	0.0%	0.0%	-26.6%	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%	-93.0%	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	510	-	-	-	-	-41%	+84%	-0.2%	0.4%	0.0%	0.0%	-90.7%	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%	-79.5%	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	CO_2	0	0	-	-	-	-	-87%	+87%	0.0%	0.0%	0.0%	0.0%	-22.2%	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	14	-	-	-	-	-79%	+79%	0.0%	0.0%	0.0%	0.0%	-30.0%	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%	17.5%	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	238	-	-	-	-	-15%	+28%	0.0%	0.0%	0.0%	0.0%	10.0%	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	155	-	-	-	-	-13%	+13%	0.0%	0.0%	0.0%	0.0%	69.2%	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	59	44	-	-	-	-	-11%	+11%	0.0%	0.0%	0.0%	0.0%	-25.7%	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%	-20.7%	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)	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-2022		T	I	J	K		L		M	
Category		GHG	FY1990 emissions / removals	FY2022 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 FY2022		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	22,479	-2%	+2%	-4%	+4%	-4%	+4%	-0.1%	0.1%	-0.1%	0.1%	-41.9%	0.0%	1.9%	0.0%	0.0%	-0.1%	0.1%	0.1%	0.1%
2.A. Mineral Industry	2. Lime Production	CO_2	6,674	4,650	-3%	+3%	-2%	+2%	-4%	+4%	0.0%	0.0%	0.0%	0.0%	-30.3%	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	148	-3%	+3%	-5%	+5%	-6%	+6%	0.0%	0.0%	0.0%	0.0%	-52.6%	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	1,727	-3%	+3%	-5%	+5%	-6%	+6%	0.0%	0.0%	0.0%	0.0%	-42.9%	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	2,449	909	-	-	-	-	-2%	+1%	0.0%	0.0%	0.0%	0.0%	-62.9%	0.0%	0.1%	NA	NA	NA	NA	0.0%	0.0%
2.B. Chemical Industry	Other Production Except Ammonia	CO_2	3,662	2,549	-	-	-	-	-55%	+55%	-0.2%	0.2%	-0.1%	0.1%	-30.4%	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	186	-2%	+2%	-112%	+112%	-112%	+112%	-0.1%	0.1%	0.0%	0.0%	-71.6%	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	19	-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	97	-2%	+2%	-162%	+162%	-162%	+162%	-0.2%	0.2%	0.0%	0.0%	-93.5%	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	26	-	-	-	-	-58%	+51%	0.0%	0.0%	0.0%	0.0%	-37.4%	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	5,208	-	-	-	-	-4%	+4%	0.0%	0.0%	0.0%	0.0%	-28.0%	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	15	-5%	+5%	-163%	+163%	-163%	+163%	0.0%	0.0%	0.0%	0.0%	-27.0%	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	2	-5%	+5%	-163%	+163%	-163%	+163%	0.0%	0.0%	0.0%	0.0%	-59.1%	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	2,207	2,328	-	-	-	-	-51%	+51%	-0.1%	0.1%	-0.1%	0.1%	5.5%	0.0%	0.2%	NA	NA	NA	NA	0.0%	0.0%
2.E. Electronics Industry		N_2O	13	448	-	-	-	-	-5%	+5%	0.0%	0.0%	0.0%	0.0%	3277.4%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
2.G. Other Product Manufacture and Use		N_2O	245	92	-	-	-	-	-5%	+5%	0.0%	0.0%	0.0%	0.0%	-62.7%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
2.H. Other		CO_2	874	885	-	-	-	-	-2%	+2%	0.0%	0.0%	0.0%	0.0%	1.3%	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	63	-	-	-	-	-2%	+2%	0.0%	0.0%	0.0%	0.0%	4499.0%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
2.B. Chemical Industry	9.b. Fluorochemical Production (Fugitive Emissions)	PFCs	304	67	-	-	-	-	-2%	+2%	0.0%	0.0%	0.0%	0.0%	-78.1%	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	34	-	-	-	-	-2%	+2%	0.0%	0.0%	0.0%	0.0%	-99.1%	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	19	-	-	-	-	-2%	+2%	0.0%	0.0%	0.0%	0.0%	633.8%	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	0.0%	NA	NA	NA	NA	0.0%	0.0%
2.C. Metal Industry	4. Magnesium Production	SF_6	151	282	-	-	-	-	-5%	+5%	0.0%	0.0%	0.0%	0.0%	86.7%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
2.E. Electronics Industry		HFCs	55	97	-10%	+10%	-100%	+100%	-100%	+100%	0.0%	0.0%	0.0%	0.0%	76%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.E. Electronics Industry		PFCs	1,314	1,503	-10%	+10%	-80%	+80%	-81%	+81%	-0.1%	0.1%	-0.1%	0.1%	14.4%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.E. Electronics Industry		SF_6	951	423	-10%	+10%	-300%	+300%	-300%	+300%	-0.2%	0.2%	-0.1%	0.1%	-55.5%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.E. Electronics Industry		NF_3	25	317	-10%	+10%	-70%	+70%	-71%	+71%	0.0%	0.0%	0.0%	0.0%	1150.6%	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	42,810	-	-	-	-	-6%	+6%	NA	NA	-0.2%	0.2%	NA	NA	3.6%	NA	NA	-0.5%	0.5%	0.5%	0.5%
2.F. Product uses as substitutes for ODS	2. Foam Blowing Agents	HFCs	1	2,591	-	-	-	-	-50%	+50%	0.0%	0.0%	-0.1%	0.1%	212155%	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	426	-	-	-	-	-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	129	-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	1,406	-10%	+10%	-	-	-10%	+10%	0.0%	0.0%	0.0%	0.0%	-66.7%	0.0%	0.1%	NA	NA	0.0%	0.0%	0.0%	0.0%
2.G. Other Product Manufacture and Use		HFCs	6	6	-5%	+5%	-200%	+200%	-200%	+200%	0.0%	0.0%	0.0%	0.0%	-11.2%	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	72	-	-	-	-	-35%	+35%	0.0%	0.0%	0.0%	0.0%	395.7%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
2.G. Other Product Manufacture and Use		SF_6	9,085	1,397	-	-	-	-	-22%	+143%	-0.2%	1.1%	0.0%	0.2%	-84.6%	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-2022		T	I	J	K		L		M	
Category		GHG	FY1990 emissions / removals	FY2022 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 FY2022		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	3,781	-1%	+1%	-26%	+32%	-26%	+32%	-0.1%	0.1%	-0.1%	0.1%	-29.7%	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	4,486	-1%	+1%	-40%	+49%	-40%	+49%	-0.2%	0.2%	-0.2%	0.2%	-3.8%	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%	14.0%	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	351	-1%	+1%	-69%	+69%	-72%	+157%	0.0%	0.1%	0.0%	0.1%	-21.0%	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	38	-9%	+9%	-50%	+50%	-51%	+51%	0.0%	0.0%	0.0%	0.0%	-39.6%	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	2,273	-1%	+1%	-20%	+20%	-20%	+20%	0.0%	0.0%	0.0%	0.0%	-24.1%	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	555	-50%	+50%	-71%	+112%	-87%	+123%	0.0%	0.1%	0.0%	0.1%	-1.2%	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	183	-1%	+1%	-20%	+20%	-20%	+20%	0.0%	0.0%	0.0%	0.0%	77.5%	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	631	-50%	+50%	-71%	+112%	-87%	+123%	0.0%	0.1%	-0.1%	0.1%	-1.3%	0.0%	0.1%	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%	14.0%	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	182	-1%	+1%	-20%	+20%	-20%	+20%	0.0%	0.0%	0.0%	0.0%	-70.7%	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	1,068	-50%	+50%	-71%	+112%	-87%	+123%	-0.1%	0.1%	-0.1%	0.1%	9.2%	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	66	-9%	+9%	-20%	+20%	-22%	+22%	0.0%	0.0%	0.0%	0.0%	19.1%	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	224	-51%	+51%	-71%	+112%	-87%	+123%	0.0%	0.0%	0.0%	0.0%	-26.1%	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%	-56.6%	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%	-82.0%	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	940	-9%	+9%	-106%	+447%	-106%	+447%	-0.1%	0.5%	-0.1%	0.4%	-31.7%	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	13,068	-1%	+1%	-6%	+6%	-6%	+6%	-0.1%	0.1%	-0.1%	0.1%	-3.8%	0.0%	1.1%	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	1,013	-1%	+1%	-113%	+113%	-113%	+113%	-0.2%	0.2%	-0.1%	0.1%	-38.2%	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	1,364	-	-	-	-	-38%	+96%	0.0%	0.1%	0.0%	0.1%	-6.1%	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	16	-1%	+1%	-65%	+200%	-65%	+200%	0.0%	0.0%	0.0%	0.0%	-34.6%	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	286	-1%	+1%	-70%	+200%	-70%	+200%	0.0%	0.1%	0.0%	0.1%	-23.8%	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	345	-	-	-	-	-2%	+2%	0.0%	0.0%	0.0%	0.0%	-14.5%	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	108	-1%	+1%	-75%	+200%	-75%	+200%	0.0%	0.0%	0.0%	0.0%	-1.3%	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	783	-9%	+9%	-106%	+447%	-106%	+447%	-0.1%	0.4%	-0.1%	0.3%	-18.2%	0.0%	0.1%	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	1,290	-9%	+9%	-115%	+287%	-115%	+287%	-0.2%	0.4%	-0.1%	0.3%	-24.1%	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	30	-1%	+1%	-296%	+296%	-296%	+296%	0.0%	0.0%	0.0%	0.0%	-61.1%	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	8	-1%	+1%	-300%	+300%	-300%	+300%	0.0%	0.0%	0.0%	0.0%	-63.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.G. Liming		CO_2	550	203	-1%	+1%	-50%	+50%	-50%	+50%	0.0%	0.0%	0.0%	0.0%	-63.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.H. Urea Application		CO_2	182	208	-1%	+1%	-50%	+50%	-50%	+50%	0.0%	0.0%	0.0%	0.0%	14.5%	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-2022		T	I	J	K		L		M	
Category		GHG	FY1990 emissions / removals	FY2022 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 FY2022		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	-84,713	-59,107	-	-	-	-	-9%	+9%	-0.6%	0.6%	-0.5%	0.5%	-30.2%	0.0%	4.9%	0.0%	0.0%	-0.4%	0.4%	0.4%	0.4%
4.A. Forest Land	2. Land Converted to Forest Land	CO_2	-9,578	-656	-	-	-	-	-9%	+9%	-0.1%	0.1%	0.0%	0.0%	-93.1%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
4.B. Cropland	1. Cropland Remaining Cropland	CO_2	7,372	4,447	-	-	-	-	-24%	+24%	-0.1%	0.1%	-0.1%	0.1%	-39.7%	0.0%	0.4%	NA	NA	NA	NA	0.0%	0.0%
4.B. Cropland	2. Land Converted to Cropland	CO_2	650	372	-	-	-	-	-19%	+19%	0.0%	0.0%	0.0%	0.0%	-42.8%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
4.C. Grassland	1. Grassland Remaining Grassland	CO_2	478	286	-	-	-	-	-9%	+9%	0.0%	0.0%	0.0%	0.0%	-40.2%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
4.C. Grassland	2. Land Converted to Grassland	CO_2	485	129	-	-	-	-	-21%	+21%	0.0%	0.0%	0.0%	0.0%	-73.5%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
4.D. Wetlands	1. Wetland Remaining Wetland	CO_2	-601	-357	-	-	-	-	-16%	+16%	0.0%	0.0%	0.0%	0.0%	-40.7%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
4.D. Wetlands	2. Land Converted to Wetlands	CO_2	73	17	-	-	-	-	-23%	+23%	0.0%	0.0%	0.0%	0.0%	-76.2%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
4.E. Settlements	1. Settlements Remaining Settlements	CO_2	-1,015	-1,472	-	-	-	-	-39%	+39%	0.0%	0.0%	-0.1%	0.1%	45.1%	0.0%	0.1%	NA	NA	NA	NA	0.0%	0.0%
4.E. Settlements	2. Land Converted to Settlements	CO_2	11,389	4,198	-	-	-	-	-44%	+44%	-0.4%	0.4%	-0.2%	0.2%	-63.1%	0.0%	0.3%	NA	NA	NA	NA	0.0%	0.0%
4.F. Other Land	2. Land Converted to Other Land	CO_2	2,279	401	-	-	-	-	-84%	+84%	-0.2%	0.2%	0.0%	0.0%	-82.4%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
4.G. Harvested Wood Products		CO_2	-515	-1,918	-	-	-	-	-30%	30%	0.0%	0.0%	-0.1%	0.1%	272.8%	0.0%	0.2%	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	-	-	-	-	-31%	31%	0.0%	0.0%	0.0%	0.0%	-38.7%	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	-	-	-	-	-66%	+66%	0.0%	0.0%	0.0%	0.0%	-28.6%	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	-1%	+1%	-75%	+200%	-75%	+200%	0.0%	0.0%	0.0%	0.0%	-52.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
4.(III) N_2O Emissions from N Mineralization/Immobilization		N_2O	847	387	-	-	-	-	-59%	+159%	0.0%	0.1%	0.0%	0.1%	-54.4%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
4.(IV) Biomass Burning		CH_4	53	35	-	-	-	-	-141%	+141%	0.0%	0.0%	0.0%	0.0%	-34.7%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
4.(IV) Biomass Burning		N_2O	20	16	-	-	-	-	-86%	+86%	0.0%	0.0%	0.0%	0.0%	-16.3%	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-2022		T	I	J	K		L		M	
Category		GHG	FY1990 emissions / removals	FY2022 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 FY2022		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 Disposal Site (MSW)	CH_4	6,681	1,021	-	-	-	-	-33%	+33%	-0.2%	0.2%	0.0%	0.0%	-84.7%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.A. Solid Waste Disposal	1. Managed Disposal Site (IW)	CH_4	4,409	607	-	-	-	-	-29%	+29%	-0.1%	0.1%	0.0%	0.0%	-86.2%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.A. Solid Waste Disposal	3. Uncategorized Disposal Site (Inappropriate Dispo	CH_4	2	8	-60%	+60%	-42%	+41%	-74%	+73%	0.0%	0.0%	0.0%	0.0%	278.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.B. Biological Treatment of Soild Waste	1. Composting	CH_4	60	86	-30%	+30%	-79%	+79%	-84%	+84%	0.0%	0.0%	0.0%	0.0%	41.8%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.B. Biological Treatment of Soild Waste	1. Composting	N_2O	161	226	-30%	+30%	-167%	+167%	-170%	+170%	0.0%	0.0%	0.0%	0.0%	40.8%	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)	CO_2	5,554	2,858	-	-	-	-	-7%	+7%	0.0%	0.0%	0.0%	0.0%	-48.5%	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	3,670	2,866	-30%	+30%	-2%	+2%	-30%	+30%	-0.1%	0.1%	-0.1%	0.1%	-21.9%	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 (IW Solid)	CO_2	2,172	3,180	-	-	-	-	-30%	+30%	-0.1%	0.1%	-0.1%	0.1%	46.4%	0.0%	0.3%	0.0%	0.0%	-0.1%	0.1%	0.1%	0.1%
5.C. Incineration and Open Burning of Waste	1. Waste Incineration (Specially-contorolled IW)	CO_2	916	1,322	-60%	+60%	-2%	+2%	-60%	+60%	0.0%	0.0%	-0.1%	0.1%	44.3%	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%	-2%	+2%	-30%	+30%	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	-	-	-	-	-29%	+52%	0.0%	0.0%	0.0%	0.0%	-91.7%	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%	-32%	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%	-87.7%	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 Solid)	CH_4	3	7	-	-	-	-	-84%	+334%	0.0%	0.0%	0.0%	0.0%	162.4%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
5.C. Incineration and Open Burning of Waste	1. Waste Incineration (Specially-contorolled IW)	CH_4	0	1	-60%	+60%	-100%	+216%	-117%	+224%	0.0%	0.0%	0.0%	0.0%	385.2%	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%	-99.1%	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)	N_2O	272	89	-	-	-	-	-27%	+27%	0.0%	0.0%	0.0%	0.0%	-67.4%	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	17	-30%	+30%	-76%	+76%	-81%	+81%	0.0%	0.0%	0.0%	0.0%	331.9%	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	947	1,045	-30%	+30%	-84%	+84%	-89%	+89%	-0.1%	0.1%	-0.1%	0.1%	10.4%	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 (IW Solid)	N_2O	57	26	-	-	-	-	-50%	50%	0.0%	0.0%	0.0%	0.0%	-53.7%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
5.C. Incineration and Open Burning of Waste	1. Waste Incineration (Specially-contorolled IW)	N_2O	5	9	-60%	+60%	-44%	+44%	-74%	+74%	0.0%	0.0%	0.0%	0.0%	74.0%	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%	-99.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	1. DWW (Sewage Treatment Plant)	CH_4	242	360	-5%	+5%	-31%	+31%	-31%	+31%	0.0%	0.0%	0.0%	0.0%	48.9%	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 Wastewater Treatment Plant)	CH_4	851	881	-	-	-	-	-31%	+31%	0.0%	0.0%	0.0%	0.0%	3.6%	0.0%	0.1%	NA	NA	NA	NA	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	1. DWW (Human Waste treatment Plant)	CH_4	147	6	-10%	+10%	-84%	+84%	-84%	+84%	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)	CH_4	1,728	331	-10%	+10%	-58%	+58%	-59%	+59%	-0.1%	0.1%	0.0%	0.0%	-80.9%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	2. IWW (Industrial Wastewater 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%	-87.5%	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 Plant)	N_2O	370	391	-5%	+5%	-100%	+146%	-100%	+146%	0.0%	0.0%	0.0%	0.1%	5.7%	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 Wastewater Treatment Plant)	N_2O	403	425	-	-	-	-	-42%	42%	0.0%	0.0%	0.0%	0.0%	5.6%	0.0%	0.0%	NA	NA	NA	NA	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	1. DWW (Human Waste treatment Plant)	N_2O	59	3	-10%	+10%	-87%	+87%	-88%	+88%	0.0%	0.0%	0.0%	0.0%	-95.3%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	1. DWW (Natural Decomposition)	N_2O	738	501	-10%	+10%	-58%	+58%	-59%	+59%	0.0%	0.0%	0.0%	0.0%	-32.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D. Wastewater Treatment and Discharge	2. IWW (Industrial Wastewater 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%	-87.5%	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	654	-10%	+10%	-1%	+1%	-10%	+10%	0.0%	0.0%	0.0%	0.0%	-6.9%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

A		B	C	D	E		F		G		H-1990		H-2022		T	I	J	K		L		M	
Indirect CO_2	from Energy Sector	Ind CO_2	1,041	456	-	-	-	-	-22%	+39%	0.0%	0.0%	0.0%	0.0%	-56.2%	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	4,449	1,365	-	-	-	-	-31%	+59%	-0.1%	0.2%	0.0%	0.1%	-69.3%	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 CRF tables and the IEA statistics

In the report of the individual review of the greenhouse gas inventory of Japan submitted in 2006 (FCCC/ARR/2006/JPN), which was conducted from January to February 2007, the ERT (Expert Review Team) recommended that in the next NIR submission Japan provide a clear explanation for the discrepancies found between the data in the CRF tables and the IEA statistics. In response to this recommendation, Japan has provided the detailed information on the Annex of the NIR regarding the discrepancies of the FY2005 data between the CRF tables and the IEA statistics. Also, in the individual review report of the GHG inventory of Japan submitted in 2010 (FCCC/ARR/2010/JPN), the updating of this information with the latest available inventory year data was recommended by the ERT. In response to this recommendation, the detailed information regarding the discrepancies of the reported value between the CRF used until the 2023 submission and the IEA statistics is hereby updated with the FY2021 actual data. The IEA statistical data used in the explanation were extracted from the *World Energy Statistics*, July 2023 Edition, OECD/IEA.

In summary, these discrepancies occurred; because (a) the CRF tables 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 CRF tables 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 CRF 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 CRF tables (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 CRF tables 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 for each of the discrepancies noted by the ERT.

a) Differences in exports of jet kerosene and residual fuel oil

<ERT findings on FCCC/ARR/2006/JPN>

Exports of liquid fuels are between 40 and 70 per cent lower in the IEA data; the differences are due in particular to differences in the figures for jet kerosene and residual fuel oil, with the largest errors occurring in recent years.

<Explanation 1: Exports of jet kerosene>

The figures for jet kerosene exports reported in the CRF tables are different from those in the IEA statistics because the CRF 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 FY2021 (reference)

CRF Table 1.A(b)
Exports: 5,713.86×10^3 kL
IEA statistics
Exports: 1,319.88×10^3 t [5,713.86×10^3 kL (exports) - 4,029.05×10^3 kL (bonded exports) = 1,684.81×10^3 kL. 1,684.81×10^3 kL × 0.7834 t/kL (density) = 1,319.88×10^3 t] <Remarks> International aviation: 3,765.57 × 10^3 t [4,029.05×10^3 kL (bonded exports) + 777.65×10^3 kL (bonded imports) = 4,806.70×10^3 kL. 4,806.70×10^3 kL × 0.78 t/kL (density) = 3,765.57×10^3 t]

<Explanation 2: Exports of residual fuel oil>

The figures for exports of residual fuel oil reported in the CRF tables are different from those in the IEA statistics because the CRF 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 CRF 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 FY2021 (reference)

CRF Table 1.A(b)
Exports: 7,920.10×10^3 kL [446.97×10^3 kL (fuel oil A) + 0.00×10^3 kL (fuel oil B) + 7,473.13×10^3 kL (fuel oil C for general use) + 0.00×10^3 kL (fuel oil C for power generation) = 7,920.10×10^3 kL]
IEA statistics
Exports: 2,013.31×10^3 t [0.00×10^3 kL (fuel oil B) + 7,473.13×10^3 kL (fuel oil C for general use) + 0.00×10^3 kL (fuel oil C for power generation) - 5,236.12×10^3 kL (bonded exports of fuel oils B and C) = 2,237.01×10^3 kL. 2,237.01×10^3 kL × 0.9000 t/kL (density) = 2,013.31×10^3 t] <Remarks> International marine bunkers: 4,712.50×10^3 t [5,236.12×10^3 kL (bonded exports of fuel oils B and C) + 0.00×10^3 kL (bonded imports of fuel oils B and C) = 5,236.12×10^3 kL. 5,236.12×10^3 kL × 0.9000 t/kL (density) = 4,712.50 × 10^3 t]

b) Differences in imports of jet kerosene and gas/diesel oil

<ERT findings on FCCC/ARR/2006/JPN>

Imports of jet kerosene have been reported to the IEA, but are shown as zero in the CRFs for the years 1990–1997, while imports of gas/diesel oil are systematically about 80 per cent lower in the CRF tables than in the IEA figures.

<Explanation 1: Imports of jet kerosene>

The figures for jet kerosene imports reported in the CRF tables are different from those in the IEA statistics because the CRF 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 FY2021 (reference)

CRF Table 1.A(b)
Imports: 4,933.80 × 10^3 kL [127.10×10^3 kL (imports) + 777.65×10^3 kL (bonded imports) + 4,029.05×10^3 kL (bonded exports) = 4,933.80×10^3 kL]
IEA statistics
Imports: 708.78 × 10^3 t [127.10×10^3 kL (imports) + 777.65×10^3 kL (bonded imports) = 904.75×10^3 kL. 904.75×10^3 kL × 0.7834 t/kL (density) = 708.78×10^3 t]

<Explanation 2: Imports of gas/diesel oil>

The figures for imports of gas/diesel oil reported in the CRF tables are different from those in the IEA statistics, because the CRF 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 FY2021 (reference)

CRF Table 1.A(b)
Imports: 1,733.88×10^3 kL [1,713.12×10^3 kL (imports of gas/diesel oil) + 8.10×10^3 kL (bonded imports of gas/diesel oil) + 12.67×10^3 kL (bonded exports of gas/diesel oil) = 1,733.88×10^3 kL]
IEA statistics
Imports: 1,572.63×10^3 t [1,713.12×10^3 kL (imports of gas/diesel oil) + 8.10×10^3 kL (bonded imports of gas/diesel oil) + 143.57×10^3 kL (imports of fuel oil A) + 0.73×10^3 kL (bonded imports of fuel oil A) = 1,865.51×10^3 kL. 1,865.51×10^3 kL × 0.8430 t/kL (density) = 1,572.63×10^3 t]

c) Differences in imports of coking coal

<ERT findings on FCCC/ARR/2006/JPN>

Furthermore, the figures for imports of coking coal are systematically lower in the CRF tables than those in the IEA statistics, with the largest discrepancy occurring in 1999.

<Explanation: Imports of coking coal>

The imported amounts of coking coal in the CRF and the IEA statistics in physical units are basically the same.

Table A 3-5 Imports of coking coal in FY2021 (reference)

CRF Table 1.A(b)
Imports: 43,803.43×10^3 t
IEA statistics
Imports: 43,803.43×10^3 t

d) Differences in stock changes in liquid and gaseous fuels

<ERT findings on FCCC/ARR/2006/JPN>

In addition, the data on stock changes are not consistent for liquid and gaseous fuels.

It should be noted that the plus-minus signs of stock changes in the CRF differ from those of the IEA. The changes in the CRF 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 CRF table and the IEA statistics with respect to changes in crude oil stock occurred because the figures reported in the CRF 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 FY2021 (reference)

CRF Table 1.A(b)
Stock changes: 944.51×10^3 kL [-(-690.55×10^3 kL (crude oil for refining) - 253.96×10^3 kL (crude oil for power generation)) = 944.51×10^3 kL]
IEA statistics
Stock changes: -985.35×10^3 t [(9,573.28×10^3 kL (opening stock) + 46,267.00×10^3 kL (opening national stockpile) + 661.00×10^3 kL (opening stock carried by oil tankers) - 618.00×10^3 kL (opening joint stockpile with Abu Dhabi)) - (9,658.74×10^3 kL (closing stock) + 45,476.00×10^3 kL (closing national stockpile) + 2,408.00×10^3 kL (closing stock carried by oil tankers) - 507.00×10^3 kL (closing joint stockpile with Abu Dhabi)) = -1,152.46×10^3 kL. -1,152.46×10^3 kL × 0.8550 t/kL (density) = -985.35×10^3 t]

<Explanation 2: Changes in NGL stock>

Stock changes concerning NGL in FY2021 were reported as 0 in the CRF 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 CRF tables. The estimated value is 0 in FY2021.

<Explanation 3: Changes in gasoline stock>

The figures for stock of gasoline reported in the CRF tables 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 FY2021 (reference)

CRF Table 1.A(b)
Stock changes: 65.51×10^3 kL
IEA statistics
Stock changes: -47.05×10^3 t [(1,502.59×10^3 kL (opening stock) +585.00×10^3 kL (opening national stockpile) -6.99×10^3 kL (opening gasoline inventories for others (*Monthly Report of Current Production Statistics*, METI)) -3.68×10^3 kL (opening gasoline inventories for others (*Monthly Report of Mineral Resources and Petroleum Products Statistics*, METI)) - (1,568.09×10^3 kL (closing stock) +585.42×10^3 kL (closing national stockpile) -8.43×10^3 kL (closing gasoline inventories for others (*Monthly Report of Current Production Statistics*, METI)) -4.32×10^3 kL (closing gasoline inventories for others (*Monthly Report of Mineral Resources and Petroleum Products Statistics*, METI)) = -63.84×10^3 kL. -63.84×10^3 kL × 0.7370 t/kL (density) = -47.05×10^3 t]

<Explanation 4: Changes in jet kerosene stock>

The figures for changes in jet kerosene stock reported in the CRF tables are basically the same as the figures in the IEA statistics.

Table A 3-8 Changes in jet kerosene stock in FY2021 (reference)

CRF Table 1.A(b)
Stock changes: 49.47×10^3 kL
IEA statistics
Stock changes: -38.76×10^3 t [687.16×10^3 kL (opening stock) - 736.63×10^3 kL (closing stock) = -49.47×10^3 kL. -49.47×10^3 kL × 0.7834 t/kL (density) = -38.76×10^3 t]

<Explanation 5: Changes in kerosene stock>

The figures reported in the CRF tables 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 FY2021 (reference)

CRF Table 1.A(b)
Stock changes: -346.66×10^3 kL
IEA statistics
Stock changes: 281.91×10^3 t [($1,484.35\times10^3$ kL (opening stock) + 317.00×10^3 kL (opening national stockpile)) - ($1,137.69\times10^3$ kL (closing stock) + 317.33×10^3 kL (closing national stockpile)) = 346.33×10^3 kL. 346.33×10^3 kL × 0.8140 t/kL (density) = 281.91×10^3 t]

<Explanation 6: Changes in gas/diesel oil stock>

The figures for gas/diesel stock reported in the CRF tables 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 FY2021 (reference)

CRF Table 1.A(b)
Stock changes: -35.67×10^3 kL
IEA statistics
Stock changes: 86.46×10^3 t [($1,224.14\times10^3$ kL (gas/diesel oil, opening stock) + 712.33×10^3 kL (fuel oil A, opening stock) + 374.00×10^3 kL (gas/diesel oil, opening national stockpile) + 152.00×10^3 kL (fuel oil A, closing national stockpile)) - ($1,188.46\times10^3$ kL (gas/diesel oil, closing stock) + 645.10×10^3 kL (fuel oil A, closing stock) + 374.16×10^3 kL (gas/diesel oil, closing national stockpile) + 152.18×10^3 kL (fuel oil A, closing national stockpile)) = 102.56×10^3 kL. 102.56×10^3 kL × 0.8430 t/kL (density) = 86.46×10^3 t]

<Explanation 7: Changes in residual fuel oil stock>

The figures for residual fuel oil stock reported in the CRF tables were different from those in the IEA

statistics because the CRF 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 FY2021 (reference)

CRF Table 1.A(b)
Stock changes: -188.43×10^3 kL [67.23×10^3 kL (fuel oil A) + 0.00×10^3 kL (fuel oil B) + 121.20×10^3 kL (fuel oil C for general use) + 0.00×10^3 kL (fuel oil C for power generation) = -188.43×10^3 kL]
IEA statistics
Stock changes: 109.08×10^3 t [1,076.83×10^3 kL (fuel oil B and C, opening stock) - 955.63×10^3 kL (fuel oil B and C, opening stock) = 121.20×10^3 kL. 121.20×10^3 kL × 0.9000 t/kL (density) = 109.08×10^3 t]

<Explanation 8: Changes in LPG stock>

The figures for changes in LPG stock reported in the CRF tables 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 FY2021 (reference)

CRF Table 1.A(b)
Stock changes: 5.86×10^3 t
IEA statistics
Stock changes: -5.86×10^3 t [(1,566.11×10^3 t (opening stock) + 1,394.00×10^3 t (opening national stockpile)) - (1,571.97×10^3 t (closing stock) + 1,394.00×10^3 t (closing national stockpile)) = -5.86×10^3 t]

<Explanation 9: Changes in naphtha stock>

The figures for changes in naphtha stock reported in the CRF tables are the same as the figures in the IEA statistics.

Table A 3-13 Changes in naphtha stock in FY2021 (reference)

CRF Table 1.A(b)
Stock changes: -18.65×10^3 kL
IEA statistics
Stock changes: 13.74×10^3 t [1,361.05×10^3 kL (opening stock) - 1,342.41×10^3 kL (closing stock) = 18.65×10^3 kL. 18.65×10^3 kL × 0.7370 t/kL (density) = 13.74×10^3 t]

<Explanation 10: Changes in bitumen stock>

The figures for changes in bitumen stock reported in the CRF tables were slightly different from the figures reported under bitumen in the IEA statistics because the bitumen data in the CRF tables included asphalt and other heavy oil and paraffin products. The IEA statistics reported figures for only asphalt under bitumen, and the figures for other heavy oil and paraffin products reported in the CRF tables under bitumen were included in the figures reported under paraffin waxes in the IEA statistics.

Table A 3-14 Changes in bitumen stock in FY2021 (reference)

CRF Table 1.A(b)
Stock changes: 33.47×10^3 t
IEA statistics
Stock changes in bitumen: -35.45×10^3 t [161.70×10^3 t (opening stock) - 197.15×10^3 t (closing stock) = -35.45×10^3 t]

<Explanation 11: Changes in lubricants stock>

The figures for changes in lubricants stock reported in the CRF tables are basically the same as the figures in the IEA statistics.

Table A 3-15 Changes in lubricants stock in FY2021 (reference)

CRF Table 1.A(b)
Stock changes: -4.83×10^3 kL
IEA statistics
Stock changes: 4.31×10^3 t [450.60×10^3 kL (opening stock) - 445.77×10^3 kL (closing stock) = 4.83×10^3 kL. 4.83×10^3 kL × 0.8910 t/kL (density) = 4.31×10^3 t]

<Explanation 12: Changes in petroleum coke stock>

The figures for changes in petroleum coke stock reported in the CRF tables are the same as the figures in the IEA statistics.

Table A 3-16 Changes in petroleum coke stock in FY2021 (reference)

CRF Table 1.A(b)
Stock changes: 42.12×10^3 t
IEA statistics
Stock changes: -42.12×10^3 t [10.61×10^3 t (opening stock) - 52.73×10^3 t (closing stock) = -42.12×10^3 t]

<Explanation 13: Changes in refinery feedstock stock>

The figures for changes in refinery feedstock stock reported in the CRF 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 CRF tables.

The changes in slack wax and coke stocks were not reported in the CRF tables 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 FY2021 (reference)

CRF Table 1.A(b)
Stock changes: -911.64×10^3 kL [483.71×10^3 kL (slack gasoline) + 125.40×10^3 kL (slack kerosene) + 112.38×10^3 kL (slack diesel oil or gas oil) + 190.14×10^3 kL (slack fuel oil) + 0.00×10^3 kL (feedstock oil for refinery and mixing) = -911.64×10^3 kL]
IEA statistics
Stock changes: 729.24×10^3 t [(2,205.42×10^3 kL (slack gasoline, opening stock) - 1,721.70×10^3 kL (slack gasoline, closing stock)) × 0.7370 t/kL (density) + (450.91×10^3 kL (slack kerosene, opening stock) - 325.50×10^3 kL (slack kerosene, closing stock)) × 0.8140 t/kL (density) + (763.00×10^3 kL (slack diesel oil or gas oil, opening stock) - 650.62×10^3 kL (slack diesel oil or gas oil, closing stock)) × 0.8430 t/kL (density) + (3,701.22×10^3 kL (slack fuel oil, opening stock) - 3,472.36×10^3 kL (slack fuel oil, closing stock)) × 0.9000 t/kL (density) + (413.10×10^3 kL (slack lubricant, opening stock) - 451.82×10^3 kL (slack lubricant, closing stock)) × 0.8910 t/kL (density) + (33.79×10^3 kL (slack wax, opening stock) - 30.25×10^3 kL (slack wax, closing stock)) × 0.8160 t/kL (density) + (38.45×10^3 kL (slack coke, opening stock) - 36.78×10^3 kL (slack coke, closing stock)) × 0.9436 t/kL (density) = 729.24×10^3 t]

<Explanation 14: Changes in natural gas stock>

The figures for changes in natural gas stock (imported liquefied natural gas (LNG) and domestic natural gas) reported in the CRF tables were different from those in the IEA statistics because of the differences in the methods used for estimation of changes in the imported LNG stock and the treatment of changes in city gas stock. The source figures for the domestic natural gas stock were the same for reporting of the CRF and the IEA statistics because the statistical data existed in Japan. The estimation method for imported LNG were different between the CRF tables and the IEA statistics. The figures for stock changes reported to the CRF tables were the difference between the stock of imported LNG at the end of the previous fiscal year and the stock at the end of the current fiscal year, both from national statistics. On the other hand, the figures for stock changes reported to the IEA includes the inventory change calculated as the difference between the inventory volume at the end of the previous year and the inventory volume at the end of the current year in the *Electric Power Statistics* and the *Current Survey of Production Concerning Gas Industry*. Note that the figures reported to the IEA until FY2019 were the difference between the stock of imported LNG at the end of the previous fiscal year and the stock at the end of the relevant fiscal year, with the former calculated as one-half of the LNG import in March of the previous year, and the latter as one-half of the LNG import in March of the relevant year. One reason for reporting the estimated data to IEA was that the national statistics did not catch stocks of LNG in the past and the stock data have been estimated in this way since then. The figures for stock of natural gas reported in the CRF tables 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 FY2021 (reference)

CRF Table 1.A(b)
Stock changes: 1,412.79 TJ [-42.71×10^3 t (LNG) × 54.73 MJ/kg (GCV) - 0.477×10^6 m^3-SATP (indigenous natural gas) × 38.38 MJ/m^3-SATP (GCV) + 23.540×10^6 m^3-SATP (city gas) × 40.05 MJ/m^3-SATP (GCV) = 1,412.79 TJ]
IEA statistics
Stock changes: 34,567.63 TJ [{72.16×10^3 t (LNG, opening stock (*Mineral Resources and Petroleum Products Statistics*)) + 3,005.15×10^3 t (LNG, opening stock (*Electric Power Statistics*)) + 1,424.09×10^3 t (LNG, opening stock (*Current Survey of Production Concerning Gas Industry*))} × 54.73 MJ/kg (GCV in previous year) + 170.865×10^6 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) = 253,095.43 TJ (opening stock). {114.87×10^3 t (LNG, closing stock (*Mineral Resources and Petroleum Products Statistics*)) + 2,186.83×10^3 t (LNG, closing stock (*Electric Power Statistics*)) + 1,567.97×10^3 t (LNG, closing stock (*Current Survey of Production Concerning Gas Industry*))} × 54.73 MJ/kg (GCV in current year) + 171.329×10^6 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) = 218,527.80 TJ (closing stock). 253,095.43 TJ (opening stock) - 218,527.80 TJ (closing stock) = 34,567.63 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 were used for the activity data of fuel combustion in energy sector.

The *General Energy Statistics* (Energy Balance Table) 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 supply/conversion and consumption data in *General Energy Statistics* use official statistics and are structured with the minimum of estimation and adjustment. (Kainou, 2012)

General Energy Statistics (Energy Balance Table) 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, 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 *General Energy Statistics* supply and demand sectors (rows) comprise 3 major sectors — primary energy supply [#01], energy transformation & own use [#08], and final energy consumption [#19] — plus the necessary sub-categories and a more detailed breakdown of the sub-categories. (Refer to the following *General Energy Statistics* simplified table.)

The *General Energy Statistics* (complete Energy Balance Tables) for the years since FY1990 is available on the following internet site:

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* (Energy Balance Table)

Table A 3-19 Energy balance simplified table (General Energy Statistics, FY1990, 1995)

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)														19,779,116	18,176,727	1,602,389
#08	Energy Transformation & Own Use	-3,151,561	1,278,447	-8,961,984	5,498,947	-1,980,245	510,901	-210,804	-818,519	0	-317,978	-1,883,500	2,785,372	1,017,841	-6,233,084	-6,170,659	-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	-432,341	-4,367	-27,139	-87,643	-65,995	0	-170,247	-997	407,089	0	-676,433	-676,433	0
#14	Auto Steam Generation	-147,046	-135,509	0	-640,424	-4,241	-61,907	-109,183	0	0	-145,775	0	0	1,106,341	-137,744	-137,744	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	32,053	3,161	-109,856	-109,856	0
#19	Final Energy Consumption	401,151	1,226,745	0	7,525,213	57,638	510,901	56,385	0	0	0	0	2,753,319	1,014,680	13,546,031	12,006,068	1,539,963
#20	Industry	401,119	1,223,865	0	3,901,181	57,638	167,823	7,989	0	0	0	0	2,077,712	1,013,395	8,850,723	7,351,512	1,499,211
#21	Agriculture, Fishery, Mining and Construction	133	5,090	0	615,958	1,753	2,182	0	0	0	0	0	84,671	2,276	712,064	522,757	189,306
#22	Manufacturing	400,852	1,218,775	0	2,187,376	55,885	100,469	0	0	0	0	0	1,475,333	935,052	6,373,742	5,179,378	1,194,364
#23	Food, Beverages, Tobacco and Feed	48	0	0	52,848	0	8,102	0	0	0	0	0	57,526	49,454	167,978	167,978	0
#24	Textile Mill Products	544	0	0	50,417	0	4,699	0	0	0	0	0	72,141	92,180	219,981	219,981	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	1,458,730	25,021	9,582	0	0	0	0	0	211,987	234,151	1,992,885	811,934	1,180,951
#27	Ceramic, Stone and Clay Products	236,521	37,016	0	202,577	854	13,546	0	0	0	0	0	112,242	42,437	645,194	632,466	12,728
#28	Iron and Steel	156,771	1,121,208	0	211,240	25,309	23,952	0	0	0	0	0	383,523	136,967	2,058,970	2,058,285	685
#29	Non-Ferrous Metals	15,811	11,378	0	56,332	322	9,162	0	0	0	0	0	62,825	17,411	173,241	173,241	0
#30	Machinery	15	13,891	0	170,851	4,698	33,072	0	0	0	0	0	402,666	76,719	701,912	701,912	0
#31	Miscellaneous	194	0	0	36,985	0	6,489	0	0	0	0	0	152,112	38,000	233,781	233,781	0
#32	Commercial Industry	133	0	0	1,097,847	0	65,172	7,989	0	0	0	0	517,708	76,067	1,764,917	1,649,377	115,540
#33	Residential	0	2,880	0	606,330	0	343,074	48,395	0	0	0	0	615,093	1,284	1,617,056	1,617,056	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

1995FY	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	3,725,382	-91,908	10,166,812	1,642,449	2,477,257	0	280,834	728,509	0	380,411	2,693,458	0	0	22,003,203	20,202,409	1,800,794
#02	Indigenously Produced	153,374	0	32,455	0	95,250	0	278,350	728,509	0	380,411	2,693,458	0	0	4,361,806	0	0
#03	Import	3,575,648	18,016	10,171,504	2,226,338	2,382,172	0	2,491	0	0	0	0	0	0	18,376,169	0	0
#04	Total Primary Energy Supply	3,729,022	18,016	10,203,959	2,226,338	2,477,422	0	280,841	728,509	0	380,411	2,693,458	0	0	22,737,975	20,937,181	1,800,794
#05	Export	-75	-103,811	0	-717,045	0	0	-6	0	0	0	0	0	0	-820,938	0	0
#06	Stockpile Change / Supply (+: withdrawal/ -: build-up)	-3,565	-6,113	-37,147	133,156	-165	0	0	0	0	0	0	0	0	86,166	0	0
#07	Domestic Primary Energy Supply (Supply)	3,725,382	-91,908	10,166,812	1,642,449	2,477,257	0	280,834	728,509	0	380,411	2,693,458	0	0	22,003,203	20,202,409	1,800,794
	(Demand)														21,953,847	20,153,053	1,800,794
#08	Energy Transformation & Own Use	-3,316,691	1,148,397	-10,063,320	6,946,658	-2,418,050	685,997	-224,089	-728,509	0	-380,411	-2,693,458	3,146,438	1,055,422	-6,841,616	-6,776,341	-65,275
#09	Manufacture of Coal Products (+: output/ -: input)	-1,899,695	1,792,057	0	-24,231	0	0	0	0	0	0	0	0	0	-131,869	-131,869	0
#10	Oil Products (+: output/ -: input)	0	0	-9,375,750	9,417,232	5,773	0	0	0	0	0	0	0	-103,260	-56,005	0	-56,005
#11	Gas Conversion and Production (+: output/ -: input)	0	-12,205	0	-180,538	-723,679	915,060	-37	0	0	0	0	0	0	-1,400	-1,400	0
#12	Power Generation	-1,072,304	-219,914	-669,401	-835,632	-1,750,119	-663	-27,002	-667,399	0	0	-2,691,935	3,054,038	0	-4,880,332	-4,880,332	0
#13	Auto Power Generation	-182,384	-138,015	-539	-439,106	-5,482	-45,424	-97,713	-61,110	0	-202,462	-1,523	440,633	0	-733,126	-733,126	0
#14	Auto Steam Generation	-160,158	-127,828	-669	-672,326	-4,887	-98,261	-99,257	0	0	-174,443	0	0	1,145,850	-191,980	-191,980	0
#15	Heat Supply/ Other Energy Transformation	-2,274	1,637	0	7,394	54,485	-65,586	-99	0	0	-3,505	0	-2,548	15,823	5,326	-3,669	8,995
#16	Own Use and Loss	-2,978	-139,799	-1,058	-322,242	-86	-19,128	0	0	0	0	0	-345,686	-2,990	-833,968	-833,968	0
#17	Transformation and Consumption Stockpile Change (+: withdrawal/ -: build-up)	3,103	-7,537	-15,903	-3,893	5,944	0	20	0	0	0	0	0	0	-18,265	0	-18,265
#18	Statistical Discrepancy (+: excess/ -: shortage)	-45,916	425	103,492	0	991	0	0	0	0	0	0	8,299	-17,935	49,356	49,356	0
#19	Final Energy Consumption	454,606	1,056,064	0	8,589,106	58,216	685,997	56,745	0	0	0	0	3,138,139	1,073,357	15,112,231	13,376,712	1,735,519
#20	Industry	454,575	1,054,427	0	4,275,255	58,216	286,618	7,099	0	0	0	0	2,302,990	1,071,989	9,511,170	7,808,151	1,703,019
#21	Agriculture, Fishery, Mining and Construction	82	1,590	0	581,369	1,571	2,963	0	0	0	0	0	82,313	1,944	671,831	500,242	171,589
#22	Manufacturing	454,325	1,052,837	0	2,523,875	56,645	160,422	36	0	0	0	0	1,428,202	969,692	6,646,035	5,231,004	1,415,031
#23	Food, Beverages, Tobacco and Feed	82	0	0	63,054	0	14,756	0	0	0	0	0	67,365	70,106	215,364	215,364	0
#24	Textile Mill Products	823	0	0	46,242	14	6,320	0	0	0	0	0	66,179	92,448	212,026	212,026	0
#25	Pulp, Paper and Paper Products	0	0	0	35,625	5	10,330	36	0	0	0	0	132,614	274,405	453,016	453,016	0
#26	Chemical and Allied Products, Oil and Coal Products	6,103	31,971	0	1,779,429	21,427	16,674	0	0	0	0	0	211,871	248,201	2,315,676	916,500	1,399,176
#27	Ceramic, Stone and Clay Products	236,215	34,354	0	216,168	1,758	15,743	0	0	0	0	0	105,979	43,204	653,421	637,774	15,647
#28	Iron and Steel	210,894	972,148	0	205,461	26,313	38,977	0	0	0	0	0	357,325	137,052	1,948,170	1,947,962	208
#29	Non-Ferrous Metals	10,236	9,869	0	54,938	96	10,237	0	0	0	0	0	52,361	14,066	151,803	151,803	0
#30	Machinery	4	14,444	0	166,069	7,128	54,690	0	0	0	0	0	400,874	73,276	716,485	716,485	0
#31	Miscellaneous	203	0	0	38,803	0	8,020	0	0	0	0	0	132,454	41,334	220,815	220,815	0
#32	Commercial Industry	168	0	0	1,170,011	0	123,233	7,063	0	0	0	0	792,475	100,354	2,193,304	2,076,905	116,398
#33	Residential	0	1,637	0	706,407	0	399,238	49,646	0	0	0	0	767,630	1,368	1,925,926	1,925,926	0
#34	Transportation	31	0	0	3,607,445	0	141	0	0	0	0	0	67,518	0	3,675,135	3,642,635	32,500
#35	Passenger	31	0	0	1,952,379	0	20	0	0	0	0	0	63,676	0	2,016,106	1,991,138	24,968
#36	Freight	0	0	0	1,655,066	0	121	0	0	0	0	0	3,842	0	1,659,029	1,651,497	7,532
#37	Non-energy and Feedstock Use	5,446	25,104	0	1,692,935	12,033	0	0	0	0	0	0	0	0	1,735,519	0	1,735,519

Table A 3-20 Energy balance simplified table (General Energy Statistics, FY2000, 2005)

2000FY	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	4,203,202	-3,821	9,634,832	1,528,928	3,058,878	0	273,860	745,903	0	409,621	2,858,092	0	0	22,709,495	20,834,946	1,874,549
#02	Indigenously Produced	66,912	0	28,034	0	106,340	0	269,127	745,903	0	409,621	2,858,092	0	0	4,484,028	0	0
#03	Import	4,139,375	76,219	9,733,303	2,252,207	2,952,403	0	4,746	0	0	0	0	0	0	19,158,252	0	0
#04	Total Primary Energy Supply	4,206,287	76,219	9,761,337	2,252,207	3,058,742	0	273,873	745,903	0	409,621	2,858,092	0	0	23,642,280	21,767,731	1,874,549
#05	Export	-112	-78,077	0	-617,396	0	0	-13	0	0	0	0	0	0	-695,597	0	0
#06	Stockpile Change / Supply (+: withdrawal/ -: build-up)	-2,972	-1,963	-126,505	-105,883	136	0	0	0	0	0	0	0	0	-237,187	0	0
#07	Domestic Primary Energy Supply (Supply)	4,203,202	-3,821	9,634,832	1,528,928	3,058,878	0	273,860	745,903	0	409,621	2,858,092	0	0	22,709,495	20,834,946	1,874,549
	(Demand)														22,708,010	20,833,461	1,874,549
#08	Energy Transformation & Own Use	-3,705,208	1,114,629	-9,622,842	7,213,287	-3,022,830	806,834	-223,800	-745,903	0	-403,364	-2,858,092	3,414,115	1,158,073	-6,875,103	-6,769,290	-105,813
#09	Manufacture of Coal Products (+: output/ -: input)	-1,738,478	1,664,686	0	-33,697	0	0	0	0	0	0	0	0	0	-107,489	-107,489	0
#10	Oil Products (+: output/ -: input)	0	0	-9,331,059	9,412,678	6,972	0	0	0	0	0	0	0	-137,327	-48,736	0	-48,736
#11	Gas Conversion and Production (+: output/ -: input)	0	-9,573	0	-150,046	-925,341	1,084,614	-31	0	0	0	0	0	0	-377	-377	0
#12	Power Generation	-1,513,154	-219,155	-301,245	-544,697	-2,130,517	-1,632	-27,676	-679,439	0	0	-2,851,772	3,320,803	0	-4,948,485	-4,948,485	0
#13	Auto Power Generation	-222,305	-114,011	-83	-431,513	-9,034	-71,592	-99,374	-66,464	0	-178,038	-6,320	457,645	0	-741,088	-741,088	0
#14	Auto Steam Generation	-198,902	-69,828	-135	-672,981	-7,845	-128,034	-96,581	0	0	-220,572	0	0	1,276,053	-118,825	-118,825	0
#15	Heat Supply/ Other Energy Transformation	-708	0	0	-34,671	48,869	-63,384	-116	0	0	-4,755	0	-3,940	22,648	-36,057	-3,078	-32,978
#16	Own Use and Loss	-4,240	-132,502	-518	-335,337	-519	-13,139	0	0	0	0	0	-360,392	-3,302	-849,949	-849,949	0
#17	Transformation and Consumption Stockpile Change (+: withdrawal/ -: build-up)	-27,422	-4,989	10,199	3,549	-5,414	0	-22	0	0	1	0	0	0	-24,098	0	-24,098
#18	Statistical Discrepancy (+: excess/ -: shortage)	76,007	60,164	11,990	0	-14,343	0	0	0	0	0	0	-87,528	-44,806	1,485	1,485	0
#19	Final Energy Consumption	421,987	1,050,644	0	8,742,214	50,391	806,834	50,059	0	0	6,256	0	3,501,643	1,202,878	15,832,907	14,064,171	1,768,736
#20	Industry	421,941	1,050,644	0	4,211,600	50,391	386,796	17,219	0	0	6,256	0	2,573,494	1,201,572	9,919,913	8,185,339	1,734,574
#21	Agriculture, Fishery, Mining and Construction	47	1,744	0	533,670	1,930	2,959	0	0	0	0	0	76,566	1,530	618,447	464,944	153,503
#22	Manufacturing	421,754	1,048,900	0	2,495,178	48,461	178,337	12,142	0	0	6,256	0	1,458,395	1,076,657	6,746,080	5,252,652	1,493,429
#23	Food, Beverages, Tobacco and Feed	34	0	0	66,373	0	21,171	0	0	0	0	0	77,661	79,504	244,744	244,744	0
#24	Textile Mill Products	257	0	0	34,473	1	5,858	0	0	0	0	0	57,534	79,810	177,932	177,932	0
#25	Pulp, Paper and Paper Products	0	0	0	26,153	71	8,250	12,142	0	0	0	0	141,091	287,154	474,862	474,862	0
#26	Chemical and Allied Products, Oil and Coal Products	556	36,239	0	1,880,427	23,397	22,408	0	0	0	0	0	214,319	352,672	2,530,018	1,037,905	1,492,113
#27	Ceramic, Stone and Clay Products	185,818	24,256	0	170,732	1,681	19,036	0	0	0	6,235	0	97,488	33,996	539,242	538,078	1,164
#28	Iron and Steel	234,952	984,233	0	186,004	22,393	58,891	0	0	0	19	0	380,689	143,640	2,010,821	2,010,670	152
#29	Non-Ferrous Metals	4,209	10,185	0	49,230	238	14,836	0	0	0	19	0	57,827	23,072	159,615	159,615	0
#30	Machinery	0	4,282	0	122,206	919	37,437	0	0	0	2	0	395,641	65,343	625,829	625,829	0
#31	Miscellaneous	137	0	0	36,370	0	13,133	0	0	0	0	0	154,431	45,703	249,775	249,775	0
#32	Commercial Industry	140	0	0	1,182,751	0	205,500	5,078	0	0	0	0	1,038,532	123,385	2,555,386	2,467,744	87,643
#33	Residential	0	0	0	768,778	0	418,897	32,840	0	0	0	0	861,286	1,306	2,083,107	2,083,107	0
#34	Transportation	46	0	0	3,761,837	0	1,141	0	0	0	0	0	66,864	0	3,829,887	3,795,725	34,162
#35	Passenger	46	0	0	2,190,118	0	172	0	0	0	0	0	63,385	0	2,253,720	2,227,912	25,808
#36	Freight	0	0	0	1,571,719	0	969	0	0	0	0	0	3,479	0	1,576,167	1,567,813	8,354
#37	Non-energy and Feedstock Use	19	19,641	0	1,740,553	8,523	0	0	0	0	0	0	0	0	1,768,736	0	1,768,736

2005FY	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	4,765,771	15,805	9,517,554	1,173,834	3,291,376	0	380,850	671,487	0	428,091	2,660,242	0	0	22,905,011	20,957,081	1,947,930
#02	Indigenously Produced	28,110	0	33,051	0	134,612	0	375,440	671,487	0	428,091	2,660,242	0	0	4,331,033	0	0
#03	Import	4,737,747	81,303	9,473,040	2,127,563	3,156,903	0	5,461	0	0	0	0	0	0	19,582,017	0	0
#04	Total Primary Energy Supply	4,765,856	81,303	9,506,092	2,127,563	3,291,515	0	380,901	671,487	0	428,091	2,660,242	0	0	23,913,050	21,965,120	1,947,930
#05	Export	-85	-49,269	-4	-880,259	0	0	-51	0	0	0	0	0	0	-929,668	0	0
#06	Stockpile Change / Supply (+: withdrawal/ -: build-up)	0	-16,228	11,466	-73,470	-138	0	0	0	0	0	0	0	0	-78,371	0	0
#07	Domestic Primary Energy Supply (Supply)	4,765,771	15,805	9,517,554	1,173,834	3,291,376	0	380,850	671,487	0	428,091	2,660,242	0	0	22,905,011	20,957,081	1,947,930
	(Demand)														22,930,867	20,982,937	1,947,930
#08	Energy Transformation & Own Use	-4,310,565	1,121,057	-9,510,672	7,253,671	-3,227,280	966,321	-354,038	-671,487	0	-421,786	-2,660,242	3,561,797	1,199,658	-7,053,567	-6,930,529	-123,038
#09	Manufacture of Coal Products (+: output/ -: input)	-1,730,636	1,633,464	0	-18,801	0	0	0	0	0	0	0	0	0	-115,974	-115,974	0
#10	Oil Products (+: output/ -: input)	0	0	-9,209,723	9,278,075	8,203	0	0	0	0	0	0	0	-139,784	-63,230	0	-63,230
#11	Gas Conversion and Production (+: output/ -: input)	0	-1,994	0	-99,300	-1,315,246	1,414,464	-46	0	0	0	0	0	0	-2,121	-2,121	0
#12	Power Generation	-2,146,038	-189,378	-301,537	-546,895	-1,910,075	-58,869	-52,804	-614,127	0	0	-2,660,242	3,440,790	0	-5,039,177	-5,039,177	0
#13	Auto Power Generation	-250,929	-106,559	-20	-400,617	-16,206	-115,803	-132,042	-57,360	0	-178,129	0	502,550	0	-755,114	-755,114	0
#14	Auto Steam Generation	-215,125	-66,543	-37	-572,779	-12,856	-183,042	-168,956	0	0	-238,466	0	0	1,317,573	-140,231	-140,231	0
#15	Heat Supply/ Other Energy Transformation	-633	0	0	-54,980	63,151	-81,254	-146	0	0	-5,124	0	-4,129	25,072	-58,042	-4,085	-53,958
#16	Own Use and Loss	-6,994	-129,554	-91	-331,117	-16,279	-9,176	0	0	0	0	0	-377,413	-3,203	-873,827	-873,827	0
#17	Transformation and Consumption Stockpile Change (+: withdrawal/ -: build-up)	39,791	-18,378	736	86	-27,972	0	-44	0	0	-68	0	0	0	-5,850	0	-5,850
#18	Statistical Discrepancy (+: excess/ -: shortage)	33,648	93,728	6,882	0	-566	0	0	0	0	0	0	-127,656	-31,892	-25,856	-25,856	0
#19	Final Energy Consumption	421,558	1,043,135	0	8,427,505	64,662	966,321	26,812	0	0	6,305	0	3,689,453	1,231,550	15,877,300	14,052,408	1,824,892
#20	Industry	421,521	1,043,135	0	4,155,482	64,662	526,270	4,278	0	0	6,305	0	2,675,355	1,230,224	10,127,232	8,338,013	1,789,218
#21	Agriculture, Fishery, Mining and Construction	34	524	0	458,565	2,758	3,115	0	0	0	0	0	62,366	1,350	528,712	427,884	100,828
#22	Manufacturing	421,249	1,042,611	0	2,443,487	61,905	259,987	25	0	0	6,305	0	1,435,326	1,115,783	6,786,676	5,181,312	1,605,364
#23	Food, Beverages, Tobacco and Feed	39	0	0	61,918	0	32,399	0	0	0	0	0	90,886	88,379	273,620	273,620	0
#24	Textile Mill Products	231	0	0	26,382	0	6,957	0	0	0	0	0	46,647	64,926	145,143	145,143	0
#25	Pulp, Paper and Paper Products	506	0	0	23,810	119	10,603	25	0	0	0	0	134,820	282,635	452,517	452,517	0
#26	Chemical and Allied Products, Oil and Coal Products	971	39,347	0	1,944,660	31,470	31,462	0	0	0	0	0	213,259	392,864	2,654,033	1,049,205	1,604,828
#27	Ceramic, Stone and Clay Products	163,358	21,640	0	132,156	2,541	22,808	0	0	0	6,300	0	81,904	29,084	459,793	459,385	408
#28	Iron and Steel	255,935	977,970	0	153,000	25,440	89,558	0	0	0	0	0	381,853	151,733	2,035,490	2,035,362	129
#29	Non-Ferrous Metals	2,993	9,518	0	41,262	315	19,808	0	0	0	0	0	55,633	26,351	155,879	155,879	0
#30	Machinery	1	3,742	0	89,291	2,334	63,972	0	0	0	5	0	402,516	65,339	627,200	627,200	0
#31	Miscellaneous	206	0	0	30,915	0	17,593	0	0	0	0	0	145,060	52,339	246,113	246,113	0
#32	Commercial Industry	238	0	0	1,253,430	0	263,168	4,253	0	0	0	0	1,177,662	113,092	2,811,843	2,728,817	83,026
#33	Residential	0	0	0	729,070	0	436,076	22,534	0	0	0	0	946,067	1,326	2,135,072	2,135,072	0
#34	Transportation	37	0	0	3,542,953	0	3,974	0	0	0	0	0	68,031	0	3,614,996	3,579,323	35,674
#35	Passenger	37	0	0	2,079,246	0	591	0	0	0	0	0	64,483	0	2,144,357	2,117,707	26,651
#36	Freight	0	0	0	1,463,707	0	3,383	0	0	0	0	0	3,548	0	1,470,639	1,461,616	9,023
#37	Non-energy and Feedstock Use	32	18,343	0	1,790,263	16,254	0	0	0	0	0	0	0	0	1,824,892	0	1,824,892

Table A 3-21 Energy balance simplified table (General Energy Statistics, FY2010, 2013)

2010FY 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	4,983,144	14,115	8,127,286	730,774	3,994,115	1,105	436,391	715,871	0	529,798	2,462,243	0	0	21,994,843	20,129,681	1,865,162
#02 Indigenously Produced	25,764	0	30,637	0	149,324	0	421,586	715,871	0	529,798	2,462,243	0	0	4,335,224	0	0
#03 Import	4,957,466	29,909	8,140,499	1,946,768	3,844,997	0	14,857	0	0	0	0	0	0	18,934,496	0	0
#04 Total Primary Energy Supply	4,983,230	29,909	8,171,136	1,946,768	3,994,321	0	436,443	715,871	0	529,798	2,462,243	0	0	23,269,720	21,404,558	1,865,162
#05 Export	-87	-19,695	0	-1,187,778	0	0	-51	0	0	0	0	0	0	-1,207,611	0	0
#06 Stockpile Change / Supply (+: withdrawal/ -: build-up)	0	3,901	-43,851	-28,216	-205	1,105	0	0	0	0	0	0	0	-67,266	0	0
#07 Domestic Primary Energy Supply (Supply)	4,983,144	14,115	8,127,286	730,774	3,994,115	1,105	436,391	715,871	0	529,798	2,462,243	0	0	21,994,843	20,129,681	1,865,162
(Demand)														21,904,092	20,038,930	1,865,162
#08 Energy Transformation & Own Use	-4,523,260	1,090,966	-8,133,969	6,531,206	-3,956,138	1,087,984	-415,108	-715,871	0	-522,602	-2,462,243	3,799,511	1,003,332	-7,216,193	-7,081,770	-134,423
#09 Manufacture of Coal Products (+: output/ -: input)	-1,704,578	1,611,327	0	-20,407	0	0	0	0	0	-87	0	0	0	-113,745	-113,745	0
#10 Oil Products (+: output/ -: input)	0	0	-7,949,128	8,038,093	5,579	0	-8,588	0	0	0	0	0	-146,978	-61,021	0	-61,021
#11 Gas Conversion and Production (+: output/ -: input)	0	0	0	-73,311	-1,646,183	1,719,690	0	0	0	0	0	0	0	196	196	0
#12 Power Generation	-2,087,400	-207,076	-189,297	-374,290	-2,342,899	-59,859	-49,324	-574,862	0	-5,678	-2,462,243	3,474,987	0	-4,877,940	-4,877,940	0
#13 Auto Power Generation	-440,814	-104,816	-46	-309,149	-149,028	-133,884	-172,142	-141,010	0	-282,311	0	704,757	0	-1,028,442	-1,028,442	0
#14 Auto Steam Generation	-240,628	-76,411	-90	-378,538	-27,268	-168,223	-184,754	0	0	-229,472	0	0	1,130,616	-174,768	-174,768	0
#15 Heat Supply/ Other Energy Transformation	0	0	0	-46,256	202,348	-219,351	-577	0	0	-4,068	0	-4,126	24,418	-47,613	-1,932	-45,681
#16 Own Use and Loss	-20,471	-134,613	-62	-293,998	-4,773	-50,390	0	0	0	0	0	-376,108	-4,724	-885,138	-885,138	0
#17 Transformation and Consumption Stockpile Change (+: withdrawal/ -: build-up)	-29,368	2,555	4,654	-10,938	6,086	0	278	0	0	-987	0	0	0	-27,720	0	-27,720
#18 Statistical Discrepancy (+: excess/ -: shortage)	68,210	49,980	-6,683	-133	-29,647	0	0	0	0	0	0	72,004	-62,980	90,751	90,751	0
#19 Final Energy Consumption	391,674	1,055,101	0	7,262,113	67,624	1,089,088	21,284	0	0	7,196	0	3,727,507	1,066,312	14,687,899	12,957,160	1,730,739
#20 Industry	391,630	1,055,101	0	3,299,255	67,624	657,371	4,834	0	0	7,196	0	2,610,719	1,065,029	9,158,761	7,463,498	1,695,263
#21 Agriculture, Fishery, Mining and Construction	87	140	0	388,832	5,064	2,672	0	0	0	0	0	46,151	1,392	444,339	370,971	73,368
#22 Manufacturing	391,306	1,052,992	0	2,202,486	62,560	281,280	350	0	0	7,196	0	1,337,460	976,583	6,312,213	4,754,491	1,557,722
#23 Food, Beverages, Tobacco and Feed	28	91	0	48,933	0	39,753	0	0	0	0	0	92,249	99,108	280,163	280,163	0
#24 Textile Mill Products	153	0	0	13,284	0	7,678	0	0	0	0	0	35,909	49,765	106,789	106,789	0
#25 Pulp, Paper and Paper Products	322	0	0	19,939	333	5,171	344	0	0	89	0	124,019	228,675	378,892	378,892	0
#26 Chemical and Allied Products, Oil and Coal Products	1,051	49,884	0	1,854,130	34,826	27,260	0	0	0	0	0	205,600	365,869	2,538,621	981,266	1,557,354
#27 Ceramic, Stone and Clay Products	128,254	17,780	0	96,287	4,255	28,179	6	0	0	6,582	0	72,551	19,889	373,784	373,603	181
#28 Iron and Steel	260,507	981,578	0	110,888	21,297	106,690	0	0	0	525	0	358,699	135,220	1,975,405	1,975,219	186
#29 Non-Ferrous Metals	2,314	8,661	0	23,668	1,024	16,292	0	0	0	137	0	52,918	10,665	115,679	115,679	0
#30 Machinery	76	3,587	0	50,678	1,849	65,643	0	0	0	0	0	376,652	58,690	557,175	557,175	0
#31 Miscellaneous	915	78	0	18,408	0	14,790	0	0	0	0	0	118,774	25,837	178,802	178,802	0
#32 Commercial Industry	237	1,970	0	707,938	0	373,418	4,485	0	0	0	0	1,227,108	87,054	2,402,209	2,338,036	64,174
#33 Residential	0	0	0	646,431	0	427,050	16,449	0	0	0	0	1,051,109	1,282	2,142,322	2,142,322	0
#34 Transportation	43	0	0	3,316,427	0	4,667	0	0	0	0	0	65,679	0	3,386,816	3,351,340	35,476
#35 Passenger	43	0	0	1,962,870	0	640	0	0	0	0	0	62,568	0	2,026,122	1,999,526	26,596
#36 Freight	0	0	0	1,353,557	0	4,027	0	0	0	0	0	3,111	0	1,360,695	1,351,815	8,880
#37 Non-energy and Feedstock Use	16	17,902	0	1,696,246	16,575	0	0	0	0	0	0	0	0	1,730,739	0	1,730,739

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)														21,092,424	19,302,446	1,789,978
#08 Energy Transformation & Own Use	-4,910,699	1,044,456	-8,070,114	5,927,286	-4,800,224	1,065,862	-518,832	-679,414	0	-530,690	-79,612	3,584,572	940,265	-7,027,143	-6,895,901	-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	-299,997	-162,729	-141,146	-270,117	-139,679	0	-308,442	0	776,069	0	-1,158,834	-1,158,834	0
#14 Auto Steam Generation	-245,306	-78,181	-79	-370,552	-26,085	-183,704	-184,695	0	0	-206,967	0	0	1,052,896	-242,672	-242,672	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	22,152	-31,375	-40,420	-40,420	0
#19 Final Energy Consumption	455,484	1,007,541	0	6,893,894	69,285	1,065,335	17,017	0	0	22,665	0	3,562,420	971,640	14,065,281	12,406,545	1,658,736
#20 Industry	455,445	1,007,541	0	3,133,139	69,285	645,074	4,815	0	0	22,665	0	2,465,511	970,470	8,773,944	7,151,535	1,622,409
#21 Agriculture, Fishery, Mining and Construction	33	242	0	339,288	5,142	2,789	0	0	0	0	0	39,780	920	388,195	326,971	61,223
#22 Manufacturing	455,172	1,004,168	0	2,123,464	64,143	260,379	396	0	0	22,665	0	1,267,998	927,489	6,125,874	4,615,456	1,510,418
#23 Food, Beverages, Tobacco and Feed	270	83	0	43,852	0	31,703	0	0	0	0	0	93,104	102,135	271,146	271,146	0
#24 Textile Mill Products	0	0	0	9,497	0	4,895	0	0	0	0	0	31,112	45,354	90,858	90,858	0
#25 Pulp, Paper and Paper Products	2,442	0	0	17,642	552	4,508	326	0	0	597	0	118,646	208,866	353,579	353,579	0
#26 Chemical and Allied Products, Oil and Coal Products	805	50,172	0	1,799,389	32,731	25,994	0	0	0	1,305	0	191,690	346,683	2,448,769	938,702	1,510,066
#27 Ceramic, Stone and Clay Products	140,686	13,944	0	97,324	4,224	26,278	70	0	0	17,675	0	67,565	21,834	389,601	389,338	263
#28 Iron and Steel	310,551	937,059	0	100,096	24,464	107,718	0	0	0	3,088	0	355,321	127,371	1,965,668	1,965,580	89
#29 Non-Ferrous Metals	2,162	8,124	0	21,292	975	15,662	0	0	0	815	0	47,043	10,060	106,134	106,134	0
#30 Machinery	17	2,929	0	50,649	2,172	60,542	0	0	0	0	0	345,688	45,020	507,017	507,017	0
#31 Miscellaneous	401	15	0	17,049	0	11,504	0	0	0	0	0	110,316	36,498	175,783	175,783	0
#32 Commercial Industry	241	3,130	0	670,387	0	381,906	4,419	0	0	0	0	1,157,732	42,061	2,259,875	2,209,108	50,768
#33 Residential	0	0	0	592,909	0	416,311	12,202	0	0	0	0	1,033,114	1,170	2,055,707	2,055,707	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 3-22 Energy balance simplified table (General Energy Statistics, FY2015, 2020)

2015FY	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	5,096,871	57,471	7,406,284	731,279	4,662,197	-833	726,484	725,930	0	535,685	78,638	0	0	20,020,005	18,219,852	1,800,153
#02	Indigenously Produced	31,982	0	20,896	0	110,598	0	694,411	725,930	0	535,685	78,638	0	0	2,198,141	0	0
#03	Import	5,064,950	80,375	7,414,496	1,952,126	4,551,428	0	32,118	0	0	0	0	0	0	19,095,492	0	0
#04	Total Primary Energy Supply	5,096,932	80,375	7,435,391	1,952,126	4,662,026	0	726,529	725,930	0	535,685	78,638	0	0	21,293,632	19,493,479	1,800,153
#05	Export	-62	-22,999	0	-1,265,963	0	0	-45	0	0	0	0	0	0	-1,289,068	0	0
#06	Stockpile Change / Supply (+: withdrawal/ -: build-up)	0	95	-29,108	45,115	171	-833	0	0	0	0	0	0	0	15,441	0	0
#07	Domestic Primary Energy Supply (Supply)	5,096,871	57,471	7,406,284	731,279	4,662,197	-833	726,484	725,930	0	535,685	78,638	0	0	20,020,005	18,219,852	1,800,153
	(Demand)														20,023,870	18,223,717	1,800,153
#08	Energy Transformation & Own Use	-4,717,988	946,675	-7,406,973	5,868,604	-4,603,709	1,072,604	-711,325	-725,930	0	-510,425	-78,638	3,464,384	883,313	-6,519,409	-6,401,197	-118,211
#09	Manufacture of Coal Products (+: output/ -: input)	-1,523,216	1,436,363	0	-19,673	0	0	0	0	0	-4,893	0	0	0	-111,419	-111,419	0
#10	Oil Products (+: output/ -: input)	0	0	-7,191,157	7,207,923	4,204	0	-14,525	0	0	0	0	0	-119,254	-112,809	0	-112,809
#11	Gas Conversion and Production (+: output/ -: input)	0	0	0	-68,503	-1,669,358	1,738,071	-116	0	0	0	0	0	0	95	95	0
#12	Power Generation	-2,375,953	-201,063	-226,562	-382,134	-2,924,727	-121,063	-52,323	-588,695	0	-5,484	-78,638	2,945,950	0	-4,010,691	-4,010,691	0
#13	Auto Power Generation	-502,927	-101,086	-39	-262,083	-159,588	-136,847	-472,130	-137,236	0	-297,981	0	843,715	0	-1,226,202	-1,226,202	0
#14	Auto Steam Generation	-243,912	-70,119	-74	-317,109	-24,529	-181,391	-171,077	0	0	-199,185	0	0	985,989	-221,406	-221,406	0
#15	Heat Supply/ Other Energy Transformation	0	0	0	5,100	165,482	-179,577	-1,026	0	0	-2,631	0	-3,609	21,309	5,046	169	4,877
#16	Own Use and Loss	-20,270	-120,506	-83	-304,499	-13,393	-46,590	0	0	0	0	0	-321,672	-4,730	-831,743	-831,743	0
#17	Transformation and Consumption Stockpile Change (+: withdrawal/ -: build-up)	-51,710	3,085	10,941	9,581	18,202	0	-128	0	0	-250	0	0	0	-10,279	0	-10,279
#18	Statistical Discrepancy (+: excess/ -: shortage)	-52,944	48,096	-690	-440	-3,324	0	0	0	0	0	0	46,215	-40,778	-3,865	-3,865	0
#19	Final Energy Consumption	431,827	956,049	0	6,600,323	61,813	1,071,770	15,159	0	0	25,260	0	3,418,170	924,091	13,504,461	11,822,520	1,681,941
#20	Industry	431,788	956,049	0	2,987,040	61,813	668,128	5,229	0	0	25,260	0	2,391,107	922,988	8,449,402	6,803,893	1,645,509
#21	Agriculture, Fishery, Mining and Construction	28	291	0	363,281	4,695	3,082	0	0	0	0	0	38,159	1,095	410,632	355,906	54,726
#22	Manufacturing	431,413	952,800	0	2,064,869	57,118	248,435	390	0	0	25,260	0	1,214,946	878,520	5,873,752	4,331,513	1,542,239
#23	Food, Beverages, Tobacco and Feed	245	80	0	32,662	0	31,205	0	0	0	0	0	91,812	83,786	239,790	239,790	0
#24	Textile Mill Products	112	0	0	7,126	10	5,463	0	0	0	0	0	33,428	50,873	97,012	97,012	0
#25	Pulp, Paper and Paper Products	1,793	0	0	15,748	534	4,531	324	0	0	1,018	0	112,149	205,821	341,917	341,917	0
#26	Chemical and Allied Products, Oil and Coal Products	4,215	49,754	0	1,797,163	27,107	21,360	0	0	0	2,008	0	188,377	332,954	2,422,937	880,952	1,541,986
#27	Ceramic, Stone and Clay Products	130,671	12,652	0	84,377	5,002	25,789	67	0	0	19,110	0	61,867	19,240	358,773	358,634	139
#28	Iron and Steel	293,938	887,304	0	85,896	22,839	105,569	0	0	0	3,125	0	337,486	116,131	1,852,287	1,852,173	114
#29	Non-Ferrous Metals	2,283	7,412	0	16,289	1,317	12,808	0	0	0	1,417	0	43,142	10,152	94,820	94,820	0
#30	Machinery	77	2,994	0	39,368	1,627	55,813	0	0	0	0	0	325,477	42,832	468,189	468,189	0
#31	Miscellaneous	363	56	0	11,753	0	11,421	0	0	0	0	0	107,870	33,253	164,716	164,716	0
#32	Commercial Industry	348	2,958	0	558,889	0	416,611	4,838	0	0	0	0	1,138,001	43,373	2,165,018	2,116,474	48,544
#33	Residential	0	0	0	531,546	0	400,326	9,930	0	0	0	0	963,880	1,102	1,906,784	1,906,784	0
#34	Transportation	39	0	0	3,081,737	0	3,317	0	0	0	0	0	63,183	0	3,148,275	3,111,843	36,433
#35	Passenger	39	0	0	1,794,236	0	320	0	0	0	0	0	60,289	0	1,854,884	1,827,225	27,659
#36	Freight	0	0	0	1,287,501	0	2,996	0	0	0	0	0	2,894	0	1,293,392	1,284,617	8,774
#37	Non-energy and Feedstock Use	9	17,701	0	1,652,658	11,574	0	0	0	0	0	0	0	0	1,681,941	0	1,681,941

2020FY	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	4,488,207	-68,861	5,311,926	1,238,093	4,270,828	723	1,186,057	662,726	0	543,424	325,880	0	0	17,959,004	16,567,020	1,391,984
#02	Indigenously Produced	18,136	0	18,636	0	90,329	0	1,097,082	662,726	0	543,424	325,880	0	0	2,756,213	0	0
#03	Import	4,470,163	25,693	5,196,277	1,933,351	4,178,883	0	89,007	0	0	0	0	0	0	15,893,373	0	0
#04	Total Primary Energy Supply	4,488,299	25,693	5,214,913	1,933,351	4,269,212	0	1,186,089	662,726	0	543,424	325,880	0	0	18,649,587	17,257,603	1,391,984
#05	Export	-92	-94,390	0	-744,069	0	0	-32	0	0	0	0	0	0	-838,582	0	0
#06	Stockpile Change / Supply (+: withdrawal/ -: build-up)	0	-164	97,013	48,811	1,616	723	0	0	0	0	0	0	0	147,999	0	0
#07	Domestic Primary Energy Supply (Supply)	4,488,207	-68,861	5,311,926	1,238,093	4,270,828	723	1,186,057	662,726	0	543,424	325,880	0	0	17,959,004	16,567,020	1,391,984
	(Demand)														17,942,875	16,550,892	1,391,984
#08	Energy Transformation & Own Use	-4,165,158	887,393	-5,307,574	4,495,366	-4,173,921	991,657	-1,175,771	-662,726	0	-513,576	-325,880	3,251,997	820,703	-5,877,493	-5,915,003	37,510
#09	Manufacture of Coal Products (+: output/ -: input)	-1,337,102	1,261,810	0	-13,474	0	0	0	0	0	-5,165	0	0	0	-93,930	-93,930	0
#10	Oil Products (+: output/ -: input)	0	0	-5,301,697	5,256,535	1,502	0	-19,630	0	0	0	0	0	-112,550	-175,839	0	-175,839
#11	Gas Conversion and Production (+: output/ -: input)	0	0	0	-77,530	-1,603,662	1,679,649	-66	0	0	0	0	0	0	-1,609	-1,609	0
#12	Power Generation	-2,457,503	-112,324	-12,359	-212,005	-2,673,009	-196,375	-378,533	-637,505	0	-130,836	-325,880	3,043,355	0	-4,092,974	-4,092,974	0
#13	Auto Power Generation	-171,702	-95,717	-31	-155,573	-42,433	-111,304	-614,817	-25,221	0	-193,106	0	572,409	0	-837,496	-837,496	0
#14	Auto Steam Generation	-212,003	-58,276	-55	-272,545	-21,689	-188,222	-159,807	0	0	-180,653	0	0	910,962	-182,288	-182,288	0
#15	Heat Supply/ Other Energy Transformation	-7,391	0	0	130,567	161,227	-168,838	-777	0	0	-3,066	0	-3,243	28,563	137,042	88	136,953
#16	Own Use and Loss	-12,903	-107,198	-1	-183,502	-13,115	-23,253	-25	0	0	0	0	-360,525	-6,273	-706,795	-706,795	0
#17	Transformation and Consumption Stockpile Change (+: withdrawal/ -: build-up)	33,446	-902	6,568	22,892	17,258	0	-2,117	0	0	-749	0	0	0	76,396	0	76,396
#18	Statistical Discrepancy (+: excess/ -: shortage)	-12,133	35,245	4,351	152	41,799	0	0	0	0	0	0	-36,359	-16,928	16,128	16,128	0
#19	Final Energy Consumption	335,182	783,286	0	5,733,306	55,108	992,379	10,286	0	0	29,848	0	3,288,356	837,630	12,065,383	10,635,889	1,429,494
#20	Industry	335,166	783,286	0	2,605,716	55,108	557,960	3,962	0	0	29,848	0	2,261,601	836,535	7,469,183	6,074,671	1,394,512
#21	Agriculture, Fishery, Mining and Construction	0	18	0	366,565	4,490	2,926	0	0	0	0	0	38,175	849	413,022	361,994	51,028
#22	Manufacturing	335,161	774,756	0	1,734,464	50,619	242,574	146	0	0	29,848	0	1,133,723	790,810	5,092,100	3,776,152	1,315,948
#23	Food, Beverages, Tobacco and Feed	17	0	0	25,419	0	31,602	0	0	0	0	0	87,617	91,530	236,185	236,185	0
#24	Textile Mill Products	0	0	0	4,446	39	5,408	0	0	0	0	0	25,922	37,777	73,592	73,592	0
#25	Pulp, Paper and Paper Products	0	0	0	12,732	400	4,580	113	0	0	760	0	96,308	175,512	290,406	290,406	0
#26	Chemical and Allied Products, Oil and Coal Products	1,860	48,209	0	1,517,939	26,214	22,562	0	0	0	2,000	0	178,770	302,327	2,099,880	784,511	1,315,370
#27	Ceramic, Stone and Clay Products	120,170	12,481	0	73,656	4,641	26,241	32	0	0	24,621	0	59,834	19,520	341,197	340,741	456
#28	Iron and Steel	213,096	712,468	0	60,519	17,528	96,706	0	0	0	2,468	0	302,881	100,656	1,506,321	1,506,198	122
#29	Non-Ferrous Metals	1,426	6,654	0	13,706	1,312	12,662	0	0	0	1,177	0	42,900	9,485	89,323	89,323	0
#30	Machinery	1	1,611	0	36,929	1,797	58,228	0	0	0	0	0	320,215	34,298	453,079	453,079	0
#31	Miscellaneous	17	0	0	11,972	0	12,065	0	0	0	0	0	104,154	35,567	163,775	163,775	0
#32	Commercial Industry	5	8,512	0	504,688	0	312,460	3,816	0	0	0	0	1,089,704	44,876	1,964,061	1,936,525	27,536
#33	Residential	0	0	0	514,467	0	433,238	6,324	0	0	0	0	967,248	1,095	1,922,371	1,922,371	0
#34	Transportation	16	0	0	2,613,123	0	1,182	0	0	0	0	0	59,507	0	2,673,828	2,638,846	34,982
#35	Passenger	16	0	0	1,455,932	0	52	0	0	0	0	0	57,063	0	1,513,064	1,486,838	26,226
#36	Freight	0	0	0	1,157,191	0	1,129	0	0	0	0	0	2,444	0	1,160,765	1,152,009	8,756
#37	Non-energy and Feedstock Use	22	18,552	0	1,400,382	10,538	0	0	0	0	0	0	0	0	1,429,494	0	1,429,494

Table A 3-23 Energy balance simplified table (General Energy Statistics, FY2021, 2022)

2021FY	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	4,815,590	-4,692	5,689,163	1,062,784	3,999,848	943	1,324,387	673,185	0	548,794	604,945	0	0	18,714,946	17,265,928	1,449,018
#02	Indigenously Produced	15,990	0	17,145	0	89,230	0	1,219,437	673,185	0	548,794	604,945	0	0	3,168,726	0	0
#03	Import	4,799,743	63,192	5,675,612	1,953,585	3,910,636	0	104,975	0	0	0	0	0	0	16,507,744	0	0
#04	Total Primary Energy Supply	4,815,733	63,192	5,692,757	1,953,585	3,999,866	0	1,324,412	673,185	0	548,794	604,945	0	0	19,676,470	18,227,452	1,449,018
#05	Export	-144	-66,167	0	-938,904	0	0	-26	0	0	0	0	0	0	-1,005,241	0	0
#06	Stockpile Change / Supply (+: withdrawal/ -: build-up)	0	-1,716	-3,595	48,104	-18	943	0	0	0	0	0	0	0	43,717	0	0
#07	Domestic Primary Energy Supply (Supply)	4,815,590	-4,692	5,689,163	1,062,784	3,999,848	943	1,324,387	673,185	0	548,794	604,945	0	0	18,714,946	17,265,928	1,449,018
	(Demand)														18,536,629	17,087,611	1,449,018
#08	Energy Transformation & Own Use	-4,380,979	920,195	-5,628,513	4,613,538	-3,921,315	1,034,596	-1,314,792	-673,185	0	-516,595	-604,945	3,348,815	835,775	-6,287,406	-6,269,237	-18,169
#09	Manufacture of Coal Products (+: output/ -: input)	-1,426,802	1,330,276	0	-14,616	0	0	0	0	0	-5,555	0	0	0	-116,697	-116,697	0
#10	Oil Products (+: output/ -: input)	0	0	-5,623,033	5,604,599	1,573	0	-19,958	0	0	0	0	0	-105,130	-141,948	0	-141,948
#11	Gas Conversion and Production (+: output/ -: input)	0	0	0	-88,107	-1,661,475	1,747,484	-59	0	0	0	0	0	0	-2,156	-2,156	0
#12	Power Generation	-2,573,865	-128,635	-9,317	-281,568	-2,388,659	-201,185	-434,877	-647,204	0	-131,536	-604,945	3,103,692	0	-4,298,099	-4,298,099	0
#13	Auto Power Generation	-174,244	-103,406	0	-166,158	-45,669	-115,448	-684,269	-25,981	0	-199,682	0	623,694	0	-891,162	-891,162	0
#14	Auto Steam Generation	-219,365	-63,504	0	-282,265	-22,426	-200,364	-171,325	0	0	-176,708	0	0	919,501	-216,456	-216,456	0
#15	Heat Supply/ Other Energy Transformation	-6,769	0	0	44,690	168,312	-175,815	-852	0	0	-3,145	0	-3,219	28,141	51,344	110	51,234
#16	Own Use and Loss	-12,359	-110,610	-5	-207,324	-12,013	-20,077	-298	0	0	0	0	-375,353	-6,738	-744,776	-744,776	0
#17	Transformation and Consumption Stockpile Change (+: withdrawal/ -: build-up)	32,426	-3,927	3,842	4,286	39,041	0	-3,154	0	0	31	0	0	0	72,545	0	72,545
#18	Statistical Discrepancy (+: excess/ -: shortage)	48,436	71,584	60,648	-266	21,231	0	0	0	0	0	0	23,385	-46,701	178,317	178,317	0
#19	Final Energy Consumption	386,175	843,919	1	5,676,588	57,302	1,035,539	9,595	0	0	32,199	0	3,325,429	882,475	12,249,223	10,818,373	1,430,849
#20	Industry	386,160	843,919	1	2,592,095	57,302	606,045	3,843	0	0	32,199	0	2,333,816	881,412	7,736,793	6,340,233	1,396,561
#21	Agriculture, Fishery, Mining and Construction	0	1	0	328,353	4,734	2,826	0	0	0	0	0	39,946	692	376,552	331,524	45,029
#22	Manufacturing	386,157	837,546	1	1,785,593	52,568	252,112	126	0	0	32,199	0	1,154,787	839,836	5,340,925	4,010,657	1,330,268
#23	Food, Beverages, Tobacco and Feed	19	0	0	28,608	0	28,042	0	0	0	0	0	88,216	106,537	251,421	251,421	0
#24	Textile Mill Products	0	0	0	4,664	41	5,555	0	0	0	0	0	27,272	40,313	77,844	77,844	0
#25	Pulp, Paper and Paper Products	0	0	0	13,358	1,029	4,501	95	0	0	704	0	99,575	183,861	303,122	303,122	0
#26	Chemical and Allied Products, Oil and Coal Products	852	48,300	1	1,564,631	25,274	24,767	0	0	0	2,010	0	179,568	303,161	2,148,563	818,572	1,329,990
#27	Ceramic, Stone and Clay Products	117,320	13,040	0	71,971	4,262	23,948	31	0	0	26,938	0	57,951	16,007	331,468	331,298	169
#28	Iron and Steel	267,676	774,563	0	61,626	20,260	109,822	0	0	0	2,548	0	324,957	109,559	1,671,010	1,670,902	109
#29	Non-Ferrous Metals	1,395	6,461	0	14,605	1,415	17,542	0	0	0	1,292	0	42,009	10,074	94,793	94,793	0
#30	Machinery	0	1,652	0	37,513	1,703	57,370	0	0	0	0	0	323,015	45,860	467,113	467,113	0
#31	Miscellaneous	290	0	0	11,922	0	11,577	0	0	0	0	0	99,644	41,495	164,929	164,929	0
#32	Commercial Industry	3	6,372	0	478,148	0	351,108	3,717	0	0	0	0	1,139,083	40,884	2,019,315	1,998,052	21,264
#33	Residential	0	0	0	453,774	0	428,548	5,751	0	0	0	0	933,312	1,063	1,822,448	1,822,448	0
#34	Transportation	15	0	0	2,630,720	0	946	0	0	0	0	0	58,301	0	2,689,982	2,655,693	34,289
#35	Passenger	15	0	0	1,439,591	0	36	0	0	0	0	0	55,901	0	1,495,542	1,470,052	25,490
#36	Freight	0	0	0	1,191,129	0	910	0	0	0	0	0	2,400	0	1,194,440	1,185,640	8,799
#37	Non-energy and Feedstock Use	13	19,536	1	1,400,401	10,898	0	0	0	0	0	0	0	0	1,430,849	0	1,430,849

2022FY	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	4,718,172	-2,423	5,967,517	645,781	3,939,625	-214	1,370,006	659,544	0	537,490	478,998	0	0	18,314,495	16,717,571	1,596,925
#02	Indigenously Produced	16,491	0	15,135	0	83,181	0	1,247,787	659,544	0	537,490	478,998	0	0	3,038,626	0	0
#03	Import	4,701,773	24,704	5,962,250	1,819,117	3,859,628	0	122,251	0	0	0	0	0	0	16,489,722	0	0
#04	Total Primary Energy Supply	4,718,264	24,704	5,977,385	1,819,117	3,942,809	0	1,370,038	659,544	0	537,490	478,998	0	0	19,528,348	17,931,423	1,596,925
#05	Export	-92	-23,248	0	-1,145,829	0	0	-32	0	0	0	0	0	0	-1,169,202	0	0
#06	Stockpile Change / Supply (+: withdrawal/ -: build-up)	0	-3,879	-9,868	-27,506	-3,184	-214	0	0	0	0	0	0	0	-44,651	0	0
#07	Domestic Primary Energy Supply (Supply)	4,718,172	-2,423	5,967,517	645,781	3,939,625	-214	1,370,006	659,544	0	537,490	478,998	0	0	18,314,495	16,717,571	1,596,925
	(Demand)														18,190,569	16,593,644	1,596,925
#08	Energy Transformation & Own Use	-4,378,031	883,592	-5,958,812	4,890,906	-3,882,960	1,007,225	-1,360,891	-659,544	0	-505,484	-478,998	3,268,488	825,581	-6,348,928	-6,045,333	-303,595
#09	Manufacture of Coal Products (+: output/ -: input)	-1,344,528	1,249,843	0	-16,027	0	0	0	0	0	-5,086	0	0	0	-115,798	-115,798	0
#10	Oil Products (+: output/ -: input)	0	0	-5,950,884	5,943,264	1,356	0	-19,175	0	0	0	0	0	-104,829	-130,267	0	-130,267
#11	Gas Conversion and Production (+: output/ -: input)	0	0	0	-102,289	-1,592,954	1,692,188	0	0	0	0	0	0	0	-3,055	-3,055	0
#12	Power Generation	-2,572,319	-108,571	-7,243	-286,122	-2,251,516	-201,286	-476,905	-637,455	0	-139,861	-478,998	3,002,641	0	-4,157,633	-4,157,633	0
#13	Auto Power Generation	-150,999	-87,659	0	-180,409	-52,422	-114,885	-685,466	-22,089	0	-181,525	0	618,386	0	-857,068	-857,068	0
#14	Auto Steam Generation	-200,766	-55,599	0	-285,320	-23,055	-201,822	-173,428	0	0	-176,051	0	0	909,146	-206,896	-206,896	0
#15	Heat Supply/ Other Energy Transformation	-6,098	0	0	22,137	140,347	-150,636	-890	0	0	-3,156	0	-3,359	28,007	26,353	851	25,502
#16	Own Use and Loss	-25,198	-105,081	0	-191,945	-10,548	-16,334	-702	0	0	0	0	-349,180	-6,744	-705,734	-705,734	0
#17	Transformation and Consumption Stockpile Change (+: withdrawal/ -: build-up)	-78,122	-9,341	-685	-12,383	-94,168	0	-4,324	0	0	194	0	0	0	-198,830	0	-198,830
#18	Statistical Discrepancy (+: excess/ -: shortage)	141	94,509	8,706	-410	-359	0	0	0	0	0	0	18,336	3,005	123,927	123,927	0
#19	Final Energy Consumption	340,000	786,660	0	5,537,098	57,024	1,007,010	9,114	0	0	32,006	0	3,250,151	822,576	11,841,640	10,548,311	1,293,330
#20	Industry	339,985	786,660	0	2,356,570	57,024	602,585	3,836	0	0	32,006	0	2,263,528	821,545	7,263,739	6,006,697	1,257,043
#21	Agriculture, Fishery, Mining and Construction	0	87	0	297,689	4,604	2,183	0	0	0	0	0	38,459	470	343,492	301,141	42,352
#22	Manufacturing	339,978	780,684	0	1,650,025	52,421	259,168	146	0	0	32,006	0	1,117,245	775,378	5,007,051	3,804,690	1,202,362
#23	Food, Beverages, Tobacco and Feed	0	0	0	28,388	0	33,971	0	0	0	0	0	87,949	69,336	219,644	219,644	0
#24	Textile Mill Products	0	0	0	5,828	43	6,574	0	0	0	0	0	27,638	40,858	80,941	80,941	0
#25	Pulp, Paper and Paper Products	0	0	0	13,465	1,250	6,126	113	0	0	487	0	96,334	179,716	297,491	297,491	0
#26	Chemical and Allied Products, Oil and Coal Products	736	43,634	0	1,421,000	24,471	22,021	0	0	0	2,067	0	172,615	292,014	1,978,559	776,477	1,202,083
#27	Ceramic, Stone and Clay Products	106,681	11,926	0	75,631	4,666	25,806	33	0	0	26,888	0	58,522	16,273	326,426	326,254	171
#28	Iron and Steel	232,149	722,326	0	63,428	20,185	102,405	0	0	0	2,564	0	308,041	106,636	1,557,734	1,557,627	108
#29	Non-Ferrous Metals	977	6,715	0	15,659	1,297	15,145	0	0	0	1,399	0	41,883	10,171	93,246	93,246	0
#30	Machinery	0	2,803	0	37,186	1,806	61,510	0	0	0	0	0	308,173	41,563	453,042	453,042	0
#31	Miscellaneous	411	0	0	12,939	0	16,355	0	0	0	0	0	99,416	39,308	168,429	168,429	0
#32	Commercial Industry	7	5,888	0	408,856	0	341,233	3,691	0	0	0	0	1,107,824	45,697	1,913,196	1,900,867	12,329
#33	Residential	0	0	0	442,475	0	403,605	5,278	0	0	0	0	928,323	1,031	1,780,712	1,780,712	0
#34	Transportation	15	0	0	2,738,053	0	820	0	0	0	0	0	58,301	0	2,797,189	2,760,902	36,287
#35	Passenger	15	0	0	1,555,309	0	36	0	0	0	0	0	55,901	0	1,611,261	1,583,916	27,345
#36	Freight	0	0	0	1,182,744	0	784	0	0	0	0	0	2,400	0	1,185,928	1,176,986	8,942
#37	Non-energy and Feedstock Use	24	17,558	0	1,264,375	11,372	0	0	0	0	0	0	0	0	1,293,330	0	1,293,330

A3.2.2 General Energy Statistics and CRTs

In order to report CO_2 emissions in the CRTs, the submission of which is required under the Paris Agreement, emissions reported under the sectors in *General Energy Statistics* (Energy Balance Table) are to be reported under each sector in CRTs. The correspondence of categories between *General Energy Statistics* and CRT table 1.A(a) 'sectoral approach' is indicated in Table A 3-24.

Values subtracting energy consumption reported under 'non-energy and feedstock use' [#950000] from energy consumption reported under 'energy transformation & own use' [#200000], 'industry' [#600000], 'residential' [#700000], and 'transportation' [#800000] in *General Energy Statistics* (Energy Balance Table) are used for activity data. Because energy consumption reported under 'non-energy and feedstock use' [#950000] was used for the purposes other than combustion and was considered not emitting CO_2, these values were deducted. 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 *2006 IPCC Guidelines* requires carbon dioxide emitted from auto power generation, etc., to be counted in the corresponding sector. In Japan's Energy Balance Table (*General Energy Statistics*), fuel consumption used for auto power generation and auto steam generation are presented under 'auto power generation' [#250000], 'auto steam generation' [#260000] in the energy transformation sector. However, auto power generation and auto steam generation actually belong to industry sector. Hence, carbon dioxide emissions from "auto power generation" and "auto steam generation" are allocated to each section of '1.A.2 Manufacturing industries and construction' and '1.A.4 Other sectors'.

In 'energy transformation & own use', 'manufacture of coal products' [#210000], 'oil products' [#220000], 'gas conversion and production' [#230000], 'power generation' [#240000], 'auto power generation' [#250000], 'auto steam generation' [#260000], 'heat supply' [#270000], and 'own use & loss' [#300000] are calculated, and other sectors ('other energy transformation' and 'transformation and consumption stockpile change') are excluded from calculations.

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. (Ministry of the Environment, 2006)

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 CO, 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. (Ministry of the Environment, 2015)

Table A 3-24 Correspondence between sectors of General Energy Statistics (Detailed Sector) and of the CRT table 1.A(a)

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
		District heat supply	#270000
		Own use; District heat supply	#301500
		Auto power generation; Production, transmission and distribution of electricity (until 2015)	#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 and miscellaneous	#253175
		Auto steam generation, Manufacture of coal products and miscellaneous	#263175
		Final energy consumption; Manufacture of coal products and miscellaneous	#626550
		Gas conversion and production	#230000
		Own use; Gas conversion and production	#301300
1.A.2	Manufacturing industries and construction		
1.A.2.a	Iron and steel	Auto power generation; Manufacture of iron and steel	#253250
		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	#263260
		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

Table A 3-24 Correspondence between sectors of General Energy Statistics (Detailed Sector) and of the CRT table 1.A(a) (cont.)

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; Freight truck and lorry	#851000
			Non-energy and feedstock use; Transportation (bus, freight 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	-
1.A.4	Other sectors			
1.A.4.a	Commercial/institutional		Auto power generation (except for Production, transmission and distribution of electricity [#255330] (until 2015), Agriculture, fishery, mining and construction [#251000] and Manufacturing [#252000])	#250000
			Auto steam generation (except for Agriculture, fishery, mining and construction [#261000] and Manufacturing [#262000])	#260000
			Final energy consumption; Commercial industry	#650000
			Non-energy and feedstock use; Commercial	#951800
1.A.4.b	Residential		Final energy consumption; Residential	#700000
			Non-energy and feedstock use; Household	#952000
1.A.4.c	Agriculture/forestry/fishing			
		i Stationary	Auto power generation; Agriculture, fishery, mining and construction	#251000
			Auto steam generation; Agriculture, fishery, mining and construction	#261000
			Final energy consumption; Agriculture, forestry and fishery [#610000]; stationary sources	
			Non-energy and feedstock use; Agriculture, fishery, mining and construction	#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: #9xxxxx items are subtracted as a Non-energy use activity.

The ERT recommended that Japan provide a table in the NIR mapping the various types of fuels as reported in the energy balance with the corresponding fuels as reported in CRF table 1.A(d) (FCCC/ARR/2014/JPN). Table A 3-25 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 3-25 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. Quality Standard for Diesel Oil

The carbon emission factor for liquid fuels (diesel oil) in 1.A.3.b (Road transportation) is the lowest in Annex I Parties for two reasons. One is because the quality standard for diesel oil in Japan is different from other countries. Crude oil with high sulfur content imported from the Middle East must be decomposed and go through ultra-deep desulfurization to become low-sulfur diesel oil (<10 ppm) according to Japanese automobile exhaust gas regulations. The other reason is because gas oil used for purposes other than road transport is called "fuel oil A" to distinguish it from diesel oil. The carbon balance of Japanese petroleum refineries including diesel oil and fuel oil A nearly matches according to statistics, so these carbon emission factors are not irregular.

In the individual review on Japanese greenhouse gas inventory conducted in September 2012, the ERT (Expert Review Team) asked Japan for the possibility of involving the information on Japanese quality standard of diesel oil in the future NIR. In correspondence to the question, Japan has provided the information on Japanese quality requirement of diesel oil mainly used for automobile engine in the Table A 3-26 below. In this standard, the 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.

Table A 3-26 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	2.7 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 2204:2007)

A3.4. Conversion factors of calorific values

The ERT recommended that Japan include in the NIR detailed information on the conversion factors used to convert gross calorific values (GCV) to net calorific values (NCV) for all fuels (FCCC/ARR/2014/JPN). For reference, the following table provides the ratio of NCV to GCV, which are derived from GCV and NCV obtained from the standard values of FY2018.

Table A 3-27 Ratio of NCV to GCV (for reference)

Fuel	NCV/GCV	Fuel	NCV/GCV
Coal		Oil	
Imported steel making coal	0.92	Crude oil	0.94
Coking coal	0.92	NGL/condensate	0.94
PCI coal	0.92	Crude Oil - Power Generation Use	0.94
Imported steam coal	0.95	Bituminous Mixture Fuel / Orimulsion	0.95
Indigenous Produced Steam Coal	0.94	Oil Products	
Imported anthracite	0.97	LPG	0.93
Coal products		Propane	0.93
Coke	0.98	Butane	0.93
Coal Tar	0.95	Naphtha	0.94
Coke oven gas	0.90	Reformate	0.94
Blast furnace gas	0.98	Gasoline	0.94
Blast Furnace Gas - Power Generation Use	0.98	Premium Gasoline	0.94
Converter furnace gas	1.00	Regular Gasoline	0.94
Combustible natural gas		Jet fuel oil	0.94
Imported natural gas (LNG)	0.91	Jet fuel oil -Gasoline based	0.94
Indigenous natural gas	0.91	Jet fuel oil -Kerosene based	0.94
Imported natural gas (Vaporized LNG)	0.91	Kerosene	0.94
Indigenous Natural Gas	0.91	Diesel oil	0.94
Boil Off Gas from Crude Oil	0.91	Fuel oil A	0.94
City gas	0.91	Fuel oil C	0.95
Direct Supply LPG	0.93	Fuel oil B	0.94
Renewable Energy		Fuel Oil C - Power Generation Use	0.95
Black Liquor	0.87	Lubricants	0.94
Waste Woods	0.90	Other heavy oil products	0.95
Woods	0.95	Asphalt	0.95
Bioethanol	0.91	Petroleum coke	0.98
Biodiesel	0.91	Galvanic Furnace Gas	1.00
Gas Biomass	0.92	Refinery gas	0.92

Reference: Calculated from Agency for Natural Resources and Energy (2020). *2006 IPCC Guidelines* (Vol. 2, page 1.16) for Coal tar and Bituminous mixture fuel/Orimulsion.

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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 sketches 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 check ・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 expert (SE)

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 from one category to another
- 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 information needed for the documentation box is properly entered
- 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 removal.

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 units 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 places 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 experiences 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 soundness of estimation methods, AD, EFs, and other items.
- Confirming the soundness 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 this submitted inventory. In addition, the QAWG also identified insufficient explanations in the NID. These findings lead to improve 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 is protected by using a password, and confidential files are distinguished from others, together with restricted access. 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:

   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 from the Industrial Processes and Product Use (IPPU) sector were

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

identified, the emissions from the Energy sector are estimated by subtracting the emissions of the IPPU sector from the emissions listed in the *General Survey of the Emissions of Air Pollutants*. For estimation method in 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 by small facilities by fuel type was calculated by subtracting energy consumption by fuel type, identified by the *General Survey of the Emissions of Air Pollutants*, from energy consumption by 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 1.90, 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.

For reference, Table A 5-5 shows the outline of motor vehicle exhaust emission standards of air pollutants.

- ***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	2014	2015	2016	2017	2018	2019	2020	2021	2022
Gasoline	Light vehicle	0.23	0.16	0.16	0.08	0.15	0.10	0.08	0.06	0.09	0.07	0.07	0.05	0.05	0.04	0.04
	Passenger vehicle (including LPG)	0.24	0.20	0.20	0.08	0.14	0.07	0.06	0.05	0.09	0.08	0.06	0.06	0.06	0.04	0.03
	Light cargo truck	0.87	0.66	0.38	0.20	0.27	0.23	0.19	0.18	0.32	0.32	0.25	0.26	0.24	0.17	0.14
	Small cargo truck	1.12	0.90	0.48	0.09	0.15	0.08	0.07	0.06	0.14	0.10	0.07	0.07	0.07	0.05	0.04
	Regular cargo truck	1.83	1.09	0.56	0.16	0.33	0.23	0.23	0.20	0.24	0.20	0.16	0.12	0.11	0.08	0.07
	Bus	4.45	3.65	2.44	0.09	0.15	0.06	0.06	0.05	0.08	0.08	0.10	0.07	0.07	0.07	0.06
	Special-purpose vehicle	1.47	0.87	0.43	0.12	0.32	0.17	0.15	0.12	0.31	0.22	0.17	0.16	0.14	0.11	0.09
Diesel	Passenger vehicle	0.64	0.53	0.44	0.45	0.47	0.38	0.34	0.26	0.40	0.39	0.35	0.28	0.33	0.31	0.30
	Small cargo truck	1.33	1.10	1.01	1.00	1.06	0.89	0.79	0.73	1.87	1.02	0.96	0.94	0.94	0.91	0.88
	Regular cargo truck	5.35	4.59	4.33	4.50	3.26	2.73	2.64	2.40	3.05	2.50	2.28	1.96	1.86	1.73	1.61
	Bus	4.23	3.83	3.60	4.07	3.38	3.23	3.13	2.96	3.74	3.46	3.25	3.04	3.29	2.97	2.80
	Special-purpose vehicle	3.38	2.76	2.15	3.63	2.97	2.41	2.24	2.05	3.21	2.97	2.75	2.42	2.32	2.17	2.01

Table A 5-3 CO emission factors for automobiles [g-CO/km]

Fuel	Vehicle Type	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Gasoline	Light vehicle	1.75	1.55	1.54	0.97	1.51	1.22	1.08	0.94	1.39	1.32	1.29	1.26	1.31	1.29	1.20
	Passenger vehicle (including LPG)	2.32	2.06	2.03	0.94	1.37	0.92	0.81	0.75	1.33	1.27	1.16	1.14	1.19	1.08	0.94
	Light cargo truck	10.42	8.54	5.51	2.77	2.87	2.76	2.38	2.27	2.46	2.48	2.06	2.21	1.98	1.64	1.46
	Small cargo truck	9.66	10.08	8.31	2.05	2.73	1.61	1.40	1.25	1.67	1.19	1.05	1.00	0.98	0.92	0.81
	Regular cargo truck	12.62	10.60	8.95	3.62	7.53	5.04	4.77	4.36	4.18	3.06	2.89	2.25	2.21	1.99	1.84
	Bus	26.21	25.08	21.94	2.07	2.62	1.78	1.65	1.57	1.79	1.72	1.60	1.61	1.88	1.40	1.33
	Special-purpose vehicle	12.47	10.67	8.92	2.30	5.34	3.44	3.09	2.76	3.51	2.23	1.79	1.95	1.94	1.61	1.46
Diesel	Passenger vehicle	0.48	0.43	0.43	0.37	0.39	0.29	0.22	0.17	0.24	0.23	0.20	0.11	0.10	0.08	0.07
	Small cargo truck	0.98	0.90	0.81	0.59	0.45	0.34	0.30	0.25	0.54	0.34	0.28	0.21	0.19	0.14	0.11
	Regular cargo truck	3.22	2.99	2.44	2.04	1.10	0.72	0.65	0.55	0.50	0.36	0.31	0.21	0.18	0.15	0.13
	Bus	2.58	2.53	2.20	2.03	1.24	1.05	0.98	0.89	0.86	0.76	0.66	0.55	0.55	0.44	0.38
	Special-purpose vehicle	2.11	1.89	1.30	1.60	0.93	0.58	0.50	0.43	0.53	0.48	0.41	0.29	0.26	0.21	0.18

Table A 5-4 NMVOC emission factors for automobiles [g-NMVOC/km]

Fuel	Vehicle Type	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Gasoline	Light vehicle	0.08	0.03	0.03	0.03	0.08	0.05	0.04	0.04	0.05	0.05	0.04	0.03	0.04	0.03	0.03
	Passenger vehicle (including LPG)	0.11	0.07	0.06	0.02	0.06	0.04	0.03	0.03	0.06	0.06	0.06	0.05	0.06	0.05	0.04
	Light cargo truck	0.64	0.37	0.16	0.09	0.14	0.12	0.10	0.10	0.12	0.11	0.08	0.09	0.08	0.06	0.05
	Small cargo truck	0.71	0.53	0.21	0.04	0.07	0.04	0.04	0.03	0.10	0.05	0.04	0.04	0.04	0.04	0.03
	Regular cargo truck	0.99	0.58	0.28	0.06	0.17	0.13	0.14	0.11	0.14	0.07	0.06	0.05	0.06	0.05	0.04
	Bus	2.16	1.90	1.32	0.04	0.07	0.04	0.03	0.03	0.06	0.05	0.06	0.05	0.07	0.05	0.05
	Special-purpose vehicle	0.97	0.47	0.19	0.05	0.16	0.10	0.09	0.08	0.24	0.09	0.08	0.08	0.08	0.08	0.07
Diesel	Passenger vehicle	0.11	0.10	0.10	0.09	0.10	0.08	0.07	0.05	0.06	0.05	0.04	0.03	0.03	0.02	0.02
	Small cargo truck	0.39	0.34	0.26	0.20	0.14	0.09	0.08	0.07	0.14	0.09	0.07	0.06	0.05	0.03	0.02
	Regular cargo truck	1.62	1.47	1.03	0.75	0.35	0.21	0.19	0.15	0.14	0.08	0.06	0.05	0.04	0.03	0.02
	Bus	1.26	1.24	0.98	0.80	0.43	0.34	0.32	0.28	0.32	0.26	0.21	0.18	0.17	0.12	0.10
	Special-purpose vehicle	1.09	0.96	0.52	0.57	0.27	0.16	0.13	0.12	0.14	0.11	0.08	0.06	0.05	0.04	0.03

Table A 5-5 Outline of motor vehicle exhaust emission standards (for reference)

			1990	1991	1992	1993	1994	1995	1997	1998	1999	2000	2001	2002	2003	2004	2005	2007	2008	2009	2010	2011	2016	2018	2019	Note
Gasoline and LPG	Light passenger vehicle and passenger vehicle	CO	2.1	2.1								0.67					1.15		1.15			1.15		1.15		
		HC	0.25	0.25								0.08					0.05		0.05			0.05		0.1		
		NOx	0.25	0.25								0.08					0.05		0.05			0.05		0.05		
		Unit	g/km	g/km								g/km					g/km		g/km			g/km		g/km		
		Mode	10	10·15								10·15					10·15+11		10·15+JC08C			JC08H+JC08C		WLTC		
		CO	60									19														
		HC	7									2.2														
		NOx	4.4									1.4														
		Unit	g/test									g/test														
		Mode	11									11														
	Truck and bus	CO	13	13						6.5				3.3				4.02	4.02			4.02			4.02	
	Light cargo truck	HC	2.1	2.1						0.25				0.13				0.05	0.05			0.05			0.1	
		NOx	0.5	0.5						0.25				0.13				0.05	0.05			0.05			0.05	
		Unit	g/km	g/km						g/km				g/km				g/km	g/km			g/km			g/km	
		Mode	10	10·15						10·15				10·15				10·15+11	10·15+JC08C			JC08H+JC08C			WLTC	
		CO	100							76				38												
		HC	13							7				3.5												
		NOx	5.5							4.4				2.2												
		Unit	g/test							g/test				g/test												
		Mode	11							11				11												
	Light duty	CO	2.1	2.1								0.67					1.15		1.15			1.15		1.15		
		HC	0.25	0.25								0.08					0.05		0.05			0.05		0.1		
		NOx	0.25	0.25								0.08					0.05		0.05			0.05		0.05		7)
		Unit	g/km	g/km								g/km					g/km		g/km			g/km		g/km		
		Mode	10	10·15								10·15					10·15+11		10·15+JC08C			JC08H+JC08C		WLTC		
		CO	60									19														
		HC	7									2.2														
		NOx	4.4									1.4														
		Unit	g/test									g/test														
		Mode	11									11														
	Medium duty	CO	13	13			13			6.5			2.1				2.55		2.55			2.55		2.55		
		HC	2.1	2.1			2.1			0.25			0.08				0.05		0.05			0.05		0.15		
		NOx	0.7	0.7			0.4			0.4			0.13				0.07		0.07			0.07		0.07		7)
		Unit	g/km	g/km			g/km			g/km			g/km				g/km		g/km			g/km		g/km		
		Mode	10	10·15			10·15			10·15			10·15				10·15+11		10·15+JC08C			JC08H+JC08C		WLTC		
		CO	100				100			76			24													
		HC	13				13			7			2.2													
		NOx	6.5				5			5			1.6													
		Unit	g/test				g/test			g/test			g/test													
		Mode	11				11			11			11													
	Heavy duty	CO	1.2		102			102		51			16				16									
		HC	410		6.2			6.2		1.8			0.58				0.23									
		NOx	650		5.5			4.5		4.5			1.4				0.7									7)
		Unit	ppm		g/kWh			g/kWh		g/kWh			g/kWh				g/kWh									8)
		Mode	6		G13			G13		G13			G13				JE05									
	Common name						Short-term regulation			Long-term regulation			New short-term regulation				New long-term regulation									

			1990	1991	1992	1993	1994	1995	1997	1998	1999	2000	2001	2002	2003	2004	2005	2007	2008	2009	2010	2011	2016	2018	2019	Note
Diesel	Passenger vehicle	CO	2.1	2.1	2.1				2.1	2.1				0.63			0.63		0.63	0.63				0.63		
		HC	0.4	0.4	0.4				0.4	0.4				0.12			0.024		0.024	0.024				0.024		
		NOx	0.5|0.9	0.5|0.9	0.5|0.6				0.4|0.6	0.4			0.28|0.3			0.14|0.15		0.14|0.15	0.08				0.15		9)
		Unit	g/km	g/km	g/km				g/km	g/km				g/km			g/km		10·15+JC08C					g/km		
		Mode	10	10·15	10·15				10·15	10·15				10·15			10·15+11		↑	JC08H+JC08C				WLTC		
	Truck and bus	CO	2.1	2.1		2.1			2.1					0.63			0.63		0.63	0.63				0.63		
	Light duty	HC	0.4	0.4		0.4			0.4					0.12			0.024		0.024	0.024				0.024		
		NOx	0.9	0.9		0.6			0.4					0.28			0.14		0.14	0.08				0.15		10)
		Unit	g/km	g/km		g/km			g/km					g/km			g/km		10·15+JC08C					g/km		
		Mode	10	10·15		10·15			10·15					10·15			10·15+11		↑	JC08H+JC08C				WLTC		
	Medium duty	CO	790			2.1			2.1						0.63		0.63		0.63	0.63					0.63	
		HC	510			0.4			0.4						0.12		0.024		0.024	0.024					0.024	
		NOx	380/260			1.3			0.7						0.49		0.25		0.25	0.15					0.24	10)
		Unit	ppm			g/km			g/km						g/km		g/km		10·15+JC08C						g/km	11)
		Mode	6			10·15			10·15						10·15		10·15+11		↑	JC08H+JC08C					WLTC	
	Heavy duty	CO	790				7.4		7.4	7.4	7.4				2.22	2.22	2.22		2.22	2.22			2.22	2.22	2.22	
		HC	510				2.9		2.9	2.9	2.9				0.87	0.87	0.17		0.17	0.17			0.17	0.17	0.17	
		NOx	400/260				6/5		4.5	4.5	4.5				3.38	3.38	2		0.7	0.7			0.4	0.4	0.4	10)
		Unit	ppm				g/kWh		(2.5-3.5t)	(3.5-12t)	(>12t)				(2.5-12t)	(>12t)	g/kWh		(>12t)	(3.5-12t)			(>7.5t)	(tractor)	(3.5-7.5t)	11)
		Mode	6				D13										JE05		JE05				WHDC			
	Common name					Short-term regulation			Long-term regulation			New short-term regulation					New long-term regulation		Post new long-term regulation							

Note:
1) This table is compiled based on the materials prepared by Ministry of the Environment and Ministry of Land, Infrastructure, Transport and Tourism.
2) This table omits the regulations of particular matter (PM) and fuel evaporation for the vehicles above and the regulations of exhaust gas for motorcycles and off-road vehicles.
3) The values in this table represent average value for new vehicle type.
4) 1990 column represents the regulations as of 1990 and other columns represent the years the regulations started for new vehicle type.
5) The shaded letters show the difference from the previous regulation.
6) HC do not include methane since the regulations enforced since 2005.
7) For gasoline and LPG vehicles, "light duty vehicles" are vehicles with gross vehicle weight (GVW) of 1.7t or less.
Until 2000, "middle duty vehicles" are vehicles with GVW of 1.7-2.5t and "heavy duty vehicles" are vehicles with GVW of more than 2.5t.
Since 2001, "middle duty vehicles" are vehicles with GVW of 1.7-3.5t and "heavy duty vehicles" are vehicles with GVW of more than 3.5t.
8) Different regulations are adopted for LPG heavy duty vehicles until 1997, but omitted from this table for simplicity.
9) 0.5|0.9 in diesel passenger vehicles stands for "0.5 for small size vehicles (vehicle weight of 1,265 kg or less) and 0.9 for medium size vehicles (vehicle weight of more than 1,265 kg)".
10) For diesel vehicles, "light duty vehicles" are vehicles with GVW of 1.7t or less.
Until 2004, "middle duty vehicles" are vehicles with GVW of 1.7-2.5t and "heavy duty vehicles" are vehicles with GVW of more than 2.5t.
Since 2005, "middle duty vehicles" are vehicles with GVW of 1.7-3.5t and "heavy duty vehicles" are vehicles with GVW of more than 3.5t.
11) "380/260" for diesel truck and bus in 1990s stands for "380 for direct injection and 260 for indirect injection".

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 5-6 Sulfur content (by weight) by fuel type

Fuel	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
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%	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%	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%	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 5-7 Classification of fuel evaporative gases

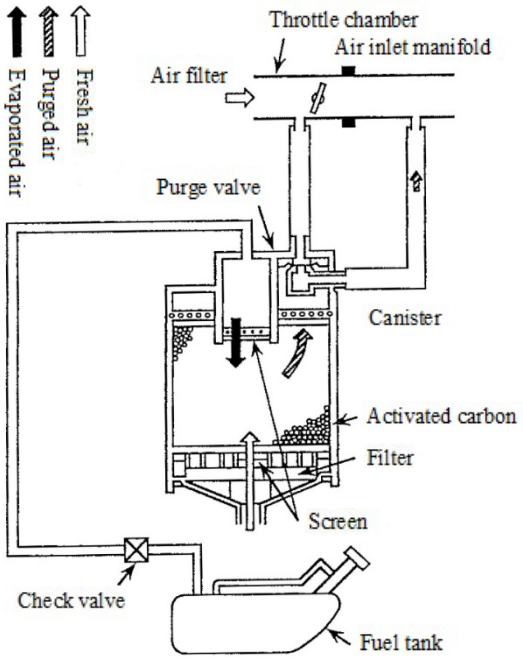
Types	Description
Diurnal Breathing Loss (DBL)	Evaporated gas which is generated when gasoline vapor, generated mainly due to the change in temperature during parking, is vented to the atmosphere after breakthrough[1)] from the canister[2)].
Hot Soak Loss (HSL)	Evaporated gas which is generated from 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 5-8.

[2] Regarding concrete volatile element composition, please refer to Yokota *et al.* (2011) for example.

Table A 5-8 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 5-9 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 5-10 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 5-11 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 5-12 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 included in the category "Venting (Oil)" (1.B.2.c.i.1) and "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 "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 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 Natural Gas Association.

Table A 5-13 Emission factor for NMVOC leaks from oil production

Emission source	Emission factor [kg-NMVOC/kL]	Disaggregation factor (Leaks)	Emission factor (Leaks) [kg-NMVOC/kL]
Onshore (lower-emitting technologies)	1.25	9%	0.11
Offshore	1.06	20%	0.21

- ***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.

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

[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*.

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 5-14.

Table A 5-14 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 5-15 are used for activity data for this category.

Table A 5-15 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 Steam day of crude oil distillation unit at normal pressure, by Steam day per year by the emission factor. Steam day 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 : Fugitive Barrel per Stream Day [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: Barrels per Stream Day) by *Sekiyu Shiryô* (Sekiyu Tsushin) is used for activity data. Stream days in a year are calculated by multiplying 365 days (366 days for leap years: FY1991, 1995, 1999, 2003, 2007, 2011, 2015, 2019) by the annual operating ratio of the crude oil distillation units at normal pressure, which is provided by *Sekiyu Shiryô* (=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 “Oil transport (1.B.2.a.iii)”; 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

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. 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. As for the NMVOC emissions when lowering measuring instruments into wells at servicing, the estimation methods are provided in the section “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 *2006 IPCC Guidelines*.

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

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***

For NMVOC emission factors of fugitive emissions from gas production, the default values for fugitive emissions of gas production from onshore and offshore gas fields (onshore: 5.5×10^{-4}, offshore: 9.1×10^{-5} kt-NMVOC/million m^3), which are indicated in the *2006 IPCC Guidelines*, are used.

- ***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*.

A5.1.1.3.i. 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.j. 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 “Oil transport (1.B.2.a.iii)”).

- ***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.k. 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.l. Venting (Oil) (1.B.2.c.i.1)

a) Category Description

This category provides the estimation method for NMVOC emissions from venting in the petroleum industry.

b) Methodological Issues

- ***Estimation Method***

The emissions are estimated by multiplying the amount of domestic production of crude oil by the

NMVOC default emission factor given in the *2006 IPCC Guidelines*.

$$E = AD \times EF$$

E : NMVOC emissions from venting in oil production [kt-NMVOC]
AD : Amount of domestic crude oil production [1000 kL]
EF : Emission factor per crude oil production [kt-NMVOC/1000 kL]

- ***Emission factors***

For the emission factor, the NMVOC default emission factor for venting in oil production (4.3×10^{-4} kt-NMVOC/1000 kL) given 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.m. Flaring (Oil) (1.B.2.c.ii.1)

a) Category Description

This category provides the estimation method for NMVOC emissions from flaring in the petroleum industry.

b) Methodological Issues

- ***Estimation Method***

The emissions are estimated by multiplying the amount of domestic production of crude oil by the NMVOC default emission factor given in the *2006 IPCC Guidelines*.

$$E = AD \times EF$$

E : NMVOC emissions from flaring in oil production [kt-NMVOC]
AD : Amount of domestic crude oil production [1000 kL]
EF : Emission factor per crude oil production [kt-NMVOC/1000 kL]

- ***Emission factors***

For the emission factor, the NMVOC default emission factor for flaring in oil production (2.1×10^{-5} kt-NMVOC/1000 kL) given 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.n. Flaring (Gas) (1.B.2.c.ii.2)

a) Category Description

This category provides the estimation method for NMVOC emissions from flaring in the natural gas

industry.

b) Methodological Issues

- ***Estimation Method***

The emissions are estimated by multiplying the amount of domestic production of natural gas by the NMVOC default emission factor given in the *2006 IPCC Guidelines*.

$$E = AD \times EF$$

E : NMVOC emissions from flaring in gas production [kt-NMVOC]
AD : Amount of domestic natural gas [1000 m^3]
EF : Emission factor per natural gas production [kt-NMVOC/1000 m^3]

- ***Emission factors***

For the emission factor, the NMVOC default emission factor for flaring in gas production (6.2×10^{-7} kt-NMVOC/1000 kL) given in the *2006 IPCC Guidelines* is used.

- ***Activity Data***

The activity data for this category are the production amount 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*.

A5.1.1.3.o. Flaring (Combined) (1.B.2.c.ii.3)

a) Category Description

In Japan, the statistical data are reported for two categories of oil and natural gas. Therefore, the fugitive emissions whose categories can be distinguished are reported in “Flaring (Oil)” (1.B.2.c.ii.1) or in “Flaring (Gas)” (1.B.2.c.ii.2) respectively. In this category, NMVOC emissions arising from exploration and test before production of oil and natural gas, which are unable to be distinguished by their categories of oil industry or natural gas industry, are reported.

b) Methodological Issues

- ***Estimation Method***

The NMVOC emissions 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 from well drilling and well testing [kt-NMVOC]
AD : Amount of domestic crude oil [1000 kL]
EF : Emission factor per crude oil production [kt-NMVOC/1000 kL]

As for NMVOC emissions from flaring in well drilling and well testing, the default values are not prepared for oil industry and gas industry separately, but the total of both values is indicated in the *2006 IPCC Guidelines*, thus the emissions are estimated together and reported in this category. In addition, the emissions include venting, because the default values do not disaggregate flaring and venting.

For the fugitive emissions arising from exploration and test before production of oil and natural gas, the default emission factors, which are established using the crude oil production as activity data, are

indicated in the *2006 IPCC Guidelines*. However, the correlation between the emissions which accompany exploration and testing of natural gas fields, and the crude oil production amount, and the correlation between the emissions from exploration and testing and the production amount from commercial plants are not clear. Especially, as for the emissions from the exploration of wells, the number of exploratory wells is extremely small compared to the number of operating wells in Japan, thus there is a possibility of overestimation if the crude oil production amount is adopted as activity data.

- ***Emission factors***

For the emission factor, the sum of NMVOC default emission factors for flaring and venting in well drilling and well testing (well drilling: 8.7×10^{-7}, well testing: 1.2×10^{-5} kt-NMVOC/1000 kL) given in the *2006 IPCC Guidelines* is used.

- ***Activity Data***

The activity data for this category are the production amount 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*.

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:

$$E=\Sigma\{N\times(1-R)\}$$

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} : SO_X volume before treatment
V_{after} : SO_X 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

[5] The emissions in the process of manufacturing were estimated in "A5.1.2.2.n Chemicals Manufacture"

amount of paint.

$$E = AD \times EF$$

E : NMVOC emissions from use of paint [1000t -NMVOC]
AD : Sales amount of paint [1000t]
EF : Emission factors per sales amount of paint [t-NMVOC/t]

- ***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 use of paint. 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 solvent”

$$E = AD - A - B$$

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 [1000t -NMVOC]
AD : Sales amount of chlorine cleaners [1000t]
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 [1000t -NMVOC]
AD : Used weight of each non-chlorine cleaner [1000t]
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
FY1990-1999	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.
FY2000	Used weight of each type of cleaner in the *Study on the VOC Emission Inventory* was adopted for activity data.
FY2001-2004	Estimated by interpolating the activity data for FY2000 and FY2005.
FY2005-	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 Manufacturing Equipment

a) Category Description

NMVOCs are emitted from the use of thinner for cleaning manufacturing equipment.

b) Methodological Issues

- ***Estimation Method***

NMVOC emissions from the use of thinner for cleaning 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 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, which 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, deducting the amount from the total sales volume of thinner, was adopted for activity data.
2005-	Estimated by deducting 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 diluent in the process of printing. Ink included in stationaries, solvent for cleaning of printing machine (estimated as "A5.1.2.2.d thinner for cleaning 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 solvent (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.

- ***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 adhesive

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. 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 aerosols

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 rate 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 rate of products was classified according to the *Yearbook of chemical industry* from the VOC content rate 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 rate and atmospheric emission rate based on classification in *Yearbook of Chemical Industry*

Cosmetic products		VOC content rate	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%
Fragrance	Perfume and cologne	7.5%	100%
Body care	Lip balm	10.0%	100%
	Sunscreen and cosmetics for sun-burns	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 5-36 and Table A 5-37).

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 rate 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 rate for car washing and repairing products

Product		VOC	VOC content rate
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 in *Statistical Yearbook of Motor Vehicle Transport* (Ministry of Land, Infrastructure, Transport and Tourism).Consumption of car washing and repairing products per vehicle was estimated by dividing the production weight for each type of chemical product for car 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 average value was used to reflect the trend of travel distance per vehicle because 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 by interpolation, using activity data in FY1996 and FY1999.

[7] Three-year average was used since the FY2005 value drastically increased from the previous year.

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.

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* by the 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* by 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

Fiscal Year (FY)	Method of establishing activity data	
	Emissions under the PRTR	Emissions from sources not required to report under the PRTR
1990-2000	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.*	
2001-2012	The atmospheric emissions of N, N-dimethylformamide from the plastic product manufacturing industry, reported under the PRTR is used as emissions.	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.
2013-		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.

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.

[8] The value of the year with the highest ratio was used to avoid underestimation.

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.

A5.1.2.3 Others – Food and Beverage Industry (2.H.2.) (NMVOCs)

A5.1.2.3.a. Foods (Fermentation)

a) Category Description

NMVOCs are released as a fugitive emission in alcohol in the process of manufacturing foods or beverages. For the estimation of NMVOC emissions from this source category, alcohol which is generated by bread making and alcoholic brewing is included in the calculation; it is 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 factor 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***

$$E = AD \times ABV \times EF$$

E : NMVOC emissions from alcohol brewing [t -NMVOC]
AD : Production volume of alcoholic drinks [1000 kL]
ABV: Ethyl alcohol content rate [%] (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 the emission factor for bread making.

As for emission factor for brewing alcoholic drinks, the ethyl alcohol content provided in European Environment Agency's *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2009* was also used (TableA5-65). 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* (TableA5-66). The ethyl alcohol content provided in the *Study on the VOC Emission Inventory* was used for spirits and liquor. (TableA5-67).

Table A 5-65 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 brewed volume
Whiskey	15	kg/100L- volume of brewed ethyl alcohol
Spirits	0.4	kg/100L- volume of 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 5-66 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 5-67 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))

a) Methodological Issues

1) Biomass Burning in Forest Land (4(IV))

- ***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} : NC ratio

- ***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)

➢ ***NC ratio***

The following values are applied to NC ratio of NO_X.

NC 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.

2) **From burning of pruned branches from orchard trees (4(IV))**

- ***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 5-68 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.

3) **Biomass Burning in Grassland (4(IV))**

- ***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* 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.]
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 5-69 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.–)

- ***Estimation Method***

The NO_X, CO, NMVOCs, and SO_X emissions from the specified sources were calculated by multiplying the incineration amount of 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 (municipal solid waste; continuous system)] and [1302: Waste incinerator (municipal solid waste; batch system)]). The incineration material was [53: Municipal solid waste].) 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 5-70 NO_X and SO_X emission factors for municipal waste 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]											
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]											
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 5-71 CO emission factors for municipal waste by type of incineration method [kg-CO/t]

Furnace type	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Continuous incinerator	557	557	555	554	554	553	553	553	553	554	554	554	554	555	555
Semi-continuous incinerator	548	548	567	591	611	609	614	607	600	603	611	603	611	615	615
Batch type incinerator	8,237	8,237	8,298	8,341	8,270	8,274	8,274	8,279	8,281	8,239	8,241	8,241	8,244	8,244	8,244
Gasification melting furnace	567	567	567	567	567	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 5-72 NMVOC emission factors for municipal waste by type of incineration method [kg-NMVOC/t]

Furnace type	1990	1995	2000	2005	2010	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
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	0.3	0.3	0.3
Semi-continuous incinerator	7.8	7.8	8.5	2.2	2.4	2.3	2.4	2.3	2.3	2.3	2.4	2.3	2.4	2.4	2.4
Batch type incinerator	9.1	9.1	9.5	1.5	1.3	1.3	1.3	1.3	1.3	1.2	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	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 municipal waste 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.–)

● ***Estimation Method***

NO_X, CO, NMVOCs, and SO_X emissions from the specified sources were calculated by multiplying the incineration amount of industrial waste 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 industrial solid waste using the emission amount and amount of treated industrial solid waste identified by the *General Survey of the Emissions of Air Pollutants*. The categories of incinerator types included: [1303: Waste incinerator (industrial solid waste; continuous system)] and [1304: Waste incinerator (industrial solid waste; batch system)]. The incinerator fuel covered the categories [23: Fuel Wood] and [54: Industrial solid waste]). The six types of industrial waste were "Paper/cardboard, wood", "Sludge", "Waste oil", "Plastics", "Textiles", and "Animal and vegetable residues/animal carcasses". Category [23: Sawn Timber] was used for "Paper/cardboard, wood", "Waste textiles", and "Animal and vegetable residues/animal carcasses", while category [54: Industrial waste] 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 5-73 NO_X and SO_X emission factors for industrial waste 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]												
Waste oil	0.999	1.034	1.222	1.278	1.092	1.158	1.297	1.296	1.294	1.415	1.415	"Fuel wood 23"
Plastics												
Paper/cardboard	1.545	3.674	2.891	1.885	1.869	1.312	1.147	1.172	1.180	5.818	5.818	"Industrial waste 54"
Wood												
Textile												
Animal and vegetable residues/ animal carcasses												
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	"Fuel wood 23"
SO_X EF [kg-SO_X/t]												
Waste oil	1.179	0.973	1.828	1.720	1.816	1.882	1.151	1.148	1.162	1.343	1.352	"Fuel wood 23"
Plastics												
Paper/cardboard	1.528	1.236	1.601	1.472	1.474	1.274	1.250	1.276	1.290	2.116	2.118	"Industrial waste 54"
Wood												
Textile												
Animal and vegetable residues/ animal carcasses												
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	"Fuel wood 23"

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 industrial solid waste. The six types of industrial waste 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 5-74 CO emission factors for industrial waste by waste type

Item	CO EF [g-CO/t]
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 5-75 NMVOC emission factors for industrial waste by waste type

Item	NMVOC EF [g-NMVOC/t]
Waste oil	0.54
Plastics	3.40
Paper/cardboard	2.48
Wood	
Textile	
Animal and vegetable residues/ animal carcasses	
Sludge (incl. sewage sludge)	1.61

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.–)

- ***Estimation Method***

NO_X, CO, NMVOCs, and SO_X emissions from the specified sources were calculated by multiplying the amount of industrial waste 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 industrial waste 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 industrial waste 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.-)

- ***Estimation Method***

CO and NMVOC emissions from this source were estimated by multiplying the amounts of fuel/raw material burned 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 5-76 CO emission factors from incineration in conjunction with use of waste as fuel and raw material

Application	CO EF [kg-CO/t]							
	Waste oil	RDF	RPF	Waste tires		Plastics	Plastics (Liquefaction)	Wood
				–FY2004	FY2005–			
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	0.034	3.64
Cement kilns	–	19.8	32.2	23.0	36.5	32.2	–	–
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 municipal solid waste and industrial waste, emission factors were determined from documents with estimates of emissions of CH_4 and NMVOCs per unit calorific values.

Table A 5-77 NMVOC emissions factors from incineration in conjunction with use of waste as fuel and raw material

Application	NMVOC EF [kg-NMVOC/t]							
	Waste oil	RDF	RPF	Waste tires		Plastics	Plastics (Liquefaction)	Wood
				–FY2004	FY2005–			
Boilers	0.015	0.00027	0.00043	0.00031	0.00049	0.00043	0.010	0.12
Cement kilns	–	–	0.043	0.031	0.049	0.043	–	–
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
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 5-78 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 kilotonnes 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".

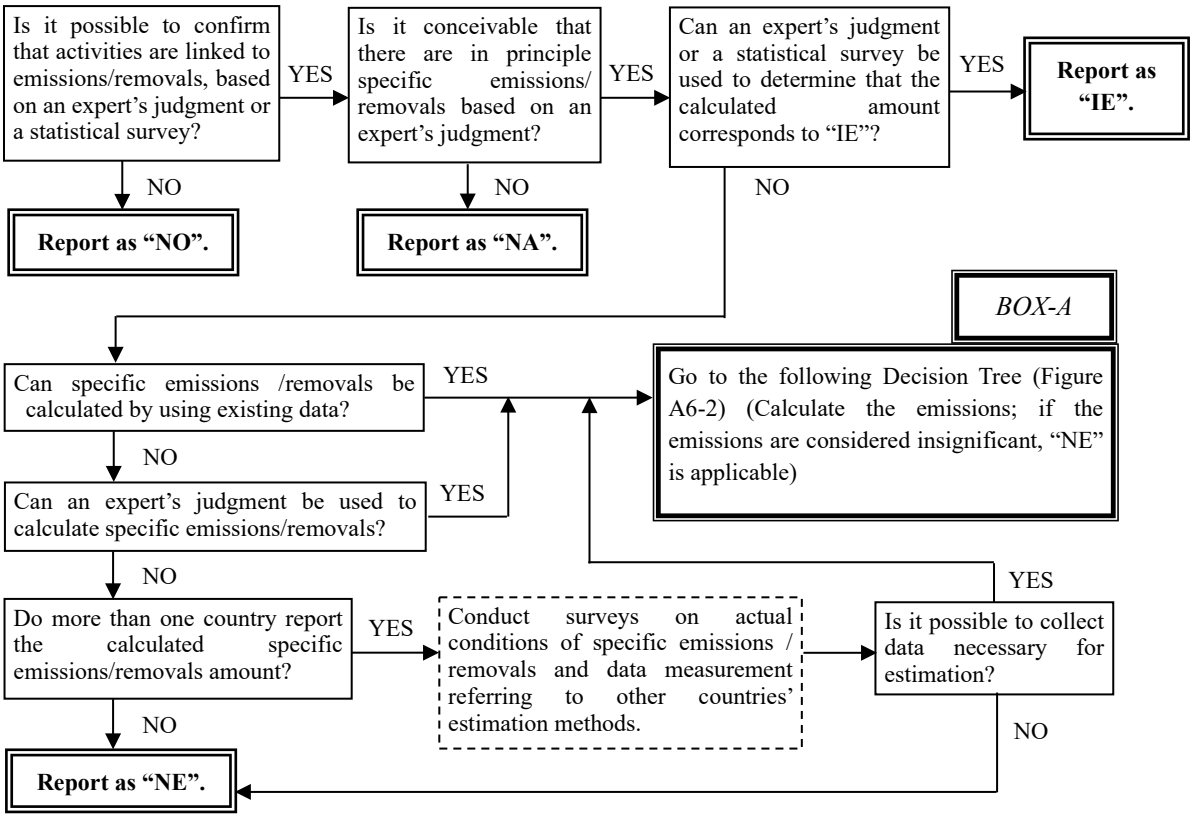

Figure A 6-1 Decision tree for application of notation keys

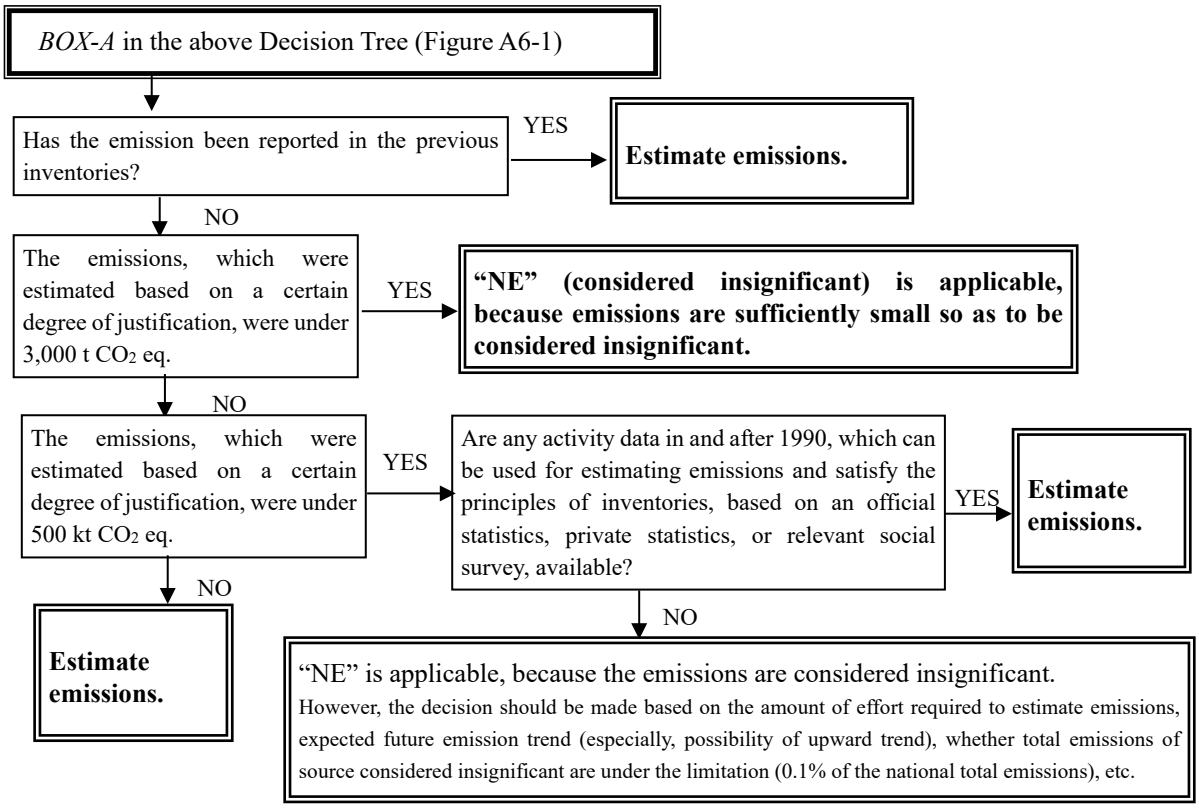

Figure A 6-2 Decision tree for determining applicability of "NE" when the emissions are considered insignificant

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 1.14 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.C.		CO_2 transport and storage		CO_2	<0.007
#4	2.C.7.	IPPU	Rare Earths Production		CO_2	<0.6
#5					PFCs	<0.4
#6	2.D.3.		NMVOC incineration		CH_4	<0.2
#7			NMVOC incineration		N_2O	<1
#8	2.F.1.		Refrigeration and Air Conditioning Equipment	Fugitive emissions from refrigerant containers	HFCs	<63
#9	2.G.2.		SF_6 and PFCs from other product use	Soundproof windows	SF_6	<0.3
#10	3.A.4.-	Agriculture	Enteric Fermentation	Deer	CH_4	<2.6
#11				Alpaca	CH_4	<0.08
#12	3.B.4.-		Manure Management	Deer	CH_4	<0.03
#13				Reindeer	CH_4	<0.01
#14				Fox	CH_4	<0.04
#15				Other poultries (duck, turkey, etc.)	CH_4	<0.9
#16				Deer	N_2O	<0.5
#17				Reindeer	N_2O	<0.02
#18				Fox	N_2O	<0.01
#19				Other poultries (duck, turkey, etc.)	N_2O	<0.3
#20	4.D.1.	LULUCF	Wetlands	Peat extraction	CO_2	<50
#21	4.D.			Biomass Burning	CH_4	<0.16
#22					N_2O	<0.14
#23	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

Category	Excel file name	Contents
	JPN_20xx_1990 - JPN_20xx_20yy	Common reporting tables generated by ETF Reporting Tool（CRT）
1. Energy	1A-L3-CO2-1990-20xx - 1A-L3-CO2-20yy-20xx	CO_2 emissions from fuel combustions
	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 furnace and off-road vehicle
	1A-L3-HC-20xx	CH_4, NMVOC emissions from furnace and off-road vehicle
	1A-L3-N2O-20xx	N_2O emissions from furnace and off-road vehicle
	1A-L3-NOxSO2-20xx	NOx, SO_2 emissions from fuel combustion (except transport sector)
	1A-L2-nonCO2-ADEF-20xx	Activity data and emission factors of non-CO_2 from fuel combustion (except transport sector)
	1A-L2-NOxSO2-ADEF-20xx	Activity data and emission factors of NOx, SO_2 from fuel combustion (except transport sector)
	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 sector) (except CO_2)
	1A3-L2-ADEF-20xx	Activity data and emission factors for mobile combustion (transport sector)
	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 other 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-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 on 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 emissions from smoking
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-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

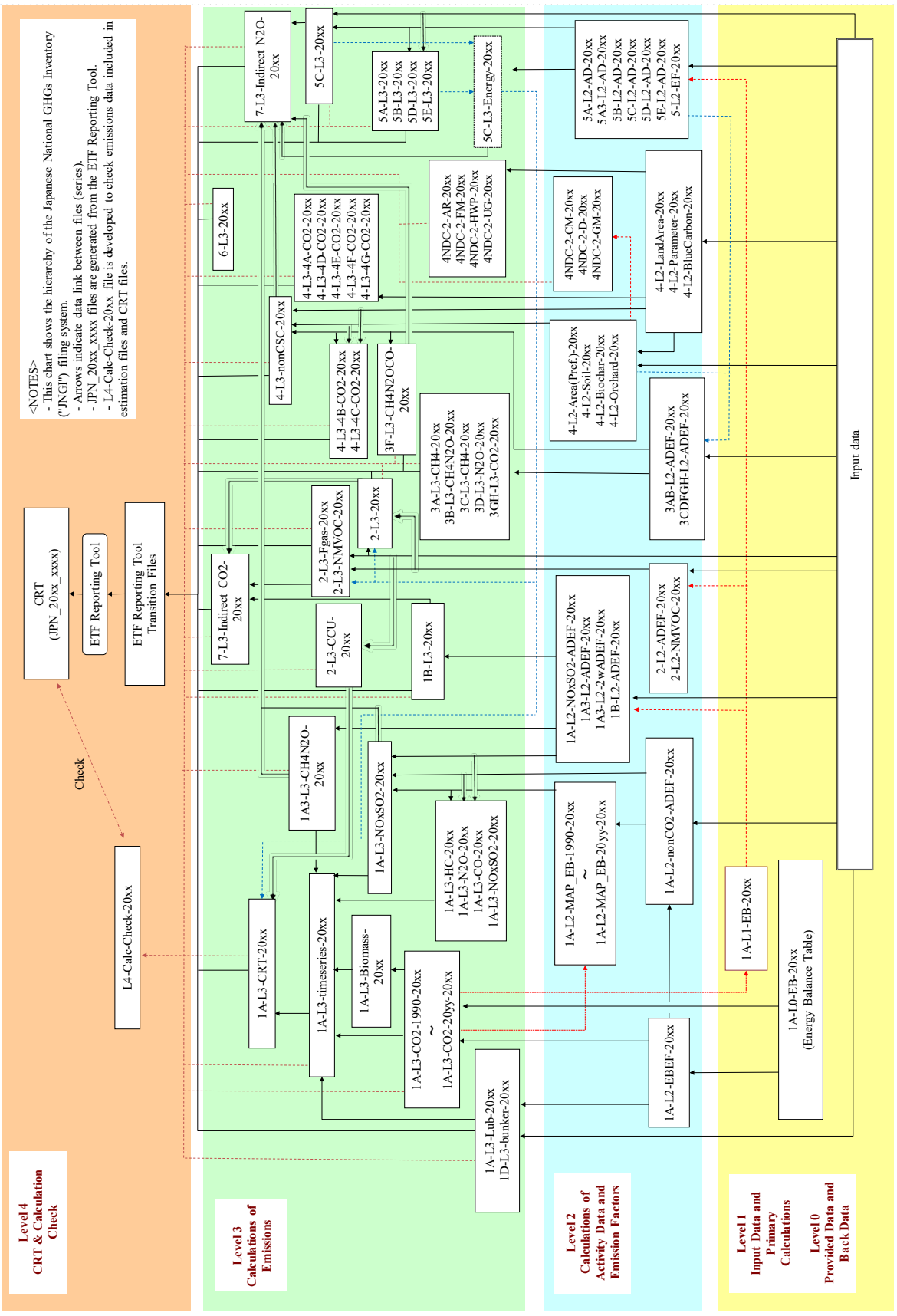

Figure A 7-1 Hierarchical structure of Japan's National GHG Inventory File System

Annex 8. Common Reporting Tables

Following Decision 5/CMA.3, the final version of the reporting tool for the electronic reporting of the common reporting tables (CRTs) is to be made available by June 2024 by the UNFCCC Secretariat.

Japan intends to submit the CRTs after the above-mentioned tool is made available and when the data of Japan's inventory can be accurately reflected in the exported tables.

Annex 9. Methodological Details of the LULUCF Sector Accounting in the NDC

A9.1. Summary of Greenhouse Gas (GHG) Emissions by Sources and Removals by Sinks in the LULUCF Sector in the NDC

A9.1.1 Activities Subject to GHG Emissions and Removals Estimation, Their Scope, and Estimation Methodology Tiers in the LULUCF Sector in the NDC

This annex chapter, based on Decision 4/CMA.1, describes the activities subject to estimation of GHG emissions by sources and removals by sinks in 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 GHG emissions and removals in the LULUCF sector in the NDC to be reported in "4. Structured summary" of Common Tabular Formats (CTF) in the Biennial Transparency Report (BTR).

GHG emissions and removals in 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. The scope is basically 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), as well as urban greening (UG) in which scope has been expanded from revegetation (RV). These activities are collectively referred to as NDC-LULUCF activities. 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 NDC-LULUCF activities

NDC-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

R: Reported, NA: Not Applicable, NO: Not Occurring, IE: Included Elsewhere, IO: Instantaneous Oxidation

Table A 9-2 Methodological tiers used to calculate each NDC-LULUCF activity

NDC-LULUCF Activity	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				

A9.1.2 Accounting Approach and Accounting Quantity for each NDC-LULUCF Activity

The accounting approach used for each NDC-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 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, as in the second commitment period of the Kyoto Protocol, the net-net approach was applied, using 1990 as the base year. In UG activities, the area of urban green space that have been established, serviced, or conserved is subject to calculation. In such net sink activities, it is important to maintain and enhance removals as an absolute amount in each year, so the net removals for the relevant fiscal year from the UG activity were directly accounted for as the amount of removals. This is equivalent to the gross-net accounting approach. The amount of those activities in FY2022 (after applying the accounting approaches) was 50,181 kt-CO_2eq. removal.

The annual accounted values before the target year, 2030, provided in this Annex chapter are presented only as a reference to indicate where Japan currently stands. Since our NDC target for 2030 was set as a single year net GHG emissions and removals target, the NDC-LULUCF removals will be accounted for only in the target year (2030). Values up to FY2020 are historical achievements which had already been accounted for in the 2020 target, while values from FY2021 indicate the status during the NDC period (Table A 9-3).

Table A 9-3 Accounting quantities for NDC-LULUCF activities

NDC-LULUCF activity	Accounting quantities [kt CO_2 eq.]								
	Archives							NDC period	
	2014	2015	2016	2017	2018	2019	2020	2021	2022
Afforestation/reforestation	-1,882	-1,864	-1,567	-1,504	-1,369	-1,652	-1,578	-1,510	-1,452
Deforestation	3,164	3,371	3,336	2,919	2,882	3,323	3,318	2,762	2,762
Forest management	-62,327	-58,870	-57,325	-56,687	-55,358	-51,140	-48,893	-49,329	-46,985
Cropland management	-1,517	-2,004	-2,245	-3,068	-3,795	-3,371	-3,479	-3,858	-3,082
Grazing land management	1,254	980	686	517	264	358	165	-139	48
Urban greening	-1,777	-1,748	-1,729	-1,706	-1,669	-1,642	-1,595	-1,552	-1,472
Total accounting quantity	-63,086	-60,135	-58,844	-59,530	-59,046	-54,124	-52,062	-53,627	-50,181

(CO_2) +: Emissions, -: Removals

A9.2. Scope of Estimations for each NDC-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 from AR activity are difficult to distinguish from HWP 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 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, which were not subject to reporting and estimation under Revegetation (RV) activity of the Kyoto Protocol, and green spaces conserved by zoning.

A9.3. Methods for Estimating and Accounting for GHG Emissions and Removals for each NDC-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

	Unit	1990-2014	1990-2015	1990-2016	1990-2017	1990-2018	1990-2019	1990-2020	1990-2021	1990-2022
AR accumulated occurrence area	kha	98.1	98.9	99.8	99.7	99.7	99.5	99.3	99.3	99.2

A9.3.1.2. Methods for Calculating for Carbon Stock Changes and GHG Emissions

a) Living Biomass

■ **Methodology**

The annual stock of living biomass that accumulates after conversion from other land uses to forests are to be included in this estimation. The calculation was based on the Tier 2 stock-change 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 from AR activities cannot be distinguished from that from FM activities, 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
AR net removals and accounting quantity		-1,882.19	-1,863.60	-1,566.86	-1,504.02	-1,369.16	-1,651.58	-1,578.17	-1,510.49	-1,452.42
	Living biomass	-1,483.82	-1,466.88	-1,170.96	-1,116.28	-985.52	-1,272.92	-1,204.00	-1,139.79	-1,085.29
	Dead wood	-59.00	-59.43	-59.94	-59.38	-59.35	-59.18	-59.08	-59.13	-59.11
	Litter	-100.28	-96.93	-93.54	-88.48	-84.54	-80.71	-76.72	-72.92	-69.47
	Mineral soils	-239.09	-240.36	-242.41	-239.88	-239.76	-238.77	-238.36	-238.65	-238.55
	Organic soils	NO	NO	NO	NO	NO	NO	NO	NO	NO
	Harvested wood products (HWP)	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
	Fertilization (N_2O)	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
	N mineralization in mineral soil (N_2O)	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Biomass burning (CH_4, N_2O)	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 in several prefectures 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
D Accumulated occurrence area	285.2	294.0	302.7	309.7	316.7	321.8	326.9	331.1	335.2
Area of occurrence in a single year	7.7	8.8	8.8	7.0	7.0	5.1	5.1	4.1	4.1

A9.3.2.2. Methods for Calculating for Carbon Stock Change 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 from D activity and the accounting quantity

[kt-CO_2eq.]

	2014	2015	2016	2017	2018	2019	2020	2021	2022
D Emissions and accounting quantity	3,163.85	3,370.54	3,335.58	2,918.79	2,881.67	3,323.05	3,318.41	2,761.76	2,762.40
Living biomass	1,309.75	1,503.74	1,502.32	1,212.28	1,205.79	1,728.81	1,740.96	1,318.38	1,325.99
Dead wood	281.35	323.03	323.03	260.51	260.51	228.78	228.78	171.93	171.94
Litter	137.86	158.29	158.29	127.65	127.65	112.10	112.10	84.25	84.25
Mineral soils	1,346.78	1,300.41	1,268.93	1,237.40	1,208.65	1,176.41	1,160.65	1,114.31	1,107.76
Organic soils	NO	NO	NO	NO	NO	NO	NO	NO	NO
Harvested wood products (HWP)	IO	IO	IO	IO	IO	IO	IO	IO	IO
Other gases	88.10	85.07	83.01	80.95	79.07	76.96	75.93	72.89	72.47
Fertilization (N_2O)	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
N mineralization in mineral soil (N_2O)	88.10	85.07	83.01	80.95	79.07	76.96	75.93	72.89	72.47
Biomass burning (CH_4, N_2O)	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 FY2022 was calculated subtracting duplicate from the cumulative number of plots surveyed from the first year of the survey, 2007, to the end of FY2022. Since the current survey result applied for same plot, the FM activities implemented from 1990 to the end of the FY2022 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 FY2022. Since the total forest area in FY2022 from the Forest Registers and the satellite images were used, the area of D activities that occurred in 2022 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 of the area of FM for FY2022)

Sub-category / Tree species		Region	Private forest	National forest
Intensively managed forest	Japanese cedar	Tohoku, Kita-kanto, Hokuriku, Tosan	0.90	0.92
		Minami-kanto, Tokai	0.76	0.89
		Kinki, Chugoku, Shikoku, Kyusyu	0.81	0.91
	Hinoki cypress	Tohoku, Kanto, Chubu	0.86	0.92
		Kinki, Chugoku, Shikoku, Kyusyu	0.88	0.94
	Japanese larch	All	0.90	0.86
	Other	All	0.75	0.85
Semi-natural forest / All		All	0.49	0.68

Note:

1) Approximately 22,400 surveyed points nationwide as of the end of FY2022
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 5% 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 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 (FY2022) [kha]

Protected / Conserved forest type	Private forest	National forest	Total
Protection forest	2,865	4,570	7,434
Area for conservation facility installation project	1	0	1
Protected forest	0	633	633
Special protected zones in national parks	43	115	158
Class I special zones in national parks	41	170	211
Class II special zones in national parks	138	200	338
Special protected zones in quasi-national parks	8	37	45
Class I special zones in quasi-national parks	30	106	136
Class II special zones in quasi-national parks	94	88	182
Special zone in national environment conservation area	2	9	11
Special seed forest	1	1	1
Total (excluding duplicate designations)	3,222 (2,765)	5,928 (4,325)	9,150 (7,090)

Reference: NFRDB (1st April 2023)
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
Area subject to FM	15,544.4	15,596.5	15,689.2	15,834.2	15,952.5	16,031.4	16,099.0	16,162.4	16,211.2
Ikusei-rin forest	8,518.8	8,619.8	8,693.9	8,821.9	8,905.0	8,929.1	8,994.2	9,051.0	9,118.8
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

A9.3.3.2. Methods for Calculating 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 includes 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 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 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 under AR activities, 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.

$$Inflow_{i,D,RW} = Harvest_{RW,i} \times \{(Stock_{i,D,ST} \times D_i)/Harvest_{ST,i}\}$$

$Inflow_{i,D,RW}$	: 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* [ha]

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 in Chapter 6. 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 change 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 amount recorded 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. 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 emissions and removals, 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 from FM activity and the accounting quantity

[kt-CO_2 eq.]

	2014	2015	2016	2017	2018	2019	2020	2021	2022
FM accounting quantity	-62,327.26	-58,869.87	-57,324.98	-56,687.26	-55,357.88	-51,139.86	-48,893.07	-49,328.98	-46,985.21
FMRL	1,344.07	1,384.55	1,423.37	1,460.04	1,501.54	1,548.72	1,596.36	1,649.73	1,697.00
(Forest)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
(HWP)	1,344.07	1,384.55	1,423.37	1,460.04	1,501.54	1,548.72	1,596.36	1,649.73	1,697.00
FM net removals	-60,983.19	-57,485.32	-55,901.61	-55,227.22	-53,856.34	-49,591.14	-47,296.71	-47,679.25	-45,288.21
Living biomass	-55,351.71	-51,794.66	-50,035.72	-49,148.31	-47,735.55	-43,648.61	-42,034.10	-41,474.86	-39,415.46
Dead wood	-2,287.81	-2,387.92	-2,511.91	-2,652.42	-2,783.29	-2,885.85	-2,997.89	-3,070.10	-3,157.03
Litter	-82.78	-1.44	61.06	93.88	129.59	176.09	216.65	258.73	305.46
Mineral soils	-2,420.17	-2,292.14	-2,147.93	-2,013.34	-1,862.83	-1,695.28	-1,536.89	-1,379.52	-1,221.05
Organic soils	NO	NO	NO	NO	NO	NO	NO	NO	NO
Harvested wood products (HWP)	-925.08	-1,081.11	-1,336.67	-1,595.16	-1,676.30	-1,613.60	-1,019.77	-2,096.73	-1,880.56
Other gases	84.36	71.96	69.55	88.12	72.05	76.12	75.30	83.23	80.41
Fertilization (N_2O)	0.80	0.76	0.76	0.76	0.76	0.76	0.76	0.76	0.76
Organic soil drainage (CH_4, N_2O)	NO	NO	NO	NO	NO	NO	NO	NO	NO
N mineralization in mineral soil (N_2O)	65.53	66.35	67.70	68.53	69.30	71.19	72.40	74.72	76.55
Biomass burning (CH_4, N_2O)	18.02	4.85	1.09	18.83	1.98	4.16	2.14	7.75	3.10

(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 of Chapter 6. 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
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
Area of mineral soils (excluding area subject to D)	4,444.6	3,749.7	3,728.9	3,706.3	3,681.6	3,659.6	3,638.8	3,615.7	3,591.9	3,569.9

A9.3.4.2. Methods for Calculating for Carbon Stock Change 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 change in living biomass subject to CM activities [t-C/yr]
$\Delta C_{orchard_LB_SC}$: Carbon stock change in living biomass in orchards [t-C/yr]
$\Delta C_{annualcrop_LB_SC}$: Carbon stock change (gain) in living biomass of annual crops in rice fields and upland fields [t-C/yr]
$\Delta C_{LB_conversion_to_others}$: Carbon stock change (loss) 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 change 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 model (Roth C) 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 of Chapter 6.

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 accounting quantity was calculated using the net-net approach with 1990 as the base year. The results of the calculations 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
CM accounting quantity	-	-1,517.35	-2,004.11	-2,245.12	-3,068.26	-3,795.12	-3,370.86	-3,479.12	-3,857.88	-3,081.68
Base year emissions	7,684.34	7,684.34	7,684.34	7,684.34	7,684.34	7,684.34	7,684.34	7,684.34	7,684.34	7,684.34
CM net emissions	7,684.34	6,166.99	5,680.24	5,439.23	4,616.09	3,889.23	4,313.49	4,205.23	3,826.47	4,602.67
Living biomass	416.11	168.13	221.91	231.96	201.96	263.37	234.67	289.26	260.05	256.33
Dead wood	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Litter	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mineral soils	5,928.83	4,767.49	4,228.74	3,979.10	3,186.58	2,397.86	2,850.20	2,687.40	2,339.31	3,120.70
Organic soils	1,244.45	1,175.16	1,173.77	1,172.47	1,171.65	1,171.65	1,172.00	1,171.86	1,170.18	1,168.63
Other gases	94.96	56.20	55.82	55.70	55.90	56.34	56.61	56.71	56.93	57.00
Organic soil drainage (CH_4)	26.75	26.98	26.89	26.84	26.74	26.72	26.73	26.72	26.61	26.53
N mineralization in mineral soil (N_2O)	33.98	5.74	5.84	6.14	6.82	7.74	8.37	8.93	9.63	10.18
Biomass burning (CH_4, N_2O)	34.23	23.48	23.09	22.71	22.34	21.89	21.51	21.07	20.68	20.29

(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 cropland 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
Area subject to GM	646.6	607.8	606.5	603.4	601	598.6	596.8	595.1	593.4	591.3
Area of mineral soils (excluding area subject to D)	604.7	548.9	547.1	543.4	540.8	538.2	536.1	534.3	532.1	529.5

A9.3.5.2. Methods for Calculating for Carbon Stock Change and GHG Emissions

a) Living Biomass

The carbon stock change in living biomass in the area subject to GM activities was calculated from the carbon stock change that occurred after conversion and the loss of carbon stock in living biomass due to conversion from pastureland. Carbon stock change was 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 change in dead wood and litter in grassland do not occur as described in section 6.6.1. a), the carbon stock change 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 model (Roth C) 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 amounts of emissions were calculated using the net-net approach with 1990 as the base year. 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
GM accounting quantity	-	1,253.94	980.33	685.97	517.05	263.85	357.52	165.18	-139.05	47.92
Base year emissions	237.51	237.51	237.51	237.51	237.51	237.51	237.51	237.51	237.51	237.51
GM net emissions/removals	237.51	1,491.45	1,217.84	923.47	754.55	501.36	595.03	402.69	98.46	285.43
Living biomass	-255.00	15.71	18.04	14.42	19.63	32.34	25.20	15.23	15.33	6.51
Dead wood	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Litter	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Mineral soils	461.18	1,433.53	1,155.79	877.07	702.99	437.12	537.96	355.61	51.32	247.15
Organic soils	27.02	36.32	38.04	27.76	27.73	27.70	27.68	27.66	27.62	27.59
Other gases	4.31	5.88	5.97	4.22	4.21	4.20	4.20	4.19	4.18	4.17
Organic soil drainage (CH_4)	2.37	3.18	3.33	2.43	2.43	2.43	2.42	2.42	2.42	2.42
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
Biomass burning (CH_4, N_2O)	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 of Chapter 6 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
Area subject to UG		132.3	128.6	126.2	124.1	121.3	117.6	114.0	110.8	104.7
	Green spaces conserved by zoning	4.5	4.6	4.6	4.6	4.6	4.7	4.7	4.7	3.2
	Facility green space	127.8	124.1	121.6	119.4	116.7	112.9	109.3	106.1	101.5

A9.3.6.2. Methods for Calculating Carbon Stock Change 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 from UG Activity and the accounting quantity

[kt-CO_2]

	2014	2015	2016	2017	2018	2019	2020	2021	2022
UG net removals and accounting quantity	-1,777.13	-1,747.83	-1,728.94	-1,705.99	-1,669.29	-1,642.49	-1,595.44	-1,552.47	-1,471.98
Living biomass	-1,408.29	-1,383.09	-1,369.18	-1,352.40	-1,322.52	-1,304.41	-1,266.26	-1,231.68	-1,162.74
Dead wood	IE	IE	IE	IE	IE	IE	IE	IE	IE
Litter	-19.96	-19.87	-19.79	-19.63	-19.50	-19.22	-18.94	-18.81	-18.47
Mineral soils	-348.88	-344.87	-339.97	-333.97	-327.27	-318.86	-310.24	-301.98	-290.76
Organic soils	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
Fertilization (N_2O)	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
N mineralization in mineral soil (N_2O)	NA	NA	NA	NA	NA	NA	NA	NA	NA
Biomass burning (CH_4, N_2O)	NO	NO	NO	NO	NO	NO	NO	NO	NO

(CO_2) +: Emissions, -: Removals

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, *"FY2023 Report on Forest GHG Inventory Information Development Project (FM Forests Survey)" (in Japanese)*, 2024
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 (=1 kL)
L	litter
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

4. Other Abbreviations

Table AB-6 Abbreviations

	Terms	Definition
A	AD	Activity Data
	ARD	Afforestation, Reforestation and Deforestation
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
	CRF	Common Reporting Format
	CRT	Common Reporting Tables
	CS-EF	Country-Specific Emission Factor
	CY	Calendar Year
E	EEA	European Environment Agency
	EF	Emission Factor
	EMEP	European Monitoring and Evaluation Programme
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	Good Practice Guidance
	GPG (2000)	*Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (2000)*
	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
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
	MIC	Ministry of Internal Affairs and Communications
	MLIT	Ministry of Land, Infrastructure and Transport and Tourism
	MSW	Municipal Solid 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
	NIR	National Inventory Report
Q	QA/QC	Quality Assurance / Quality Control
	QAWG	Quality Assurance Working Group

Table AB-6 Abbreviations (Continued)

	Terms	Definition
R	RDF	Refuse Derived Fuel
	RPF	Refuse Paper and Plastic Fuel
	RV	Revegetation
T	THC	Total Hydrocarbon
U	UG	Urban Greening
	UNFCCC	United Nations Framework Convention on Climate Change