

National Greenhouse Gas Inventory Report of JAPAN

2019

**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



National Greenhouse Gas Inventory Report of JAPAN (2019)

Content reviewed by

Low-carbon Society Promotion Office, Global Environment Bureau, Ministry of the Environment,
Japan

Primary Authors

Greenhouse Gas Inventory Office of Japan (GIO), Center for Global Environmental Research (CGER),
National Institute for Environmental Studies (NIES)

Head, Collaborative Research Group

Yukihiro NOJIRI

GHG Inventory Experts

Elsa HATANAKA, Takefumi ODA, Hiroshi ITO, Naofumi KOSAKA, Midori YANAGAWA,
Atsuko HAYASHI, Akiko TANAKA, Hiromi YOSHINAGA, Eriko HIRATA

Collaborative Authors

Mitsubishi UFJ Research and Consulting Co., Ltd.

Keiichi IGARASHI, Satoshi KAWANISHI, Kazumasa KAWASHIMA,
Takashi MORIMOTO, Masaaki NAKAMURA, Atsushi SATO, Yutaro SHOGAKI,
Takuji TERAKAWA, Hiroyuki UEDA, Masato YANO

Suuri Keikaku Co., Ltd.

Yasuo FUJISHIMA, Souichi MORIMOTO, Ryuta NITTA, Masakazu OKADA, Atsushi SATO

Copies available from:

Center for Global Environmental Research (CGER)

National Institute for Environmental Studies (NIES)

16-2 Onogawa, Tsukuba, Ibaraki 305-8506 Japan

Phone: +81-29-850-2777 Fax: +81-29-850-2219

E-mail: www-cger@nies.go.jp

<http://www.cger.nies.go.jp/en/activities/supporting/publications/report/index.html>

Copyright 2019:

NIES: National Institute for Environmental Studies

This publication is printed on paper manufactured entirely from recycled material (Rank A), in accordance with the Act on Promotion of Procurement of Eco-Friendly Goods and Services by the State and Other Entities.

Foreword

On the basis of Article 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC) and Decision 2/CMP.8, all Parties to the Convention and the Kyoto Protocol are required to submit national inventories of greenhouse gas emissions and removals. Therefore, the inventories on emissions and removals of greenhouse gases and precursors are reported in the Common Reporting Format (CRF) and in this National Inventory Report, in accordance with the UNFCCC Inventory Reporting Guidelines (Decision 24/CP.19 Annex I) and Decision 2/CMP.8.

This Report 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 (CO₂); methane (CH₄); nitrous oxide (N₂O); hydrofluorocarbons (HFCs); perfluorocarbons (PFCs); sulfur hexafluoride (SF₆); nitrogen trifluoride (NF₃), and indirect CO₂), precursors (nitrogen oxides (NO_x), carbon monoxide (CO), non-methane volatile organic compounds (NMVOC)), and sulfur oxides (SO_x). Supplementary information under Article 7.1 of the Kyoto Protocol is presented as well.

The structure of this report is prepared in line with the structure specified in the Appendix of the UNFCCC Inventory Reporting Guidelines.

The Executive Summary focuses on the latest trends in emissions and removals of greenhouse gases in Japan. Chapter 1 deals with background information on greenhouse gas inventories, national inventory arrangements, the inventory preparation process, methodologies and data sources used, key category analysis, QA/QC plan, 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 CO₂ and N₂O. Chapter 10 provides the explanations on improvements and recalculations (data revision, addition of new categories, etc.) made since the previous submission, and Chapters 11 through 15 provide supplementary information under Article 7.1 of the Kyoto Protocol. Annexes offer additional information to assist further understanding of Japan's inventory.

For the latest updates or changes in data, refer to the web-site (URL: www-gio.nies.go.jp) of the Greenhouse Gas Inventory Office of Japan (GIO).

April, 2019

Low-carbon Society Promotion Office
Global Environment Bureau
Ministry of the Environment

Preface

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

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

Upon preparation of this report, we have made further efforts to improve it through receiving feedback from many internal and external experts. We hope this report will be used widely and accurately as an index of what Japan should accomplish with regard to emission reductions under the Paris Agreement and other international obligations, and as an index that shows the extent of Japan's measures implemented against global warming.

I also thank Ms. Naoko Ikeda, together with Ms. Mutsuko Fujii, Ms. Yoko Owai, and Ms. Kumiko Shiba, our assistants, who supported us with the smooth operation of GIO.

April, 2019



Yukihiro Nojiri
Head, Collaborative Research Group
Greenhouse Gas Inventory Office of Japan (GIO)
Center for Global Environmental Research (CGER)
National Institute for Environmental Studies (NIES)

Table of Contents

Foreword	i
Preface	iii
Contents	v
EXECUTIVE SUMMARY OF NATIONAL GHGS INVENTORY REPORT OF JAPAN	1
E.S.1. Background Information on GHGs Inventories, Climate Change	1
E.S.2. Summary of National Emission and Removal Related Trends	2
E.S.2.1. GHG Inventory	2
E.S.2.2. KP-LULUCF Activities	4
E.S.3. Overview of Source and Sink Category Emission Estimates and Trends	5
E.S.3.1. GHG Inventory	5
E.S.3.2. KP-LULUCF Activities	6
CHAPTER 1. INTRODUCTION	1-1
1.1. Background Information on Japan's Greenhouse Gas Inventory and Climate Change	1-1
1.2. A Description of Japan's National Inventory Arrangements	1-1
1.2.1. Institutional, Legal and Procedural Arrangements	1-1
1.2.1.1. Institutional and legal Arrangement 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 UNFCCC inventory review	1-4
1.2.2. Overview of Inventory Planning, Preparation and Management	1-6
1.2.3. Quality Assurance, Quality Control and Verification Plan	1-7
1.2.3.1. QA/QC Procedures Applied	1-7
1.2.3.2. QA/QC Plan	1-11
1.2.3.3. Verification Activities	1-11
1.2.3.4. Treatment of Confidential Information	1-11
1.2.4. Changes in the National Inventory Arrangements since the Previous Annual GHG Inventory Submission	1-11
1.3. Inventory Preparation, and Data Collection, Processing and Storage	1-11
1.3.1. Annual cycle of the inventory preparation	1-11
1.3.2. Process of the inventory preparation	1-12
1.3.3. Documentation and Archiving of Inventory Information	1-14
1.3.3.1. Documentation of information	1-14
1.3.3.2. Archiving of information	1-14
1.3.3.3. QC activity for documentation and archiving of inventory information	1-15
1.4. Brief General Description of Methodologies and Data Sources Used (including tiers used)	1-15
1.4.1. Collection Process of Activity Data	1-15
1.4.2. Selection Process of Emission Factors and Estimation Methods	1-16
1.4.3. Improvement Process of Estimations for Emissions and Removal	1-16
1.5. Brief Description of Key Categories	1-17
1.5.1. GHG Inventory	1-17
1.5.2. KP-LULUCF Activity	1-19

1.6. General Uncertainty Assessment, including Data on the Overall Uncertainty for the Inventory Totals	1-19
1.6.1. GHG Inventory	1-19
1.6.2. KP-LULUCF Activity	1-20
1.7. General Assessment of the Completeness	1-21
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	2-3
2.1.3. CH ₄	2-7
2.1.4. N ₂ O	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
2.4. Emissions and removals from KP-LULUCF activities	2-22
CHAPTER 3. ENERGY (CRF 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	3-3
3.2.1.1. Methodological Issues of the Reference Approach	3-4
3.2.1.2. Difference in Energy Consumption	3-5
3.2.1.3. Difference in CO ₂ Emissions	3-5
3.2.1.4. Comparison between Differences in Energy Consumption and that of CO ₂ Emissions	3-6
3.2.1.5. Causes of the difference between Reference Approach and Sectoral Approach	3-7
3.2.2. International Bunker Fuels	3-9
3.2.3. Feedstocks and Non-Energy Use of Fuels	3-12
3.2.4. CO ₂ Emissions from Energy Industries (1.A.1.:CO ₂)	3-14
3.2.5. CH ₄ and N ₂ O Emissions from Energy Industries (1.A.1.:CH ₄ , N ₂ O)	3-28
3.2.6. CO ₂ Emissions from Manufacturing Industries and Construction (1.A.2.:CO ₂)	3-39
3.2.7. CH ₄ and N ₂ O Emissions from Manufacturing Industries and Construction	

(1.A.2.:CH ₄ , N ₂ O)	3-42
3.2.8. CO ₂ Emissions from Transport (1.A.3.:CO ₂)	3-45
3.2.9. CH ₄ and N ₂ O Emissions from Transport (1.A.3.:CH ₄ , N ₂ O)	3-49
3.2.9.1. Domestic Aviation (1.A.3.a.)	3-49
3.2.9.2. Road Transportation (1.A.3.b.)	3-52
3.2.9.3. Railways (1.A.3.c.)	3-61
3.2.9.4. Domestic Navigation (1.A.3.d.)	3-63
3.2.9.5. Other Transportation (1.A.3.e.)	3-64
3.2.10. CO ₂ Emissions from Other Sectors and Other (1.A.4., 1.A.5: CO ₂)	3-65
3.2.11. CH ₄ and N ₂ O Emissions from Other Sectors and Other (1.A.4., 1.A.5:CH ₄ and N ₂ O)	3-67
3.2.12. Emissions from waste incineration with energy recovery	3-70
3.3. Fugitive Emissions from Fuels (1.B.)	3-74
3.3.1. Solid Fuels (1.B.1.)	3-74
3.3.1.1. Coal Mining and Handling (1.B.1.a.)	3-74
3.3.1.2. Solid Fuel Transformation (1.B.1.b.)	3-82
3.3.1.3. Others (Uncontrollable combustion and burning coal dumps) (1.B.1.c.)	3-83
3.3.2. Oil, Natural Gas and Other Emissions from Energy Production (1.B.2.)	3-84
3.3.2.1. Oil (1.B.2.a.)	3-84
3.3.2.2. Natural Gas (1.B.2.b.)	3-90
3.3.2.3. Venting and Flaring (1.B.2.c.)	3-99
3.3.2.4. Other (Fugitive Emissions Associated with the Geothermal Power Generation) (1.B.2.d.)	3-106
3.4. CO ₂ transport and storage (1.C.)	3-108
3.4.1. Transport of CO ₂ (1.C.1.)	3-108
3.4.1.1. Pipelines (1.C.1.a.)	3-108
3.4.1.2. Ships (1.C.1.b.)	3-109
3.4.1.3. Other (1.C.1.c.)	3-109
3.4.2. Injection and Storage (1.C.2.)	3-109
3.4.2.1. Injection (1.C.2.a.)	3-109
3.4.2.2. Storage (1.C.2.b.)	3-109
3.4.3. Other (1.C.3.)	3-110
3.4.4. Information item	3-110
 CHAPTER 4. INDUSTRIAL PROCESSES AND PRODUCT USE (CRF 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 (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.)	4-22
4.3.4. Caprolactam, glyoxal and glyoxylic acid production (2.B.4.)	4-23
4.3.4.1. Caprolactam Production (2.B.4.a)	4-23
4.3.4.2. Glyoxal Production (2.B.4.b)	4-24
4.3.4.3. Glyoxylic acid Production (2.B.4.c)	4-25
4.3.5. Carbide Production (2.B.5.)	4-26
4.3.5.1. Silicon Carbide Production (2.B.5.a)	4-26
4.3.5.2. Calcium Carbide Production and Use (2.B.5.b)	4-28
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 Production (2.B.8.a)	4-31
4.3.8.2. Ethylene Production (2.B.8.b)	4-33
4.3.8.3. 1,2-Dichloroethane and Chloroethylene (2.B.8.c)	4-34
4.3.8.4. Ethylene oxide Production (2.B.8.d)	4-36
4.3.8.5. Acrylonitrile Production (2.B.8.e)	4-39
4.3.8.6. Carbon Black Production (2.B.8.f)	4-40
4.3.8.7. Styrene Production (2.B.8.g.-)	4-42
4.3.8.8. Phthalic anhydride Production (2.B.8.g.-)	4-43
4.3.8.9. Maleic anhydride Production (2.B.8.g.-)	4-45
4.3.8.10. Hydrogen Production (2.B.8.g.-)	4-46
4.3.9. Fluorochemical Production (2.B.9.)	4-47
4.3.9.1. By-product Emissions: Production of HCFC-22 (2.B.9.-)	4-47
4.3.9.2. Fugitive Emissions (2.B.9.-)	4-49
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 Production (2.C.1.a)	4-51
4.4.1.2. Use of Electric Arc Furnaces in Steel Production (2.C.1.a)	4-51
4.4.1.3. Pig Iron Production (2.C.1.b)	4-53
4.4.1.4. Limestone and dolomite use in Iron and Steel Production (2.C.1.b)	4-53
4.4.1.5. Direct reduced iron production (2.C.1.c)	4-55
4.4.1.6. Sinter Production (2.C.1.d)	4-55
4.4.1.7. Pellet Production (2.C.1.e)	4-55
4.4.2. Ferroalloys Production (2.C.2.)	4-56
4.4.3. Aluminum Production (2.C.3.)	4-57
4.4.3.1. By-product emissions (2.C.3.-)	4-57
4.4.3.2. F-gases used in foundries (2.C.3.-)	4-59
4.4.4. Magnesium Production (2.C.4.)	4-59
4.4.5. Lead production (2.C.5.)	4-60
4.4.6. Zinc production (2.C.6.)	4-60
4.5. Non-energy products from fuels and solvent use (2.D.)	4-60
4.5.1. Lubricant use (2.D.1.)	4-61

4.5.2. Paraffin wax use (2.D.2.)	4-62
4.5.3. Other (2.D.3.)	4-63
4.5.3.1. Urea used as a catalyst (2.D.3.-)	4-63
4.5.3.2. NMVOC Incineration (2.D.3.-)	4-65
4.5.3.3. Road Paving with Asphalt (2.D.3.-)	4-67
4.5.3.4. Asphalt Roofing (2.D.3.-)	4-67
4.6. Electronics industry (2.E.)	4-67
4.6.1. Semiconductor (2.E.1.)	4-67
4.6.2. Liquid Crystals (2.E.2.)	4-69
4.6.3. Photovoltaics (2.E.3.)	4-70
4.6.4. Heat transfer fluid (2.E.4.)	4-71
4.7. Product uses as substitutes for ODS (2.F.)	4-71
4.7.1. Refrigeration and Air Conditioning Equipment (2.F.1.)	4-71
4.7.1.1. Domestic Refrigeration Production, Use and Disposal (2.F.1.-)	4-71
4.7.1.2. Commercial Refrigeration Production, Use and Disposal (2.F.1.-)	4-73
4.7.1.3. Transport Refrigeration Production, Use and Disposal (2.F.1.-)	4-78
4.7.1.4. Industrial Refrigeration Production, Use and Disposal (2.F.1.-)	4-78
4.7.1.5. Stationary Air-Conditioning (Household) Production, Use and Disposal (2.F.1.-)	4-78
4.7.1.6. Mobile Air-Conditioning Production, Use and Disposal (2.F.1.-)	4-80
4.7.2. Foam Blowing Agents (2.F.2.)	4-82
4.7.2.1. Closed Cells (2.F.2.-)	4-82
4.7.2.2. Open Cells (2.F.2.-)	4-85
4.7.3. Fire Protection (2.F.3.)	4-86
4.7.4. Aerosols (2.F.4.)	4-87
4.7.4.1. Metered Dose Inhalers (2.F.4.-)	4-87
4.7.4.2. Aerosols (2.F.4.-)	4-89
4.7.5. Solvents (2.F.5.)	4-91
4.7.6. Other applications (2.F.6.)	4-93
4.8. Other product manufacture and use (2.G.)	4-93
4.8.1. Electrical Equipment (2.G.1.)	4-93
4.8.2. SF ₆ and PFCs from other product use (2.G.2.)	4-95
4.8.2.1. Military applications (2.G.2.-)	4-95
4.8.2.2. Accelerators (2.G.2.-)	4-96
4.8.2.3. Soundproof windows (2.G.2.-)	4-97
4.8.2.4. Adiabatic properties: shoes and types (2.G.2.-)	4-97
4.8.2.5. Other - Railway Silicon Rectifiers (2.G.2.-)	4-97
4.8.3. N ₂ O from product uses (2.G.3.)	4-98
4.8.3.1. Medical applications (2.G.3.a)	4-98
4.8.3.2. Other (2.G.3.b)	4-99
4.9. Other (2.H.)	4-100
4.9.1. Food and beverages industry (2.H.2.)	4-100
 CHAPTER 5. AGRICULTURE (CRF 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. Buffalo, Sheep, Goats, Horses & Swine (3.A.2., 3.A.3., 3.A.4.)	5-8
5.2.3. Other Livestock (3.A.4.-)	5-10
5.3. Manure Management (3.B.)	5-10
5.3.1. Cattle, Swine and Poultry (Hen and Broiler) (3.B.1., 3.B.3., 3.B.4.)	5-11
5.3.2. Buffalo, Sheep, Goats, Horses, Rabbit and Mink (3.B.2., 3.B.4.)	5-23
5.3.3. Other Livestock (3.B.4.-)	5-25
5.3.4. Indirect N ₂ O emissions (3.B.5.)	5-26
5.3.4.1. Atmospheric Deposition (3.B.5.-)	5-26
5.3.4.2. Nitrogen Leaching and Run-off (3.B.5.-)	5-28
5.4. Rice Cultivation (3.C.)	5-28
5.4.1. Irrigated (Intermittently Flooded (Single Aeration) and Continuously Flooded) (3.C.1.)	5-28
5.4.2. Rainfed & Deep Water and Other (3.C.2., 3.C.3., 3.C.4.)	5-37
5.5. Agricultural Soils (3.D.)	5-37
5.5.1. Direct Soil Emissions (3.D.a.)	5-37
5.5.1.1. Inorganic N Fertilizers (3.D.a.1.)	5-37
5.5.1.2. Organic Fertilizer (3.D.a.2.)	5-41
5.5.1.3. Urine and dung deposited by grazing animals (3.D.a.3.)	5-46
5.5.1.4. Crop Residues (3.D.a.4.)	5-46
5.5.1.5. Mineralization/Immobilization Associated with Loss/Gain of Soil Organic Matter (3.D.a.5.)	5-51
5.5.1.6. Plowing of Organic Soil (3.D.a.6.)	5-53
5.5.2. Indirect Emissions (3.D.b.)	5-54
5.5.2.1. Atmospheric Deposition (3.D.b.1.)	5-54
5.5.2.2. Nitrogen Leaching and Run-off (3.D.b.2.)	5-57
5.6. Prescribed Burning of Savannas (3.E.)	5-58
5.7. Field Burning of Agricultural Residues (3.F.)	5-58
5.8. Liming (3.G.)	5-61
5.9. Urea application (3.H.)	5-62
5.10. Other carbon-containing fertilizers (3.I.)	5-63
5.11. Other (3.J.)	5-63
CHAPTER 6. LAND USE, LAND-USE CHANGE AND FORESTRY (CRF SECTOR 4)	6-1
6.1. Overview of Sector	6-1
6.2. Land-use definitions and the classification systems used and their correspondence to the land use, land-use change and forestry categories	6-2
6.3. Approaches for estimating land areas and land-use database used for the inventory preparation	6-4
6.3.1. Survey methods and due dates of major land area statistics	6-4
6.3.2. Land area estimation methods	6-4
6.3.3. Land-use transition matrix	6-5
6.4. Parameters for estimating carbon stock changes from land use conversions	6-7
6.5. Forest land (4.A.)	6-9

6.5.1. Forest land remaining Forest land (4.A.1.)	6-10
6.5.2. Land converted to Forest land (4.A.2)	6-20
6.6. Cropland (4.B)	6-24
6.6.1. Cropland remaining Cropland (4.B.1)	6-25
6.6.2. Land converted to Cropland (4.B.2)	6-33
6.7. Grassland (4.C)	6-38
6.7.1. Grassland remaining Grassland (4.C.1)	6-38
6.7.2. Land converted to Grassland (4.C.2)	6-41
6.8. Wetlands (4.D)	6-46
6.8.1. Wetlands remaining Wetlands (4.D.1)	6-46
6.8.2. Land converted to Wetlands (4.D.2)	6-47
6.9. Settlements (4.E)	6-50
6.9.1. Settlements remaining Settlements (4.E.1)	6-51
6.9.2. Land converted to Settlements (4.E.2)	6-57
6.10. Other land (4.F)	6-64
6.10.1. Other land remaining Other land (4.F.1)	6-65
6.10.2. Land converted to Other land (4.F.2)	6-65
6.11. Harvested Wood Products (4.G)	6-69
6.11.1. Buildings	6-69
6.11.2. Wood used for other than buildings	6-74
6.11.3. Paper and paperboard	6-77
6.12. Direct N ₂ O emissions from N inputs to managed soils (4. (I))	6-80
6.13. Emissions and Removals from Drainage and Rewetting and Other Management of Organic and Mineral soils (4.(II))	6-82
6.14. Direct N ₂ O emissions from N mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils (4.(III))	6-84
6.15. Indirect nitrous oxide (N ₂ O) emissions from managed soils (4.(IV))	6-86
6.16. Biomass burning (4.(V))	6-88
CHAPTER 7. WASTE (CRF 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.)	7-5
7.2.1. Managed Disposal Sites (5.A.1.)	7-7
7.2.2. Unmanaged Waste Disposal Sites (5.A.2.)	7-18
7.2.3. Uncategorized Waste Disposal Sites (5.A.3.)	7-18
7.2.3.1. Inappropriate Disposal (5.A.3.-)	7-18
7.3. Biological Treatment of Solid Waste (5.B.)	7-20
7.3.1. Composting (5.B.1)	7-21
7.3.2. Anaerobic Digestion at Biogas Facilities (5.B.2.)	7-23

7.4. Incineration and Open Burning of Waste (5.C.)	7-24
7.4.1. Waste Incineration (without Energy Recovery) (5.C.1.)	7-29
7.4.1.1. Municipal Solid Waste (5.C.1.-)	7-29
7.4.1.2. Industrial Waste (5.C.1.-)	7-39
7.4.1.3. Specially-Controlled Industrial Waste (5.C.1.-)	7-47
7.4.2. Open Burning of Waste (5.C.2.)	7-51
7.4.2.1. Municipal Solid Waste (5.C.2.-)	7-51
7.4.2.2. Industrial Waste (5.C.2.-)	7-51
7.4.3. Waste Incineration and Energy Use (Reported on Energy Sector) (1.A.)	7-54
7.4.3.1. Waste Incineration with Energy Recovery (1.A.)	7-54
7.4.3.2. Direct Use of Waste as Alternative Fuel (1.A.)	7-56
7.4.3.3. Incineration of Waste Processed as Fuel (1.A.)	7-67
7.5. Wastewater Treatment and Discharge (5.D.)	7-72
7.5.1. Domestic Wastewater (5.D.1.)	7-73
7.5.1.1. Sewage Treatment Plant (5.D.1.-)	7-73
7.5.1.2. Domestic Sewage Treatment Plant (Mainly <i>Johkasou</i>) (5.D.1.-)	7-76
7.5.1.3. Human-Waste Treatment Plant (5.D.1.-)	7-78
7.5.1.4. Natural Decomposition of Domestic Wastewater (5.D.1.-)	7-83
7.5.2. Industrial Wastewater (5.D.2.)	7-86
7.5.2.1. Industrial Wastewater Treatment (5.D.2.-)	7-86
7.5.2.2. Natural Decomposition of Industrial Wastewater (5.D.2.-)	7-90
7.5.2.3. Landfill Leachate Treatment (5.D.2.-)	7-94
7.6. Other (5.E.)	7-96
7.6.1. Decomposition of Petroleum-Derived Surfactants (5.E.-)	7-97
 CHAPTER 8. OTHER	 8-1
8.1. Overview of Sector	8-1
8.2. CO ₂ , CH ₄ , N ₂ O, HFCs, PFCs, SF ₆ , and NF ₃	8-1
8.3. NO _x , CO, NMVOC, and SO _x	8-1
 CHAPTER 9. INDIRECT CO ₂ 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
10.1.1. General Issues	10-1
10.1.2. Recalculations in Each Sector	10-1
10.2. Implications for Emission Levels	10-1
10.2.1. GHG Inventory	10-1
10.2.2. KP-LULUCF Inventory	10-9
10.3. Implication for Emission Trends, including Time Series Consistency	10-10
10.3.1. GHG Inventory	10-10
10.4. Recalculations and improvement plan, including response to the review process	10-10
10.4.1. Improvements after submission of the inventory	10-10
10.4.1.1. Methodology for estimating emissions and removals of GHGs	10-10

10.4.1.2. National Greenhouse Gas Inventory Report _____	10-13
10.4.1.3. Improvements by following UNFCCC-ERT recommendations _____	10-13
10.4.2. Planned Improvements _____	10-14
CHAPTER 11. SUPPLEMENTARY INFORMATION ON LULUCF ACTIVITIES UNDER ARTICLE 3, PARAGRAPHS 3 AND 4 OF THE KYOTO PROTOCOL _____	11-1
11.1. Summary of removal related trends, and emissions and removals from KP LULUCF activities _____	11-1
11.2. Information relating to the decision 3/CMP.11 in paragraph 8 _____	11-2
11.3. General information _____	11-2
11.3.1. Definition of forest and any other criteria _____	11-2
11.3.2. Elected activities under Article 3, paragraph 4 of the Kyoto Protocol _____	11-3
11.3.2.1. Forest Management _____	11-4
11.3.2.2. Cropland Management _____	11-4
11.3.2.3. Grazing Land Management _____	11-4
11.3.2.4. Revegetation _____	11-4
11.3.3. Description of how the definitions of each activity under Article 3.3 and each elected activity under Article 3.4 have been implemented and applied consistently over time _____	11-5
11.3.4. Description of precedence conditions and/or hierarchy among elected Article 3.4 activities, and how they have been consistently applied in determining how land was classified _____	11-5
11.4. Land-related information _____	11-5
11.4.1. Spatial assessment unit used for determining the area of the units of land under Article 3.3 _____	11-5
11.4.2. Methodology used to develop the land transition matrix _____	11-5
11.4.2.1. Description of land transition matrix (CRF-NIR Table 2) _____	11-5
11.4.2.2. Overview of the procedures to estimate emissions and removals _____	11-6
11.4.2.3. Afforestation/Reforestation and Deforestation _____	11-7
11.4.2.4. Forest Management _____	11-9
11.4.2.5. Cropland Management _____	11-12
11.4.2.6. Grazing Land Management _____	11-12
11.4.2.7. Revegetation _____	11-12
11.4.3. Maps and/or database to identify the geographical locations, and the system of identification codes for the geographical locations _____	11-17
11.5. Activity-specific information _____	11-18
11.5.1. Methods for carbon stock change and GHG emission and removal estimates _____	11-18
11.5.1.1. Description of the methodologies and the underlying assumptions used _____	11-18
11.5.1.2. Justification when omitting any carbon pool or GHG emissions/removals from activities under Article 3.3, forest management and elected activities under Article 3.4 _____	11-46
11.5.1.3. Information relating to exclusions of emission from natural disturbances _____	11-46
11.5.1.4. Information relating to Harvest Wood Product (HWP) _____	11-46
11.5.1.5. Information on whether or not indirect and natural GHG emissions and	

removals have been factored out _____	11-47
11.5.1.6. QA/QC and verification _____	11-47
11.5.1.7. Changes in data and methods since the previous submission (recalculations) _____	11-48
11.5.1.8. Uncertainty estimates _____	11-49
11.5.1.9. Information on other methodological issues (methods dealing with the effects of natural disturbances) _____	11-52
11.5.1.10. The year of the onset of an activity _____	11-53
11.6. Article 3.3 _____	11-54
11.6.1. Information that demonstrates that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2020 and are direct human-induced _____	11-54
11.6.2. Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation _____	11-54
11.7. Article 3.4 _____	11-54
11.7.1. Information that demonstrates that activities under Article 3.4 have occurred since 1 January 1990 and are human-induced _____	11-54
11.7.1.1. Forest Management _____	11-54
11.7.1.2. Cropland Management _____	11-55
11.7.1.3. Grazing Land Management _____	11-55
11.7.1.4. Revegetation _____	11-55
11.7.2. Information relating to cropland management, grazing land management and revegetation for the base year and the commitment period _____	11-56
11.7.3. Information that demonstrates the emissions and removals resulting from elected Article 3.4 activities are not accounted for under activities under Article 3.3 activities _____	11-56
11.7.3.1. Information on emissions and removals by FM activities are not accounted for under Article 3.3 activities _____	11-56
11.7.3.2. Information on emissions and removals from CM activities are not accounted under Article 3.3 activities _____	11-56
11.7.3.3. Information on emissions and removals from GM activities are not accounted under Article 3.3 activities _____	11-57
11.7.3.4. Information on emissions and removals from RV activities are not accounted under Article 3.3 activities _____	11-57
11.7.4. Information relating to the conversion of natural forests to planted forests _____	11-57
11.7.5. Information on forest reference level (Consistency) _____	11-57
11.7.6. Information relating forest management reference (technical correction) _____	11-57
11.7.7. Information on newly established forest will reach at least the equivalent carbon stock _____	11-57
11.8. Other information _____	11-58
11.8.1. Key category analysis for Article 3.3 activities and any elected activities under Article 3.4 _____	11-58
11.8.2. Further improvements _____	11-58
11.9. Information relating to Article 6 _____	11-59
11.10. Information on the reporting status of the Annex II to decision 2/CMP.8 _____	11-59

CHAPTER 12. INFORMATION ON ACCOUNTING OF KYOTO UNITS _____	12-1
12.1. Summary of information reported in the SEF tables _____	12-1
12.2. Discrepancies and notifications _____	12-1
12.3. Publicly accessible information _____	12-1
12.4. Calculation of the commitment period reserve (CPR) _____	12-2
CHAPTER 13. INFORMATION ON CHANGES IN NATIONAL SYSTEM _____	13-1
CHAPTER 14. INFORMATION ON CHANGES IN NATIONAL REGISTRY _____	14-1
14.1. Summary of changes made on national registry of Japan in 2018 _____	14-1
14.2. Information relevant to the changes made on national registry of Japan _____	14-1
CHAPTER 15. INFORMATION ON MINIMIZATION OF ADVERSE IMPACTS IN ACCORDANCE WITH ARTICLE 3, PARAGRAPH 14 _____	15-1
15.1. Overview _____	15-1
15.2. Actions to minimize adverse impacts in accordance with Article 3, paragraph 14 _____	15-1
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. DETAILED METHODOLOGICAL DESCRIPTIONS FOR INDIVIDUAL SOURCE OR SINK CATEGORIES _____	ANNEX3-1
A3.1. Methodology for Estimating Emissions of Precursors _____	Annex3-1
A3.1.1 Energy Sector _____	Annex3-1
A3.1.2 Industrial Processes and Product Use (IPPU) _____	Annex3-28
A3.1.3 Agriculture _____	Annex3-61
A3.1.4 Land Use, Land-Use Change and Forestry _____	Annex3-62
A3.1.5 Waste _____	Annex3-64
A3.1.6 Other sectors _____	Annex3-68
ANNEX 4. THE NATIONAL ENERGY BALANCE FOR THE MOST RECENT INVENTORY YEAR _____	ANNEX4-1
A4.1. Discrepancies between the figures reported in the CRF tables and the IEA statistics	Annex4-1
A4.2. General Energy Statistics _____	Annex4-11
A4.2.1. General Energy Statistics Overview _____	Annex4-11
A4.2.2. General Energy Statistics and CRF _____	Annex4-16
A4.3. Quality Standard for Diesel Oil _____	Annex4-20

ANNEX 5. ASSESSMENT OF COMPLETENESS, DEFINITION OF NOTATION KEYS, AND SOURCES AND SINKS REPORTED AS “NE”	ANNEX5-1
A5.1. Assessment of Completeness	Annex5-1
A5.2. Definition of Notation Keys	Annex5-1
A5.3. Decision Tree for Application of Notation Keys	Annex5-2
A5.4. Emission sources reported as “NE” (considered insignificant) in Japan	Annex5-3
A5.5. Source and sink categories not estimated in Japan’s inventory	Annex5-4
ANNEX 6. HIERARCHICAL STRUCTURE OF JAPAN’S NATIONAL GHG INVENTORY FILE SYSTEM	ANNEX6-1

Abbreviations

Executive Summary of National GHGs Inventory Report of Japan

E.S.1. Background Information on GHGs Inventories, Climate Change

Japan reports the greenhouse gas (GHG) inventories, which contain the information on emissions and removals of GHGs, including indirect GHGs and SO_x in Japan for FY1990 to FY2017¹, on the basis of Articles 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC) and Decision 2/CMP.8.

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 made 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 inventory, Japan also applies the *2013 Supplement to the 2006 IPCC Guidelines: Wetlands (Wetlands Guidelines)* and the *2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (KP Supplement (2013))*.

Japan's national inventory is reported in accordance with the *UNFCCC Reporting Guidelines on Annual Inventories* (Decision 24/CP.19 Annex I, hereinafter referred to as the *UNFCCC Inventory Reporting Guidelines*) 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 CO₂ 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

E.S.2.1. GHG Inventory

Total GHGs emissions² in FY2017 (excluding LULUCF³, including indirect CO₂⁴, hereafter, definition omitted) were 1,292 million tonnes (in CO₂ eq.). They increased by 1.3% compared to the emissions in FY1990.

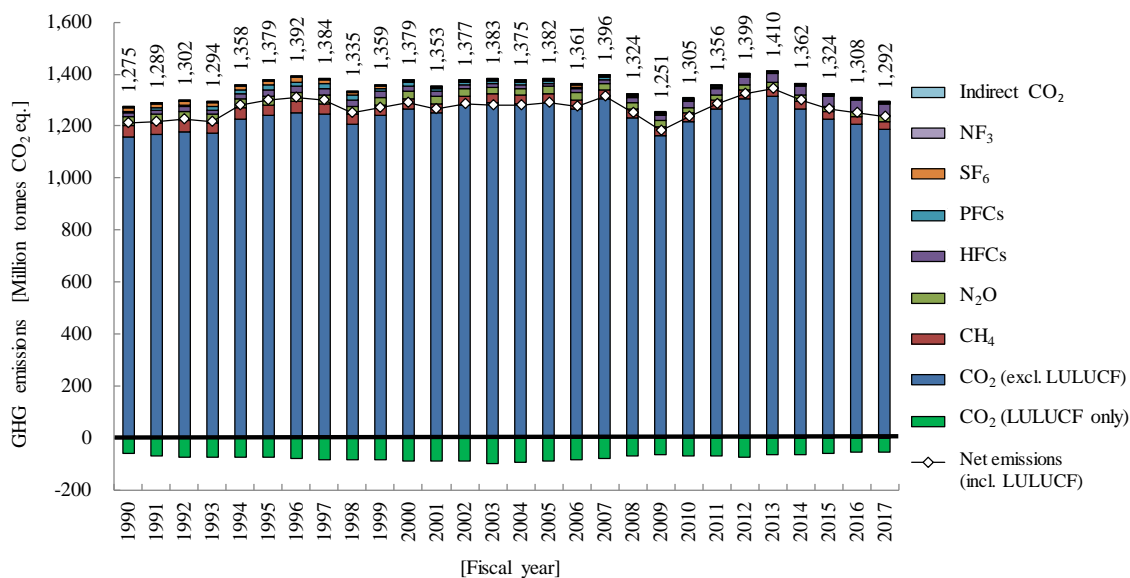


Figure 1 Trends in GHGs emission and removals in Japan

² The sum of CO₂, CH₄, N₂O, HFCs, PFCs, SF₆, and NF₃ emissions converted to CO₂ 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 CO₂. The coefficients are drawn from the *Fourth Assessment Report (2007)* issued by the IPCC.

³ Abbreviation of “Land Use, Land-Use Change and Forestry”

⁴ Carbon monoxide (CO), methane (CH₄) and non-methane volatile organic compounds (NMVOC) are oxidized in the atmosphere in the long term and converted to CO₂. Indirect CO₂ means value in CO₂ equivalent of these emissions. However, emissions of derived from combustion origin and biomass origin of CO, CH₄ and NMVOC are excluded to avoid double counting and/or by concept of carbon neutral.

Table 1 Trends in GHGs emission and removals in Japan

[Million tonnes CO ₂ eq.]	GWP	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
CO ₂ (excl. LULUCF) *1	1	1,158.5	1,170.0	1,179.8	1,172.7	1,227.6	1,240.0	1,252.1	1,245.3	1,205.6	1,242.2
CO ₂ (incl. LULUCF) *1	1	1,095.7	1,099.2	1,105.9	1,095.8	1,151.0	1,162.4	1,169.9	1,160.7	1,119.6	1,155.9
CO ₂ (LULUCF only)	1	-62.8	-70.8	-73.9	-76.9	-76.6	-77.6	-82.2	-84.6	-86.0	-86.3
CH ₄ (excl. LULUCF)	25	44.3	43.2	44.0	40.0	43.3	41.9	40.7	39.9	38.1	38.0
CH ₄ (incl. LULUCF)	25	44.4	43.3	44.1	40.1	43.4	41.9	40.8	40.0	38.2	38.0
N ₂ O (excl. LULUCF)	298	31.8	31.5	31.7	31.6	32.8	33.2	34.3	35.1	33.5	27.4
N ₂ O (incl. LULUCF)	298	32.0	31.7	31.9	31.8	33.0	33.4	34.5	35.3	33.7	27.6
HFCs	HFC-134a: 1,430 etc.	15.9	17.3	17.8	18.1	21.1	25.2	24.6	24.4	23.7	24.4
PFCs	PFC-14: 7,390 etc.	6.5	7.5	7.6	10.9	13.4	17.6	18.3	20.0	16.6	13.1
SF ₆	22,800	12.9	14.2	15.6	15.7	15.0	16.4	17.0	14.5	13.2	9.2
NF ₃	17,200	0.03	0.03	0.03	0.04	0.1	0.2	0.2	0.2	0.2	0.3
Indirect CO ₂	1	5.5	5.3	5.0	4.8	4.8	4.7	4.7	4.5	4.2	4.1
Gross Total (excluding LULUCF, excluding indirect CO ₂)		1,270.0	1,283.8	1,296.5	1,289.1	1,353.4	1,374.5	1,387.1	1,379.4	1,330.9	1,354.5
Net Total (including LULUCF, excluding indirect CO ₂)		1,207.5	1,213.3	1,222.9	1,212.4	1,277.1	1,297.2	1,305.2	1,295.1	1,245.2	1,268.4
Gross Total (excluding LULUCF, including indirect CO ₂)		1,275.5	1,289.1	1,301.6	1,293.9	1,358.2	1,379.2	1,391.8	1,384.0	1,335.0	1,358.6
Net Total (including LULUCF, including indirect CO ₂)		1,213.0	1,218.6	1,228.0	1,217.3	1,281.9	1,301.9	1,309.9	1,299.7	1,249.3	1,272.6

[Million tonnes CO ₂ eq.]	GWP	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CO ₂ (excl. LULUCF) *1	1	1,265.0	1,250.3	1,279.6	1,287.8	1,283.0	1,290.3	1,267.2	1,302.9	1,232.2	1,163.0
CO ₂ (incl. LULUCF) *1	1	1,176.8	1,161.6	1,189.4	1,187.4	1,186.2	1,198.7	1,181.0	1,221.7	1,161.2	1,095.7
CO ₂ (LULUCF only)	1	-88.2	-88.7	-90.2	-100.4	-96.8	-91.6	-86.2	-81.2	-71.0	-67.3
CH ₄ (excl. LULUCF)	25	38.0	37.1	36.3	34.9	35.9	35.7	35.0	35.3	34.9	34.0
CH ₄ (incl. LULUCF)	25	38.0	37.2	36.4	34.9	36.0	35.7	35.1	35.3	35.0	34.1
N ₂ O (excl. LULUCF)	298	29.9	26.3	25.8	25.6	25.5	25.0	24.9	24.3	23.5	22.9
N ₂ O (incl. LULUCF)	298	30.1	26.5	26.0	25.8	25.7	25.2	25.1	24.5	23.7	23.1
HFCs	HFC-134a: 1,430 etc.	22.9	19.5	16.2	16.2	12.4	12.8	14.6	16.7	19.3	20.9
PFCs	PFC-14: 7,390 etc.	11.9	9.9	9.2	8.9	9.2	8.6	9.0	7.9	5.7	4.0
SF ₆	22,800	7.0	6.1	5.7	5.4	5.3	5.1	5.2	4.7	4.2	2.4
NF ₃	17,200	0.3	0.3	0.4	0.4	0.5	1.5	1.4	1.6	1.5	1.4
Indirect CO ₂	1	4.2	3.8	3.5	3.4	3.3	3.2	3.1	3.0	2.7	2.5
Gross Total (excluding LULUCF, excluding indirect CO ₂)		1,374.8	1,349.4	1,373.2	1,379.2	1,371.8	1,379.0	1,357.4	1,393.4	1,321.4	1,248.6
Net Total (including LULUCF, excluding indirect CO ₂)		1,286.9	1,261.0	1,283.3	1,279.1	1,275.2	1,287.6	1,271.5	1,312.5	1,250.7	1,181.6
Gross Total (excluding LULUCF, including indirect CO ₂)		1,379.1	1,353.2	1,376.7	1,382.6	1,375.1	1,382.1	1,360.5	1,396.4	1,324.1	1,251.1
Net Total (including LULUCF, including indirect CO ₂)		1,291.2	1,264.7	1,286.8	1,282.4	1,278.5	1,290.8	1,274.6	1,315.4	1,253.4	1,184.1

[Million tonnes CO ₂ eq.]	GWP	2010	2011	2012	2013	2014	2015	2016	2017	Changes in emissions/removals (2017)	
										1990	Previous year
CO ₂ (excl. LULUCF) *1	1	1,214.4	1,264.5	1,305.9	1,315.1	1,264.9	1,224.5	1,206.2	1,188.1	2.6%	-1.5%
CO ₂ (incl. LULUCF) *1	1	1,143.6	1,194.4	1,232.8	1,248.7	1,200.1	1,164.7	1,151.4	1,130.4	3.2%	-1.8%
CO ₂ (LULUCF only)	1	-70.8	-70.1	-73.1	-66.4	-64.8	-59.8	-54.8	-57.7	-8.0%	5.4%
CH ₄ (excl. LULUCF)	25	34.5	33.5	32.6	32.3	31.7	30.8	30.5	30.1	-32.2%	-1.4%
CH ₄ (incl. LULUCF)	25	34.6	33.6	32.7	32.4	31.7	30.9	30.6	30.2	-32.1%	-1.4%
N ₂ O (excl. LULUCF)	298	22.3	21.9	21.5	21.6	21.2	20.8	20.3	20.5	-35.6%	1.0%
N ₂ O (incl. LULUCF)	298	22.5	22.0	21.7	21.8	21.4	21.0	20.4	20.6	-35.5%	1.0%
HFCs	HFC-134a: 1,430 etc.	23.3	26.1	29.4	32.1	35.8	39.3	42.6	44.9	181.7%	5.4%
PFCs	PFC-14: 7,390 etc.	4.2	3.8	3.4	3.3	3.4	3.3	3.4	3.5	-46.3%	4.1%
SF ₆	22,800	2.4	2.2	2.2	2.1	2.1	2.2	2.2	2.1	-83.4%	-4.6%
NF ₃	17,200	1.5	1.8	1.5	1.6	1.1	0.6	0.6	0.4	1279.3%	-29.1%
Indirect CO ₂	1	2.4	2.3	2.2	2.2	2.2	2.2	2.1	2.1	-61.3%	0.7%
Gross Total (excluding LULUCF, excluding indirect CO ₂)		1,302.7	1,353.8	1,396.6	1,408.1	1,360.1	1,321.5	1,305.8	1,289.6	1.5%	-1.2%
Net Total (including LULUCF, excluding indirect CO ₂)		1,232.2	1,283.9	1,323.7	1,341.9	1,295.5	1,261.9	1,251.2	1,232.2	2.0%	-1.5%
Gross Total (excluding LULUCF, including indirect CO ₂)		1,305.1	1,356.1	1,398.8	1,410.3	1,362.2	1,323.6	1,307.9	1,291.7	1.3%	-1.2%
Net Total (including LULUCF, including indirect CO ₂)		1,234.6	1,286.2	1,326.0	1,344.1	1,297.7	1,264.0	1,253.3	1,234.3	1.8%	-1.5%

*1 Excluding indirect CO₂

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

E.S.2.2. KP-LULUCF Activities

In accordance with the decision 2/CMP.8 in paragraph 4 adopted by the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (COP/MOP8), Japan reports afforestation/reforestation (AR), deforestation (D), forest management (FM), cropland management (CM), grazing land management (GM), and revegetation (RV) as LULUCF activities under article 3, paragraphs 3 and 4 of the Kyoto Protocol for the second commitment period⁵. The breakdown of emissions and removals for each activity is shown in Table 2. For detailed information, see Chapter 11.

Table 2 Accounting summary for activities under articles 3.3 and 3.4 of the Kyoto Protocol
(CRF Accounting table)

GREENHOUSE GAS SOURCE AND SINK ACTIVITIES	Base Year (1990)	NET EMISSIONS/REMOVALS				
		2013	2014	2015	2016	2017
(kt CO ₂ eq)						
A. Article 3.3 activities						
A.1. Afforestation/reforestation		-1607	-1610	-1604	-1598	-1569
Excluded emissions from natural disturbances		NA	NA	NA	NA	NA
Excluded subsequent removals from land subject to natural disturbances		NA	NA	NA	NA	NA
A.2. Deforestation		2029	2032	2141	2137	1846
B. Article 3.4 activities						
B.1. Forest management						
Net emissions/removals		-51065	-51394	-49002	-46463	-46135
Excluded emissions from natural disturbances		NA	NA	NA	NA	NA
Excluded subsequent removals from land subject to natural disturbances		NA	NA	NA	NA	NA
Any debits from newly established forest (CEF-ne)		NA	NA	NA	NA	NA
Forest management reference level (FMRL)		0	0	0	0	0
Technical corrections to FMRL		1097	1284	1438	1581	1724
Forest management cap						
B.2. Cropland management (if elected)	10281	3625	4370	4291	4764	4515
B.3. Grazing land management (if elected)	841	-273	-95	-161	-219	-257
B.4. Revegetation (if elected)	-79	-1223	-1241	-1262	-1280	-1290
B.5. Wetland drainage and rewetting (not elected)	NA	NA	NA	NA	NA	NA

* The total values and results of summing up each element are not always the same because of the difference in display digit.

⁵ The emissions/removals occurring from Kyoto Protocol Article 3.3. and 3.4 activities correspond to a part of the LULUCF emission/removals reported under the Convention. Detailed information on LULUCF under the Convention can be found in chapter 6 of this report, and the same for KP-LULUCF activities can be found in chapter 11.

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

E.S.3.1. GHG Inventory

The breakdown of GHGs emissions and removals in FY2017 by sector⁶ shows that the energy (excluding indirect CO₂, hereafter, definition omitted) accounts for 88.0% of total GHGs emissions. It is followed by the industrial processes and product use sector (excluding indirect CO₂, hereafter, definition omitted) (7.7%), the agriculture sector (2.6%), the waste sector (1.6%), and indirect CO₂ emissions (0.2%).

Removals by the LULUCF in FY2017 were equivalent to 4.4% of total GHGs emissions.

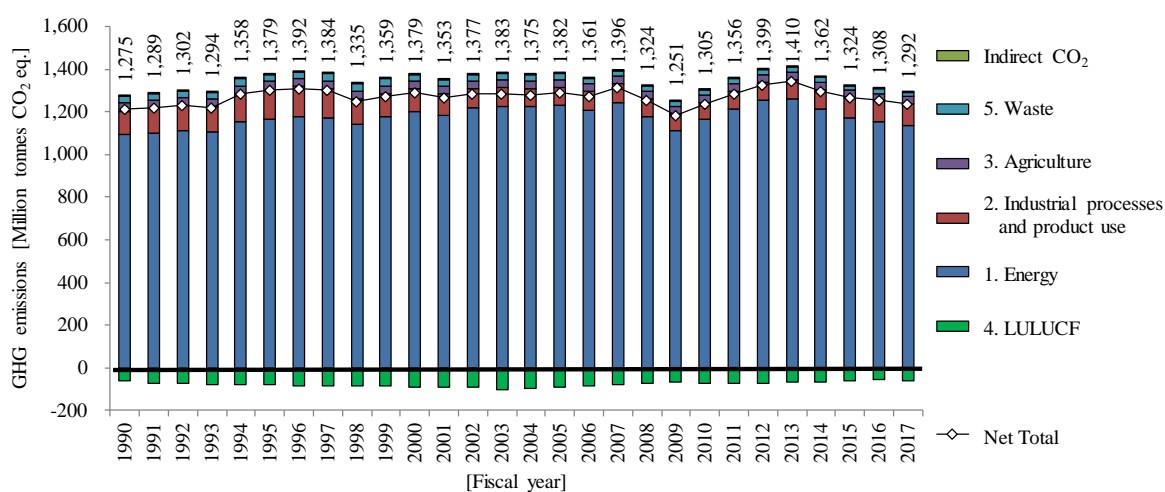


Figure 2 Trends in GHGs emissions and removals in each sector

⁶ As indicated in the 2006 IPCC Guidelines and the CRF.

Table 3 Trends in GHGs emissions and removals in each sector

[Million tonnes CO ₂ eq.]	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
1. Energy ^{*1}	1,091.9	1,102.2	1,110.6	1,104.5	1,155.3	1,167.4	1,178.2	1,173.4	1,139.4	1,176.0
2. Industrial processes and product use ^{*1}	111.1	115.4	117.3	119.5	127.0	137.2	139.5	136.5	123.8	111.1
3. Agriculture	37.3	36.5	37.8	34.6	38.2	36.9	36.1	35.8	34.5	34.7
4. LULUCF ^{*2}	-62.5	-70.5	-73.6	-76.6	-76.3	-77.3	-81.9	-84.3	-85.7	-86.1
5. Waste	29.7	29.7	30.9	30.4	32.9	33.1	33.3	33.7	33.3	32.7
Indirect CO ₂	5.5	5.3	5.0	4.8	4.8	4.7	4.7	4.5	4.2	4.1
Gross Total (excluding LULUCF, excluding indirect CO ₂)	1,270.0	1,283.8	1,296.5	1,289.1	1,353.4	1,374.5	1,387.1	1,379.4	1,330.9	1,354.5
Net Total (including LULUCF, excluding indirect CO ₂)	1,207.5	1,213.3	1,222.9	1,212.4	1,277.1	1,297.2	1,305.2	1,295.1	1,245.2	1,268.4
Gross Total (excluding LULUCF, including indirect CO ₂)	1,275.5	1,289.1	1,301.6	1,293.9	1,358.2	1,379.2	1,391.8	1,384.0	1,335.0	1,358.6
Net Total (including LULUCF, including indirect CO ₂)	1,213.0	1,218.6	1,228.0	1,217.3	1,281.9	1,301.9	1,309.9	1,299.7	1,249.3	1,272.6

[Million tonnes CO ₂ eq.]	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1. Energy ^{*1}	1,198.0	1,185.7	1,217.4	1,226.1	1,221.8	1,228.5	1,205.6	1,241.8	1,174.2	1,112.6
2. Industrial processes and product use ^{*1}	109.2	98.1	91.2	89.8	86.4	87.7	90.6	89.7	85.3	77.8
3. Agriculture	35.2	34.7	35.0	33.9	35.1	35.2	34.9	36.0	35.4	34.7
4. LULUCF ^{*2}	-87.9	-88.4	-89.9	-100.1	-96.5	-91.3	-85.9	-81.0	-70.7	-67.0
5. Waste	32.5	30.8	29.7	29.4	28.4	27.6	26.3	25.9	26.6	23.5
Indirect CO ₂	4.2	3.8	3.5	3.4	3.3	3.2	3.1	3.0	2.7	2.5
Gross Total (excluding LULUCF, excluding indirect CO ₂)	1,374.8	1,349.4	1,373.2	1,379.2	1,371.8	1,379.0	1,357.4	1,393.4	1,321.4	1,248.6
Net Total (including LULUCF, excluding indirect CO ₂)	1,286.9	1,261.0	1,283.3	1,279.1	1,275.2	1,287.6	1,271.5	1,312.5	1,250.7	1,181.6
Gross Total (excluding LULUCF, including indirect CO ₂)	1,379.1	1,353.2	1,376.7	1,382.6	1,375.1	1,382.1	1,360.5	1,396.4	1,324.1	1,251.1
Net Total (including LULUCF, including indirect CO ₂)	1,291.2	1,264.7	1,286.8	1,282.4	1,278.5	1,290.8	1,274.6	1,315.4	1,253.4	1,184.1

[Million tonnes CO ₂ eq.]	2010	2011	2012	2013	2014	2015	2016	2017
1. Energy ^{*1}	1,162.5	1,213.2	1,253.7	1,261.1	1,211.9	1,173.0	1,155.4	1,137.0
2. Industrial processes and product use ^{*1}	81.1	83.1	85.7	90.0	92.6	93.6	96.6	99.3
3. Agriculture	35.7	35.2	34.6	34.6	34.1	33.6	33.4	33.2
4. LULUCF ^{*2}	-70.5	-69.9	-72.9	-66.2	-64.5	-59.6	-54.5	-57.5
5. Waste	23.3	22.3	22.6	22.4	21.5	21.3	20.3	20.1
Indirect CO ₂	2.4	2.3	2.2	2.2	2.2	2.2	2.1	2.1
Gross Total (excluding LULUCF, excluding indirect CO ₂)	1,302.7	1,353.8	1,396.6	1,408.1	1,360.1	1,321.5	1,305.8	1,289.6
Net Total (including LULUCF, excluding indirect CO ₂)	1,232.2	1,283.9	1,323.7	1,341.9	1,295.5	1,261.9	1,251.2	1,232.2
Gross Total (excluding LULUCF, including indirect CO ₂)	1,305.1	1,356.1	1,398.8	1,410.3	1,362.2	1,323.6	1,307.9	1,291.7
Net Total (including LULUCF, including indirect CO ₂)	1,234.6	1,286.2	1,326.0	1,344.1	1,297.7	1,264.0	1,253.3	1,234.3

*1 Excluding indirect CO₂

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

E.S.3.2. KP-LULUCF Activities

See section 2.2 of this executive summary.

Chapter 1. Introduction

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

Japan hereby reports the greenhouse gas (GHG) inventories, which contain the 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 FY2017¹, on the basis of Article 4 and 12 of the United Nations Framework Convention on Climate Change (UNFCCC) and Decision 2/CMP.8.

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)*, which was made 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 inventory, Japan also applies the *2013 Supplement to the 2006 IPCC Guidelines: Wetlands (Wetlands Guidelines)* and the *2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol (KP Supplement (2013))*.

Japan's national inventory is reported in accordance with the *UNFCCC Reporting Guidelines on Annual Greenhouse Gas Inventories* (Decision 24/CP.19 Annex I, hereinafter referred to as the *UNFCCC Inventory Reporting Guidelines*) decided by the Conference of the Parties.

1.2. A Description of Japan's National Inventory Arrangements

1.2.1. Institutional, Legal and Procedural Arrangements

1.2.1.1. Institutional and legal Arrangement 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 of Chapter 1 General Provisions, the Act on Promotion of Global Warming Countermeasures², which determines the domestic measures for the UNFCCC and Kyoto Protocol. The Ministry of the Environment (MOE), with the cooperation of relevant ministries, agencies and organizations, prepares Japan's national inventory and compiles supplementary information required under Decision 2/CMP.8 etc., which is annually submitted in accordance with the UNFCCC and the Kyoto Protocol.

The MOE takes 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 Format (CRF) tables and National Inventory Report (NIR), are done by the Greenhouse Gas Inventory Office of Japan (GIO), which belongs to the Center for Global Environmental Research of the National Institute for Environmental Studies. The relevant ministries, agencies and organizations provide the GIO the appropriate data (e.g., activity data, emission factors,

¹ "FY (fiscal year)" is used because the major part of CO₂ emission estimate is on the fiscal year basis (April to March).

² Enacted in October, 1998. The latest amendment was made on May 27, 2016.

GHG emissions and removals) through compiling various statistics and also provide relevant information on supplementary information required under Decision 2/CMP.8 etc. The relevant ministries and agencies check the inventories (i.e., CRF, NIR), 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 by the MOE and are submitted to the UNFCCC Secretariat by the Ministry of Foreign Affairs.

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

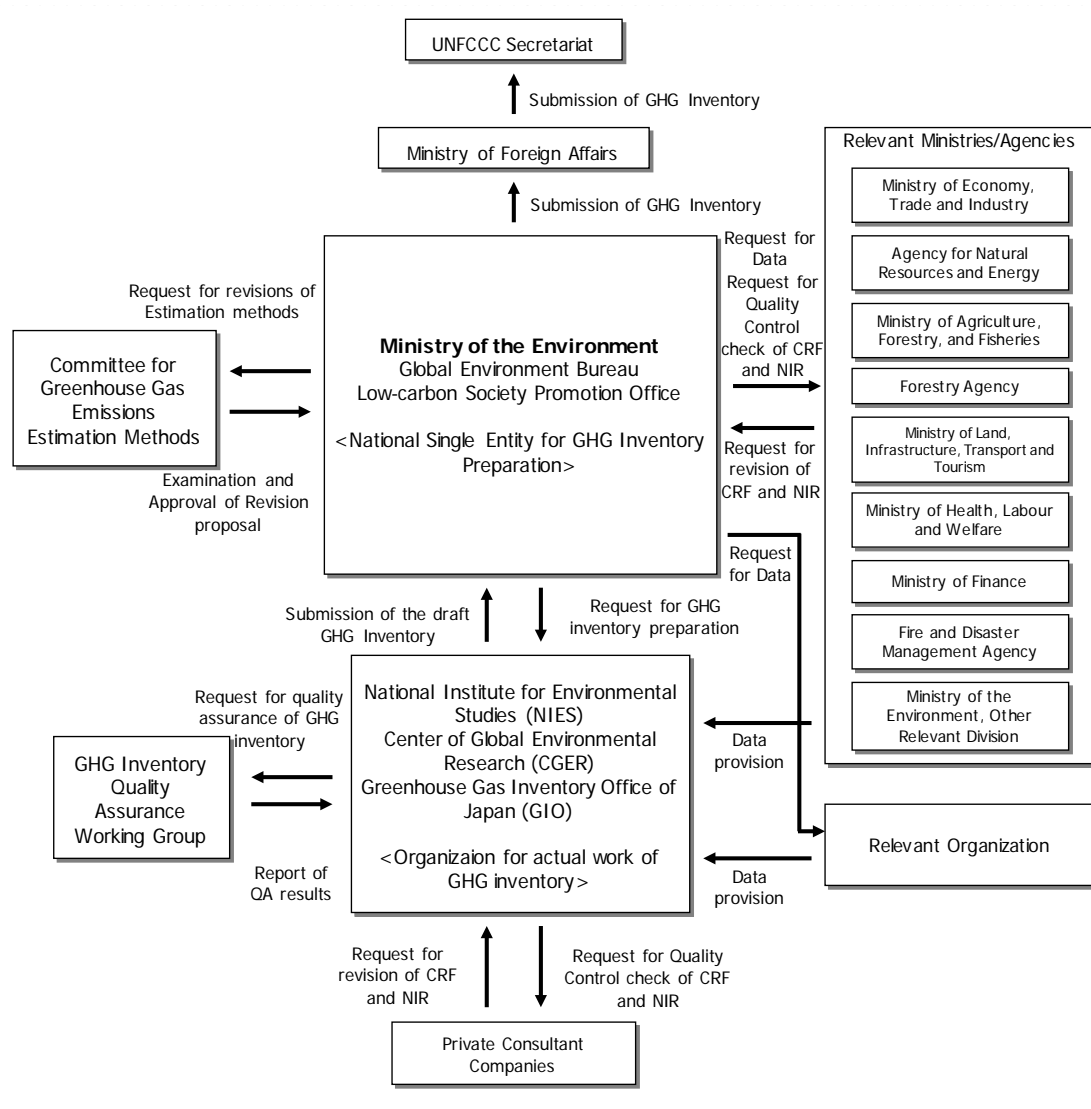


Figure 1-1 Japan’s institutional arrangement for the national inventory preparation

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 (Low-carbon Society Promotion Office, Global Environment Bureau)*

- The single national agency responsible for preparing Japan's inventory, which was designated pursuant to the UNFCCC Inventory Reporting Guidelines and the Kyoto Protocol Article 5.1.
- It is responsible for editing and submitting the inventory.
- It coordinates the Quality Assurance and Quality Control (QA/QC) activities for the inventory.
- It prepares the QA/QC plan.
- It prepares the inventory improvement plan.

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

- Performs the actual work of inventory compilation. Responsible for inventory calculations, editing, and the archiving and management of all data.

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 (CRF, NIR, JNGI files, and other information) prepared by the GIO (Category-specific QC).
- (When necessary), responding to questions from expert review teams (ERTs) 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 ERTs.

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 ERTs about the statistics controlled by relevant organizations, or about certain data they have prepared, and preparing comments on draft reviews.

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 consider 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 problems (Breakout group on Energy and Industrial Processes, Breakout group on Transport, Breakout group on F-gases [HFCs, PFCs, SF₆, and NF₃], Breakout group on Agriculture, Breakout group on Waste, Breakout group on LULUCF and Breakout group on NMVOC) are set up. The inventory WG, breakout groups comprise experts in various fields, and consider suggestions for inventory improvements.

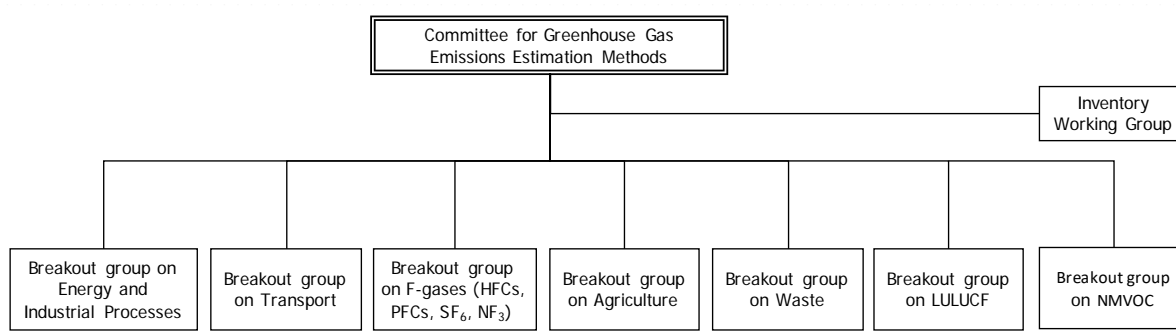


Figure 1-2 Structure of the Committee for the Greenhouse Gas Emissions Estimation Methods

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 (CRF, NIR, JNGI files) compiled by the MOE and the GIO.
- (When necessary), providing support for responding to questions from ERTs and for preparing comments on draft reviews.
- (When necessary), providing support for responding to in-country review by ERTs.

7) GHG Inventory Quality Assurance Working Group (QAWG)

The GHG Inventory Quality Assurance Working Group (the QAWG) is an organization that is 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 UNFCCC inventory review

The convention inventory and Kyoto Protocol supplementary information on sinks that Japan submits each year are to be reviewed by an ERTs pursuant to UNFCCC inventory review guidelines³, Kyoto Protocol Article 8, Decision 22/CMP.1, and other requirements. Specifically, rigorous checks are

³ Decision 13/CP.20 Annex

performed in accordance with the designated guidelines⁴ 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 view of the fact that ensuring the transparency of the inventory is a matter of importance, since Japan does not have a reduction commitment under the second commitment period of the Kyoto Protocol, the system shown in Figure 1-3 is used for responding to reviews.

[Basic structure]

The MOE (Low-carbon 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 companies⁵ that are involved in inventory compilation cooperate with review response through activities including providing relevant information, support for source material preparation, and QC implementation.

⁴ UNFCCC Inventory Reporting Guidelines, 2006 IPCC Guidelines, and the KP Supplement (2013)

⁵ Private consultant companies cooperate in correspondence of the reviews based on the operating agreement with the Ministry of the Environment.

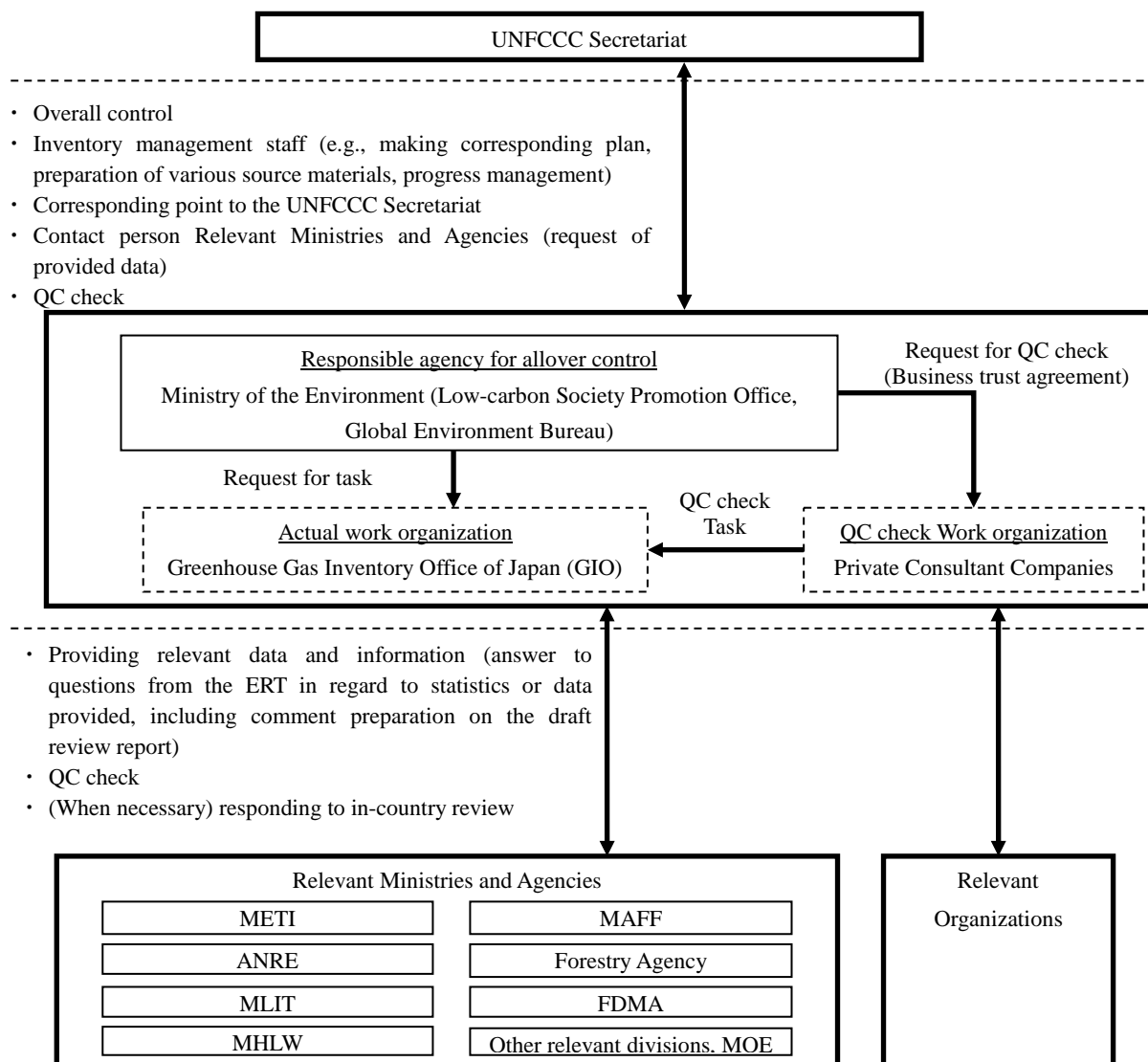


Figure 1-3 Basic structure of Japan's national system corresponding to inventory review

1.2.2. Overview of Inventory Planning, Preparation and Management

MOE (Low-carbon Society Promotion Office, Global Environment Bureau) is the single national agency responsible for preparing Japan's inventory, and the GIO performs the actual work of inventory compilation. Relevant ministries and organizations are also involved in the preparation of the inventory, mainly by preparing AD, EFs, and other data needed for inventory compilation. Private consulting companies are contracted by MOE to perform tasks related to QC of the inventory, mainly prepared by MOE and GIO.

The Committee, run by MOE, considers the methods, AD and EFs used. Under the Committee, the inventory WG that examines crosscutting issues, and breakout groups that consider sector-specific problems (Breakout group on Energy and Industrial Processes, Breakout group on Transport, Breakout group on F-gases, Breakout group on Agriculture, Breakout group on Waste, Breakout group on LULUCF and Breakout group on NMVOC) are set up.

The emissions and removals are prepared in accordance with the Inventory Reporting Guidelines (See

sectoral chapters for details). The key category analysis is performed in accordance with the *2006 IPCC Guidelines*, and both Approach 1 and 2 are applied (See section 1.5 for results). No additional key categories were identified using the qualitative approach. Key categories have been identified for activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol following the guidance on establishing the relationship between the activities under the Kyoto Protocol and the associated key categories in the UNFCCC inventory. The key category analysis is used to prioritize inventory improvements. The uncertainty analysis is carried out in accordance with the *2006 IPCC Guidelines*, and Approach 1 is applied (See section 1.6 for results).

QC procedures are used in the inventory and are documented as part of the QA/QC plan (See section 1.2.3 for details). As part of inventory QA, detailed reviews (expert peer reviews) are regularly performed by experts not directly involved in inventory compilation for each emission source and sink.

Japan has a centralized archiving system, which includes the archiving of disaggregated EFs and AD, and documentation on how these factors and data have been generated and aggregated for the preparation of the inventory. The archived information also includes internal documentation on QA/QC procedures, UNFCCC review and QA peer review, and documentation on annual key categories identification and planned inventory improvements. The archiving system is run by GIO and is comprised of electronic and paper versions of documents.

1.2.3. Quality Assurance, Quality Control and Verification Plan

1.2.3.1. 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 archive 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—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 1-1 sketches Japan's QA/QC activities.

Table 1-1 Summary of Japan's QA/QC activity

	Implementing entity	Main contents of activity
QC (Quality Control)	Ministry of the Environment (Low-carbon Society Promotion Office, Global Environment Bureau)	<ul style="list-style-type: none"> • Coordinating QA/QC activities for inventory preparation • Establishing QA/QC plan • Developing inventory improvement plan
	Greenhouse Gas Inventory Office of Japan, Center for Global Environmental Research, National Institute for Environmental Studies (GIO)	<ul style="list-style-type: none"> • Conducting general QC check • Archiving QA/QC activity records and relevant data and documents • Developing inventory improvement plan • Revising QA/QC plan
	Relevant Ministry and Agencies	<ul style="list-style-type: none"> • 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	<ul style="list-style-type: none"> • Discussing and assessing estimation methods, EFs, and AD (Category-specific QC)
	Private Consultant Companies	<ul style="list-style-type: none"> • Checking JNGI files and inventory prepared by GIO (Category-specific QC)
QA (Quality Assurance)	Inventory Quality Assurance Working Group (QAWG)	<ul style="list-style-type: none"> • Conducting expert peer review of inventory

1.2.3.1.a. QC activity

a) 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 the sectoral experts (SEs), who perform the work of compiling the emissions/removals estimation files for each category, the CRF master files and NIR; 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.

This section describes the QC activities of the GIO in parts 1) and 2).

1) 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

2) National inventory compiler (NIC)

The NIC performs mainly the following QC activities.

- Confirming that CRF Reporter data provided by SEs are imported 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

b) QC procedure for source and sink each category

The following category-specific QC activities are performed in Japan:

1) QC by private consultant companies (External QC)

QC on the estimation files and CRF and NIR 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.

2) QC through coordination with the relevant ministries and agencies (External QC)

The relevant ministries and agencies are sent the sets of files for estimation, CRF, NIR, 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.

3) 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.

c) 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.

1.2.3.1.b. 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.

a) GHG Inventory Quality Assurance Working Group (QAWG)

1) 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 and 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

2) 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 CRF and NIR.

3) Activities in FY2018

The Waste sector was reviewed by two experts in FY2018, and the schedule was as follows.

Table 1-2 Schedule for the review by the QAWG in FY2018

Schedule	Matter
May to early June 2018	Selection of experts
June	Visit and briefing to the experts by secretariat
July to August	Review by the experts (The detailed review of the GHG inventory, the listing of dubious and controversial points, and proposal for improvements)
September 5	Holding of the QAWG meeting
November, and January 2019	Bringing up of suggestions from the QAWG to the Committee and relevant breakout group in the Committee for discussion
March to April	Describing a summary of QAWG activities and results in the inventory Reporting to QAWG experts the results of the examination of correspondence to suggestions

Key data and the methods of estimation used in Waste sector have been validated by the QAWG. Identified issues by the QAWG were brought up to the Committee and 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 and incorrect descriptions to improve transparency and accuracy, and it made quality improvement of this NIR.

The MOE and the secretariat will annually determine the sectors/categories reviewed by the QAWG, and the entire GHG inventory will be covered within next few year's QAWGs.

1.2.3.2. QA/QC Plan

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 under the UNFCCC, and the supplementary information on sinks under Kyoto Protocol Articles 3.3 and 3.4, as stipulated in Decision 2/CMP.8.

1.2.3.3. 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 - 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.

1.2.3.4. 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.

1.2.4. Changes in the National Inventory Arrangements since the Previous Annual GHG Inventory Submission

In line with paragraph 50 (J) of the UNFCCC Inventory Reporting Guidelines and paragraph 21 of the annex to decision 15/CMP.1, Japan reports the changes in its national inventory arrangements from the previous inventory submission.

1.3. Inventory Preparation, and Data Collection, Processing and Storage

1.3.1. Annual cycle of the inventory preparation

Table 1-3 shows the annual cycle of the inventory preparation. The inventory preparation cycle is set in

conjunction with Japan's fiscal year calendar (starting April 1 and ending March 31 the next year) In Japan, in advance of the estimation of national inventory submitted to the UNFCCC (submission deadline: April 15), preliminary figures are estimated and published as a document for an official announcement (In preliminary figures, only GHG emissions excluding removals are published.).

Table 1-3 Annual cycle of the inventory preparation

*Inventory preparation in fiscal year "n"

Process	Relevant Entities	Calendar 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 the 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 a draft of CRF	GIO, Private consultant										→	→	→			
6 Preparation of a draft of NIR	GIO, Private consultant										→	→	→			
7 Implementation of the exterior QC and the coordination with the relevant ministries and agencies	MOE, GIO, Relevant Ministries/Agencies, Private consultant											→	→	→		
8 Correction of the drafts of CRF and NIR	MOE, GIO, Private consultant													→	→	
9 Submission and official announcement of the national inventory	MOE, Ministry of Foreign Affairs, GIO															★

1.3.2. 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 or related to the inventory preparation process, is organized in order to perform peer review and assure the inventory's quality and to find out possible improvements.

This QAWG reviews the appropriateness of the estimation methodologies, AD, EFs, and the contents of CRF and NIR. The GIO integrates the items identified for improvement by the QAWG into the inventory improvement plan, and utilizes them in discussions on the inventory estimation methods and in subsequent inventory preparation.

2) Discussion on the inventory improvement (Step 2)

The MOE and the GIO identify the items, which need to be addressed by the Committee, based on the results of the previous inventory review of the UNFCCC, the recommendations of the QAWG, the items needing improvement as identified at former Committee's meetings, as well as 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 the meeting of the Committee for the Greenhouse Gas Emission Estimation Methods [evaluation and examination of estimation methods by experts] (Step 3)

The MOE holds the meeting 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 the supplementary information required under Decision 2/CMP.8 are collected.

5) Preparation of a draft of CRF [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 inter-connecting links among themselves 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 NIR (Step 6)

The draft of NIR is prepared by following the general guidelines made by the MOE and the GIO. The MOE and the GIO identify the points, which need to be revised or require an additional description by taking the discussion at step 2 into account. The GIO prepares new NIR by updating data, and by adding and revising descriptions in the previous NIR.

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 CRF (the 0th 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 re-calculating the total amounts of GHG emissions and removals determined by utilizing the same files. Because of this cross-check, any possible data input and emission estimation mistakes are avoided. They also check the content and descriptions of the initial draft of NIR (the 0th draft) prepared by the GIO. JNGI files, draft CRF and draft NIR, 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 official announcements as electronic computer files to the MOE and the relevant ministries and agencies, and requests them to check contents of the primary drafts. The data, which are estimated based on confidential data, are only sent out for confirmation to the ministry and/or agency which provided these confidential data.

8) Correction of the drafts of CRF and NIR (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 of revision coordinate contents of revision and then 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 to be the final versions.

9) Submission and official announcement of the national inventory (Step 9)

The MOE submitted the completed inventory to the Ministry of Foreign Affairs, and the Ministry of Foreign Affairs submitted the inventory 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 (<http://www.env.go.jp/>) with additional relevant information. The inventory is also published on the GIO's website (<http://www-gio.nies.go.jp/>).

1.3.3. 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 (all JNGI files, NIR word files, and CRFs) needed for inventory compilation is electronically archived at MOE as well.

1.3.3.1. 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.

- The inventory related files submitted every year to the UNFCCC Secretariat
- Published materials for preliminary and finalized data
- Statistical data and provided data (including data providers, time period when provided, and other related information) used in compiling the inventory
- 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 UNFCCC inventory reviews, review reports and records of questions and answers with ERTs

1.3.3.2. Archiving of information

1) Archiving electronic information

i) Inventory-related electronic information

- Each year's JNGI files and CRF- and NIR-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 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.

ii) Backup and risk management of electronic information

- The server, hosted by the Center for Global Environmental Research of the National Institute for Environmental Studies (in which GIO is included), and where inventory-related information is stored, is automatically backed up to two other locations every day.
- Once a year, after submission of the annual inventory to the UNFCCC Secretariat, all inventory-

related electronic information is saved to CD-ROMs and other electronic media and archived.

2) Archiving 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.

1.3.3.3. QC activity for documentation and archiving of inventory information

Immediately after the inventory is submitted to the UNFCCC Secretariat, the GIO carries out QC activities related to the documentation and archive of inventory information.

1.4. Brief General Description of Methodologies and Data Sources Used (including tiers 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 emission status in Japan.

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 estimation of emissions, which are assumed to be quite low (e.g., “1.B.2.a.ii fugitive emissions from fuel (oil and natural gas” (CO₂ and CH₄)) etc.

1.4.1. Collection Process 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. This system manages all the information related to provision of data. The main relevant ministries, agencies, and relevant organizations, and their statistics and data are as shown in Table 1-4.

Table 1-4 Main relevant ministries, agencies, and the relevant organizations, and their statistics and data

Ministries/Agencies/Organizations		Major data or statistics
Relevant Ministries/ Agencies	Ministry of the Environment	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
	Ministry of Economy, Trade and Industry	General Energy Statistics / Yearbook of Chemical Industry Statistics / Yearbook of Ceramics and Building Materials 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
	Ministry of Land, Infrastructure, Transport and Tourism	Statistical Yearbook of Motor Vehicle Fuel Consumption / Survey on Current State of Land Use, Survey on Current State of Urban Park Development
	Ministry of Agriculture, Forestry and Fisheries	Livestock Statistics / Statistics of Arable and Planted Land Area / Yearbook of Fertilizer Statistics (Pocket Edition)/ Forest Status Survey/ National Forest Resources Database
Relevant Organizations	Federation of Electric Power Companies	Amount of Fuel Used by Pressurized Fluidized Bed Boilers
	Japan Coal Energy Center	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

1.4.2. Selection Process 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.

1.4.3. Improvement Process of Estimations for Emissions and Removal

In Japan, improvements in calculation methods are considered in accordance with necessity whenever an inventory item requiring improvement is identified because of, for example, a UNFCCC 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 system for calculating, reporting, and publishing GHG emissions. 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.

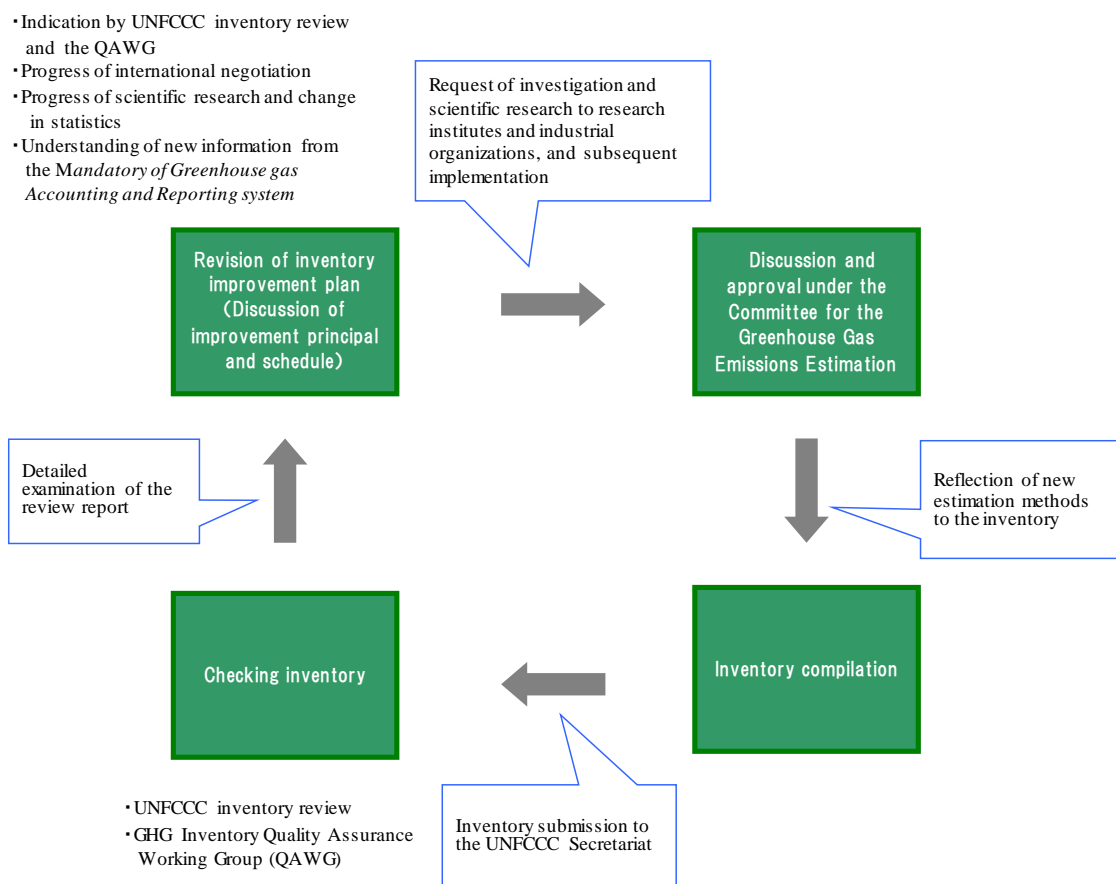


Figure 1-4 Diagram of the inventory improvement process

1.5. Brief Description of Key Categories

Key category analysis is carried out in accordance with the *2006 IPCC Guidelines* and the *KP Supplement (2013)* (Approach 1, Approach 2 level assessment and trend assessment).

1.5.1. GHG Inventory

In FY2017, 44 sources and sinks were identified as Japan's key categories (Table 1-5). For the base year of the UNFCCC (FY1990), 40 sources and sinks were identified as key categories (Table 1-6). More detailed information is described in Annex 1.

Table 1-5 Japan's key categories in FY2017

	A IPCC Code	B IPCC Category	C GHGs	Ap1-L	Ap1-T	Ap2-L	Ap2-T
#1	1.A.1.	Energy Industries	Solid Fuels	CO2	#1	#1	#1
#2	1.A.3.	Transport	b. Road Transportation	CO2	#2		#3
#3	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO2	#3	#7	#2
#4	1.A.1.	Energy Industries	Gaseous Fuels	CO2	#4	#3	#6
#5	1.A.4.	Other Sectors	Liquid Fuels	CO2	#5	#5	#5
#6	1.A.1.	Energy Industries	Liquid Fuels	CO2	#6	#2	#7
#7	4.A	Forest Land	1. Forest Land remaining Forest Land	CO2	#7	#12	#4
#8	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO2	#8	#4	#11
#9	1.A.4.	Other Sectors	Gaseous Fuels	CO2	#9	#8	#23
#10	2.F	Product uses as substitutes for ODS	1. Refrigeration and Air conditioning	HFCs	#10	#6	#10
#11	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO2	#11	#9	#31
#12	2.A	Mineral Product	1. Cement Production	CO2	#12	#11	#24
#13	3.C	Rice Cultivation		CH4	#13		#28
#14	5.C	Incineration and Open Burning of Waste		CO2	#14		#14
#15	1.A.3.	Transport	d. Domestic Navigation	CO2	#15	#21	
#16	1.A.3.	Transport	a. Domestic Aviation	CO2	#16	#23	
#17	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO2	#17	#18	#13
#18	1.A.4.	Other Sectors	Other Fossil Fuels	CO2	#18		#18
#19	3.A	Enteric Fermentation		CH4	#19		#12
#20	2.C	Metal Production	1. Iron and Steel Production	CO2	#20		#21
#21	4.B	Cropland	1. Cropland remaining Cropland	CO2		#16	#20
#22	3.B	Manure Management		N2O			#9
#23	3.D	Agricultural Soils	1. Direct Emissions	N2O			#27
#24	5.A	Solid Waste Disposal		CH4		#15	#12
#25	2.D	Non-energy Products from Fuels and Solvent Use		CO2			#15
#26	2.F	Product uses as substitutes for ODS	2. Foam Blowing Agents	HFCs		#25	#19
#27	2.B	Chemical Industry	Other products except Ammonia	CO2			#17
#28	1.A.1.	Energy Industries		N2O			#27
#29	5.D	Wastewater Treatment and Discharge		N2O			#30
#30	2.E	Electronics Industry		PFCs			#16
#31	3.D	Agricultural Soils	2. Indirect Emissions	N2O			#8
#32		Indirect CO2	from IPPU sector	Ind CO2		#24	#29
#33	2.G	Other Product Manufacture and Use		SF6		#13	#21
#34	2.F	Product uses as substitutes for ODS	5. Solvents	PFCs		#22	
#35	1.A.3.	Transport	b. Road Transportation	N2O			#26
#36	5.C	Incineration and Open Burning of Waste		N2O			#22
#37	4.E	Settlements	2. Land converted to Settlements	CO2		#26	
#38	4.A	Forest Land	2. Land converted to Forest Land	CO2		#17	#19
#39	1.B	Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	CH4		#19	
#40	2.E	Electronics Industry		SF6			#25
#41	2.B	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N2O			#11
#42	2.B	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	HFCs		#10	#30
#43	2.B	Chemical Industry	3. Adipic Acid Production	N2O		#14	#20
#44	2.B	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	SF6		#20	

N.B.1) Ap1-L: Approach 1-Level Assessment, Ap1-T: Approach 1-Trend Assessment,
Ap2-L: Approach 2-Level Assessment, Ap2-T: Approach 2-Trend Assessment

N.B.2) Figures recorded in the Level and Trend columns indicate the ranking of individual level and trend assessments.

Table 1-6 Japan's key categories in FY1990

A IPCC Code	B IPCC Category	C GHGs	Ap1-L	Ap2-L	
#1	1.A.2. Manufacturing Industries and Construction	Solid Fuels	CO2	#1	#1
#2	1.A.3. Transport	b. Road Transportation	CO2	#2	#3
#3	1.A.1. Energy Industries	Liquid Fuels	CO2	#3	#4
#4	1.A.2. Manufacturing Industries and Construction	Liquid Fuels	CO2	#4	#6
#5	1.A.4. Other Sectors	Liquid Fuels	CO2	#5	#8
#6	1.A.1. Energy Industries	Solid Fuels	CO2	#6	#7
#7	1.A.1. Energy Industries	Gaseous Fuels	CO2	#7	#19
#8	4.A Forest Land	1. Forest Land remaining Forest Land	CO2	#8	#2
#9	2.A Mineral Product	1. Cement Production	CO2	#9	#21
#10	1.A.4. Other Sectors	Gaseous Fuels	CO2	#10	
#11	2.B Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	HFCs	#11	
#12	1.A.3. Transport	d. Domestic Navigation	CO2	#12	
#13	3.C Rice Cultivation		CH4	#13	#32
#14	5.C Incineration and Open Burning of Waste		CO2	#14	#17
#15	1.A.2. Manufacturing Industries and Construction	Gaseous Fuels	CO2	#15	
#16	4.B Cropland	1. Cropland remaining Cropland	CO2	#16	#10
#17	5.A Solid Waste Disposal		CH4	#17	#15
#18	3.A Enteric Fermentation		CH4	#18	#14
#19	2.G Other Product Manufacture and Use		SF6	#19	#5
#20	2.C Metal Production	1. Iron and Steel Production	CO2	#20	
#21	2.B Chemical Industry	3. Adipic Acid Production	N2O	#21	
#22	1.A.3. Transport	a. Domestic Aviation	CO2	#22	
#23	4.A Forest Land	2. Land converted to Forest Land	CO2	#23	#30
#24	1.A.4. Other Sectors	Other Fossil Fuels	CO2	#24	#22
#25	2.A Mineral Product	2. Lime Production	CO2	#25	
#26	1.B Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	CH4	#26	#11
#27	3.D Agricultural Soils	1. Direct Emissions	N2O	#27	#24
#28	Indirect CO2	from IPPU sector	Ind CO2		#16
#29	1.A.2. Manufacturing Industries and Construction	Other Fossil Fuels	CO2		#31
#30	3.B Manure Management		N2O		#12
#31	4.E Settlements	2. Land converted to Settlements	CO2		#29
#32	2.B Chemical Industry	Other products except Ammonia	CO2		#18
#33	1.A.3. Transport	b. Road Transportation	N2O		#13
#34	3.D Agricultural Soils	2. Indirect Emissions	N2O		#9
#35	5.D Wastewater Treatment and Discharge		N2O		#28
#36	2.D Non-energy Products from Fuels and Solvent Use		CO2		#25
#37	2.B Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N2O		#20
#38	2.E Electronics Industry		PFCs		#26
#39	5.C Incineration and Open Burning of Waste		N2O		#27
#40	2.E Electronics Industry		SF6		#23

N.B.1) Ap1-L: Approach 1-Level Assessment, Ap2-L: Approach 2-Level Assessment

N.B.2) Figures recorded in the Level and Trend columns indicate the ranking of individual level and trend assessments.

1.5.2. KP-LULUCF Activity

As a result of analysis implemented in accordance with the 2006 IPCC Guidelines and the KP Supplement (2013), "Afforestation/Reforestation", "Deforestation", "Forest management", "Cropland management", and "Revegetation" activities (CO₂) were identified as key categories for Japan's KP-LULUCF activities in FY2017. More detailed information is described in section 11.8 of chapter 11.

1.6. General Uncertainty Assessment, including Data on the Overall Uncertainty for the Inventory Totals

1.6.1. GHG Inventory

Total net GHG emissions in Japan for FY2017 were approximately 1,234 million tonnes (CO₂

equivalents). The total net emissions uncertainties calculated by approach 1 (propagation of error) were -4% to +2% and the uncertainties introduced into the trend in the total emissions were -5% to +3%. More detailed information on the uncertainty assessment is described in Annex 2.

Table 1-7 Uncertainty of Japan's GHG inventory

Category	GHGs	C Base year emissions / removals kt-CO ₂ eq.	D 2017 emissions / removals kt-CO ₂ eq.	G-1990		G-2017		I Inventory trend in national emissions for 2017 increase with respect to 1990 %	J Uncertainty introduced into the trend in total national emissions (-) % (+) %	
				(-) %	(+) %	(-) %	(+) %		(-) %	(+) %
1A. Fuel Combustion (CO ₂)	CO ₂	1,078,839	1,128,396	-5%	+2%	-4%	+2%	4.6%	-5.1%	+2.7%
1A. Fuel Combustion (Stationary:CH ₄ ,N ₂ O)	CH ₄ , N ₂ O	3,916	5,541	-23%	+29%	-25%	+28%	41.5%	0.0%	+0.0%
1A. Fuel Combustion (Transport:CH ₄ ,N ₂ O)	CH ₄ , N ₂ O	4,031	1,817	-32%	+92%	-30%	+87%	-54.9%	0.0%	+0.0%
1B. Fugitive Emissions from Fuels	CO ₂ , CH ₄ , N ₂ O	5,165	1,278	-40%	+80%	-22%	+39%	-75.3%	0.0%	+0.0%
2. IPPU (CO ₂ ,CH ₄ ,N ₂ O)	CO ₂ , CH ₄ , N ₂ O	75,715	48,312	-4%	+4%	-5%	+5%	-36.2%	-0.1%	+0.1%
2. IPPU (HFCs,PFCs,SF ₆ ,NF ₃)	HFCs, PFCs, SF ₆ , NF ₃	35,354	50,982	-7%	+33%	-7%	+8%	44.2%	-0.5%	+0.5%
3. Agriculture	CO ₂ , CH ₄ , N ₂ O	37,253	33,196	-10%	+24%	-9%	+20%	-10.9%	0.0%	+0.0%
4. LULUCF	CO ₂ , CH ₄ , N ₂ O	-62,475	-57,458	-15%	+15%	-13%	+13%	-8.0%	-0.4%	+0.4%
5. Waste	CO ₂ , CH ₄ , N ₂ O	29,732	20,110	-10%	+11%	-12%	+12%	-32.4%	-0.2%	+0.2%
Indirect CO ₂	Ind CO ₂	5,474	2,118	-28%	+50%	-27%	+48%	-61.3%	0.0%	+0.0%
Total Net Emissions		1,213,002	1,234,291	-4.5%	+2.2%	-3.7%	+2.1%	1.8%	-5.2%	+2.7%

1.6.2. KP-LULUCF Activity

Japan's net removals in FY2017 were 42.9 million tonnes (CO₂ equivalents) and the uncertainty was 16%. More detailed information on the uncertainty assessment is described in section 11.5.1.7 of chapter 11.

Table 1-8 Uncertainty of Japan's KP-LULUCF activities

Greenhouse gas source and sink activities	GHGs	Emissions/Removals [kt CO ₂ eq.]		Emissions/Removals Uncertainty [%]		Emissions/Removals Uncertainty as % of net removals [%]	
			%	(-)[%]	(+)[%]	(-)[%]	(+)[%]
Article 3.3 activities Afforestation and Reforestation	CO ₂ , N ₂ O, CH ₄	-1,569	-4%	-34%	34%	-1%	1%
Article 3.3 activities Deforestation	CO ₂ , N ₂ O, CH ₄	1,846	4%	-22%	22%	1%	-1%
Article 3.4 activities Forest management	CO ₂ , N ₂ O, CH ₄	-46,135	-108%	-14%	14%	-15%	15%
Article 3.4 activities Cropland management	CO ₂ , N ₂ O, CH ₄	4,515	11%	-33%	33%	3%	-3%
Article 3.4 activities Grazing land management	CO ₂ , N ₂ O, CH ₄	-257	-1%	-11%	11%	0%	0%
Article 3.4 activities Revegetation	CO ₂ , N ₂ O, CH ₄	-1,290	-3%	-33%	33%	-1%	1%
Total		-42,890	-100%	-16%	16%		

1.7. General Assessment of the Completeness

In this inventory report, emissions from some categories are not estimated and reported as “NE”.

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. See Annex 5 for a list of not-estimated emission source categories.

➤ *Impacts of the Great East Japan Earthquake*

In order to check impacts of the Great East Japan Earthquake, which occurred on March 11, 2011, on completeness, accuracy and consistency of AD, we carried out investigations by questionnaires and hearing to all of the relevant ministries, agencies and organizations which are responsible for management of statistics used in estimation of GHG emissions and removals. As a result, we confirmed that the impacts of the Great East Japan Earthquake on the statistics, including missing data in them, were insignificant in the total emissions and removals. Since the inventory was prepared after experts’ assessment and review of estimation methodologies, etc. taking into account the investigation results, completeness, accuracy and consistency of the inventory are considered to be assured. However, for some statistical data, investigation and checks on the data continued since the impacts of the earthquake on the data were still insufficient. Based on the ongoing investigation results, GHG emissions from wastes and refuses due to disaster are reported in Chapter 7 (waste sector).

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 FY2017^{1,2} (excluding LULUCF³, including indirect CO₂⁴, hereafter, definition omitted) were 1,292 million tonnes (in CO₂ eq.). They increased by 1.3% compared to the emissions in FY1990.

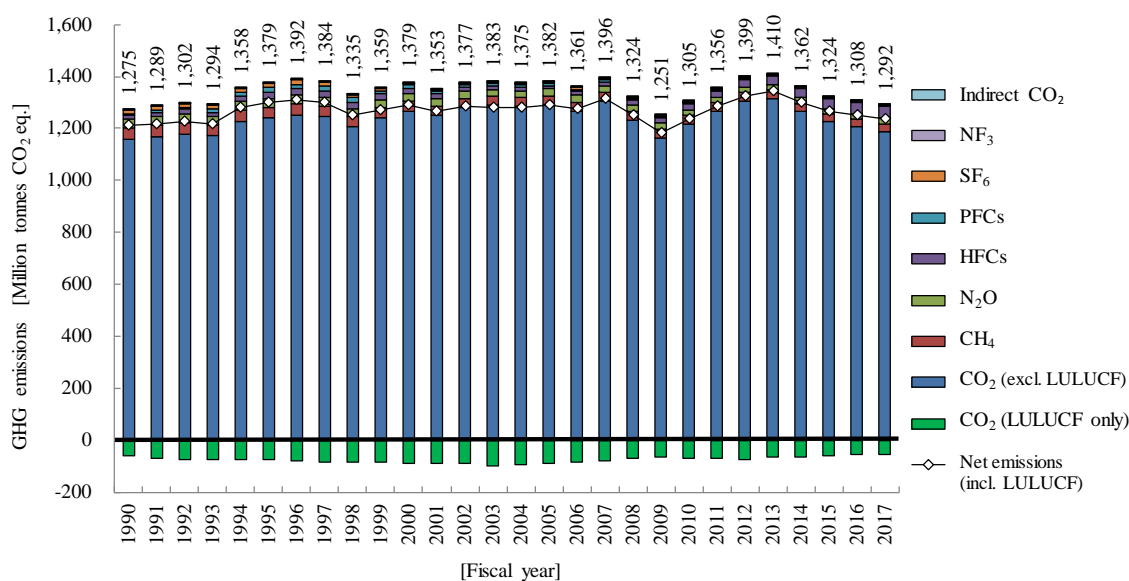


Figure 2-1 Trends in GHG emissions and removals in Japan

CO₂ emissions in FY2017 were 1,188 million tonnes (excluding LULUCF, excluding indirect CO₂, hereafter, definition omitted), accounting for 92.0% of total GHG emissions. They increased by 2.6% since FY1990 and decreased by 1.5% compared to the previous year. CO₂ removals⁵ in FY2017 were 57.7 million tonnes, which were equivalent to 4.5% of total GHG emissions. They decreased by 8.0% since FY1990 and increased by 5.4% compared to the previous year.

¹ “FY” (fiscal year), from April of the reporting year through March of the next year, is used because CO₂ is the primary GHGs emissions and estimated on a fiscal year basis. “CY” stands for calendar year.

² The sum of CO₂, CH₄, N₂O, HFCs, PFCs, SF₆, and NF₃ emissions converted to CO₂ 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 CO₂. The coefficients are drawn from the *Fourth Assessment Report* (2007) issued by the Intergovernmental Panel on Climate Change (IPCC).

³ Abbreviation of “Land Use, Land-Use Change and Forestry”

⁴ Carbon monoxide (CO), methane (CH₄) and non-methane volatile organic compounds (NMVOC) are oxidized in the atmosphere in the long term and converted to CO₂. Indirect CO₂ means the CO₂ equivalent value of these emissions. However, emissions derived from combustion-origin and biomass-origin CO, CH₄, and NMVOC are excluded to avoid double counting and/or by the concept of carbon neutrality.

⁵ Since the inventory to be submitted under the UNFCCC reports all GHG emissions and removals from the LULUCF sector, these values do not correspond to emissions and removals under the Kyoto Protocol.

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
CO ₂ (excl. LULUCF) *1	1	1,158.5	1,170.0	1,179.8	1,172.7	1,227.6	1,240.0	1,252.1	1,245.3	1,205.6	1,242.2
CO ₂ (incl. LULUCF) *1	1	1,095.7	1,099.2	1,105.9	1,095.8	1,151.0	1,162.4	1,169.9	1,160.7	1,119.6	1,155.9
CO ₂ (LULUCF only)	1	-62.8	-70.8	-73.9	-76.9	-76.6	-77.6	-82.2	-84.6	-86.0	-86.3
CH ₄ (excl. LULUCF)	25	44.3	43.2	44.0	40.0	43.3	41.9	40.7	39.9	38.1	38.0
CH ₄ (incl. LULUCF)	25	44.4	43.3	44.1	40.1	43.4	41.9	40.8	40.0	38.2	38.0
N ₂ O (excl. LULUCF)	298	31.8	31.5	31.7	31.6	32.8	33.2	34.3	35.1	33.5	27.4
N ₂ O (incl. LULUCF)	298	32.0	31.7	31.9	31.8	33.0	33.4	34.5	35.3	33.7	27.6
HFCs	HFC-134a: 1,430 etc.	15.9	17.3	17.8	18.1	21.1	25.2	24.6	24.4	23.7	24.4
PFCs	PFC-14: 7,390 etc.	6.5	7.5	7.6	10.9	13.4	17.6	18.3	20.0	16.6	13.1
SF ₆	22,800	12.9	14.2	15.6	15.7	15.0	16.4	17.0	14.5	13.2	9.2
NF ₃	17,200	0.03	0.03	0.03	0.04	0.1	0.2	0.2	0.2	0.2	0.3
Indirect CO ₂	1	5.5	5.3	5.0	4.8	4.8	4.7	4.7	4.5	4.2	4.1
Gross Total (excluding LULUCF, excluding indirect CO ₂)		1,270.0	1,283.8	1,296.5	1,289.1	1,353.4	1,374.5	1,387.1	1,379.4	1,330.9	1,354.5
Net Total (including LULUCF, excluding indirect CO ₂)		1,207.5	1,213.3	1,222.9	1,212.4	1,277.1	1,297.2	1,305.2	1,295.1	1,245.2	1,268.4
Gross Total (excluding LULUCF, including indirect CO ₂)		1,275.5	1,289.1	1,301.6	1,293.9	1,358.2	1,379.2	1,391.8	1,384.0	1,335.0	1,358.6
Net Total (including LULUCF, including indirect CO ₂)		1,213.0	1,218.6	1,228.0	1,217.3	1,281.9	1,301.9	1,309.9	1,299.7	1,249.3	1,272.6

[Million tonnes CO ₂ eq.]	GWP	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
CO ₂ (excl. LULUCF) *1	1	1,265.0	1,250.3	1,279.6	1,287.8	1,283.0	1,290.3	1,267.2	1,302.9	1,232.2	1,163.0
CO ₂ (incl. LULUCF) *1	1	1,176.8	1,161.6	1,189.4	1,187.4	1,186.2	1,198.7	1,181.0	1,221.7	1,161.2	1,095.7
CO ₂ (LULUCF only)	1	-88.2	-88.7	-90.2	-100.4	-96.8	-91.6	-86.2	-81.2	-71.0	-67.3
CH ₄ (excl. LULUCF)	25	38.0	37.1	36.3	34.9	35.9	35.7	35.0	35.3	34.9	34.0
CH ₄ (incl. LULUCF)	25	38.0	37.2	36.4	34.9	36.0	35.7	35.1	35.3	35.0	34.1
N ₂ O (excl. LULUCF)	298	29.9	26.3	25.8	25.6	25.5	25.0	24.9	24.3	23.5	22.9
N ₂ O (incl. LULUCF)	298	30.1	26.5	26.0	25.8	25.7	25.2	25.1	24.5	23.7	23.1
HFCs	HFC-134a: 1,430 etc.	22.9	19.5	16.2	16.2	12.4	12.8	14.6	16.7	19.3	20.9
PFCs	PFC-14: 7,390 etc.	11.9	9.9	9.2	8.9	9.2	8.6	9.0	7.9	5.7	4.0
SF ₆	22,800	7.0	6.1	5.7	5.4	5.3	5.1	5.2	4.7	4.2	2.4
NF ₃	17,200	0.3	0.3	0.4	0.4	0.5	1.5	1.4	1.6	1.5	1.4
Indirect CO ₂	1	4.2	3.8	3.5	3.4	3.3	3.2	3.1	3.0	2.7	2.5
Gross Total (excluding LULUCF, excluding indirect CO ₂)		1,374.8	1,349.4	1,373.2	1,379.2	1,371.8	1,379.0	1,357.4	1,393.4	1,321.4	1,248.6
Net Total (including LULUCF, excluding indirect CO ₂)		1,286.9	1,261.0	1,283.3	1,279.1	1,275.2	1,287.6	1,271.5	1,312.5	1,250.7	1,181.6
Gross Total (excluding LULUCF, including indirect CO ₂)		1,379.1	1,353.2	1,376.7	1,382.6	1,375.1	1,382.1	1,360.5	1,396.4	1,324.1	1,251.1
Net Total (including LULUCF, including indirect CO ₂)		1,291.2	1,264.7	1,286.8	1,282.4	1,278.5	1,290.8	1,274.6	1,315.4	1,253.4	1,184.1

[Million tonnes CO ₂ eq.]	GWP	2010	2011	2012	2013	2014	2015	2016	2017	Changes in emissions/removals (2017)	
										1990	Previous year
CO ₂ (excl. LULUCF) *1	1	1,214.4	1,264.5	1,305.9	1,315.1	1,264.9	1,224.5	1,206.2	1,188.1	2.6%	-1.5%
CO ₂ (incl. LULUCF) *1	1	1,143.6	1,194.4	1,232.8	1,248.7	1,200.1	1,164.7	1,151.4	1,130.4	3.2%	-1.8%
CO ₂ (LULUCF only)	1	-70.8	-70.1	-73.1	-66.4	-64.8	-59.8	-54.8	-57.7	-8.0%	5.4%
CH ₄ (excl. LULUCF)	25	34.5	33.5	32.6	32.3	31.7	30.8	30.5	30.1	-32.2%	-1.4%
CH ₄ (incl. LULUCF)	25	34.6	33.6	32.7	32.4	31.7	30.9	30.6	30.2	-32.1%	-1.4%
N ₂ O (excl. LULUCF)	298	22.3	21.9	21.5	21.6	21.2	20.8	20.3	20.5	-35.6%	1.0%
N ₂ O (incl. LULUCF)	298	22.5	22.0	21.7	21.8	21.4	21.0	20.4	20.6	-35.5%	1.0%
HFCs	HFC-134a: 1,430 etc.	23.3	26.1	29.4	32.1	35.8	39.3	42.6	44.9	181.7%	5.4%
PFCs	PFC-14: 7,390 etc.	4.2	3.8	3.4	3.3	3.4	3.3	3.4	3.5	-46.3%	4.1%
SF ₆	22,800	2.4	2.2	2.2	2.1	2.1	2.2	2.2	2.1	-83.4%	-4.6%
NF ₃	17,200	1.5	1.8	1.5	1.6	1.1	0.6	0.6	0.4	1279.3%	-29.1%
Indirect CO ₂	1	2.4	2.3	2.2	2.2	2.2	2.2	2.1	2.1	-61.3%	0.7%
Gross Total (excluding LULUCF, excluding indirect CO ₂)		1,302.7	1,353.8	1,396.6	1,408.1	1,360.1	1,321.5	1,305.8	1,289.6	1.5%	-1.2%
Net Total (including LULUCF, excluding indirect CO ₂)		1,232.2	1,283.9	1,323.7	1,341.9	1,295.5	1,261.9	1,251.2	1,232.2	2.0%	-1.5%
Gross Total (excluding LULUCF, including indirect CO ₂)		1,305.1	1,356.1	1,398.8	1,410.3	1,362.2	1,323.6	1,307.9	1,291.7	1.3%	-1.2%
Net Total (including LULUCF, including indirect CO ₂)		1,234.6	1,286.2	1,326.0	1,344.1	1,297.7	1,264.0	1,253.3	1,234.3	1.8%	-1.5%

*1 Excluding indirect CO₂

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

CH₄ emissions in FY2017 (excluding LULUCF) were 30.1 million tonnes (in CO₂ eq.), accounting for 2.3% of total GHG emissions. They decreased by 32.2% since FY1990 and by 1.4% compared to the previous year. N₂O emissions in FY2017 (excluding LULUCF) were 20.5 million tonnes (in CO₂ eq.), accounting for 1.6% of total GHG emissions. They decreased by 35.6% since FY1990 and increased by 1.0% compared to the previous year.

HFC emissions in CY2017 were 44.9 million tonnes (in CO₂ eq.), accounting for 3.5% of total GHG emissions. They increased by 181.7% since CY1990 and by 5.4% compared to the previous year. PFC emissions in CY2017 were 3.5 million tonnes (in CO₂ eq.), accounting for 0.3% of total GHG emissions. They decreased by 46.3% since CY1990 and increased by 4.1% compared to the previous year. SF₆ emissions in CY2017 were 2.1 million tonnes (in CO₂ eq.), accounting for 0.2% of total GHG emissions. They decreased by 83.4% since CY1990 and 4.6% compared to the previous year. NF₃ emissions in CY2017 were 0.4 million tonnes (in CO₂ eq.), accounting for 0.03% of total GHG emissions. They increased 1,279.3% since CY1990 and decreased by 29.1% compared to the previous year.

Indirect CO₂ emissions in FY2017 were 2.1 million tonnes (in CO₂ eq.), accounting for 0.2% of total GHG emissions. They decreased by 61.3% since FY1990 and increased by 0.7% compared to the previous year.

2.1.2. CO₂

CO₂ emissions in FY2017 were 1,188 million tonnes, accounting for 92.0% of total GHG emissions. They increased by 2.6% since FY1990 and decreased by 1.5% compared to the previous year.

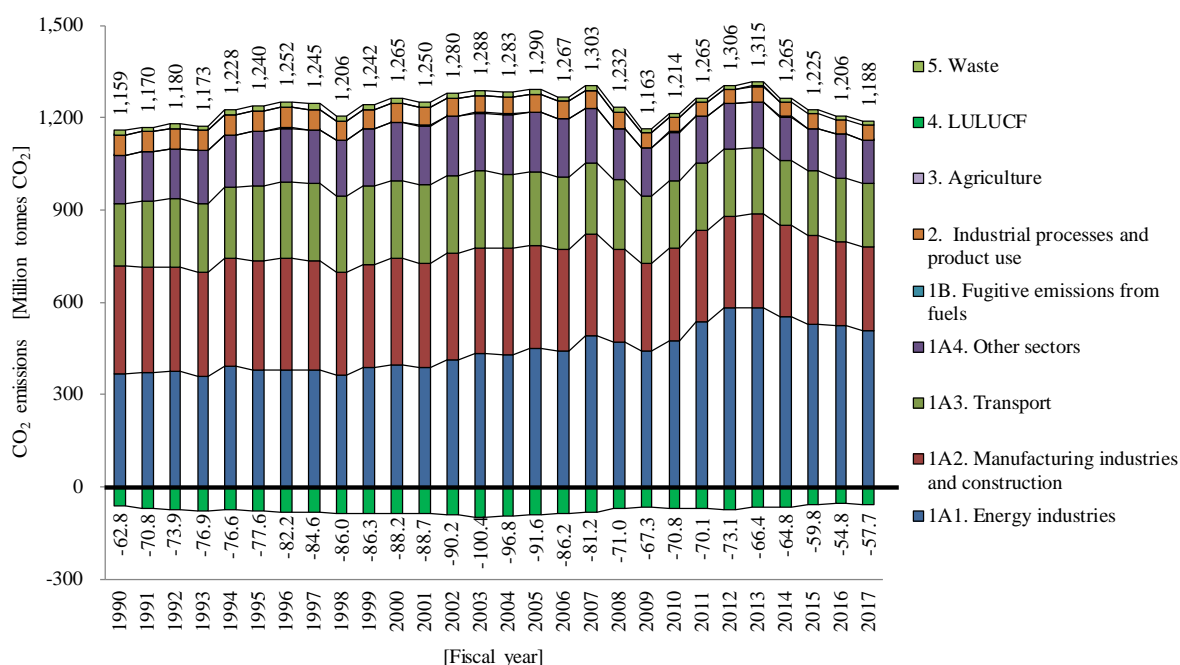


Figure 2-2 Trends in CO₂ emissions

The breakdown of CO₂ emissions in FY2017 shows that fuel combustion accounts for 95.0%, and is followed by industrial processes and product use (4.0%) and waste sectors (1.0%). As for the breakdown of CO₂ emissions within the fuel combustion category, energy industries accounts for 42.7% and is

followed by manufacturing industries and construction at 23.0%, transport at 17.3%, and other sectors⁶ at 12.1%. The main driving factor for the decrease in CO₂ emissions compared to the previous year is the decrease in CO₂ emissions from the energy industries sector.

By looking at the changes in emissions by sector, emissions from fuel combustion in the energy industries increased by 37.6% since FY1990 and decreased by 2.9% compared to the previous year. The main driving factor for the increase compared to the emissions in FY1990 is the increased solid fuel consumption for electricity power generation. Emissions from manufacturing industries and construction decreased by 22.0% since FY1990 and 1.2% compared to the previous year. The main driving factor for the decrease compared to the emissions in FY1990 is the decreased liquid fuel consumption for the other sub-sector (machinery manufacturing, etc). Emissions from transport increased by 2.1% compared to FY1990 and decreased by 0.8% compared to the previous year. The main driving factor for the increase compared to the emissions in FY1990 is the increase in emissions from passenger vehicles, compensating for the decrease in emissions from freight transportation. Emissions from other sectors decreased by 10.2% since FY1990 and increased by 1.0% compared to the previous year. The main driving factor for the decrease compared to the emissions in FY1990 is the decreased liquid fuel consumption for the commercial/institutional sub-sector.

CO₂ removals in FY2017 were 57.7 million tonnes, which were equivalent to 4.5% of total GHG emissions. They decreased by 8.0% since FY1990 and increased by 5.4% compared to the previous year.

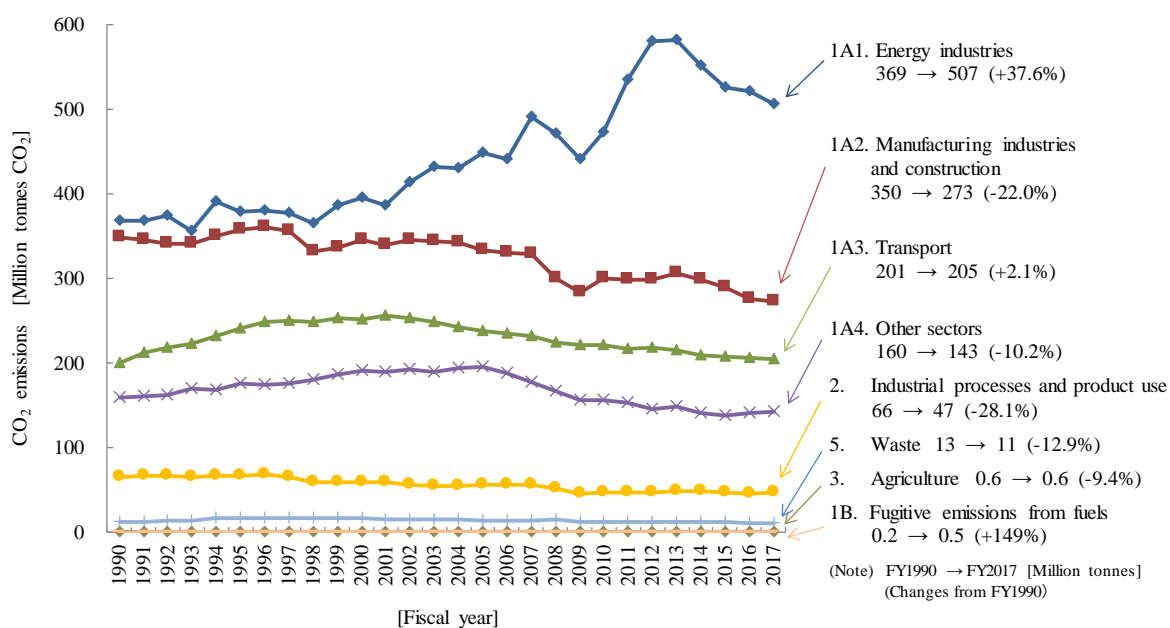


Figure 2-3 Trends in CO₂ emissions in each sector

(Figures in brackets indicate relative increase or decrease to the FY1990 values)

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

Table 2-2 Trends in CO₂ emissions and removals in each sector

[Thousand tonnes CO ₂]																
Category	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017		
IA. Fuel combustion	1,078,839	1,154,876	1,186,033	1,218,029	1,164,209	1,103,117	1,153,254	1,204,238	1,244,706	1,252,156	1,203,102	1,164,331	1,146,919	1,128,396		
IA1. Energy industries	368,529	378,904	395,495	449,660	471,726	441,431	473,849	534,791	581,482	581,970	552,756	526,922	522,057	507,090		
Public electricity and heat production	303,055	317,587	330,118	378,044	402,636	373,133	404,240	468,952	516,377	521,481	494,583	469,658	467,808	454,452		
Petroleum refining	36,397	41,085	46,978	50,888	47,880	47,184	47,715	44,478	43,298	41,800	39,732	40,071	36,384	35,802		
Manufacture of solid fuels and other energy industries	29,077	20,232	18,399	20,728	21,210	21,114	21,894	21,361	21,807	18,690	18,441	17,193	17,865	16,836		
IA2. Manufacturing industries and construction	349,703	357,556	346,635	334,187	300,777	283,828	300,375	299,341	299,004	306,554	299,172	290,369	275,864	272,680		
Iron and steel	150,689	143,096	152,113	154,175	144,769	135,644	153,172	148,895	151,308	157,630	155,167	148,935	142,682	139,786		
Non-ferrous metals	8,428	7,380	6,332	5,705	4,803	4,066	3,999	3,871	4,037	3,849	3,740	3,346	3,617	3,260		
Chemicals	58,039	64,239	59,022	54,488	49,797	48,956	49,188	48,484	46,107	48,618	47,067	46,355	42,618	43,723		
Pulp, paper and print	27,105	31,427	31,679	29,738	25,004	23,425	22,592	23,266	23,760	23,867	22,922	23,321	20,853	20,681		
Food processing, beverages and tobacco	7,649	10,132	11,511	12,217	10,096	9,906	9,925	10,900	10,653	10,280	10,046	9,044	8,982	8,544		
Non-metallic minerals	43,620	46,453	40,150	35,482	32,855	29,281	28,775	28,680	28,961	29,935	29,134	28,211	27,256			
Other	54,173	54,828	45,828	42,383	33,453	32,551	32,725	35,245	34,177	32,375	31,096	31,156	29,856	29,617		
IA3. Transport	200,986	241,993	252,656	237,777	224,773	221,488	221,969	217,138	218,004	215,115	210,130	208,853	206,955	205,226		
Domestic aviation	7,162	10,278	10,677	10,799	10,277	9,781	9,193	9,001	9,524	10,149	10,173	10,067	10,187	10,400		
Road transportation	179,213	216,223	226,256	213,317	202,583	200,656	201,457	197,148	197,158	193,437	188,520	187,641	185,714	183,880		
Railways	935	822	711	647	604	590	574	554	554	540	524	523	499	499		
Domestic navigation	13,675	14,669	15,012	13,014	11,310	10,462	10,745	10,434	10,769	10,989	10,912	10,622	10,555	10,447		
IA4. Other sectors	159,621	176,423	191,246	196,405	166,933	156,369	157,061	152,967	146,216	148,517	141,044	138,187	142,044	143,401		
Commercial/institutional	79,184	88,256	98,693	106,070	89,127	75,800	75,019	73,921	67,325	73,337	68,408	66,621	69,194	67,386		
Residential	58,167	67,477	72,226	70,395	61,704	61,351	64,217	62,541	62,626	60,319	58,014	55,393	55,715	59,267		
Agriculture/forestry/fishing	22,270	20,690	20,326	19,939	16,102	19,217	17,826	16,505	16,264	14,861	14,622	16,172	17,135	16,749		
IA5. Other	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO		
IB. Fugitive emissions from fuels	192	521	512	508	565	501	475	477	490	438	449	425	457	477		
IC. CO ₂ transport and storage	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO	NE,NO		
2. Industrial processes and product use	65,743	67,528	60,347	56,762	51,970	46,382	47,467	47,319	47,465	49,232	48,604	47,101	46,678	47,254		
3. Agriculture	609	359	443	411	440	390	403	415	520	578	551	551	551	551		
4. LULUCF	-62,778	-77,561	-88,185	-91,608	-70,984	-67,253	-70,800	-70,121	-73,123	-66,414	-64,805	-59,831	-54,772	-57,735		
5. Waste	13,132	16,714	17,644	14,600	15,048	12,572	12,825	12,069	12,704	12,673	12,175	12,131	11,560	11,444		
Total (including LULUCF)	1,095,737	1,162,438	1,176,793	1,198,702	1,161,248	1,095,708	1,143,624	1,194,397	1,232,763	1,248,664	1,200,076	1,164,707	1,151,393	1,130,387		
Total (excluding LULUCF)	1,158,515	1,239,998	1,264,978	1,290,310	1,232,232	1,162,961	1,214,424	1,264,518	1,305,886	1,315,077	1,264,880	1,224,539	1,206,166	1,188,122		

*1 Excluding indirect CO₂

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

CO₂ emissions per capita in FY2017 were 9.38 tonnes. They increased by 0.1% since FY1990 and decreased by 1.3% compared to the previous year.

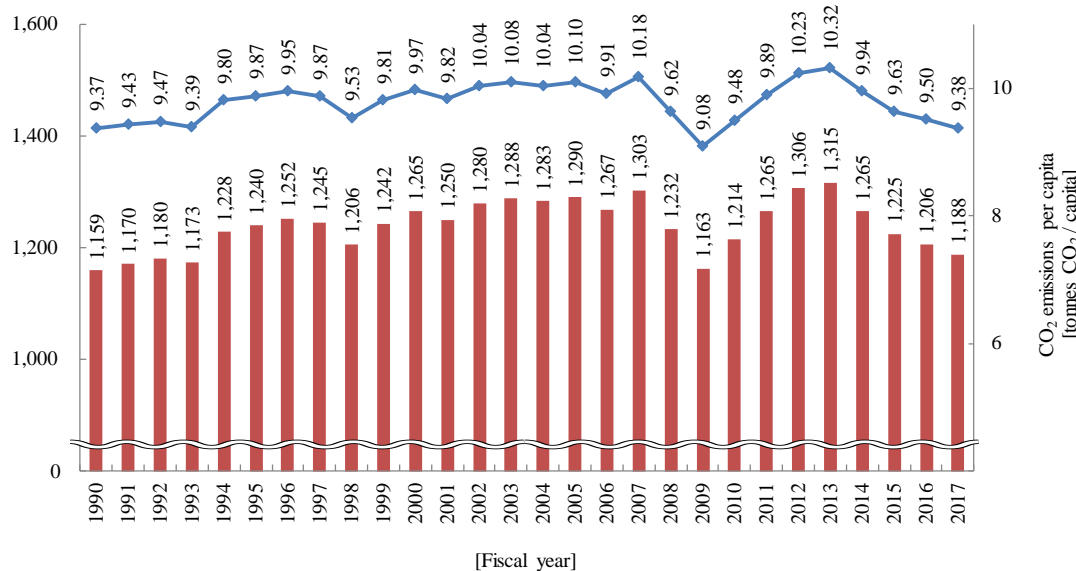


Figure 2-4 Trends in total CO₂ emissions and CO₂ emissions per capita
Source of population data: Ministry of Internal Affairs and Communications, Statistics Bureau, Population Census and Annual Report of Population Estimates

CO₂ emissions per unit of GDP (million yen) in FY2017 were 2.23 tonnes. They decreased by 20.6% since FY1990 and 3.3% compared to the previous year.

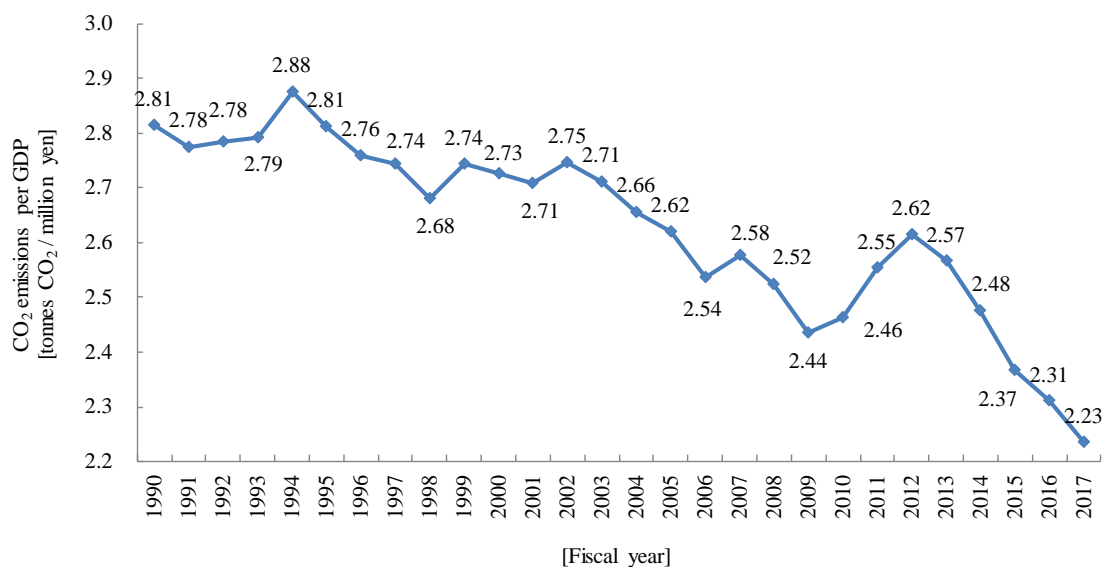


Figure 2-5 Trends in CO₂ emissions per unit of GDP

Source of GDP data: Cabinet Office, Government of Japan, *Annual Report on National Accounts*

2.1.1.3. CH₄

CH₄ emissions in FY2017 were 30.2 million tonnes (in CO₂ eq., including LULUCF), accounting for 2.3% of total GHG emissions. They decreased by 32.1% since FY1990 and by 1.4% compared to the previous year. Their decrease since FY1990 is mainly a result of a 61.4% decrease in emissions from the waste sector (solid waste disposal).

Breakdown of the FY2017 emissions shows that the largest source is rice cultivation accounting for 45%. It is followed by enteric fermentation (24%) and solid waste disposal (10%).

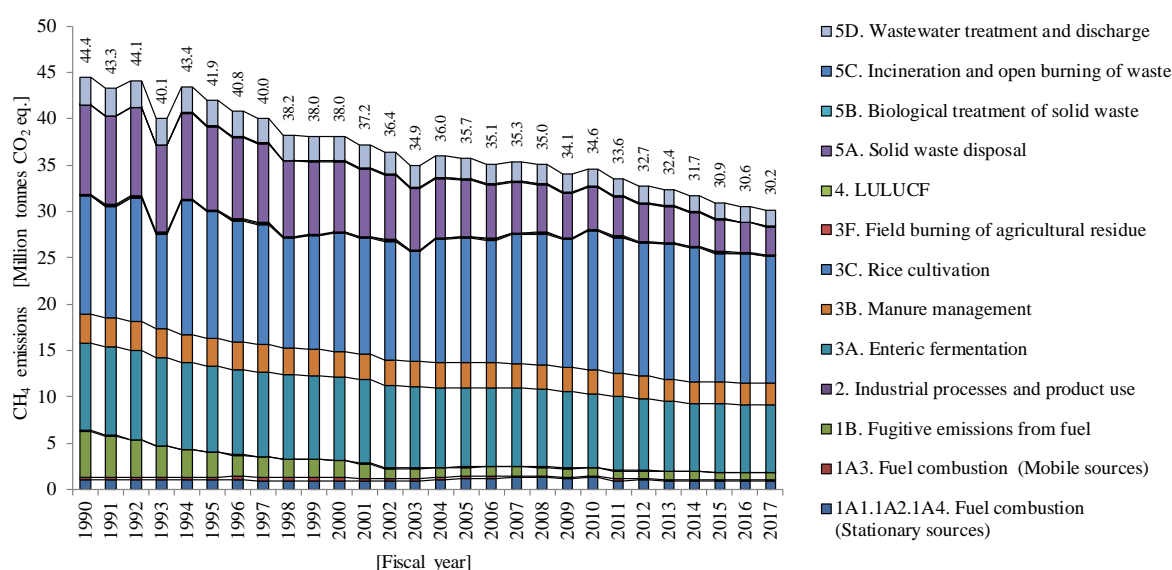


Figure 2-6 Trends in CH₄ emissions

Table 2-3 Trends in CH₄ emissions

[Thousand tonnes CO₂ eq.]

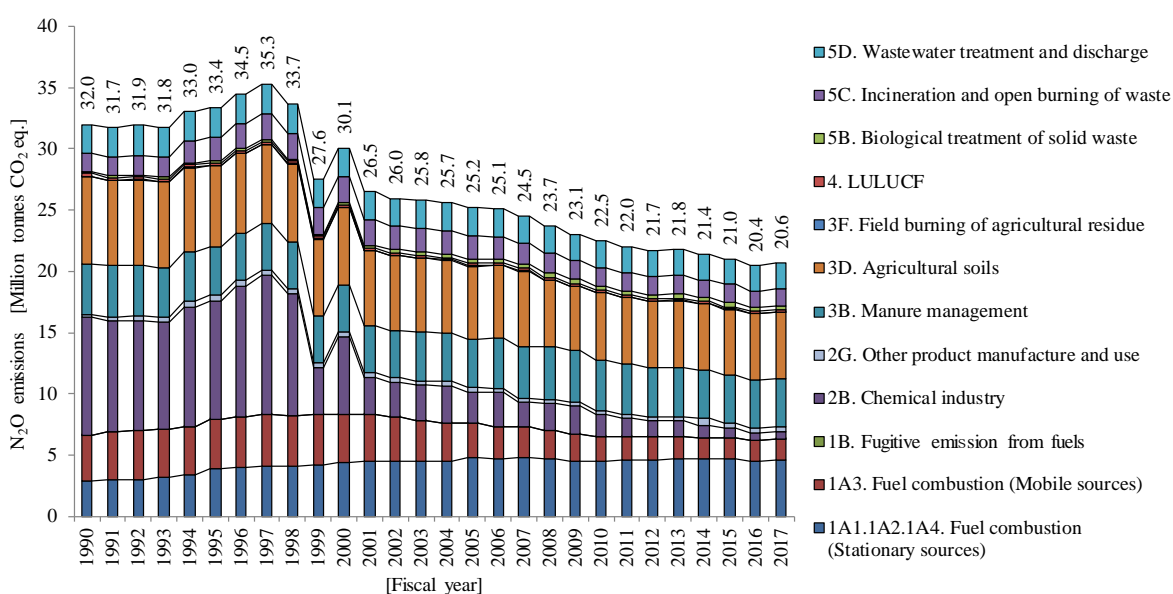
Category	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1A. Fuel combustion	1,350	1,381	1,276	1,435	1,464	1,369	1,440	1,151	1,170	1,119	1,107	1,062	1,058	1,054
1A.1. Energy industries	459	400	263	249	270	258	270	290	300	239	225	214	222	210
1A.2. Manufacturing industries and construction	360	378	371	442	506	499	538	439	465	500	524	501	491	492
1A.3. Transport	291	309	312	247	200	187	178	170	164	156	148	142	138	134
1A.4. Other sectors	239	294	330	496	487	426	455	252	241	224	211	205	207	218
1B. Fugitive emissions from fuels	4,973	2,647	1,836	976	947	916	885	867	851	816	806	787	794	801
1B.1. Solid fuels	4,760	2,394	1,563	655	590	577	564	552	545	533	538	521	510	521
1B.2. Oil and natural gas and other emissions	213	253	273	322	357	339	321	315	305	283	268	267	284	280
2. Industrial processes and product use	61	58	54	54	50	51	54	54	46	46	43	48	43	43
3. Agriculture	25,370	25,961	24,584	24,767	25,188	24,754	25,594	25,185	24,594	24,569	24,211	23,667	23,570	23,300
3A. Enteric fermentation	9,351	9,257	8,935	8,520	8,354	8,242	7,967	7,924	7,733	7,525	7,339	7,330	7,275	7,283
3B. Manure management	3,121	2,988	2,804	2,717	2,599	2,573	2,513	2,508	2,465	2,406	2,364	2,362	2,321	2,323
3C. Rice cultivation	12,771	13,605	12,749	13,445	14,157	13,863	15,041	14,680	14,325	14,565	14,437	13,908	13,907	13,627
3F. Field burning of agricultural residue	127	111	96	86	78	76	74	73	71	72	70	67	67	67
4. LULUCF	85	83	80	80	94	78	72	74	69	71	90	73	67	89
5. Waste	12,594	11,818	10,201	8,434	7,300	6,894	6,524	6,244	5,982	5,738	5,488	5,266	5,039	4,867
5A. Solid waste disposal	9,570	8,985	7,570	6,090	5,141	4,835	4,521	4,272	4,058	3,855	3,635	3,440	3,242	3,081
5B. Biological treatment of solid waste	54	53	54	95	107	106	93	102	101	100	102	102	103	103
5C. Incineration and open burning of waste	28	29	21	18	14	13	12	11	11	12	10	10	9	10
5D. Wastewater treatment and discharge	2,942	2,750	2,556	2,230	2,038	1,940	1,899	1,859	1,811	1,771	1,743	1,714	1,685	1,673
Total (including LULUCF)	44,432	41,949	38,031	35,745	35,041	34,063	34,569	33,575	32,712	32,359	31,745	30,904	30,571	30,154
Total (excluding LULUCF)	44,347	41,865	37,951	35,666	34,948	33,985	34,497	33,501	32,643	32,288	31,655	30,830	30,504	30,064

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

2.1.4. N₂O

N₂O emissions in FY2017 were 20.6 million tonnes (in CO₂ eq., including LULUCF), accounting for 1.6% of total GHG emissions. They decreased by 35.5% since FY1990 and increased by 1.0% compared to the previous year. Their decrease since FY1990 is mainly a result of a 89.8% 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 N₂O abatement equipment came on stream in the adipic acid production plant in March 1999. However, the N₂O 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 FY2017 emissions show that the largest source is agricultural soils accounting for 26%. It is followed by fuel combustion (stationary sources) (22%) and manure management (19%).

Figure 2-7 Trends in N₂O emissionsTable 2-4 Trends in N₂O emissions

Category	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1A. Fuel combustion	6,597	7,941	8,341	7,558	7,003	6,683	6,495	6,507	6,487	6,522	6,416	6,375	6,149	6,303
1A1. Energy industries	889	1,353	1,613	2,117	2,128	2,083	2,071	2,264	2,288	2,355	2,345	2,347	2,178	2,333
1A2. Manufacturing industries and construction	1,259	1,705	1,878	1,867	1,837	1,762	1,722	1,720	1,738	1,767	1,727	1,729	1,655	1,650
1A3. Transport	3,739	4,104	3,997	2,817	2,345	2,182	2,045	1,943	1,866	1,795	1,737	1,709	1,685	1,683
1A4. Other sectors	709	778	852	757	693	656	656	580	595	605	607	589	630	637
1B. Fugitive emissions from fuels	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
2. Industrial processes and product use	9,911	10,114	6,720	2,926	2,541	2,619	2,088	1,777	1,600	1,618	1,606	1,199	1,105	1,015
2B. Chemical industry	9,620	9,665	6,348	2,558	2,244	2,360	1,813	1,507	1,293	1,259	979	798	676	599
2G. Other product manufacture and use	291	449	371	368	297	259	275	270	308	359	627	402	429	416
3. Agriculture	11,274	10,580	10,177	9,975	9,758	9,521	9,733	9,572	9,496	9,483	9,368	9,356	9,321	9,344
3B. Manure management	4,114	3,941	3,804	4,013	4,266	4,269	4,158	4,113	4,035	3,967	3,913	3,910	3,912	3,916
3D. Agricultural soils	7,121	6,604	6,344	5,936	5,468	5,228	5,552	5,436	5,439	5,494	5,433	5,426	5,388	5,408
3F. Field burning of agricultural residue	39	34	30	26	24	23	23	22	22	22	22	21	21	21
4. LULUCF	218	208	198	189	185	183	181	181	182	182	185	184	185	189
5. Waste	4,006	4,525	4,638	4,590	4,221	4,047	3,966	4,010	3,949	3,966	3,812	3,874	3,688	3,799
5B. Biological treatment of solid waste	181	179	181	319	357	354	309	342	338	335	333	340	343	344
5C. Incineration and open burning of waste	1,438	1,908	2,156	1,963	1,628	1,570	1,518	1,518	1,523	1,535	1,423	1,498	1,312	1,421
5D. Wastewater treatment and discharge	2,387	2,439	2,301	2,308	2,236	2,123	2,142	2,150	2,087	2,096	2,056	2,037	2,033	2,034
Total (including LULUCF)	32,005	33,369	30,074	25,238	23,709	23,053	22,463	22,048	21,714	21,771	21,387	20,989	20,447	20,650
Total (excluding LULUCF)	31,788	33,161	29,876	25,049	23,523	22,870	22,282	21,867	21,532	21,589	21,202	20,805	20,262	20,461

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

2.1.5. HFCs

HFC emissions in CY2017⁷ were 44.9 million tonnes (in CO₂ eq.), accounting for 3.5% of total GHG emissions. They increased by 181.7% since CY1990, and by 5.4% compared to the previous year. Their increase since CY1990 is mainly a result of an increase in emissions from refrigeration and air conditioning (+41.1 million tonnes CO₂ eq.) substituting for HCFC (an ozone depleting substance), despite a decrease in emissions of HFC-23 (-99.8%) 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)

Breakdown of the CY2017 emissions shows that the largest source is refrigerants of refrigeration and air conditioning equipment accounting for 92%. It is followed by foam blowing agents (6%).

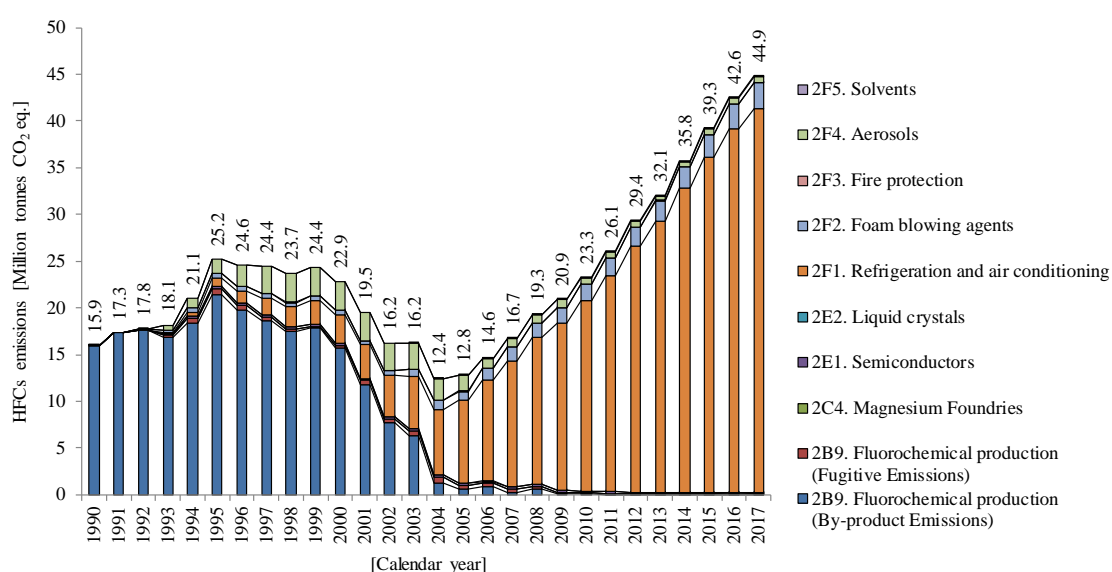


Figure 2-8 Trends in HFC emissions

Table 2-5 Trends in HFC emissions

Category	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
2B9. Fluorochemical production	15,930	22,019	15,984	1,035	900	284	181	168	138	147	124	113	172	133
By-product Emissions	15,929	21,460	15,688	586	593	50	53	16	18	16	24	30	24	38
Fugitive Emissions	2	559	296	449	306	234	128	151	120	131	101	83	149	95
2C4. Magnesium production	NO	NO	NO	NO	NO	NO	NO	1	1	1	1	1	1	1
2E. Electronics industry	1	271	285	227	237	152	168	145	124	112	115	115	119	125
2E1. Semiconductors	1	271	283	224	234	150	165	142	122	109	113	113	117	123
2E2. Liquid crystals	0,001	0.3	2	3	3	2	3	3	2	2	2	2	2	2
2F. Product uses as substitutes for ODS	1	2,923	6,583	11,522	18,157	20,498	22,967	25,792	29,098	31,844	35,544	39,032	42,280	44,625
2F1. Refrigeration and air conditioning	NO	925	2,977	8,876	15,686	17,998	20,483	23,140	26,354	29,008	32,536	35,873	38,903	41,098
2F2. Foam blowing agents	1	497	484	937	1,510	1,608	1,749	1,923	2,081	2,229	2,373	2,484	2,651	2,801
2F3. Fire protection	NO	NO	5	7	8	8	8	8	9	9	9	9	10	10
2F4. Aerosols	NO	1,502	3,117	1,695	931	845	666	634	561	489	503	540	587	600
2F5. Solvents	NO	NO	NO	6	23	39	60	86	94	109	122	126	130	116
Total	15,932	25,213	22,852	12,784	19,294	20,935	23,316	26,106	29,362	32,105	35,784	39,261	42,573	44,885

⁷ Emissions of HFCs, PFCs, SF₆, and NF₃ are estimated on a calendar year (CY) basis.

2.1.6. PFCs

PFC emissions in CY2017 were 3.5 million tonnes (in CO₂ eq.), accounting for 0.3% of total GHG emissions. They decreased by 46.3% since CY1990 and increased by 4.1% compared to the previous year. Their decrease since CY1990 is mainly a result of a decrease in emissions from the solvents. (-67.4%)

Breakdown of the CY2017 emissions show that the largest source is semiconductor manufacture accounting for 53%. It is followed by solvents such as those for washing metals (42%), and liquid crystals manufacturing (2%).

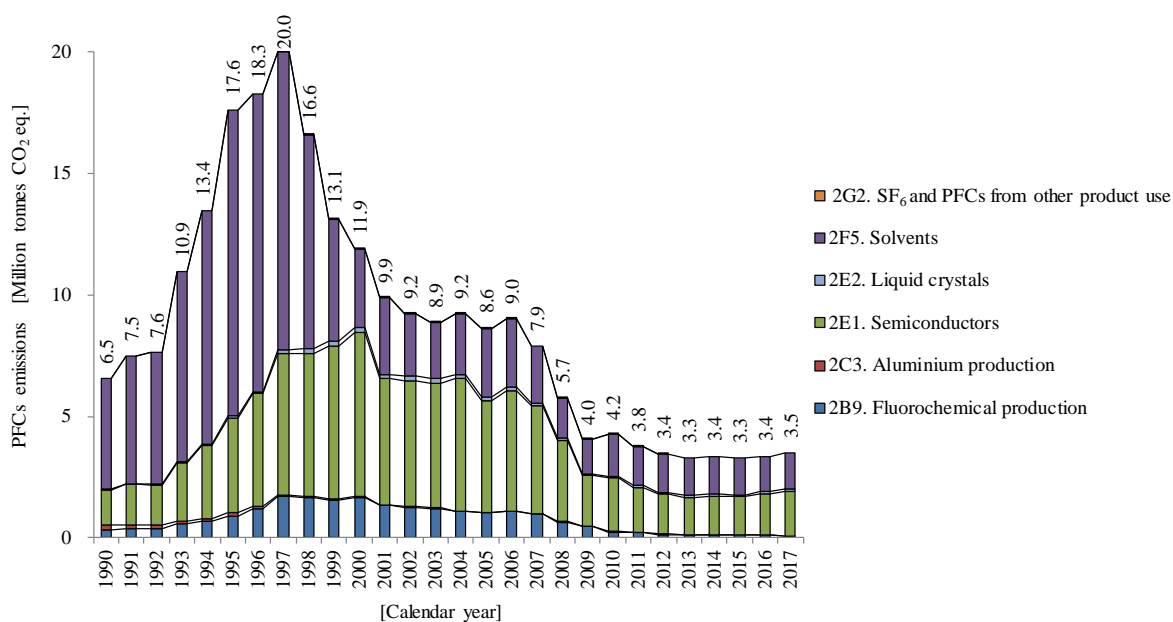


Figure 2-9 Trends in PFC emissions

Table 2-6 Trends in PFC emissions

Category	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
2B9. Fluorochemical production	331	914	1,661	1,041	649	459	248	206	148	111	107	115	97	78
2C3. Aluminium production	204	104	26	22	22	16	15	15	13	10	2	NO	NO	NO
2E. Electronics industry	1,455	4,020	6,986	4,746	3,422	2,148	2,261	1,922	1,692	1,631	1,707	1,669	1,792	1,931
2E1. Semiconductors	1,423	3,933	6,771	4,594	3,339	2,109	2,214	1,863	1,624	1,556	1,617	1,582	1,721	1,847
2E2. Liquid crystals	31	87	214	152	83	39	46	59	68	76	90	86	71	84
2F5. Solvents	4,550	12,572	3,200	2,815	1,648	1,420	1,721	1,605	1,583	1,518	1,537	1,517	1,465	1,484
2G2. SF ₆ and PFCs from other product use	NO	NO	NO	0.3	2	3	4	6	NO	10	9	8	21	20
Total	6,539	17,610	11,873	8,623	5,743	4,047	4,250	3,755	3,436	3,280	3,361	3,308	3,375	3,512

2.1.7. SF₆

SF₆ emissions in CY2017 were 2.1 million tonnes (in CO₂ eq.), accounting for 0.2% of total GHG emissions. They decreased by 83.4% 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. (-92.4%)

Breakdown of the CY2017 emissions show that the largest source is other product use (e.g. accelerator, etc.) accounting for 41%. It is followed by electrical equipment (29%) and magnesium production (12%).

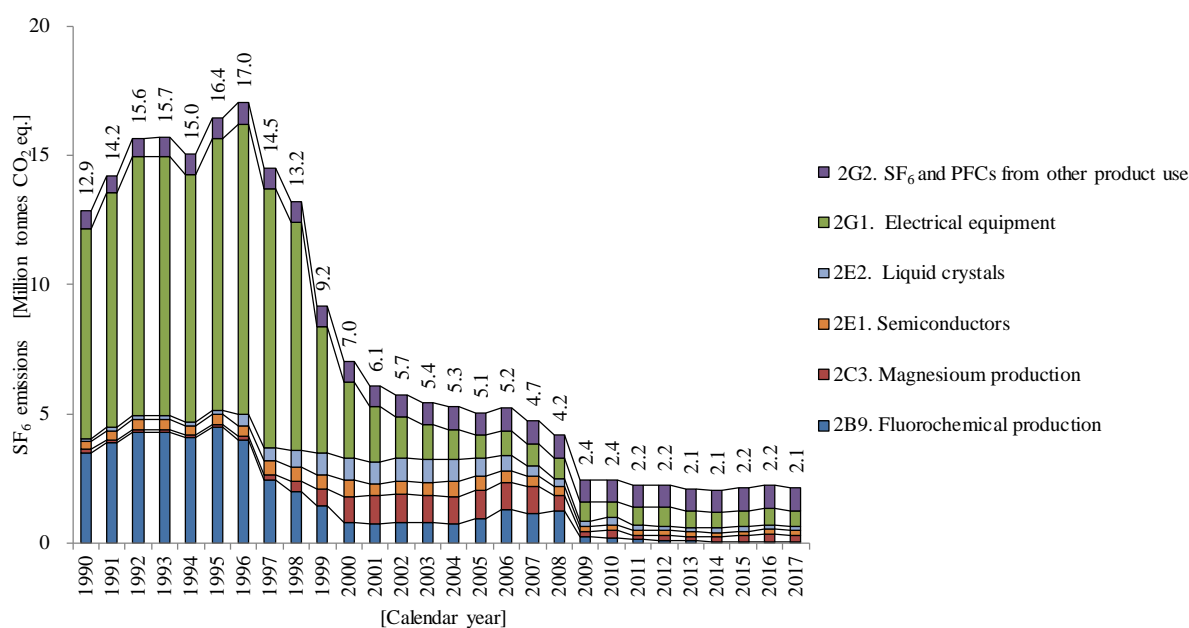


Figure 2-10 Trends in SF₆ emissions

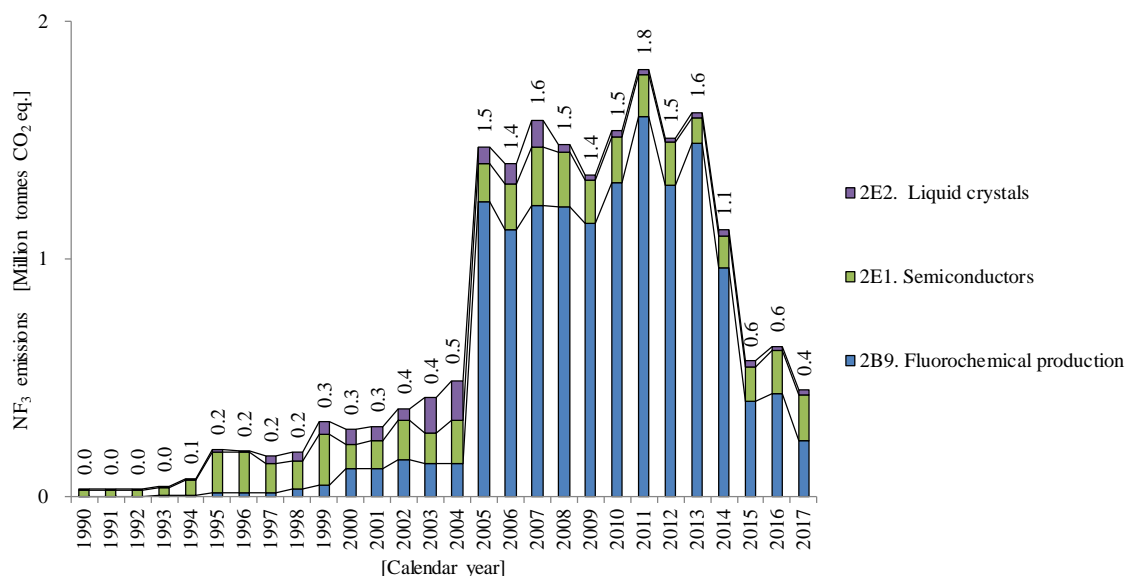
Table 2-7 Trends in SF₆ emissions

Category	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
2B9. Fluorochemical production	3,471	4,492	821	930	1,229	233	189	132	123	93	62	52	50	41
2C3. Magnesium production	147	114	980	1,104	622	228	294	182	182	160	182	228	315	246
2E. Electronics industry	419	542	1,506	1,252	625	410	494	394	356	351	366	375	349	363
2E1. Semiconductors	309	400	629	540	329	211	225	196	184	181	175	184	192	200
2E2. Liquid crystals	110	142	877	712	296	199	269	198	172	170	191	191	157	163
2G. Other product manufacture and use	8,814	11,300	3,724	1,767	1,701	1,576	1,447	1,539	1,573	1,498	1,455	1,497	1,524	1,486
2G1. Electrical equipment	8,112	10,498	2,910	899	828	711	622	707	719	643	602	610	655	620
2G2. SF ₆ and PFCs from other product use	702	802	815	867	873	865	825	832	855	855	854	887	868	866
Total	12,850	16,448	7,031	5,053	4,177	2,447	2,424	2,248	2,235	2,102	2,065	2,153	2,237	2,135

2.1.8. NF₃

NF₃ emissions in CY2017 were 0.4 million tonnes (in CO₂ eq.), accounting for 0.03% of total GHG emissions. They increased by 1,279.3% since CY1990, and decreased by 29.1% compared to the previous year. The increase since CY1990 is mainly a result of an increase in fugitives from fluorocarbon production (NF₃). (by 8,292.8%)

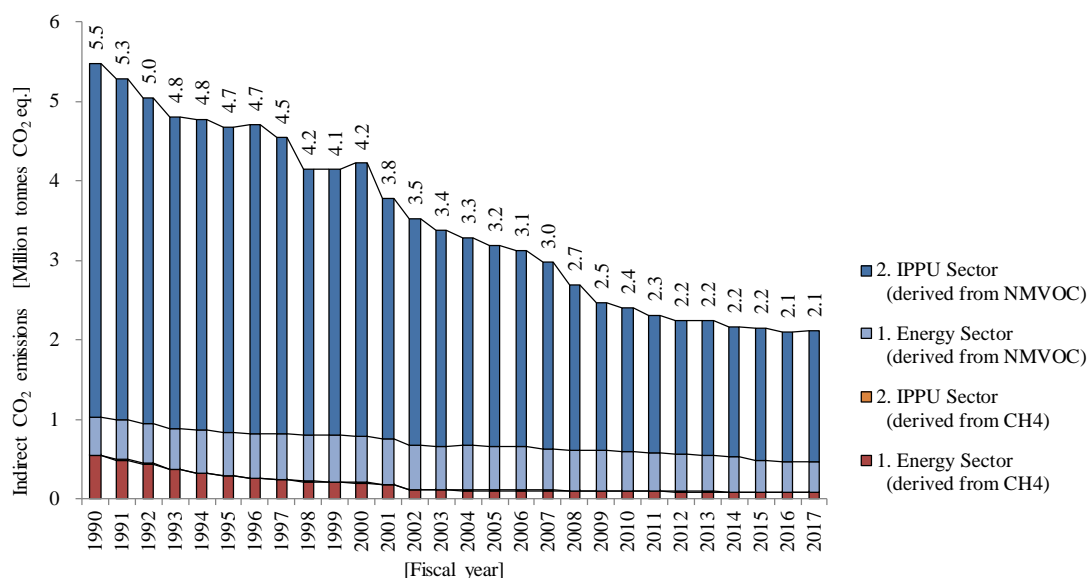
Breakdown of the CY2017 emissions show that the largest source is fluorochemical production accounting for 52%. It is followed by semiconductor manufacture (43%) and liquid crystal manufacture (5%).

Figure 2-11 Trends in NF₃ emissionsTable 2-8 Trends in NF₃ emissions

Category	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
2B9. Fluorochemical production	3	17	120	1,240	1,223	1,149	1,323	1,601	1,314	1,486	965	404	432	234
2E. Electronics industry	30	184	165	232	258	205	217	199	198	131	158	167	203	216
2E1. Semiconductors	27	168	100	161	227	182	191	175	177	110	132	145	183	194
2E2. Liquid crystals	3	16	66	71	31	23	26	24	21	21	26	22	20	22
Total	33	201	286	1,472	1,481	1,354	1,540	1,800	1,512	1,617	1,123	571	634	450

2.1.9. Indirect CO₂

Indirect CO₂⁸ emissions in FY2017 were 2.1 million tonnes (in CO₂ eq.), accounting for 0.2% of total GHG emissions. They decreased by 61.3% since FY1990, and increased by 0.73% compared to the previous year. Their decrease since FY1990 is due to the decrease in indirect CO₂ emissions derived from NMVOC 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 CO₂ emissionsTable 2-9 Trends in Indirect CO₂ emissions

[Thousand tonnes CO₂ eq.]

Emission Source	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Derived from CH ₄	554	298	208	113	110	106	103	101	99	95	93	92	92	93
1. Energy Sector	547	291	202	107	104	101	97	95	94	90	89	87	87	88
2. IPPU Sector	7	6	6	6	5	6	6	6	5	5	5	5	5	5
Derived from NMVOC	4,920	4,385	4,012	3,074	2,582	2,366	2,302	2,215	2,139	2,146	2,073	2,059	2,010	2,025
1. Energy Sector	480	545	590	548	508	500	497	482	465	463	441	390	386	379
2. IPPU Sector	4,440	3,840	3,423	2,526	2,074	1,866	1,805	1,733	1,673	1,683	1,632	1,669	1,625	1,646
Total	5,474	4,682	4,220	3,188	2,691	2,472	2,406	2,316	2,238	2,241	2,166	2,151	2,103	2,118

⁸ Emissions derived from combustion-origin and biomass-origin CO, CH₄, 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 FY2017 by sector⁹ shows that energy (excluding indirect CO₂, hereafter, definition omitted) accounts for 88.0% of total GHG emissions. It is followed by industrial processes and product use (excluding indirect CO₂, hereafter, definition omitted) (7.7%), agriculture (2.6%), waste (1.6%), and indirect CO₂ emissions (0.2%).

Removals by LULUCF in FY2017 were equivalent to 4.4% of total GHG emissions.

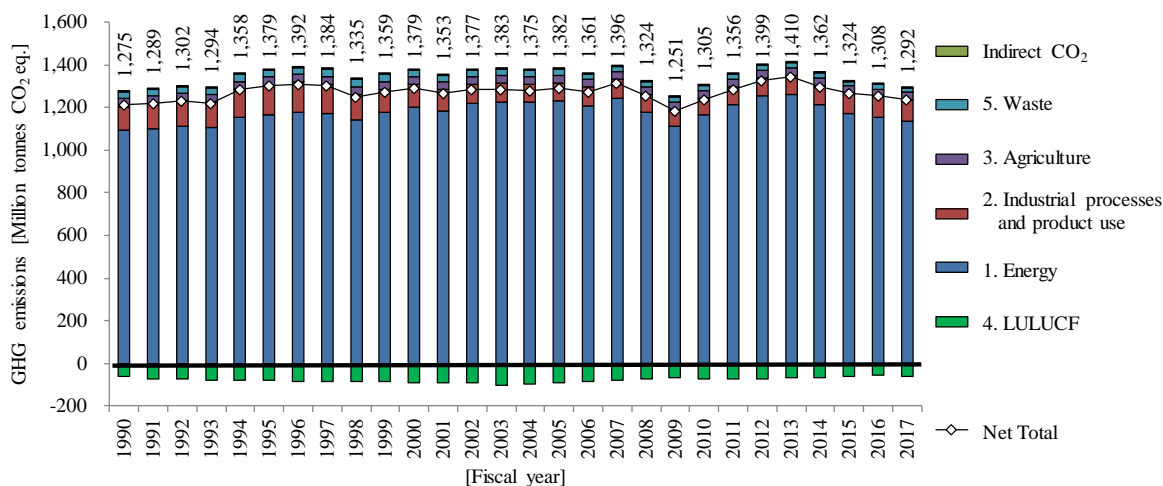


Figure 2-13 Trends in GHG emissions and removals in each sector

⁹ As indicated in the 2006 IPCC Guidelines and the CRF.

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
1. Energy ^{*1}	1,091.9	1,102.2	1,110.6	1,104.5	1,155.3	1,167.4	1,178.2	1,173.4	1,139.4	1,176.0
2. Industrial processes and product use ^{*1}	111.1	115.4	117.3	119.5	127.0	137.2	139.5	136.5	123.8	111.1
3. Agriculture	37.3	36.5	37.8	34.6	38.2	36.9	36.1	35.8	34.5	34.7
4. LULUCF ^{*2}	-62.5	-70.5	-73.6	-76.6	-76.3	-77.3	-81.9	-84.3	-85.7	-86.1
5. Waste	29.7	29.7	30.9	30.4	32.9	33.1	33.3	33.7	33.3	32.7
Indirect CO ₂	5.5	5.3	5.0	4.8	4.8	4.7	4.7	4.5	4.2	4.1
Gross Total (excluding LULUCF, excluding indirect CO ₂)	1,270.0	1,283.8	1,296.5	1,289.1	1,353.4	1,374.5	1,387.1	1,379.4	1,330.9	1,354.5
Net Total (including LULUCF, excluding indirect CO ₂)	1,207.5	1,213.3	1,222.9	1,212.4	1,277.1	1,297.2	1,305.2	1,295.1	1,245.2	1,268.4
Gross Total (excluding LULUCF, including indirect CO ₂)	1,275.5	1,289.1	1,301.6	1,293.9	1,358.2	1,379.2	1,391.8	1,384.0	1,335.0	1,358.6
Net Total (including LULUCF, including indirect CO ₂)	1,213.0	1,218.6	1,228.0	1,217.3	1,281.9	1,301.9	1,309.9	1,299.7	1,249.3	1,272.6

[Million tonnes CO ₂ eq.]	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
1. Energy ^{*1}	1,198.0	1,185.7	1,217.4	1,226.1	1,221.8	1,228.5	1,205.6	1,241.8	1,174.2	1,112.6
2. Industrial processes and product use ^{*1}	109.2	98.1	91.2	89.8	86.4	87.7	90.6	89.7	85.3	77.8
3. Agriculture	35.2	34.7	35.0	33.9	35.1	35.2	34.9	36.0	35.4	34.7
4. LULUCF ^{*2}	-87.9	-88.4	-89.9	-100.1	-96.5	-91.3	-85.9	-81.0	-70.7	-67.0
5. Waste	32.5	30.8	29.7	29.4	28.4	27.6	26.3	25.9	26.6	23.5
Indirect CO ₂	4.2	3.8	3.5	3.4	3.3	3.2	3.1	3.0	2.7	2.5
Gross Total (excluding LULUCF, excluding indirect CO ₂)	1,374.8	1,349.4	1,373.2	1,379.2	1,371.8	1,379.0	1,357.4	1,393.4	1,321.4	1,248.6
Net Total (including LULUCF, excluding indirect CO ₂)	1,286.9	1,261.0	1,283.3	1,279.1	1,275.2	1,287.6	1,271.5	1,312.5	1,250.7	1,181.6
Gross Total (excluding LULUCF, including indirect CO ₂)	1,379.1	1,353.2	1,376.7	1,382.6	1,375.1	1,382.1	1,360.5	1,396.4	1,324.1	1,251.1
Net Total (including LULUCF, including indirect CO ₂)	1,291.2	1,264.7	1,286.8	1,282.4	1,278.5	1,290.8	1,274.6	1,315.4	1,253.4	1,184.1

[Million tonnes CO ₂ eq.]	2010	2011	2012	2013	2014	2015	2016	2017
1. Energy ^{*1}	1,162.5	1,213.2	1,253.7	1,261.1	1,211.9	1,173.0	1,155.4	1,137.0
2. Industrial processes and product use ^{*1}	81.1	83.1	85.7	90.0	92.6	93.6	96.6	99.3
3. Agriculture	35.7	35.2	34.6	34.6	34.1	33.6	33.4	33.2
4. LULUCF ^{*2}	-70.5	-69.9	-72.9	-66.2	-64.5	-59.6	-54.5	-57.5
5. Waste	23.3	22.3	22.6	22.4	21.5	21.3	20.3	20.1
Indirect CO ₂	2.4	2.3	2.2	2.2	2.2	2.2	2.1	2.1
Gross Total (excluding LULUCF, excluding indirect CO ₂)	1,302.7	1,353.8	1,396.6	1,408.1	1,360.1	1,321.5	1,305.8	1,289.6
Net Total (including LULUCF, excluding indirect CO ₂)	1,232.2	1,283.9	1,323.7	1,341.9	1,295.5	1,261.9	1,251.2	1,232.2
Gross Total (excluding LULUCF, including indirect CO ₂)	1,305.1	1,356.1	1,398.8	1,410.3	1,362.2	1,323.6	1,307.9	1,291.7
Net Total (including LULUCF, including indirect CO ₂)	1,234.6	1,286.2	1,326.0	1,344.1	1,297.7	1,264.0	1,253.3	1,234.3

*1 Excluding indirect CO₂

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

2.2.1. Energy

Emissions from the energy sector in FY2017 were 1,137 million tonnes (in CO₂ equivalents). They increased by 4.1% since FY1990 and decreased by 1.6% compared to the previous year.

Breakdown of the FY2017 emissions show that CO₂ from fuel combustion accounts for 99.2%. The largest source within fuel combustion¹⁰ is solid fuel CO₂, which accounted for 40%, and is then followed by liquid fuel CO₂ (37%) and gaseous fuel CO₂ (21%).

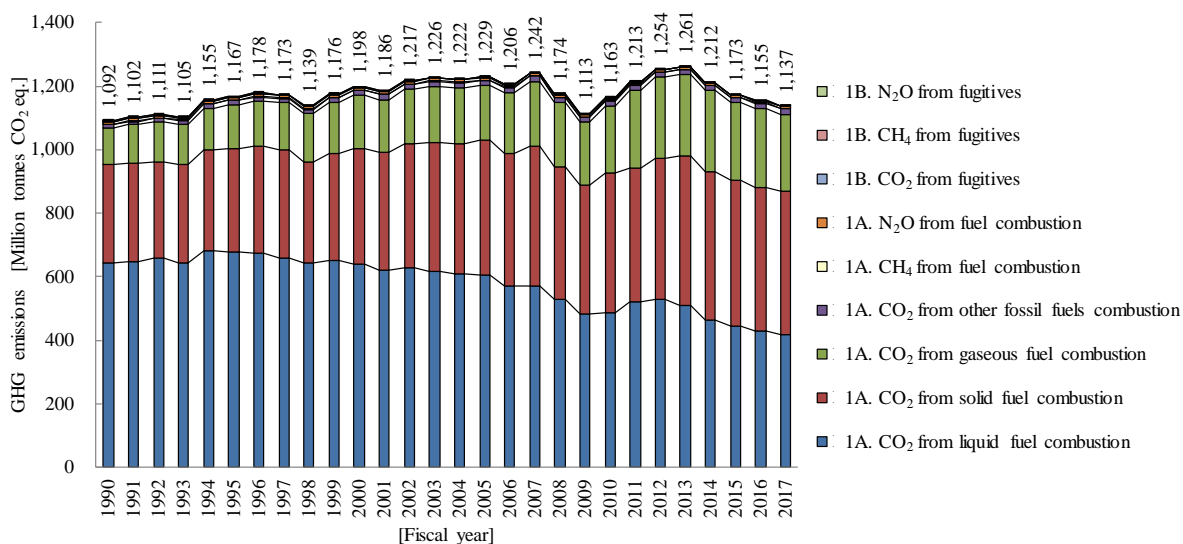


Figure 2-14 Trends in GHG emissions from the energy sector

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

	[Thousand tonnes CO ₂ eq.]													
Source category	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1A. Fuel combustion	1,086,785	1,164,199	1,195,649	1,227,022	1,172,675	1,111,169	1,161,189	1,211,896	1,252,363	1,259,797	1,210,625	1,171,767	1,154,125	1,135,753
Liquid fuel CO ₂	644,312	677,416	640,667	606,112	527,322	483,777	488,924	520,349	530,754	508,463	464,738	444,007	429,538	417,488
Solid fuel CO ₂	309,482	327,102	364,079	422,447	418,796	404,591	438,513	423,245	442,778	473,621	466,527	460,110	451,649	451,360
Gaseous fuel CO ₂	114,167	137,927	166,073	172,415	201,286	199,127	209,932	244,686	254,051	253,379	255,510	243,369	248,163	242,163
Other fossil fuels (Waste) CO ₂	10,878	12,431	15,214	17,054	16,805	15,622	15,885	15,957	17,123	16,692	16,327	16,844	17,569	17,385
CH ₄	1,350	1,381	1,276	1,435	1,464	1,369	1,440	1,151	1,170	1,119	1,107	1,062	1,058	1,054
N ₂ O	6,597	7,941	8,341	7,558	7,003	6,683	6,495	6,507	6,487	6,522	6,416	6,375	6,149	6,303
1B. Fugitive emissions from fuel	5,165	3,169	2,347	1,484	1,512	1,417	1,359	1,345	1,341	1,254	1,255	1,212	1,251	1,278
CO ₂	192	521	512	508	565	501	475	477	490	438	449	425	457	477
CH ₄	4,973	2,647	1,836	976	947	916	885	867	851	816	806	787	794	801
N ₂ O	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
1C. CO₂ transport and storage	NEN0	NEN0	NEN0	NEN0	NEN0	NEN0	NEN0	NEN0	NEN0	NEN0	NEN0	NEN0	NEN0	NEN0
Total	1,091,950	1,167,367	1,197,996	1,228,506	1,174,187	1,112,586	1,162,548	1,213,240	1,253,704	1,261,051	1,211,880	1,172,979	1,155,377	1,137,031

2.2.2. Industrial Processes and Product Use

Emissions from the industrial processes and product use sector in FY2017 were 99.3 million tonnes (in CO₂ eq.). They decreased by 10.6% since FY1990, and increased by 2.7% compared to the previous year.

The breakdown of GHG emissions from this sector in FY2017 shows that the largest source is HFCs emissions from product uses as ODS substitutes accounting for 45%. It is followed by the mineral industry emissions such as CO₂ emissions from cement production (34%) and CO₂ emissions from the metal industry (6%).

¹⁰ Fuel types are categorized in accordance with classification indicated in the 2006 IPCC Guidelines and the CRF.

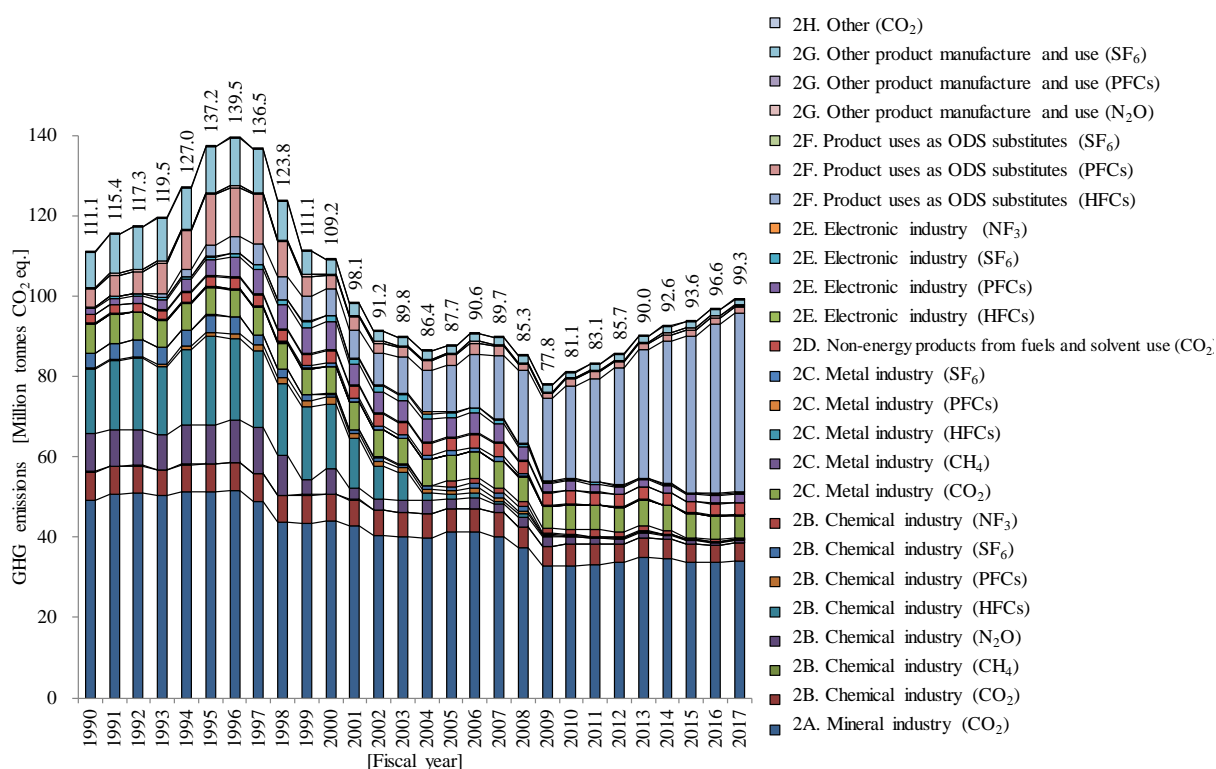


Figure 2-15 Trends in GHG emissions from the industrial processes and product use sector

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

Category	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
2A. Mineral industry (CO ₂)	49,230	51,146	43,919	41,230	37,436	32,779	32,752	33,097	33,664	35,056	34,798	33,738	33,622	34,062
2B. Chemical industry	36,433	44,158	31,780	12,633	11,384	9,392	9,218	8,753	7,696	7,913	6,947	6,104	5,754	5,595
CO ₂	7,041	7,014	6,810	5,795	5,107	4,872	5,427	5,103	4,652	4,788	4,685	4,591	4,300	4,485
CH ₄	37	37	34	34	32	36	36	36	28	28	25	32	27	25
N ₂ O	9,620	9,665	6,348	2,558	2,244	2,360	1,813	1,507	1,293	1,259	979	798	676	599
HFCs	15,930	22,019	15,984	1,035	900	284	181	168	138	147	124	113	172	133
PFCs	331	914	1,661	1,041	649	459	248	206	148	111	107	115	97	78
SF ₆	3,471	4,492	821	930	1,229	233	189	132	123	93	62	52	50	41
NF ₃	3	17	120	1,240	1,223	1,149	1,323	1,601	1,314	1,486	965	404	432	234
2C. Metal industry	7,617	7,088	7,766	7,643	6,898	5,728	6,427	6,181	6,276	6,369	6,310	6,162	6,134	5,988
CO ₂	7,244	6,850	6,740	6,497	6,237	5,468	6,101	5,965	6,061	6,181	6,107	5,916	5,801	5,723
CH ₄	23	21	20	20	18	15	18	18	18	18	18	17	16	17
HFCs	NO	NO	NO	NO	NO	NO	NO	1	1	1	1	1	1	1
PFCs	204	104	26	22	22	16	15	15	13	10	2	0	0	0
SF ₆	147	114	980	1,104	622	228	294	182	182	160	182	228	315	246
2D. Non-energy products from fuels and solvent use (CO ₂)	2,164	2,447	2,792	3,151	3,119	3,191	3,112	3,079	3,012	3,124	2,933	2,772	2,875	2,899
2E. Electronic industry	1,904	5,016	8,941	6,457	4,542	2,916	3,140	2,661	2,370	2,225	2,346	2,326	2,463	2,634
HFCs	1	271	285	227	237	152	168	145	124	112	115	115	119	125
PFCs	1,455	4,020	6,986	4,746	3,422	2,148	2,261	1,922	1,692	1,631	1,707	1,669	1,792	1,931
SF ₆	419	542	1,506	1,252	625	410	494	394	356	351	366	375	349	363
NF ₃	30	184	165	232	258	205	217	199	198	131	158	167	203	216
2F. Product uses as ODS substitutes	4,551	15,496	9,783	14,336	19,805	21,919	24,687	27,397	30,681	33,362	37,080	40,549	43,745	46,109
HFCs	1	2,923	6,583	11,522	18,157	20,498	22,967	25,792	29,098	31,844	35,544	39,032	42,280	44,625
PFCs	4,550	12,572	3,200	2,815	1,648	1,420	1,721	1,605	1,583	1,518	1,537	1,517	1,465	1,484
SF ₆	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2G. Other product manufacture and use	9,105	11,749	4,096	2,135	2,001	1,838	1,727	1,815	1,881	1,867	2,091	1,907	1,973	1,921
N ₂ O	291	449	371	368	297	259	275	270	308	359	627	402	429	416
PFCs	NO	NO	NO	0.3	2	3	4	6	NO	10	9	8	21	20
SF ₆	8,814	11,300	3,724	1,767	1,701	1,576	1,447	1,539	1,573	1,498	1,455	1,497	1,524	1,486
2H. Other (CO ₂)	64	72	87	90	72	71	76	76	76	82	80	83	79	85
Total	111,069	137,172	109,164	87,674	85,256	77,834	81,138	83,059	85,656	90,000	92,586	93,641	96,646	99,294

Despite the increase in HFC emissions from product uses as substitutes for ODS compared to FY1990, 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 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 CO₂ emissions from cement production (mineral industry) as the clinker production declined, and the decrease in N₂O emissions from adipic acid production (chemical industry) as the N₂O abatement equipment came on stream.

2.2.3. Agriculture

Emissions from the agriculture sector in FY2017 were 33.2 million tonnes (in CO₂ eq.). They decreased by 10.9% since FY1990 and by 0.7% compared to the previous year.

Breakdown of the FY2017 emissions from this sector shows that the largest source is the rice cultivation (CH₄) accounting for 41%. It is followed the enteric fermentation (CH₄) by (22%), and the agricultural soils (N₂O) (16%) as a result of the nitrogen-based fertilizer applications.

The main driving factor for the decrease in emissions since FY1990 is the decrease in CH₄ emissions from enteric fermentation due to the decrease in the number of cattle, and the decrease in N₂O emissions from the agricultural soils, because the amount of nitrogen fertilizers applied and organic fertilizers from livestock manure applied had decreased.

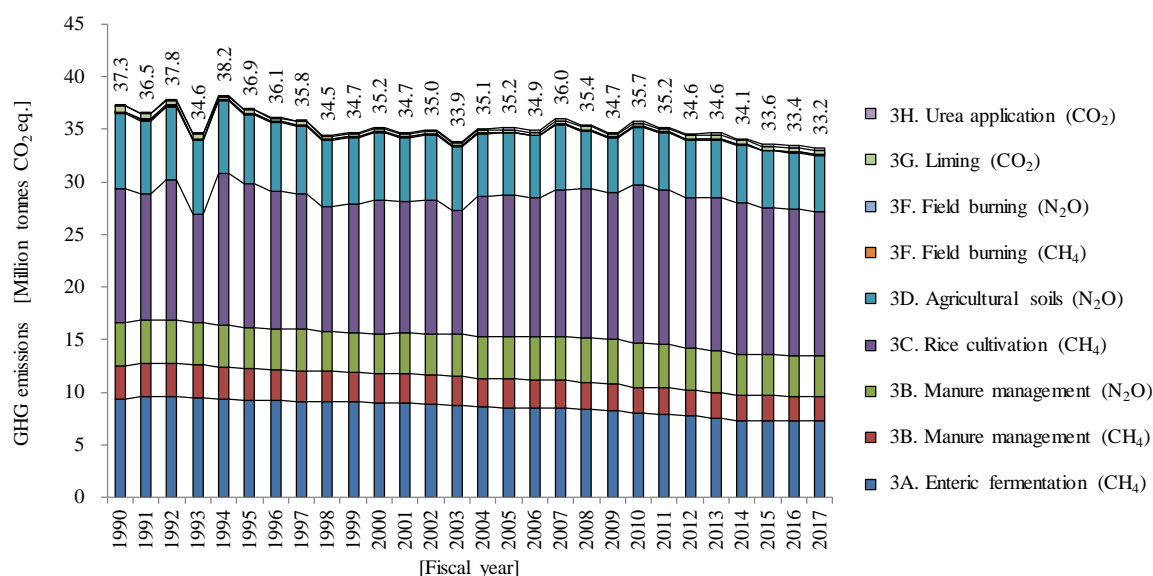


Figure 2-16 Trends in GHG emissions from the agriculture sector

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

Category	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
3A. Enteric fermentation (CH ₄)	9,351	9,257	8,935	8,520	8,354	8,242	7,967	7,924	7,733	7,525	7,339	7,330	7,275	7,283
3B. Manure management	7,235	6,929	6,608	6,730	6,865	6,842	6,671	6,621	6,501	6,373	6,277	6,272	6,233	6,239
CH ₄	3,121	2,988	2,804	2,717	2,599	2,573	2,513	2,508	2,465	2,406	2,364	2,362	2,321	2,323
N ₂ O	4,114	3,941	3,804	4,013	4,266	4,269	4,158	4,113	4,035	3,967	3,913	3,910	3,912	3,916
3C. Rice cultivation (CH ₄)	12,771	13,605	12,749	13,445	14,157	13,863	15,041	14,680	14,325	14,565	14,437	13,908	13,907	13,627
3D. Agricultural soils (N ₂ O)	7,121	6,604	6,344	5,936	5,468	5,228	5,552	5,436	5,439	5,494	5,433	5,426	5,388	5,408
3F. Field burning of agricultural residues	166	145	126	112	102	99	96	95	93	94	92	88	88	88
CH ₄	127	111	96	86	78	76	74	73	71	72	70	67	67	67
N ₂ O	39	34	30	26	24	23	23	22	22	22	22	21	21	21
3G. Liming (CO ₂)	550	304	333	231	306	270	243	247	370	380	363	363	363	363
3H. Urea application (CO ₂)	59	56	110	179	134	120	160	168	150	198	189	189	189	189
Total	37,253	36,900	35,204	35,153	35,385	34,665	35,730	35,172	34,610	34,630	34,130	33,575	33,442	33,196

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

Net removals (including CO₂, CH₄ and N₂O emissions) from the LULUCF sector in FY2017 was 57.5 million tonnes (in CO₂ eq.). They decreased by 8.0% since FY1990 and increased by 5.4% compared to the previous year. The long-term declining trend in removals from 2003 is largely due to the maturity of Japanese forests.

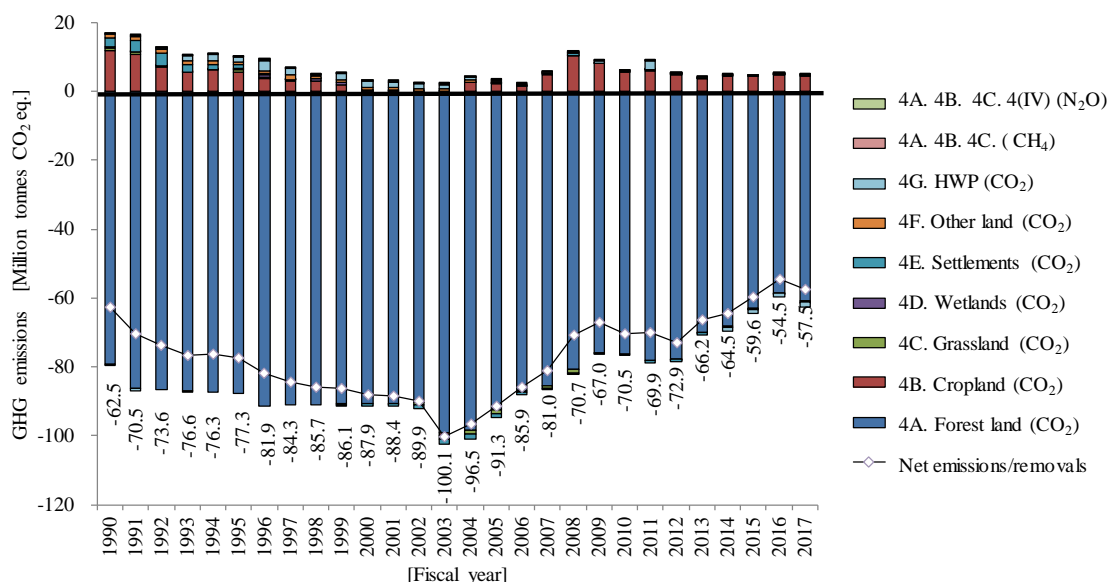


Figure 2-17 Trends in GHG emissions and removals from the LULUCF sector

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

[Thousand tonnes CO ₂ eq.]														
Category	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
4A. Forest land	-78,944	-87,481	-90,512	-92,532	-80,642	-75,762	-76,292	-78,007	-77,575	-69,879	-68,144	-62,989	-58,444	-60,702
CO ₂	-79,074	-87,612	-90,642	-92,665	-80,790	-75,893	-76,419	-78,135	-77,698	-70,006	-68,292	-63,120	-58,572	-60,854
CH ₄	10	10	9	11	26	10	5	6	2	4	23	6	1	23
N ₂ O	120	121	121	122	123	122	121	121	121	122.3	125.1	124.9	126.4	129.4
4B. Cropland	11,809	5,567	146	2,369	10,538	8,065	5,566	5,979	5,026	3,741	4,496	4,396	4,871	4,581
CO ₂	11,718	5,485	72	2,302	10,475	8,003	5,504	5,918	4,965	3,681	4,436	4,337	4,811	4,522
CH ₄	61	58	56	54	53	53	53	52	52	52	52	51	51	51
N ₂ O	30	24	18	12	10	9	9	8	8	9	9	8	8	9
4C. Grassland	1,083	715	71	-996	-1,001	-103	62	281	8	-63	119	-7	-65	-126
CO ₂	1,053	684	41	-1,026	-1,031	-134	32	250	-25	-95	87	-39	-95	-157
CH ₄	15	15	15	15	15	15	15	15	15	15	16	16	15	15
N ₂ O	15	16	15	15	15	16	15	16	17	16	16	16	15	15
4D. Wetlands	90	358	426	40	86	113	107	52	60	24	24	48	48	47
CO ₂	90	358	426	40	86	113	107	52	60	24	24	48	48	47
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
N ₂ O	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	2,645	1,093	-595	-1,034	408	-211	-300	-901	-661	-498	-344	-76	14	-111
CO ₂	2,645	1,093	-595	-1,034	408	-211	-300	-901	-661	-498	-344	-76	14	-111
CH ₄	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N ₂ O	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO
4F. Other land	1,166	960	693	163	319	232	217	179	181	163	162	186	184	191
CO ₂	1,155	950	684	156	314	227	212	175	177	160	159	182	181	188
CH ₄	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
N ₂ O	11	10	9	7	6	5	5	4	4	4	3	3	3	3
4G. HWP (CO ₂)	-365	1,481	1,830	618	-444	644	64	2,521	60	321	-874	-1,163	-1,159	-1,370
4H. Other (CO ₂)	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
4(IV) Indirect N ₂ O	41	38	35	32	31	31	31	31	31	31	31	32	32	32
Total	-62,475	-77,270	-87,907	-91,340	-70,704	-66,992	-70,547	-69,866	-72,871	-66,160	-64,530	-59,574	-54,520	-57,458

Breakdown of the FY2017 emissions and removals from this sector shows that the largest is CO₂ removals of 60.9 million tonnes, accounting for 106% of this sector's net total emissions / removals.

2.2.5. Waste

Emissions from the waste sector in FY2017 were 20.1 million tonnes (in CO₂ eq.). They decreased by 32.4% since FY1990 and by 0.9% compared to the previous year.

Breakdown of the FY2017 emissions from this sector shows that the largest source is waste incineration (CO₂), associated with waste derived from fossil fuels such as waste plastic and waste oil, accounting for 54%. It is followed by solid waste disposal (CH₄) (15%) and wastewater treatment and discharge (N₂O) (10%).

The main driving factor for the decrease in emissions since FY1990 is the decrease in CH₄ emissions from solid waste disposal on land as a result of decrease in the amount of disposal of biodegradable waste due to improvement of 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, and other recycling law (Act No.110, 2000).

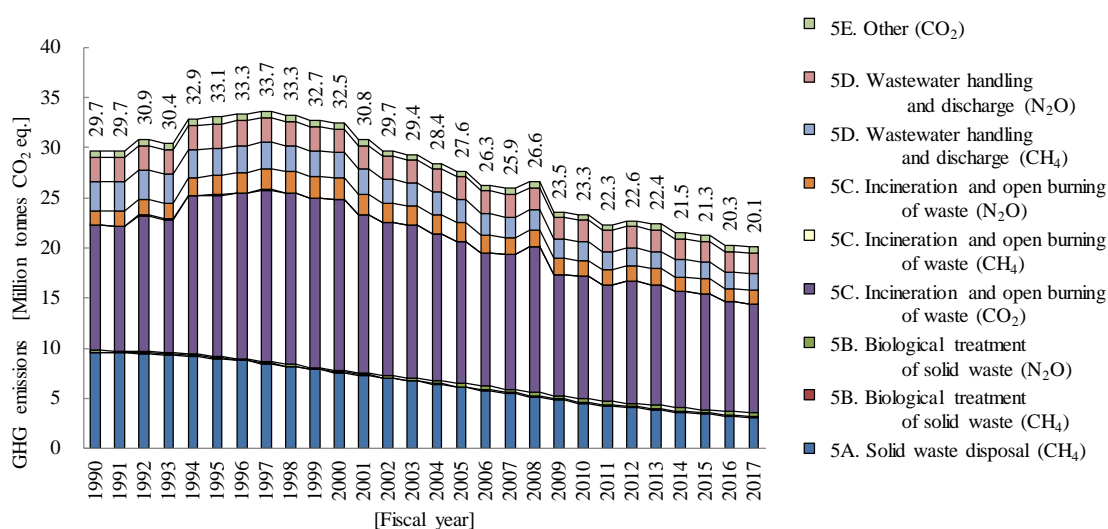


Figure 2-18 Trends in GHG emissions from the waste sector

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

Category	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
5A. Solid waste disposal (CH ₄)	9,570	8,985	7,570	6,090	5,141	4,835	4,521	4,272	4,058	3,855	3,635	3,440	3,242	3,081
5B. Biological treatment of solid waste	235	233	235	414	464	460	402	444	440	435	433	441	446	447
CH ₄	54	53	54	95	107	106	93	102	101	100	100	102	103	103
N ₂ O	181	179	181	319	357	354	309	342	338	335	333	340	343	344
5C. Incineration and open burning of waste	13,895	17,983	19,164	16,074	16,160	13,641	13,824	13,074	13,711	13,615	12,991	13,014	12,262	12,238
CO ₂	12,429	16,046	16,988	14,093	14,518	12,058	12,298	11,545	12,176	12,068	11,558	11,506	10,941	10,808
CH ₄	28	29	21	18	14	13	12	11	11	12	10	10	9	10
N ₂ O	1,438	1,908	2,156	1,963	1,628	1,570	1,515	1,518	1,523	1,535	1,423	1,498	1,312	1,421
5D. Wastewater treatment and discharge	5,329	5,189	4,857	4,538	4,274	4,063	4,041	4,010	3,898	3,867	3,799	3,751	3,717	3,708
CH ₄	2,942	2,750	2,556	2,230	2,038	1,940	1,899	1,859	1,811	1,771	1,743	1,714	1,685	1,673
N ₂ O	2,387	2,439	2,301	2,308	2,236	2,123	2,142	2,150	2,087	2,096	2,056	2,037	2,033	2,034
5E. Other (CO ₂)	703	668	656	507	530	514	527	524	528	605	617	625	619	636
Total	29,732	33,057	32,483	27,624	26,570	23,513	23,315	22,324	22,635	22,377	21,475	21,272	20,287	20,110

2.2.6. Indirect CO₂

See 2.1.9. above.

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

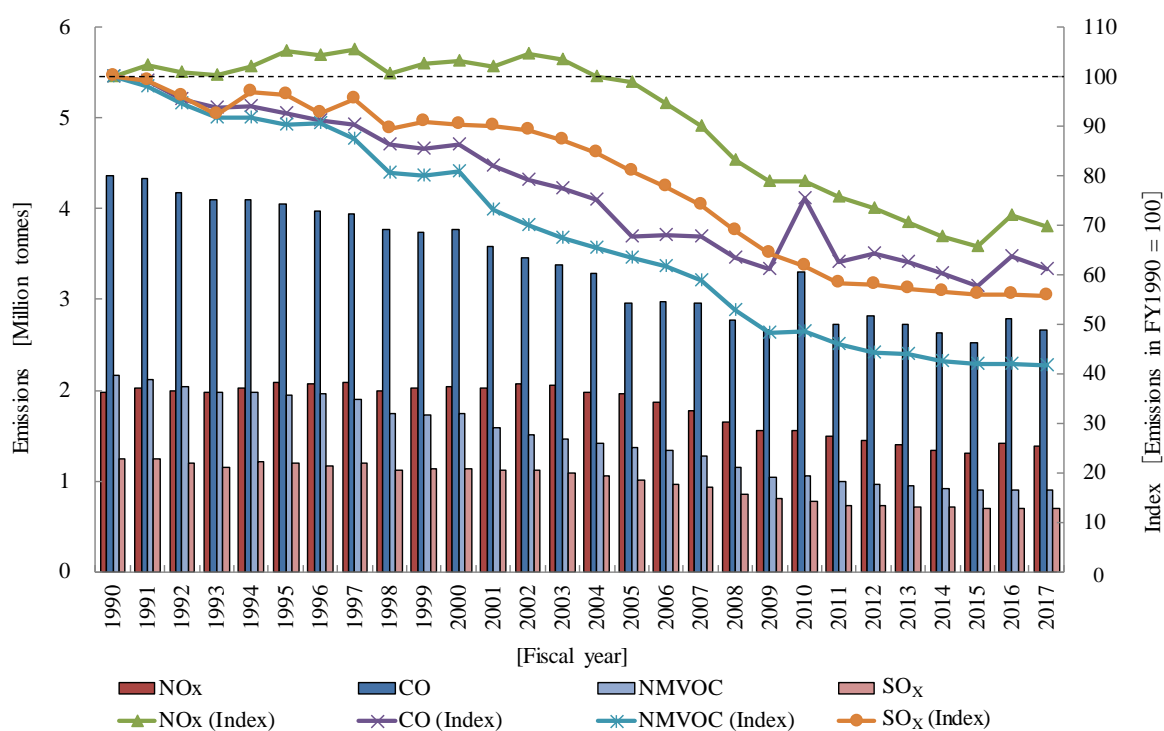
Under the revised UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention, it is required to report emissions not only of the 7 types of GHGs (CO₂, CH₄, N₂O, HFCs, PFCs, SF₆, and NF₃), but also emissions of indirect GHGs (NO_x, CO and NMVOC) as well as SO_x. Their emission trends are indicated below.

Nitrogen oxide (NO_x) emissions in FY2017 were 1.4 million tonnes. They decreased by 30.3% since FY1990 and 3.0% compared to the previous year.

Carbon monoxide (CO) emissions in FY2017 were 2.7 million tonnes. They decreased by 38.9% since FY1990 and 4.3% compared to the previous year¹¹.

Non-methane volatile organic compounds (NMVOC) emissions in FY2017 were 0.9 million tonnes. They decreased by 58.4% since FY1990 and decreased by 0.6% compared to the previous year.

Sulfur oxide (SO_x)¹² emissions in FY2017 were 0.7 million tonnes. They decreased by 44.3% since FY1990 and 0.8% compared to the previous year.



(* The line chart shows the trend as an index of FY1990 emissions set at 100.)

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

¹¹ The reason for the increase of CO emissions in FY2010 compared to the previous year is the change in the EF for road transportation, and the reason for the decrease of CO emissions in FY2011 compared to the previous year is the change in the share of furnace types in the iron and steel industry.

¹² Most SO_x consists of SO₂. For major sources, SO₂ emissions are estimated.

2.4. Emissions and removals from KP-LULUCF activities

The net removals from Kyoto Protocol Article 3.3 and 3.4 activities in FY2017 were 42.9 million tonnes (in CO₂ eq.). The breakdown of emissions and removals by each activity is shown below. For detailed information, see Chapter 11.

Table 2-16 Accounting summary for activities under articles 3.3 and 3.4 of the Kyoto Protocol (CRF Accounting table)

GREENHOUSE GAS SOURCE AND SINK ACTIVITIES	Base Year (1990)	NET EMISSIONS/REMOVALS				
		2013	2014	2015	2016	2017
(kt CO ₂ eq)						
A. Article 3.3 activities						
A.1. Afforestation/reforestation		-1607	-1610	-1604	-1598	-1569
Excluded emissions from natural disturbances		NA	NA	NA	NA	NA
Excluded subsequent removals from land subject to natural disturbances		NA	NA	NA	NA	NA
A.2. Deforestation		2029	2032	2141	2137	1846
B. Article 3.4 activities						
B.1. Forest management						
Net emissions/removals		-51065	-51394	-49002	-46463	-46135
Excluded emissions from natural disturbances		NA	NA	NA	NA	NA
Excluded subsequent removals from land subject to natural disturbances		NA	NA	NA	NA	NA
Any debits from newly established forest (CEF-ne)		NA	NA	NA	NA	NA
Forest management reference level (FMRL)		0	0	0	0	0
Technical corrections to FMRL		1097	1284	1438	1581	1724
Forest management cap						
B.2. Cropland management (if elected)	10281	3625	4370	4291	4764	4515
B.3. Grazing land management (if elected)	841	-273	-95	-161	-219	-257
B.4. Revegetation (if elected)	-79	-1223	-1241	-1262	-1280	-1290
B.5. Wetland drainage and rewetting (not elected)	NA	NA	NA	NA	NA	NA

* The total values and results of summing up each figure are not always the same because of the difference in display digit.

References

1. Cabinet Office, Government of Japan, *Annual Report on National Accounts*.
2. Intergovernmental Panel on Climate Change, *Fourth Assessment Report, 2007*.
3. Ministry of Internal Affairs and Communications, Statistics Bureau, *Annual Report of Population Estimates*.
4. Ministry of Internal Affairs and Communications, Statistics Bureau, *Population Census*.

Chapter 3. Energy (CRF sector 1)

3.1. Overview of Sector

Emissions from the energy sector consist of two main categories: fuel combustion and fugitive emissions from fuels. Fuel combustion includes emissions 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 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 CO₂ (Carbon Dioxide), CH₄ (Methane), N₂O (Nitrous Oxide), NO_x (Nitrogen Oxide), CO (Carbon Monoxide), and NMVOC (Non-Methane Volatile Organic Compounds) are emitted in the process.

In FY2017, GHG emissions (CO₂, CH₄ and N₂O) from the energy sector accounted for 1,137,031 kt-CO₂ eq., and represented 88.0% of Japan's total GHG emissions (excluding LULUCF). The emissions from the energy sector had increased by 4.1% compared to FY1990.

The methodologies are shown in the below table.

Table 3-1 Methodologies used in the energy sector

GREENHOUSE GAS SOURCE CATEGORIES	CO ₂		CH ₄		N ₂ O	
	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,T1,T3	CS,D	CS,T1,T3	CS,D
2. Manufacturing industries and construction	CS,T2	CS	CS,T1,T3	CR,CS	CS,T1,T3	CR,CS
3. Transport	T2	CS	T1,T2,T3	CS,D	T1,T2,T3	CS,D
4. Other sectors	T2	CS	T1,T3	CR,CS,D	T1,T3	CR,CS,D
5. Other						
1.B. Fugitive emissions from fuels	CS,T1	CS,D	CS,D,T1,T2,T3	CS,D	T1	D
1. Solid fuels	CS	CS	D,T1,T2,T3	CS,D	NA	NA
2. Oil and natural gas	CS,T1	CS,D	CS,T1	CS,D	T1	D
1.C. CO ₂ transport and storage	NA	NA				

(Note) D: IPCC default, T1: IPCC Tier1, T2: IPCC Tier2, T3: IPCC Tier3, 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 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.

(1.A.1) increased by 37.6% since FY1990 and decreased by 2.9% compared to the previous year. The main driving factor for the increase compared to the emissions in FY1990 is the increased solid fuel consumption for electricity 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 CO₂ emissions from manufacturing industries and construction (1.A.2) decreased by 22.0% since FY1990 and decreased by 1.2% 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). In the middle of 2000s, the CO₂ emissions were stable while the IIP increased, that implies the improvement of production efficiency due to the improvement of the operating ratio.

The CO₂ emissions from transport (1.A.3) increased by 2.1% compared to FY1990 and decreased by 0.8% compared to the previous year. The main driving factor for the increase compared to the emissions in FY1990 is the increase in emissions from passenger vehicles, compensating for the decrease in emissions from freight transportation. 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 CO₂ emissions from other sectors (1.A.4) decreased by 10.2% since FY1990 and increased by 1.0% 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 CO₂ emissions from commercial/institutional (1.A.4.a) are considered to have a moderate correlation with the *Indices of Tertiary Industry Activity* 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	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1	1.A. Fuel combustion	Final electricity consumption	TWh	765	872	973	1,025	1,022	989	1,035	997	991	990	974	949	950	964
2	1.A.2. Manufacturing	Indices of Industrial Production	CY2015=100	109.0	103.3	107.7	109.3	102.8	93.0	101.2	100.5	97.5	101.1	100.5	99.8	100.6	103.5
3	1.A.3.b. Road transportation	Vehicle kilometers traveled (VKT)	billion VKT	585	673	728	727	709	709	708	712	723	724	718	721	730	740
4	1.A.4.a. Commercial/institutional	Indices of Tertiary Industry Activity	CY2010=100	85.8	93.1	97.5	103.1	102.2	99.0	99.9	100.7	102.0	103.2	102.1	103.5	103.9	105.0

(Note) 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 *UNFCCC Inventory Reporting Guidelines* (Decision 24/CP.19 Annex I, paragraph 40). For the methodological issues of the sectoral approach, please refer to the section 3.2.4. b).

3.2.1.1. Methodological Issues of the Reference Approach

The reference approach is to calculate the CO₂ emissions from combustion, using a country's energy supply data. The CO₂ emissions estimated by the reference approach are not included in the national total and used for verification purpose. The CO₂ 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* : CO₂ emissions from fossil fuel combustion [t-CO₂]
A : Apparent energy consumption (original unit [t, kL, 10³×m³])
N : Non-energy use of fossil fuels (original unit)
GCV : Gross calorific value (higher heating value) [MJ/original unit]
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: $A = (\text{Production}) + (\text{Imports}) - (\text{Exports}) \pm (\text{Stock change} / \text{supply})$
 – (International bunkers)

Secondary fuels: $A = (\text{Imports}) - (\text{Exports}) \pm (\text{Stock change} / \text{supply})$
 – (International bunkers)

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

Term	Source ²
Production	Indigenously Produced (#110000) in Agency for Natural Resources and Energy's <i>General Energy Statistics</i> (Japan's Energy Balance Table)
Imports	Imported (#120000) in the statistics + International bunker fuels (see section 3.2.2.)
Exports	Export (#160000) in the statistics
Stock change / supply	Stockpile Change / Supply (#170000) in the statistics
International bunkers	See section 3.2.2.
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 the section 3.2.4. b).

The details of estimation results by reference approach are shown in the Common Reporting Format (CRF) table 1.A(b). The correspondence between fuels of the *General Energy Statistics* and those of the table is shown in Annex 4.

➤ *Discrepancies between the figures reported in the CRF tables and the IEA statistics*

Some discrepancies exist between the fuel data of energy supply and demand in the CRF 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 4 (A4.1).

² Numbers with # indicate the corresponding sector (row) numbers in the *General Energy Statistics* (Japan's Energy Balance Table).

3.2.1.2. Difference in Energy Consumption

As shown in Table 3-5, fluctuations of difference³ of energy consumption between the reference approach and the sectoral approach during FY1990-2017 range between -4.38% (FY2012) and -0.77% (FY2004).

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*.

The difference between those two approaches for solid fuels in FY2004 was a large value (+10.63%). It means that, in FY2004, because stocks of the coal on the consumer side (steel making coal [\$0110⁴]) 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, the difference between those two approaches for solid fuels in FY2008 was a large value (+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.

3.2.1.3. Difference in CO₂ Emissions

As shown in Table 3-6, fluctuations of a difference of CO₂ emissions between the reference approach and the sectoral approach during FY1990-2017 range between -1.89% (FY2012) and +2.38% (FY2004).

Emissions from wastes used for energy and from the incineration of wastes with energy recovery are not reported in waste incineration (5.C.) 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 (+9.94%, +6.24%), and small values in FY2005 and FY2009 (+2.05%, -1.92%). It is because of the same reason as the difference of energy consumption which is described in the previous section.

³ Difference = [(Reference approach)-(Sectoral approach)]/(Sectoral approach)

⁴ 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 (Unit: PJ)⁵

	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Reference Approach														
Liquid fuels	9,526	10,132	9,442	8,919	7,783	7,125	7,179	7,531	7,640	7,395	6,811	6,501	6,309	6,219
Solid fuels	3,285	3,602	4,179	4,763	4,920	4,385	4,979	4,653	4,864	5,284	5,080	5,137	5,022	5,024
Gaseous fuels	2,042	2,465	3,050	3,275	3,860	3,762	3,979	4,665	4,854	4,882	4,948	4,646	4,718	4,686
Other fossil fuels	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
Total RA	14,854	16,199	16,672	16,958	16,563	15,272	16,137	16,848	17,358	17,561	16,838	16,283	16,049	15,930
Sectoral Approach														
Liquid fuels	9,459	9,973	9,451	8,949	7,800	7,180	7,261	7,704	7,850	7,463	6,839	6,544	6,332	6,171
Solid fuels	3,368	3,597	3,986	4,638	4,606	4,447	4,819	4,660	4,878	5,221	5,133	5,063	4,978	4,977
Gaseous fuels	2,209	2,667	3,226	3,355	3,925	3,883	4,093	4,772	4,954	4,939	4,981	4,744	4,837	4,718
Other fossil fuels	281	318	373	457	462	442	450	450	471	461	466	462	494	495
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Total	15,318	16,555	17,035	17,399	16,793	15,952	16,624	17,586	18,153	18,084	17,419	16,813	16,641	16,361
Difference (%)														
Liquid fuels	0.71%	1.60%	-0.09%	-0.33%	-0.21%	-0.77%	-1.13%	-2.25%	-2.68%	-0.91%	-0.40%	-0.66%	-0.37%	0.79%
Solid fuels	-2.46%	0.15%	4.86%	2.70%	6.82%	-1.39%	3.32%	-0.17%	-0.29%	1.21%	-1.04%	1.45%	0.90%	0.96%
Gaseous fuels	-7.56%	-7.58%	-5.43%	-2.38%	-1.67%	-3.12%	-2.80%	-2.24%	-2.01%	-1.16%	-0.67%	-2.08%	-2.46%	-0.69%
Other fossil fuels	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
Total	-3.03%	-2.15%	-2.13%	-2.54%	-1.37%	-4.27%	-2.93%	-4.19%	-4.38%	-2.89%	-3.33%	-3.15%	-3.55%	-2.64%

Table 3-6 Comparison of CO₂ emissions (Unit: Mt-CO₂)

	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Reference Approach														
Liquid fuels	659.9	701.9	656.2	621.1	545.7	497.6	501.8	523.6	532.9	512.2	472.1	450.1	436.3	430.6
Solid fuels	295.7	323.7	377.9	431.1	444.9	396.8	450.8	420.8	439.9	474.5	457.3	462.1	451.2	450.9
Gaseous fuels	104.4	126.1	155.9	167.4	197.4	192.4	203.5	238.6	248.4	249.9	253.2	237.8	241.5	239.9
Other fossil fuels	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
Total RA	1,060	1,152	1,190	1,220	1,188	1,087	1,156	1,183	1,221	1,237	1,183	1,150	1,129	1,121
Sectoral Approach														
Liquid fuels	644.3	677.4	640.7	606.1	527.3	483.8	488.9	520.3	530.8	508.5	464.7	444.0	429.5	417.5
Solid fuels	309.5	327.1	364.1	422.4	418.8	404.6	438.5	423.2	442.8	473.6	466.5	460.1	451.6	451.4
Gaseous fuels	114.2	137.9	166.1	172.4	201.3	199.1	209.9	244.7	254.1	253.4	255.5	243.4	248.2	242.2
Other fossil fuels	10.9	12.4	15.2	17.1	16.8	15.6	15.9	16.0	17.1	16.7	16.3	16.8	17.6	17.4
Peat	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Total	1,079	1,155	1,186	1,218	1,164	1,103	1,153	1,204	1,245	1,252	1,203	1,164	1,147	1,128
Difference (%)														
Liquid fuels	2.42%	3.62%	2.43%	2.47%	3.49%	2.86%	2.64%	0.62%	0.40%	0.74%	1.58%	1.38%	1.57%	3.13%
Solid fuels	-4.47%	-1.05%	3.79%	2.05%	6.24%	-1.92%	2.79%	-0.58%	-0.65%	0.19%	-1.99%	0.43%	-0.10%	-0.11%
Gaseous fuels	-8.56%	-8.61%	-6.11%	-2.89%	-1.94%	-3.39%	-3.06%	-2.48%	-2.24%	-1.39%	-0.92%	-2.29%	-2.67%	-0.93%
Other fossil fuels	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
Total	-1.75%	-0.28%	0.34%	0.13%	2.05%	-1.48%	0.25%	-1.77%	-1.89%	-1.24%	-1.71%	-1.23%	-1.56%	-0.63%

3.2.1.4. Comparison between Differences in Energy Consumption and that of CO₂ Emissions

The difference in energy consumption and the difference in CO₂ emissions generally show a similar tendency for their trends.

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

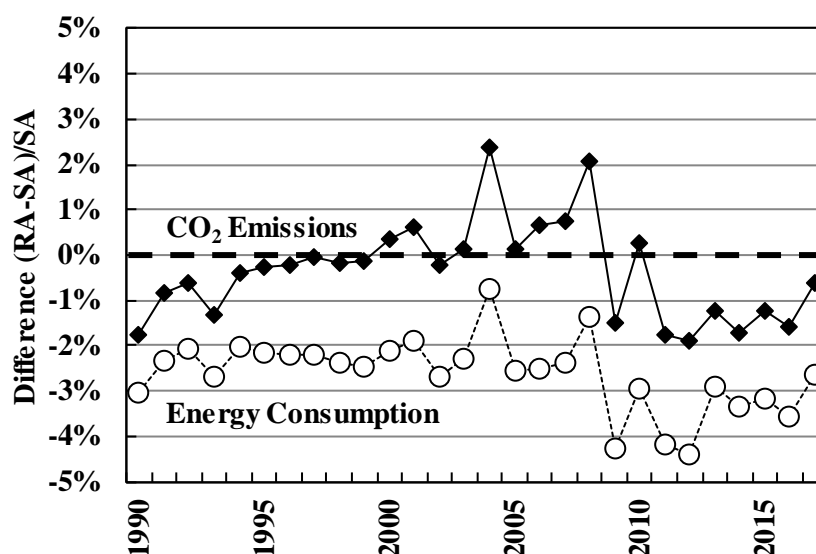


Figure 3-1 Trends in difference of energy consumption and CO₂ emissions

3.2.1.5. Causes of the difference between Reference Approach and Sectoral Approach

The difference in energy consumption and in CO₂ emissions can be explained by the difference of the amount of carbon which were deducted as feedstock and non-energy use in each approach, and ‘coal blending’ [#211000], ‘oil product blending’ [#221000], ‘coal products secondary transformation’ [#281000], ‘oil products secondary transformation’ [#282000], ‘other transformation’ [#289000], ‘transformation and consumption stockpile change’ [#350000], and ‘statistical discrepancy’ [#400000] 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. For example, the emissions from lubricants used in two stroke engines are not accounted for in the reference approach emission calculation.

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

- ***Supply Side Discrepancy [#401000]***

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, conversion, and consumption. It is sometimes difficult to guess where the discrepancies come from (relative error).

These errors induce the discrepancies among domestic supply, conversion, 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 conversion that does not belong to any of the sectors from Coke production [#212000] to Steel process gas [#215000] and from Oil refinery [#222000] to District heat supply [#270000], and actions considered to be energy conversion 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 conversions. 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 conversions. This difference can generate the variation between two approaches.

4) ***Matters related to the conversion to another fuel type***

- ***Gas Conversion and Production [#231000]***

This sector represents energy conversion arising from city gas production. City gas is made from liquid and solid fuels such as liquefied petroleum gas (LPG) and coke oven gas (COG) as well as gaseous fuels such as liquefied natural gas (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.

b) Methodological Issues

● Estimation Method

The emissions of CO₂, CH₄ and N₂O from this source are derived by multiplying the consumption of each fuel type handled by bonds by the emission factor.

● Emission Factors

➤ CO₂

The emission factors used for CO₂ are the same as those from fuel combustion (CO₂) 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 *IPCC Guidelines* (18.5 t-C/TJ based on the gross calorific value). 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* and the Japanese EF is inside the range. Therefore, Japan considers that this country-specific EF is appropriate value, comparing to the default value.

➤ CH₄, N₂O

The default values given in the *2006 IPCC Guidelines* are used for CH₄ and N₂O emission factors.

Table 3-8 Emission factors for CH₄ and N₂O from international bunkers

Transport mode	Type of fuel	CH ₄ emission factor [kg-CH ₄ /TJ(NCV)]	N ₂ O emission factor [kg-N ₂ O/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⁾

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, CH₄ and N₂O emissions from lubricants are very small in comparison to CO₂, 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*) compiled by the Ministry of Economy, Trade and Industry (METI) are used for the emissions of CO₂, CH₄, and N₂O 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 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 aircraft, 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.

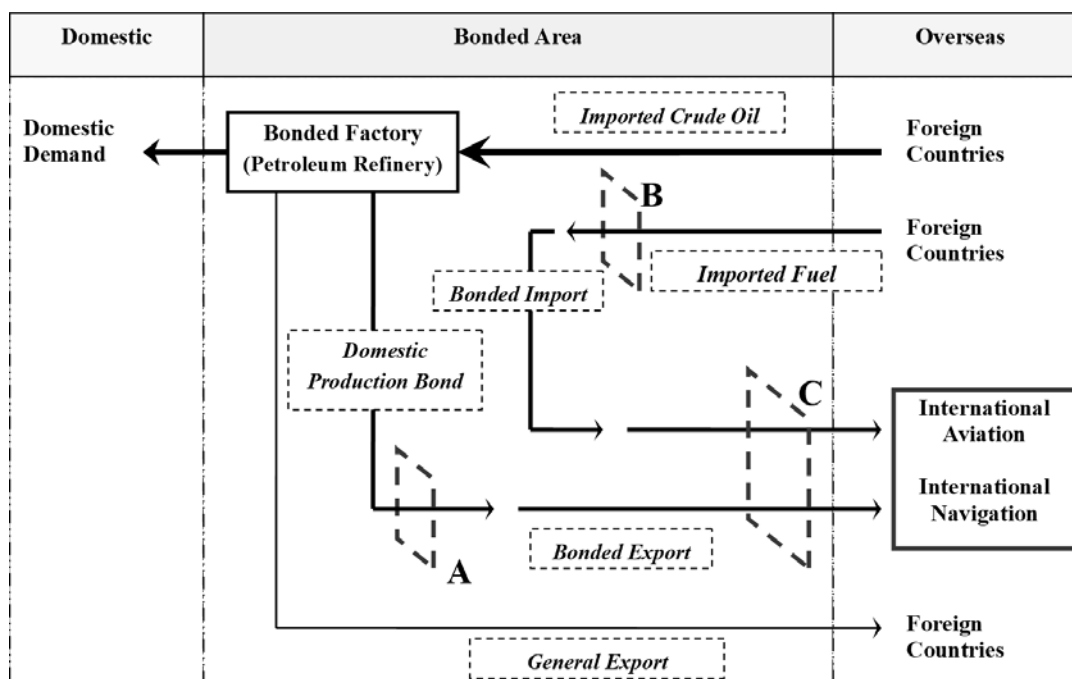


Figure 3-2 Activity data for international bunkers

➤ CO_2

The kiloliter-based consumption data given in the METI's *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* by the Agency for Natural Resources and Energy (ANRE).

➤ 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 METI.

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 METI.

3.2.3. Feedstocks and Non-Energy Use of Fuels

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 *Current Survey of Energy Consumption* which is the data source 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 *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 the Common Reporting Format (CRF) table 1.A(d). The correspondence between fuels of the *General Energy Statistics* and those of the table is shown in Annex 4.

The CO₂ 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 CO₂ emissions” column of the CRF 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 CO₂ emissions from fuel used for non-energy purpose such as feedstock

CO ₂ emitting process	CRF 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 3-18
		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	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	

1) CO₂ emissions from automobile and marine engine oils (total loss type) are included in Transport (1.A.3).

2) CO₂ 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 CO₂ 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 CO₂ emissions" column of CRF 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 CO₂ emissions from iron and steel and non-ferrous metals process

CO ₂ emitting process	Type of fuel used for non-energy purpose such as feedstock	Allocation as per IPCC Guidelines	Allocation used by the Party
Iron and steel reduction, Pig iron, Direct reduced iron, Sinter, Pellet	Coke, pulverized coal, waste plastics	2.C.1	1.A.2.a (Iron and steel)
Ferrous alloys production	Coke	2.C.2	1.A.2.a (Iron and steel)
Aluminium production	Coke	2.C.3	1.A.2.b (Non-ferrous metals)
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. CO₂ Emissions from Energy Industries (1.A.1.:CO₂)

a) Category Description

This section provides the methods for estimating CO₂ 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 FY2017, CO₂ emissions from this category accounted for 507,090 kt-CO₂, and represented 39.3% of Japan's total GHG emissions (excluding LULUCF). Public electricity and heat production (1.A.1.a) accounts for 89.6% and is the largest subcategory in energy industries (1.A.1).

The IEFs (Implied Emission Factor)⁶ of CO₂ emissions from solid fuels in 1.A.1.c (Manufacture of solid fuels and other energy industries) have been pulled up and down by fluctuation of carbon balances 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). Country-specific emission factors are used for all types of fuel.

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

E : CO₂ emissions from fossil fuel combustion [t-CO₂]

A : Energy consumption (original unit [t, kL, 10³×m³])

N : Non-energy use of fossil fuels (original unit)

GCV : Gross calorific value [MJ/original unit]

EF : Carbon content of the fuel [t-C/TJ]

OF : Oxidation factor

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.) in accordance with the *2006 IPCC Guidelines*. Please refer to Chapter 7 for further details on the estimation methods.

The CO₂ emissions from biomass are not included in the national totals but are reported in the CRFs 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 CO₂ emissions from biofuels are not considered as fossil fuel origin by adjusting the calorific value and the carbon emission

⁶ Indicators obtained by dividing the emissions in the common reporting format (CRF) by the activity data in the CRF.

factors of gasoline and diesel oil.

CO₂ generated from an oil refinery plant was captured and stored from fiscal year 2004 to 2007 and 2016 onward, and it is reported under “CO₂ amount captured” in liquid fuels of 1.A.1.b Petroleum refining of the CRF table 1.A(a). It is subtracted from the emissions estimated by the above formula. Please refer to the section 3.4.4. for details.

- **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. The emission factors are country-specific values except for a part of fuels where the default value provided in the *2006 IPCC Guidelines* was applied.

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 CO₂ by fuel types.

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

Fuel	Code ¹⁾	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017		
Solid fuels	Coal	Steel making coal	\$0110	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.6	24.6	24.6	24.6	24.6	
		Coking coal	\$0111	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.4	24.4	24.4	24.4	
		Pulverized coal injection (PCI) coal	\$0112	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5	24.5	25.1	25.1	25.1	25.1	
		Imported steam coal	\$0121	24.7	24.7	24.7	24.7	24.7	24.7	24.7	24.7	24.7	24.4	24.4	24.4	24.4	
		Imported steam coal for general use	\$0122	24.7	24.7	24.7	24.7	24.7	24.7	24.7	24.7	24.7	24.4	24.4	24.4	24.4	
		Imported steam coal for power generation use	\$0123	24.7	24.7	24.7	24.7	24.7	24.7	24.7	24.7	24.7	24.4	24.4	24.4	24.4	
		Indigenous produced steam coal	\$0124	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9	24.9	23.7	23.7	23.7	23.7	
		Hard coal, anthracite & lignite	\$0130	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.5	25.9	25.9	25.9	25.9	
	Coal Products	Coke	\$0211	29.4	29.4	29.4	29.4	29.4	29.4	29.4	29.4	30.2	30.2	30.2	30.2	30.2	
		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	
		Coal briquette	\$0213	29.4	29.4	29.4	29.4	29.4	29.4	29.4	29.4	29.4	25.9	25.9	25.9	25.9	
		Coke oven gas	\$0221	11.0	11.0	11.0	11.0	11.0	11.0	11.0	11.0	10.9	10.9	10.9	10.9	10.9	
		Blast furnace gas	\$0222	27.2	26.9	26.7	26.5	26.5	26.5	26.4	26.3	26.2	26.5	26.6	26.5	26.5	
		Converter furnace gas	\$0225	38.4	38.4	38.4	38.4	38.4	38.4	38.4	38.4	38.4	41.7	41.7	41.7	41.7	
		Oil	Crude oil for refinery use	\$0310	19.1	19.0	19.0	19.1	19.1	19.0	19.1	19.1	19.1	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	19.1	19.1	19.1	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	21.5	21.4	21.4	21.5	21.5	19.7	19.6	19.5	19.6	
Crude oil for power generation use	\$0320		19.1	19.1	19.2	19.6	19.2	19.3	19.2	19.1	19.1	19.2	19.2	19.3	19.3		
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		
Natural gas liquid (NGL) & condensate	\$0330		16.1	16.7	17.5	18.2	19.4	18.4	18.4	17.3	18.3	18.3	18.3	18.3	18.3		
NGL&condensate for refinery use	\$0331		17.4	18.1	18.0	18.3	19.4	18.4	18.4	17.3	18.4	18.3	18.3	18.3	18.3		
NGL&condensate for power generation use	\$0332		17.5	17.6	17.6	18.2	19.0	17.9	17.9	17.9	17.9	18.2	18.2	18.2	18.2		
NGL&condensate for petrochemical use	\$0333		15.6	16.2	16.8	17.6	18.8	17.9	18.0	16.9	18.2	18.3	18.2	18.2	18.3		
Liquid fuels	Oil Products		Pure naphtha	\$0420	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.2	18.6	18.6	18.6	18.6	
			Reformed feedstock Oil	\$0421	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	19.3	19.3	19.3	19.3
		Gasoline (crude oil origin) ²⁾	\$0431	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.7	18.7	18.7	18.7		
		Gasoline (biofuel blended) ³⁾		18.3	18.3	18.3	18.3	18.3	18.3	18.2	18.2	18.2	18.6	18.6	18.6	18.5	
		Jet fuel oil	\$0432	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.3	18.6	18.6	18.6	18.6	
		Kerosene	\$0433	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	18.5	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	18.7	18.7	18.7	18.7	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	18.7	18.7	18.7	18.7	18.8	18.8	18.8	18.8	
		Fuel oil A	\$0436	18.9	18.9	18.9	18.9	18.9	18.9	18.9	18.9	19.3	19.3	19.3	19.3	19.3	
		Fuel oil C	\$0437	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	19.5	20.2	20.2	20.2	20.2	
		Fuel oil B	\$0438	19.2	19.2	19.2	19.2	19.2	19.2	19.2	19.2	19.2	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	19.5	19.5	19.5	19.5	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	19.5	19.5	19.5	19.5	19.8	19.8	19.8	19.8	
		Miscellaneous oil products	Lubricant oil	\$0451	19.2	19.2	19.2	19.2	19.2	19.2	19.2	19.2	19.9	19.9	19.9	19.9	
			Other heavy oil products	\$0452	20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.8	20.4	20.4	20.4	
			Oil coke	\$0455	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	25.4	24.5	24.5	24.5	
			Galvanic furnace gas	\$0456	38.4	38.4	38.4	38.4	38.4	38.4	38.4	38.4	41.7	41.7	41.7	41.7	
Refinery gas	\$0457		14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.2	14.4	14.4	14.4			
Liquefied petroleum gas (LPG)	\$0458	16.5	16.5	16.5	16.5	16.5	16.5	16.5	16.5	16.5	16.4	16.4	16.4				
Gaseous fuels	Natural Gas	Liquefied natural gas (LNG)	\$0510	13.9	13.9	13.9	13.9	13.9	14.0	14.0	14.0	14.0	14.0	14.0	14.0		
		Indigenous natural gas	\$0520	13.9	13.9	13.9	13.9	13.9	13.9	13.9	13.9	14.0	14.0	14.0	14.0		
		Indigenous natural gas	\$0521	13.9	13.9	13.9	13.9	13.9	13.9	13.9	13.9	13.9	14.0	14.0	14.0		
		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			
		Boil off gas from crude oil	\$0523	13.9	13.9	13.9	13.9	13.9	13.9	13.9	13.9	14.0	14.0	14.0	14.0		
	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			
(Reference)	Biomass	Small scale community gas	\$0620	16.5	16.5	16.5	16.5	16.5	16.5	16.5	16.5	16.4	16.4	16.4	16.4		
		Woods	\$N131	30.2	30.2	30.2	30.9	30.9	30.9	30.9	30.9	30.9	29.6	29.6	29.6		
		Waste woods	\$N132	30.2	30.2	30.2	30.9	30.9	30.9	30.9	30.9	30.9	29.6	29.6	29.6		
		Bioethanol	\$N134	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.6	17.6	17.6		
		Biodiesel	\$N135	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.2	17.6	17.6	17.6		
		Thermal use of black liquor	\$N136	26.8	26.8	26.8	25.6	25.6	25.6	25.6	25.6	25.6	24.9	24.9	24.9		
Gas biomass	\$N137	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	12.4	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 of carbon emission factors for fuel combustion

Fuel	Code ¹⁾	References (FY1990-2012)	References (FY2013-)	
Solid fuels	Coal	Steel making coal	\$0110	-
		Coking coal	\$0111	2006 IPCC Guidelines
		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	Report on Estimation of CO ₂ Emissions in Japan
		Imported steam coal for power generation use	\$0123	Same as imported steam coal for general use
		Indigenous produced steam coal	\$0124	Report on Estimation of CO ₂ Emissions in Japan
		Hard coal, anthracite & lignite	\$0130	2006 IPCC Guidelines
		Coke	\$0211	Report on Estimation of CO ₂ Emissions in Japan
		Coal tar	\$0212	2006 IPCC Guidelines
		Coal briquette	\$0213	Report on Estimation of CO ₂ Emissions in Japan
		Coke oven gas	\$0221	2006 IPCC Guidelines
		Blast furnace gas	\$0222	Values based on the carbon balance in blast furnace and converter furnace
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	Values calculated by weighted average of emission factors by brands based on import share
		Residual and straight run fuel oil for refinery use	\$0312	Values calculated by weighted average of emission factors by brands based on import share
		Crude oil for power generation use	\$0320	Estimated by interpolating by approximate equation of crude oil for refinery use
		Bituminous mixture fuel	\$0321	2006 IPCC Guidelines
		Natural gas liquid (NGL) / condensate	\$0330	
		NGL/condensate for refinery use	\$0331	Values calculated by weighted average of emission factors by brands based on import share
		NGL/condensate for power generation use	\$0332	Values calculated by weighted average of emission factors by brands based on import share
		NGL/condensate for petrochemical use	\$0333	
		Pure naphtha	\$0420	Report on Estimation of CO ₂ Emissions in Japan
		Reformed feedstock Oil	\$0421	Values of gasoline
		Gasoline (crude oil origin)	\$0431	Report on Estimation of CO ₂ Emissions in Japan
		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	Report on Estimation of CO ₂ Emissions in Japan		
Kerosene	\$0433	Report on Estimation of CO ₂ Emissions in Japan		
Gas oil or diesel oil (crude oil origin)	\$0434	Report on Estimation of CO ₂ Emissions in Japan		
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	Report on Estimation of CO ₂ Emissions in Japan		
Fuel oil C	\$0437	Same as fuel oil C for general use		
Fuel oil B	\$0438	Report on Estimation of CO ₂ Emissions in Japan		
Fuel oil C for general use	\$0439	Report on Estimation of CO ₂ Emissions in Japan		
Fuel oil C for power generation use	\$0440	Report on Estimation of CO ₂ Emissions in Japan		
Miscellaneous oil products	Lubricant oil	\$0451	Report on Estimation of CO ₂ Emissions in Japan	
	Other heavy oil products	\$0452	Report on Estimation of CO ₂ Emissions in Japan	
	Petroleum coke	\$0455	Report on Estimation of CO ₂ Emissions in Japan	
	Galvanic furnace gas	\$0456	Values of converter furnace gas	
	Refinery gas	\$0457	Report on Estimation of CO ₂ Emissions in Japan	
	Liquefied petroleum gas (LPG)	\$0458	Values calculated by weighted average of theoretical EF 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	Values calculated by weighted average of emission factors by production area based on the share of imports by country
		Indigenous natural gas	\$0520	2006 IPCC Guidelines
		Indigenous natural gas	\$0521	Values of indigenous natural gas
		Coal mining gas	\$0522	Report on Estimation of CO ₂ Emissions in Japan
		Boil off gas from crude oil	\$0523	Values of indigenous natural gas
		City Gas	City gas	\$0610
Small scale community gas	\$0620		Values of liquefied petroleum gas	
(Reference)	Biomass	Woods	\$N131	Actual measurements provided by JPA
		Waste woods	\$N132	Actual measurements provided by JPA
		Bioethanol	\$N134	Theoretical carbon emission factor of ethanol in normal condition
		Biodiesel	\$N135	Actual measurements provided by JPA
		Thermal use of black liquor	\$N136	Actual measurements provided by JPA
		Gas biomass	\$N137	Theoretical carbon emission factor of methane in normal condition

1) Code number for fuels of the *General Energy Statistics* (Energy Balance Table)

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

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

The values used for carbon emission factors of energy sources other than blast furnace gas (BFG) and city gas were provided in “*The Report on Estimation of CO₂ Emissions in Japan* (Environmental Agency, 1992)”, “*GHGs Estimation Methods Committee Report* (Committee for the Greenhouse Gases Emissions Estimation Methods, Ministry of the Environment)”, “*Recommendation of the Draft Revised Standard Calorific Value and Carbon Emission Factor for Fossil Fuel Energy Sources in Japan*” (Kainou, 2014) and “*2006 IPCC Guidelines*”.

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

The evaluation results in *Evaluating and Analyzing the Validity of Carbon Emission Factors for Different Fuels* (Kainou, 2005) were adopted for setting emission factors. In the choice of carbon emission factors, an adequacy assessment of emission factors was conducted in *the Report on Estimation of CO₂ Emissions in Japan* (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 standard 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 values⁷ 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 appropriately judged 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.

⁷ When *Evaluating and Analyzing the Validity of Carbon Emission Factors for Different Fuels* was submitted, the *2006 IPCC Guidelines* had not been published yet. These values were reference values, and some of these reference values were revised.

- ***Methodological issues of carbon emission factors from FY2013 onward***

The values through the survey conducted by METI and the Ministry of the Environment (MOE) on the standard calorific values (CV) and carbon 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 standard CVs and CEFs from FY2013 were presented in “*Recommendation of the Draft Revised Standard Calorific Value and Carbon Emission Factor for Fossil Fuel Energy Sources in Japan*” (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 standard 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 standard 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, standard 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, standard 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 standard 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.

(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.

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

EF : Carbon emission factor [t-C/TJ]

A : Fuel consumption [TJ]

BFG : Blast Furnace Gas

coal : PCI coal

coke : Coke

CFG : Converter Furnace Gas

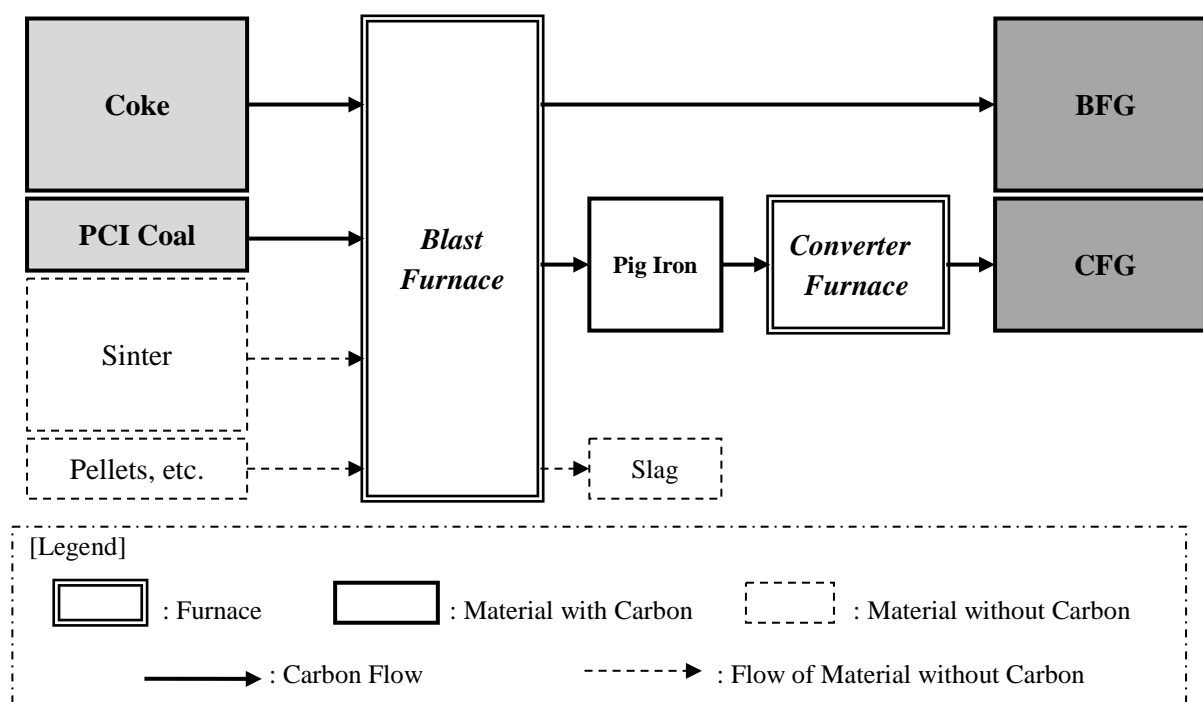


Figure 3-3 Overview of carbon flow for iron & steel manufacturing

Table 3-13 Calculation process of emission factors for BFG

Steel process gas		1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Note
Input																
PCI coal	kt-C	1,650	2,619	3,351	3,014	2,859	2,576	3,444	3,669	4,019	4,401	4,283	4,180	4,206	4,250	A
Coke	kt-C	12,739	11,400	12,221	11,497	10,928	10,458	11,194	10,137	10,187	10,870	10,917	10,270	10,196	9,739	B
Input total	kt-C	14,389	14,019	15,572	14,511	13,786	13,034	14,637	13,806	14,206	15,271	15,200	14,449	14,402	13,989	C: A + B
Output																
CFG (LDG)	kt-C	2,541	2,359	2,726	2,804	2,727	2,589	2,798	2,502	2,612	2,955	2,941	2,778	2,770	2,589	D
Difference	kt-C	11,848	11,660	12,846	11,707	11,059	10,444	11,839	11,304	11,594	12,316	12,260	11,671	11,632	11,400	E: C - D
Output																
BFG	TJ	434,801	433,504	481,768	441,357	417,636	393,685	448,708	429,625	442,758	464,522	461,735	440,073	438,870	429,842	F
EF BFG	t-C/TJ	27.2	26.9	26.7	26.5	26.5	26.5	26.4	26.3	26.2	26.5	26.6	26.5	26.5	26.5	E / F

(c) City gas

“City gas” consists of “city gas” provided by general gas supplier and “small-scale community gas” provided by small-scale community gas supplier.

Small-scale community gas suppliers:

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

General gas suppliers:

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

i : Feedstocks (COG, Kerosene, Refinery gas, LPG, LNG, Indigenous natural gas)

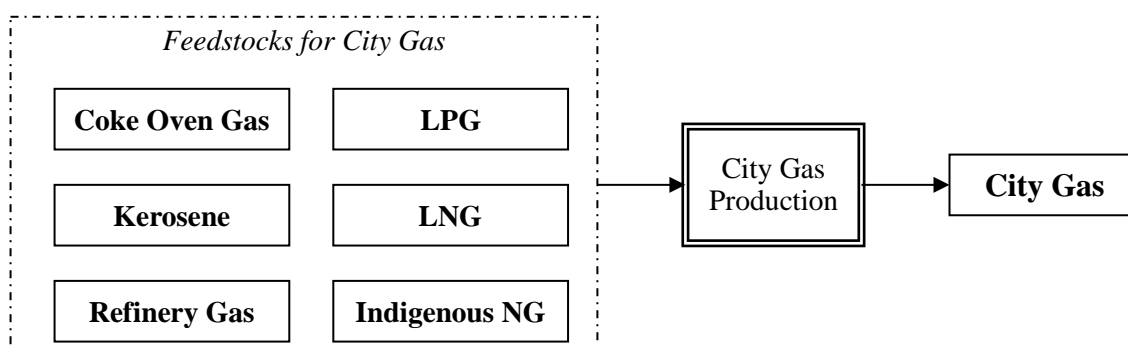


Figure 3-4 Manufacturing flow for city gas

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

City gas		1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Note
Input																
COG	kt-C	211	134	105	22	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	a2
Refinery gas	kt-C	186	199	186	145	88	94	89	83	82	67	56	37	48	43	a3
LPG	kt-C	1,957	2,129	1,809	1,092	694	706	786	869	891	930	992	818	837	947	a4
LNG	kt-C	6,473	9,429	12,051	17,146	20,065	19,865	21,357	21,957	22,216	21,709	21,863	21,868	22,907	23,252	a5
Indigenous NG	kt-C	551	661	848	1,190	1,822	1,768	1,603	1,635	1,557	1,498	1,479	1,435	1,415	1,347	a6
Input total	kt-C	9,577	12,827	15,068	19,601	22,670	22,433	23,834	24,544	24,746	24,205	24,390	24,159	25,206	25,589	A: Σa
Output																
Town gas	TJ	664,661	892,307	1,061,122	1,391,962	1,618,085	1,600,767	1,700,309	1,750,295	1,764,069	1,724,329	1,737,259	1,722,115	1,796,517	1,822,537	B
EF Town 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	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 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.

Table 3-15 Data of gaseous fuel combustion

Fired condition	Provider	Survey
Complete combustion	The Federation for Electric Power Companies Japan (FEPC)	Measurement of soot concentration of boilers to generate power in 2004

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 CO₂ 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* compiled by ANRE were used for the activity data. Table 3-16 shows the trend of energy consumption.

Table 3-16 Energy consumptions in Energy Industries (1.A.1) (unit: PJ)

Fuel ¹⁾	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Liquid fuels	2,596	2,198	1,618	1,669	1,660	1,257	1,352	1,885	2,166	1,845	1,440	1,282	1,167	1,038
Solid fuels	1,235	1,542	1,951	2,586	2,605	2,569	2,757	2,655	2,835	3,119	3,070	3,051	3,044	3,084
Gaseous fuels	1,564	1,786	2,167	2,021	2,429	2,451	2,624	3,266	3,475	3,485	3,549	3,298	3,374	3,198
Other fossil fuels	IE	IE	0	5	4	5	5	5	5	0	1	1	1	1
Biomass	0	0	0	26	26	23	28	28	28	32	33	33	52	87
Total	5,395	5,526	5,737	6,308	6,724	6,304	6,767	7,839	8,511	8,481	8,093	7,666	7,638	7,409

1) Fuel type of Common Reporting Format (CRF)

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 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, conversion 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/m³), and that homogeneous energy sources are supplied, converted and consumed. The values for supply, conversion 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, m³, etc.).
- (4) Preparing energy unit tables (unit in J).
- (5) Preparing energy-derived carbon tables (carbon content).

The *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 complete Energy Balance Tables for the years since FY1990 are available on the following internet

site:

http://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 4 (A4.2).

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; “district heat supply” [#270000] which provides energy consumption associated with heat energy and cold energy by 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, district 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 3-17 shows the correspondence between the sectors of Japan’s Energy Balance Table from the *General Energy Statistics* and those of the CRF.

Table 3-17 Correspondence between sectors of Japan’s Energy Balance Table and those of the CRF (1.A.1)

CRF		General Energy Statistics	
1A1	Energy industries		
	1A1a Public electricity and heat production	Power generation	#240000
		Own use; 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
	1A1b 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
	1A1c 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

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

➤ Gross calorific value

The gross calorific values used in *General Energy Statistics* are adopted. Table 3-18 shows the trends in gross calorific value 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 latest revision was conducted to the FY2013 values with the revision of the carbon emission factors.

The gross calorific value (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.

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 1990 to 2017 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 source of activity data. As a result, the uncertainty was determined to be -4% to +2% for CO₂ 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 CO₂ 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 Chapter 1.

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 all years were recalculated.

For the purpose of ensuring time-series consistency and comparability, the reporting category of some sources was revised. In the *General Energy Statistics*, fossil fuel consumption in the “Production, Transmission and Distribution of Electricity” [#255330] under the “Auto power production” was previously included in the Commercial/institutional subcategory (1.A.4.a), but it was reclassified into the Public electricity and heat production subcategory (1.A.1.a) for FY1990 through FY2015. In addition, the emissions from the waste incineration for energy purposes and with energy recovery reported in 1.A.1.a were reclassified into 1.A.4.a for all years in accordance with the *2006 IPCC Guidelines* because the main industry is waste disposal rather than power generation. Therefore, the emissions were recalculated for all years. For your reference, this reclassification between these subcategories does not change the total CO₂ emissions from Fuel combustion category (1.A).

Updating the statistical data and improving the estimation methodology in the waste sector, CO₂ emissions from other fossil fuels for the period of FY2005-FY2016 were recalculated. See section 7.4.3

for details.

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

3.2.5. CH₄ and N₂O Emissions from Energy Industries (1.A.1.:CH₄, N₂O)

a) Category Description

This section provides the methods for estimating CH₄ and N₂O 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).

CH₄ is generated as a result of incomplete combustion, and as such, if sufficient care is taken to ensure complete combustion, CH₄ will not be generated. N₂O is generated through the reaction of 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 N₂O will be generated. However, the reaction that produces N₂O is also dependent on temperature, with N₂O more likely to be generated at lower temperatures. More N₂O will accordingly be generated by furnaces such as fluidized bed boilers that burn fuel at low temperatures (800–900°C). N₂O can also be generated when NO_x contacts catalysts for NO_x removal.

The contribution of CH₄ and N₂O emissions from this category relative to total GHG emissions is small in Japan. The N₂O emissions from fluidized bed boilers are relatively large in this category. The N₂O emissions from fluidized bed boilers contribute to the increase of GHG emissions from this category, since fluidized bed boilers have been introduced in Japan from 1990.

The N₂O 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 N₂O emissions from solid fuels in this category.

CH₄ emitted in coke production is reported in this category. We have no measurements of the concentration of N₂O in the gas leaking from coking furnace lids, but we decided that N₂O emissions from this source are not applicable the reason being that experts say that N₂O 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, CH₄ and N₂O 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.

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

E	: Emissions from combustion of fuel by stationary sources [kg-CH ₄ , kg-N ₂ O]
EF_{ij}	: Emission factor for fuel type i , furnace type j [kg-CH ₄ /TJ, kg-N ₂ O/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, CH₄ and N₂O 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, CH₄ and N₂O emissions of gas biomass are calculated by using Tier 1, as country-specific emission factors are not available.

➤ *Coke Production*

CH₄ 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.

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

See section 7.4.3

● *Emission Factors*

➤ *Furnaces*

Chimney flue CH₄, N₂O and O₂ concentrations, theoretical (dry) exhaust gas volumes, theoretical air volumes, and higher heating values (gross calorific values (GCV)) shown in Table 3-19 were employed based on data obtained from surveys conducted in Japan (Table 3-20) 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 ₂ O/TJ]
$C_{CH_4 \text{ or } N_2O}$: CH ₄ or N ₂ O concentration in exhaust gas [ppm]
G_0'	: Theoretical exhaust gas volume for each fuel combustion (dry) [m ³ N/ original unit]
A_0	: Theoretical air volume for each fuel combustion [m ³ N/ 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 ₂ O(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 O₂ concentration in exhaust gas, as shown in the equation below.

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

C_{O_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 3-21, Table 3-22). Anomalous values were excluded according to t-testing or expert judgment when calculating the average values. Please refer to the *GHGs Estimation Methods Committee Report Part 1* (MOE, Committee for the Greenhouse Gases Emissions Estimation Methods, August 2006) 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, *Report on Emission Factor Results for Combustion Facilities*, 1997) 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 *1996 Revised IPCC Guidelines* as well as *GPG (2000)* 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 3-19 Theoretical exhaust gas and air volumes, and higher heating values for different fuels

Fuel type	Original unit	Theoretical exhaust gas volume (dry)	Higher heating value	Theoretical air volume	Remarks
		$G_0^{1)}$	$GCV^{2)}$	$A_0^{1)}$	
		m ³ N/L, kg, m ³ N	kJ/L, kg, m ³ N, kWh	m ³ N/L, kg, m ³ N	
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 MOE's *General Survey of the Emissions of Air Pollutants*, 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 based on reference materials.

Table 3-20 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, Reports on Greenhouse gas emissions estimation methodology, 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	Ministry of the Environment, 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	Ministry of the Environment, Survey on Grasp of the Actual Condition of Greenhouse Gas Emissions from Biomass Boilers Fiscal Year 2017, 2018

Table 3-21 CH₄ emission factors for different fuels and furnaces in GCV basis (unit: kg-CH₄/TJ)

Fuel	Code	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)	Blast furnace, converter furnace and open-hearth furnace (steel and non-ferrous metal)	Metal rolling furnace, metal treating furnace, metal forging furnace	Petroleum and gas furnaces	Catalytic regenerator	Brick kiln, ceramic kiln, and other kiln	Aggregate drying kiln, cement raw material drying kiln, brick raw material drying kiln	Other drying kilns	Other industrial furnaces	Gas turbine	Diesel engine	Gas engine, petrol engine	
Coal	Steel Making Coal	\$0110	0.13	31	1.7	NA	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	NA	13	13	0.054	1.5	29	6.6	13	NA	NA	NA	
	Coal Tar	\$0212															
	Coal Briquette	\$0213															
	Coke Oven Gas	\$0221															
	Blast Furnace Gas	\$0222															
Converter Furnace Gas	\$0225																
Oil	Crude Oil for Refinery	\$0310	0.10	31	1.7	NA	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	NA	0.43	0.16	NA	1.5	29	6.6	0.83	0.81	0.70	54	
	Reformed Feedstock Oil	\$0421															
	Gasoline	\$0431															
	Jet Fuel Oil	\$0432															
	Kerosene	\$0433															
	Gas Oil / Diesel Oil	\$0434															
	Fuel Oil A	\$0436															
	Fuel Oil C	\$0437															
	Fuel Oil B	\$0438															
	Fuel Oil C for General Use	\$0439															
	Fuel Oil C for Power Generation	\$0440															
	Lubricant Oil	\$0451															
	Other Heavy Oil Products	\$0452															
	Petroleum Coke	\$0455															
Natural Gas	Galvanic Furnace Gas	\$0456	0.23	31	1.70	NA	0.43	0.16	NA	1.5	29	6.62	2.29	0.81	0.70	54	
	Refinery Gas	\$0457															
	Liquefied Petroleum Gas	\$0458															
	Liquefied Natural Gas	\$0510															
	Indigenous Natural Gas	\$0520															
City Gas	Indigenous Natural Gas	\$0521	0.23	31	1.7	NA	0.43	0.16	NA	1.5	29	6.6	2.3	0.81	0.70	54	
	Coal Mining Gas	\$0522															
	Boil Off Gas from Crude Oil	\$0523															
	City Gas	\$0610															
City Gas	Small Scale Community Gas	\$0620	0.23	31	1.7	NA	0.43	0.16	NA	1.5	29	6.6	2.3	0.81	0.70	54	
		\$0620															
Biomass Energy	Woods	Power generation	\$N131	0.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
		Heat utilization															16
	Waste Wood	Power generation	\$N132	0.2	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Heat utilization															
		Thermal Use of Black Liquor	\$N136	4.3	NA	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	NA
		Non Specified	\$N138	16	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Power generation	\$N138	16	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	

Table 3-22 N₂O emission factors for different fuels and furnaces in GCV basis (unit: kg-N₂O/TJ)

Fuel	Code	Boilers			Industrial furnaces					Internal-combustion engines														
		Boiler (other than fluidized-bed boiler)	Normal pressure fluidized-bed boiler	Pressurized fluidized-bed boiler	Blast furnace	Petroleum and gas furnaces	Catalytic regenerator	Coke oven	Other industrial furnace	Gas turbine	Diesel engine	Gas engine, petrol engine												
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																						
	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	5.2	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																						
	Blast Furnace Gas	\$0222												0.17	0.17	0.17	0.047	0.21	NA	0.14	1.2	0.58	2.2	0.85
	Converter Furnace Gas	\$0225												NA										
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											
	Reformed Feedstock Oil	\$0421																						
	Gasoline	\$0431																						
	Jet Fuel Oil	\$0432																						
	Kerosene	\$0433																						
	Gas Oil / Diesel Oil	\$0434																						
	Fuel Oil A	\$0436	0.22	0.22	0.22		NA	NA	NA	NA	1.1	NA	NA	NA										
	Fuel Oil C	\$0437																						
	Fuel Oil B	\$0438																						
	Fuel Oil C for General Use	\$0439																						
	Fuel Oil C for Power Generation	\$0440																						
	Lubricant Oil	\$0451	0.19	0.19	0.19			1.15	7.3	NA	1.1	NA	NA	NA	NA									
	Other Heavy Oil Products	\$0452																						
	Petroleum Coke	\$0455																						
	Galvanic Furnace Gas	\$0456																						
Refinery Gas	\$0457	0.17	0.17	0.17	0.21	NA										0.14	1.2	0.58	2.2	0.85				
Liquified Petroleum Gas	\$0458	NA																						
Natural Gas	Liquefied Natural Gas	\$0510	0.17	0.17	0.17	NA		0.21	NA	0.14	1.2	0.58	2.2	0.85										
	Indigenous Natural Gas	\$0520																						
	Indigenous Natural Gas	\$0521																						
	Coal Mining Gas	\$0522																						
	Boil Off Gas from Crude Oil	\$0523																						
City Gas	City Gas	\$0610	0.17	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	\$N131	1.60	1.60	1.60	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	\$N132	1.60	1.60	1.60	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	NA										
	Gas Biomass	\$N137	0.09	0.09	0.09	NA	NA	NA	NA	NA	NA	NA	NA	NA										
Non Specified	\$N138	1.60	1.60	1.60	NA	NA	NA	NA	NA	NA	NA	NA	NA											

➤ **Biomass boilers**

CH₄ and N₂O emission factors by each fuel and each facility in biomass boilers are shown in Table 3-21 and Table 3-22.

Based on the actual measurements on the *Promotion of Wood Use and Energy-saving and CO₂ Reduction Demonstration Project Fiscal Year 2014* (Forestry Agency Wood Use Promotion Division) and *Survey on Grasp of the Actual Condition of Greenhouse Gas Emissions from Biomass Boilers Fiscal Year 2017* (Ministry of the Environment), the country-specific emission factors of woods, waste woods and non-specified biomass were established, by 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 3-19.

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**

CH₄ emissions from coke production come from two sources: CH₄ in combustion exhaust gas from gas leakage from the carbonization chamber to the combustion chamber, and CH₄ 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 CH₄ in the exhaust gas from coking furnaces operated by five companies at seven operating sites (surveyed by the Japan Iron and Steel Federation, 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-CH₄/t].

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

The Japan Iron and Steel Federation has had a voluntary plan in place since fiscal year 1997 to manage noxious atmospheric pollutants, and CH₄ 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 3-23 Emission factor of CH₄ from coking furnace lids, desulfurization towers, and desulfurization recycling towers

Item	Unit	1990-1996	1997-1999	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
CH ₄ EFs	kgCH ₄ /t	0.238	0.180	0.119	0.043	0.037	0.032	0.031	0.042	0.045	0.039	0.038	0.036	0.033	0.034

(Source) Japan Iron and Steel Federation 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. For FY2000 and on, actual data values are adopted.

- **CH₄ 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* (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 (*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*) 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 conversion, industry, commercial & others, and residential) 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 estimated from the *General Survey of the Emissions of Air Pollutants* and from 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 exhaustive *General Survey of the Emissions of Air Pollutants* for all facilities emitting soot and smoke was carried out in fiscal years 1989, 1992, 1995, 1996, 1999, 2008, 2011 and 2014. For years in which the exhaustive *General Survey of the Emissions of Air Pollutants* was not carried out, the percentages of fuel consumption accounted for by each furnace type were interpolated and extrapolated using the data obtained in the years when the exhaustive survey was carried out.

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.

$$A_{ijk} = A_{EBik} \times w_{ijk}$$

$$w_{ijk} = A_{MAPijk} / \sum_m A_{MAPimk}$$

A_{ijk} : Activity data for fuel type i , furnace type j , sector k [TJ]

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.

➤ *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 CH₄ 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*, both compiled by METI.

Table 3-24 Coke production amount

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Coke production	kt	47,338	42,279	38,511	38,009	36,551	34,140	37,036	34,875	35,024	35,082	33,785	32,439	33,138	32,587

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, LPG" and "Biomass Energy" from 1990 to 2016.

The uncertainties at furnaces were estimated to be -33% to +46% for CH₄ emissions and -33% to +33% for N₂O 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 the Committee for the Greenhouse Gas Emission Estimation Methods 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 CH₄ and N₂O 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 3.2.4. c) (1.A.1).

➤ *Coke production*

For activity data, the same sources are used throughout the time-series. The emission factor is based on the information provided by the Japan Iron and Steel Federation estimated using a consistent methodology throughout the time-series. Therefore, CH₄ 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 Chapter 1.

● ***Verification***

N₂O 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 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)

The actual measurement conducted in FY2009 is described here. The object of measurement was the N₂O emission factor of fluidized-bed boilers combusting solid fuels. As a result, the validity of

measurements in 1990s is confirmed because the result of the measurement in FY2009 is almost the same level of the emission factor based on the measurements in the 1990s.

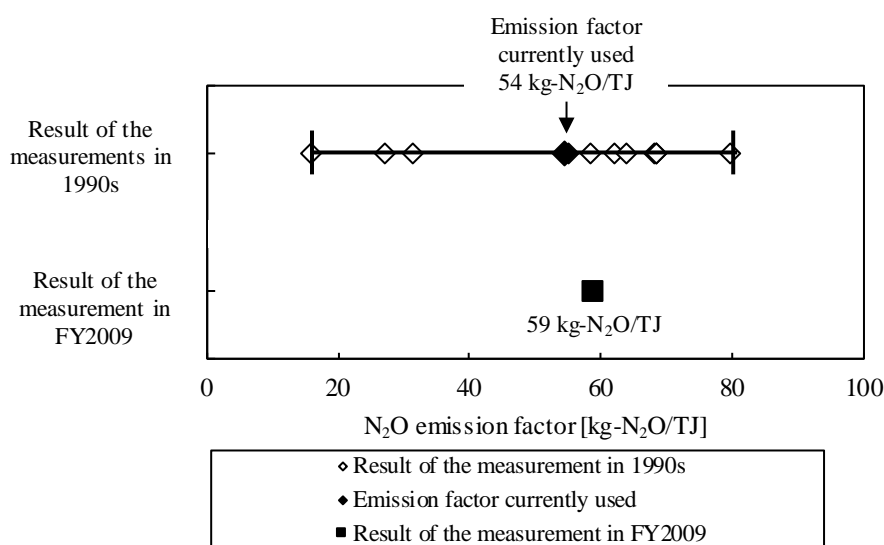


Figure 3-5 Comparison of the 1990s and FY2009 measurement results

(Note) The result of the measurement in FY2009 in the figure is the average of three measurements in a boiler

e) Category-specific Recalculations

Since the activity data for all years in the *General Energy Statistics* were revised, the CH₄ and N₂O emissions in those years were recalculated. For the recalculation of “Production, Transmission and Distribution of Electricity” under “Auto power generation” in the *General Energy Statistics*, and the waste incineration for energy purposes and with energy recovery, see 3.2.4. e) (1.A.1). Since the emissions data and the amount of production of coke for FY2016 provided by the Japan Iron and Steel Federation were revised, the CH₄ emissions in that year were recalculated.

For combustion in the biomass boilers, since CH₄ and N₂O country-specific emission factors were newly adopted, the CH₄ and N₂O emissions in all years were recalculated.

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

3.2.6. CO₂ Emissions from Manufacturing Industries and Construction (1.A.2.:CO₂)

a) Category Description

This section provides the estimation methods for determining CO₂ 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 FY2017, CO₂ emissions from this category accounted for 272,680 kt-CO₂, and represented 21.1% of Japan’s total GHG emissions (excluding LULUCF). The iron and steel (1.A.2.a) accounts for 51.3%, and is the largest source within the manufacturing industries and construction category in FY2017.

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) (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.) in accordance with the *2006 IPCC Guidelines*. Please refer to Chapter 7 for further details on the estimation methods.

The CO₂ emissions from biomass are not included in the national totals but are reported in the CRFs as reference in accordance with the *2006 IPCC Guidelines*.

● Emission Factors

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

● Activity Data

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

Table 3-25 Energy consumptions in Manufacturing Industries and Construction category (1.A.2) (unit: PJ)

Fuel	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Liquid fuels	1,958	2,113	1,905	1,539	1,146	1,083	1,042	1,090	1,033	1,032	979	914	856	843
Solid fuels	2,130	2,053	2,034	2,051	1,984	1,861	2,043	1,990	2,031	2,087	2,051	2,000	1,887	1,864
Gaseous fuels	227	344	408	599	611	592	629	654	648	636	618	620	622	627
Other fossil fuels	86	99	115	174	195	196	202	202	208	212	219	222	219	222
Biomass	227	227	240	273	294	279	298	291	286	309	303	300	272	282
Total	4,628	4,835	4,701	4,637	4,230	4,011	4,214	4,228	4,206	4,277	4,170	4,056	3,855	3,838

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: #6xxxxx⁸), 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 CO₂ emissions from energy consumption for power or steam generation to the sectors generating that power or steam. As such, these CO₂ emissions are added to those from each industry in the final energy consumption sector and are reported in 1.A.2.

Table 3-26 shows the correspondence between the sectors of Japan’s Energy Balance Table and those

⁸ x indicates any number.

of the CRF (1.A.2).

Table 3-26 Correspondence between sectors of Japan's Energy Balance Table and of the CRF (1.A.2)

CRF	General Energy Statistics	
1A2 Manufacturing industries and construction		
1A2a 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
1A2b 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
1A2c 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
1A2d 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
1A2e 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
1A2f 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
1A2g 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 1A1b, 1A1c, 1A2a through 1A2f)	#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 1A1b, 1A1c, 1A2a through 1A2f)	#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 1A1b, 1A1c, 1A2a through 1A2f)	#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 1A1b, 1A1c, 1A2a through 1A2f)	#951500
	Non-energy and feedstock use; Manufacturing industry, small and medium scale	#951700

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

c) Uncertainties and Time-series Consistency

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 Chapter 1.

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 all years were recalculated.

Updating the statistical data and improving the estimation methodology in the waste sector, CO₂ emissions from other fossil fuels in FY2005-FY2016 were recalculated. See section 7.4.3 for details.

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

3.2.7. CH₄ and N₂O Emissions from Manufacturing Industries and Construction (1.A.2.:CH₄, N₂O)**a) Category Description**

This section provides the estimation methods for determining CH₄ and N₂O 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 category also provides the estimation methods for determining CH₄ and N₂O emissions from off-road vehicles, work ships and other machinery of manufacturing industries and construction.

b) Methodological Issues● **Estimation Method**➤ *Furnaces*

Same with Energy Industries (1.A.1), CH₄ and N₂O 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 3.2.5. b) (1.A.1).

➤ *Biomass boilers*

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

➤ *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* to calculate emissions (Vol.2, Page 3.34, Fig. 3.3.1) 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 3-21 and Table 3-22, See 3.2.5. b) (1.A.1).

➤ *Biomass boilers*

See 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 *EMEP/EEA air pollutant emission inventory guidebook 2016* (Table 3-1, 1.A.2.g.vii) after conversion to the gross calorific value.

Table 3-27 Emission factors of CH₄ and N₂O for off-road vehicles and other machinery in manufacturing industries and construction (1.A.2)

Fuel	Unit	CH ₄ emission factor	N ₂ O emission factor	Source
Gasoline	g/t	665	59	<i>EMEP/EEA air pollutant emission inventory guidebook 2016</i> , 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	<i>2006 IPCC Guidelines</i> , 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 3-28, 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 (*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 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 3-28, is assumed to be the activity data of the mobile combustion, namely the off-road vehicles and other machinery.

In relation to the Table 3-28, 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 3-28 Fuel consumption ratio of mobile combustion and stationary combustion in manufacturing industries and construction (1.A.2)

CRF 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
1A2a	Manufacture of iron and steel	1%	99%	16%	84%			
1A2b	Manufacture of non-ferrous metals and products	24%	76%	1%	99%			
1A2c	Manufacture of chemical and allied products	100%	0%	1%	99%			
1A2d	Manufacture of pulp, paper and paper products	74%	26%	10%	90%			
	Printing and Allied Industries			0%	100%			
1A2e	Manufacture of food, beverages, tobacco and feed			1%	99%			
1A2f	Manufacture of Ceramic, Stone and Clay Products	7%	93%	1%	99%			
1A2g	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%			

(Source) Estimated based on *Actual condition survey of GHG emissions from manufacturing industry, Fiscal year 2014* and *Actual condition survey of GHG emissions from non-manufacturing industry, Fiscal year 2015*, both by MOE.

c) Uncertainties and Time-series Consistency**➤ Furnaces (including Biomass boilers)**

See 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 CH₄ emissions and -23% to $+91\%$ for N₂O 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 Chapter 1.

e) Category-specific Recalculations

Since the activity data for all years in the *General Energy Statistics* were revised, the CH₄ and N₂O emissions in those years were recalculated.

For combustion in the biomass boilers, since CH₄ and N₂O country-specific emission factors were newly adopted and the activity data for FY1990-2001 of non-specified biomass were revised, the CH₄ and N₂O emissions in all years were recalculated.

Updating the statistical data in the waste sector, CH₄ and N₂O emissions in FY2015 and FY2016 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).

3.2.8. CO₂ Emissions from Transport (1.A.3.:CO₂)**a) Category Description**

This section provides the methods used to estimate CO₂ 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 2017, CO₂ emissions from this category accounted for 205,226 kt-CO₂, and represented 15.9% of Japan's total GHG emissions (excluding LULUCF). The road transportation (1.A.3.b) accounts for 89.6% and is the largest within the Transport category in FY2017.

b) Methodological Issues

● Estimation Method

➤ Fuels other than lubricants

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 3.2.4. b)). In the CRFs, the CO₂ 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 CO₂ emissions from biomass are not included in the national totals in accordance with the *2006 IPCC Guidelines*.)

➤ Lubricants

CO₂ 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 : CO₂ emissions from lubricants oxidized during use [kt-CO₂]

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 other than lubricants

The emission factors elaborated in the energy industries (1.A.1) are also used in this category. See 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 4 (A4.3).

➤ 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 3-29 Energy consumptions in Transport (1.A.3.) (unit: PJ)

Fuel	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Liquid fuels	2,966	3,569	3,729	3,510	3,318	3,272	3,286	3,215	3,228	3,135	3,065	3,048	3,023	2,999
Solid fuels	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gaseous fuels	0	0	1	4	5	5	5	5	4	4	4	3	3	2
Other fossil fuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Biomass	NO	NO	NO	0	0	1	9	9	9	10	12	15	18	19
Total	2,966	3,569	3,730	3,514	3,324	3,277	3,299	3,228	3,241	3,149	3,080	3,067	3,043	3,021

➤ Fuels other than lubricants

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 CO₂, these values were deducted. (see Table 3-30)

Table 3-30 Correspondence between sectors of Japan’s Energy Balance Table and those of the CRF (1.A.3)

CRF		General Energy Statistics	
1A3	Transport		
		Final energy consumption; Passenger; Air passenger transport	#815000
1A3a	Domestic aviation	Final energy consumption; Freight; Air freight transport	#854000
		Non-energy and feedstock use; Transportation (air)	#953000
1A3b	Road transportation		
		Final energy consumption; Passenger; Passenger vehicle	#811000
		Non-energy and feedstock use; Transportation (passenger vehicle)	#953000
	i Cars	IE (1A3biii)	-
		Final energy consumption; Passenger; Bus	#811500
	ii Light duty trucks	Final energy consumption; Freight; Freight truck and lorry	#851000
		Non-energy and feedstock use; Transportation (bus, freight truck and lorry)	#953000
	iii Heavy duty trucks and buses	Final energy consumption; Passenger; Motorcycles	#812000
		Non-energy and feedstock use; Transportation (Motorcycles)	#953000
	iv Motorcycles	IE (1A3biii)	-
	v Other		
		Final energy consumption; Passenger; Railway passenger transport	#813000
1A3c	Railways	Final energy consumption; Freight; Railway freight transport	#852000
		Non-energy and feedstock use; Transportation (railways)	#953000
		Final energy consumption; Passenger; Water passenger transport	#814000
1A3d	Domestic navigation	Final energy consumption; Freight; Water freight transport	#853000
		Non-energy and feedstock use; Transportation (water)	#953000
1A3e	Other transportation	NO	-

#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 , 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* (both from METI), by R_i , or the proportion of each of engine oil to all lubricants sold to consumers (, wholesalers and retailers) 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 the *Report on the Subsidized Project of Environmental Measures of Lubricants Fiscal Year 2012* (Japan Lubricating Oil Society) 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).

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* (ANRE), 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 3-31 Consumption of total loss type engine oils

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
Two stroke engine oil for automobiles	LC_1	TJ	207	215	210	194	179	183	183	172	157	158	154	142	135	137
Cylinder oil for navigation	LC_2	TJ	5,318	5,503	7,144	6,250	5,248	4,972	4,627	4,016	3,638	3,502	3,301	3,124	2,843	2,762
Total sales of lubricants	DS	1000 kL	2,439	2,335	2,192	2,047	1,750	1,681	1,763	1,695	1,538	1,531	1,511	1,460	1,414	1,431
Proportion of sales of engine oils for automobiles	R_1	-	23%	25%	26%	26%	28%	30%	28%	28%	28%	28%	28%	26%	26%	26%
Proportion of sales of marine diesel engine oils	R_2	-	6.5%	7.1%	9.8%	9.1%	9.0%	8.9%	7.9%	7.1%	7.1%	6.8%	6.5%	6.4%	6.0%	5.8%
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

c) Uncertainties and Time-series Consistency

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 Chapter 1.

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 all years were recalculated. In addition, due to the updates of the

activity data based on the revision of the *Yearbook of Mineral Resources and Petroleum Products Statistics*, the emissions from lubricants for FY2016 were recalculated.

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

3.2.9. CH₄ and N₂O Emissions from Transport (1.A.3.:CH₄, N₂O)

This section provides the estimation methods for CH₄ and N₂O 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 CH₄ and N₂O 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 CH₄ and N₂O 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} : CH₄ and N₂O 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

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

E_{gasoline} : CH₄ and N₂O 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 CH₄ and N₂O 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 3-32)

➤ 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 CH₄ and N₂O (see Table 3-32).

Table 3-32 CH₄ and N₂O emission factors for aircraft

Type of aircraft (fuel)	Flight phase	CH ₄	N ₂ O
Jet aircraft (Jet fuel)	LTO	Varies per aircraft type (see Table 3-33)	
	Cruise	- ¹⁾	2 [kg-N ₂ O/TJ(NCV)]
Other than jet aircraft (Aviation gasoline)	-	0.5 [kg-CH ₄ /TJ(NCV)]	2 [kg-N ₂ O/TJ(NCV)]

LTO: Landing and take-off

Source: *2006 IPCC Guidelines*, Volume 2, page 3.64, Table 3.6.5

1) Excluded from calculations, as the emissions are assumed as negligible in the guidelines.

Table 3-33 CH₄ and N₂O emission factors and fuel consumption for major types of jet aircraft

Aircraft type	CH ₄ emission factor [kg/CH ₄ /LTO] ¹⁾	N ₂ O emission factor [kg/N ₂ O/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	—

Source: *2006 IPCC Guidelines*, Vol. 2, page 3.70, Table 3.6.9

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* of 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* of 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* of MLIT.

➤ *Aviation gasoline*

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

Table 3-34 Activity data used for emission estimates of aircraft

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Number of LTO cycle	1000 LTO	669	783	865	895	900	892	882	882	938	993	1,006	997	994	999
Jet fuel consumption during cruise	1000 kL	1,621	2,425	2,742	3,031	2,945	2,791	2,629	2,589	2,758	2,933	2,996	3,005	3,072	3,145
Aviation gasoline consumption	1000 kL	5.3	6.0	4.3	7.7	2.8	2.4	1.9	1.7	1.9	1.9	1.7	1.7	1.7	1.9

Table 3-35 Number of LTO cycle of major types of jet aircraft since FY2001 [1000 LTO]

Aircraft type	2001	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
B737-300/400/500	123	103	91	90	84	130	129	131	132	80	68	38
B737-800	NO	NO	33	59	97	89	97	118	130	166	165	178
B747SR	43	30	6	2	3	2	1	1	NO	1	1	NO
B747-400	56	54	41	36	22	15	16	14	8	5	7	5
B767-300	146	103	77	102	101	105	95	87	79	75	73	80
B777-200/300	69	76	91	87	89	86	91	93	87	78	74	71
A320	59	47	49	57	48	55	88	95	102	103	97	54

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 (CH₄: -57% to +100%, N₂O: -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 CH₄, and -70% to +150% for N₂O.

● **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 Chapter 1.

e) Category-specific Recalculations

The N₂O emissions from jet fuel for FY2014 and FY2015 were recalculated due to an update of the fuel consumption for cruising based on a correction of the *Statistical Yearbook of Air Transport*. The CH₄

and N₂O emissions from aviation gasoline for FY2005 through FY2016 were recalculated due to a correction of the calorific value of gasoline. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

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

This section provides the estimation methods for CH₄ and N₂O emissions from the following vehicle categories:

Table 3-36 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
Regular cargo truck	Regular vehicle used for transportation of cargo.	Yes	Yes	-	(Cargo truck)
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 3-37 Correspondence between vehicle type and sectors of the CRF (1.A.3.b)

CRF	Vehicle type, or notation key
1A3b Road transportation	
i. Cars	Light passenger vehicle and passenger vehicle
ii. Light duty trucks	IE (included in iii. Heavy duty trucks and buses)
iii. Heavy duty trucks and buses	Bus, light cargo truck, small cargo truck, regular cargo truck, and special-purpose vehicle
iv. Motorcycles	Motorcycle
v. Other	IE (included in iii. Heavy duty trucks and buses)

Different estimation methods are used between motorcycles and other road transportation vehicles, Road transportation vehicles other than motorcycles (3.2.4.2.a) and Motorcycles (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 CH₄ and N₂O 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 : CH₄ and N₂O 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 CH₄ and N₂O are established for each fuel type for each vehicle type, using the data shown in Table 3-38.

For “JAMA data”, the emission factors are established on the basis of the raw emission factors data provided by Japan Automobile Manufacturers Association. The raw emission factors are arranged as combined mode emission factors⁹ by car registration year. The emission factors are estimated by averaging the arranged emission factors of JAMA weighted by the number of vehicles of each car registration year of each car type (see Table 3-39, Table 3-40).

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 MLIT’s *Road Transport Census*. 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 N₂O 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* (MLIT). However, N₂O emission factors for passenger vehicles, buses, and special-purpose vehicles, and CH₄ emission factors for special-purpose vehicles are established by the method indicated in Table 3-38, because of the absence of actual measurement data in Japan.

The detailed method for establishing the emission factors is described in the *Greenhouse Gases Estimation Methods Committee Report Part 2 – Transportation* (MOE; August 2006).

⁹ The JAMA 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

Table 3-38 Data source of the emission factors of vehicle

Vehicle type	Gasoline		Diesel		Natural gas	
	CH ₄	N ₂ O	CH ₄	N ₂ O	CH ₄	N ₂ O
Light passenger vehicle	JAMA data	JAMA data				
Passenger vehicle	JAMA data	JAMA data	JAMA data	JAMA 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 data	JAMA data				
Small cargo truck	JAMA data	JAMA data	JAMA data	JAMA data		Established based on the actual measured data (classified as cargo truck)
Regular cargo truck	2006GL	2006GL	JAMA data	JAMA 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.

- 1) JAMA data: Calculated by using driving mode test data provided by Japan Automobile Manufacturers Association
- 2) Measured data: Using actual Japanese data other than the above JAMA data
- 3) 2006GL: Using the default values in the 2006 IPCC Guidelines.
- 4) EFs of LPG vehicle are same as those of gasoline passenger vehicle.

Table 3-39 CH₄ emission factors for road transportation [mg-CH₄/km]

Fuel	Vehicle type	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Gasoline	Light passenger vehicle	8.3	8.3	8.2	6.9	5.8	5.4	5.1	4.8	4.6	4.3	4.1	3.9	3.8	3.6
	Passenger vehicle (non-hybrid, including LPG)	14.5	14.5	14.3	11.3	9.3	8.7	8.2	7.8	7.3	6.9	6.6	6.3	6.1	5.9
	Passenger vehicle (hybrid)							2.3							
	Bus							14							
	Light cargo truck	18.7	18.7	18.0	11.7	8.4	7.8	7.2	6.7	6.2	5.8	5.4	5.1	4.8	4.6
	Small cargo truck	21.2	21.2	21.2	14.5	10.9	10.2	9.5	8.9	8.3	7.8	7.3	7.0	6.6	6.3
	Regular cargo truck							14							
	Special-purpose vehicle							14							
Diesel	Passenger vehicle	11.3	12.2	12.6	12.8	12.8	12.8	12.8	12.8	13.0	13.3	13.6	14.0	14.2	14.5
	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
	Small cargo truck	9.6	10.7	10.1	8.7	8.5	8.5	8.5	8.4	8.4	8.4	8.3	8.3	8.3	8.2
	Regular cargo truck	17.0	16.0	15.0	13.9	12.5	12.2	11.9	11.4	10.9	10.3	9.7	9.1	8.5	7.9
	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
Natural gas	Passenger vehicle							13							
	Bus							50							
	Cargo truck							93							
	Special-purpose vehicle							105							

Table 3-40 N₂O emission factors for road transportation [mg-N₂O/km]

Fuel	Vehicle type	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Gasoline	Light passenger vehicle	14.2	14.2	13.9	9.3	6.7	5.9	5.2	4.6	4.1	3.5	3.2	2.8	2.5	2.3
	Passenger vehicle (non-hybrid, including LPG)	23.7	23.7	20.3	12.2	8.3	7.2	6.2	5.5	4.9	4.3	3.9	3.6	3.3	3.1
	Passenger vehicle (hybrid)							0.5							
	Bus							25							
	Light cargo truck	23.7	23.7	21.7	12.8	8.8	8.1	7.4	6.9	6.4	5.9	5.5	5.2	4.9	4.6
	Small cargo truck	21.1	21.6	21.8	13.1	9.2	8.4	7.6	7.0	6.3	5.8	5.3	4.9	4.5	4.2
	Regular cargo truck							25							
	Special-purpose vehicle							25							
Diesel	Passenger vehicle	5.7	4.7	4.4	4.4	4.6	4.8	5.0	5.1	5.4	5.8	6.1	6.5	6.7	7.0
	Bus							3							
	Small cargo truck	9.3	10.3	11.1	11.7	12.0	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	12.8
	Regular cargo truck	15.0	15.0	14.9	16.9	27.5	30.1	31.8	33.3	35.1	37.0	38.8	40.7	42.5	44.4
	Special-purpose vehicle							3							
Natural gas	Passenger vehicle							0.2							
	Bus							38.4							
	Cargo truck							12.8							
	Special-purpose vehicle							14.5							

● 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 MLIT's *Statistical Yearbook of Motor Vehicle Transport*. 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.

The annual distance traveled by vehicle type and by fuel type since FY2010 for gasoline, diesel and LPG vehicles is given in MLIT's *Statistical Yearbook of Motor Vehicle Fuel Consumption*. *Monthly Report of Motor Vehicle Transport Statistics* 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 Vehicle* compiled by the Automobile Inspection and Registration Information Association (AIRIA). 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 Vehicle*.

Table 3-41 Distance traveled of automobile [10⁶ vehicle-km]

Fuel	Vehicle type	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Gasoline	Light passenger vehicle	15,800	40,725	72,436	106,089	125,452	132,957	136,641	137,626	146,354	150,254	156,748	160,607	169,649	176,155
	Passenger vehicle (non-hybrid)	272,902	304,297	342,901	348,524	326,265	325,115	318,911	322,697	315,837	302,713	281,922	272,858	266,825	260,401
	Passenger vehicle (hybrid)	NO	NO	NO	2,560	5,307	9,809	14,333	19,549	29,419	38,353	48,023	58,258	67,183	77,866
	Bus	90	30	20	43	69	81	314	234	181	188	193	212	212	213
	Light cargo truck	90,707	89,828	79,560	78,333	77,803	76,812	75,073	73,153	75,164	77,421	77,724	75,876	76,331	75,192
	Small cargo truck	28,972	20,286	19,582	20,853	20,664	20,437	22,228	23,058	23,162	23,172	23,176	22,994	21,467	21,365
	Regular cargo truck	364	294	270	605	867	891	1,411	1,438	1,506	1,385	1,337	1,404	1,376	1,349
	Special-purpose vehicle	662	693	1,283	1,272	1,422	1,503	2,841	2,728	2,714	2,604	2,474	2,461	2,415	2,476
Diesel	Passenger vehicle	39,831	62,934	55,437	29,124	16,677	14,028	10,357	9,308	8,461	8,075	7,875	8,632	9,245	10,596
	Bus	6,889	6,619	6,488	6,506	6,410	6,372	6,178	6,020	6,040	5,975	5,921	5,851	5,709	5,592
	Small cargo truck	43,649	48,801	45,017	32,816	28,599	26,236	23,154	22,564	22,621	22,552	22,227	21,584	20,290	19,802
	Regular cargo truck	57,824	68,143	72,434	69,361	68,562	65,292	62,856	61,156	59,395	59,091	58,976	59,368	59,124	59,539
LPG	Special-purpose vehicle	9,173	13,598	17,074	17,108	18,082	17,648	20,727	20,476	20,820	21,151	21,270	21,467	21,181	21,067
	Passenger vehicle	18,000	16,848	15,074	13,692	12,607	12,114	12,161	11,284	10,666	10,258	9,802	9,239	8,493	8,067
Natural gas	Passenger vehicle	0	0	2	6	7	7	6	5	4	3	2	2	1	1
	Bus	NO	2	15	48	57	56	52	49	47	39	34	28	22	15
	Cargo truck	0	10	79	254	317	308	303	305	283	265	254	230	198	170
	Special-purpose vehicle	0	2	18	57	71	69	67	66	65	62	56	49	39	33

● N₂O 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 N₂O 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, N₂O 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", N₂O 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 N₂O 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.¹⁰

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.

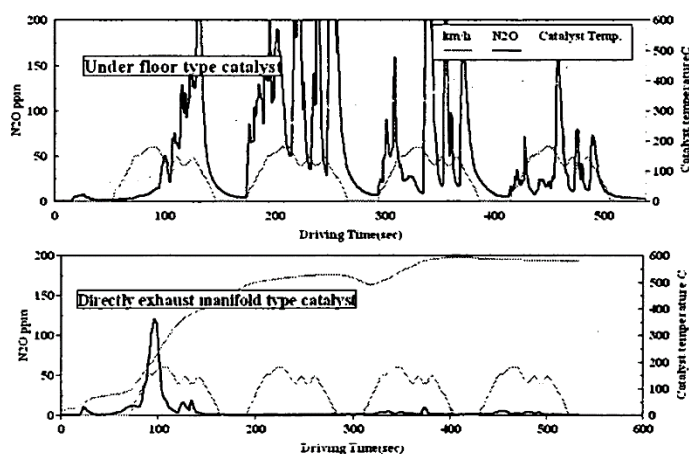


Figure 3-6 Difference of N_2O emissions by catalyst fitting position
Test mode: 11 mode, (Reference) Goto et al. (2003)

● *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”.

¹⁰ Goto et al. (2003) and Yoda et al. (2010), Refer to the References at the end of this chapter.

c) *Uncertainties and Time-series Consistency*

● *Uncertainties*

The emission factors of road transportation vehicle are established from the data provided by JAMA. 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 CH₄, and -37% to +107% for N₂O.

● *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 Vehicle* 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* 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 Chapter 1.

● *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 3-42 Annual number of vehicles by type [10^3 vehicle]

Fuel	Vehicle type	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Gasoline	Light passenger vehicle	2,715	5,966	10,084	14,350	16,883	17,484	18,004	18,586	19,348	20,230	21,026	21,477	21,761	22,051
	Passenger vehicle (non-hybrid)	29,140	33,891	37,794	40,104	38,743	38,142	37,594	37,099	36,178	35,023	33,793	32,685	31,733	30,688
	Passenger vehicle (hybrid)	NO	NO	NO	253	525	971	1,404	2,017	2,851	3,823	4,685	5,559	6,544	7,513
	Bus	8	3	2	5	7	8	9	10	11	13	14	15	16	16
	Light cargo truck	12,312	11,377	9,958	9,548	9,291	9,171	8,923	8,873	8,784	8,708	8,624	8,520	8,421	8,345
	Small cargo truck	2,820	2,144	1,901	1,988	1,900	1,857	1,826	1,813	1,788	1,772	1,760	1,750	1,750	1,747
	Regular cargo truck	41	38	39	90	117	123	128	134	138	140	146	150	153	155
Diesel	Special-purpose vehicle	141	198	393	330	292	291	287	287	290	291	293	297	299	302
	Passenger vehicle	2,994	4,924	4,254	2,126	1,276	1,060	905	796	744	730	761	855	953	1,063
	Bus	238	240	233	225	221	218	216	214	212	212	212	214	215	215
	Small cargo truck	3,711	4,002	3,480	2,545	2,142	2,040	1,954	1,896	1,853	1,824	1,801	1,780	1,767	1,755
	Regular cargo truck	2,164	2,544	2,534	2,350	2,206	2,142	2,105	2,091	2,086	2,100	2,116	2,130	2,151	2,169
LPG	Special-purpose vehicle	628	804	994	903	844	830	820	814	814	818	822	829	840	850
	All types	318	303	286	295	287	277	257	248	239	232	224	216	207	194
Natural gas	Passenger vehicle	0.0	0.0	0.2	0.6	0.8	0.8	0.7	0.6	0.4	0.3	0.2	0.2	0.1	0.1
	Bus	NO	0.0	0.3	1.1	1.3	1.3	1.2	1.2	1.1	0.9	0.8	0.7	0.6	0.4
	Cargo truck	0.0	0.5	3.9	12.8	15.5	15.3	15.0	14.5	13.7	12.9	12.1	11.0	9.5	8.2
	Special-purpose vehicle	0.0	0.2	1.5	4.8	5.8	5.8	5.6	5.4	5.2	4.9	4.4	3.9	3.3	2.8

Source: Statistics of AIRIA/ Number of Motor Vehicle and Japan Gas Association

Table 3-43 Annual mileage per vehicle [10^3 km/vehicle]

Fuel	Vehicle type	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Gasoline	Light passenger vehicle	5.8	6.8	7.2	7.4	7.4	7.6	7.6	7.4	7.6	7.4	7.5	7.5	7.8	8.0
	Passenger vehicle (non-hybrid)	9.4	9.0	9.1	8.7	8.4	8.5	8.5	8.7	8.7	8.6	8.3	8.3	8.4	8.5
	Passenger vehicle (hybrid) ¹	NO	NO	NO	10.1	10.1	10.1	10.2	9.7	10.3	10.0	10.3	10.5	10.3	10.4
	Bus	11.9	9.3	9.0	8.6	9.5	9.9	34.7	22.8	15.8	14.9	14.2	14.5	13.6	12.9
	Light cargo truck	7.4	7.9	8.0	8.2	8.4	8.4	8.4	8.2	8.6	8.9	9.0	8.9	9.1	9.0
	Small cargo truck	10.3	9.5	10.3	10.5	10.9	11.0	12.2	12.7	13.0	13.1	13.2	13.1	12.3	12.2
	Regular cargo truck	8.8	7.7	6.9	6.7	7.4	7.3	11.0	10.7	10.9	9.9	9.2	9.4	9.0	8.7
Diesel	Special-purpose vehicle	4.7	3.5	3.3	3.9	4.9	5.2	9.9	9.5	9.4	8.9	8.4	8.3	8.1	8.2
	Passenger vehicle	13.3	12.8	13.0	13.7	13.1	13.2	11.4	11.7	11.4	11.1	10.4	10.1	9.7	10.0
	Bus	28.9	27.6	27.9	28.9	29.0	29.2	28.6	28.1	28.4	28.2	27.9	27.4	26.5	26.0
	Small cargo truck	11.8	12.2	12.9	12.9	13.4	12.9	11.8	11.9	12.2	12.4	12.3	12.1	11.5	11.3
	Regular cargo truck	26.7	26.8	28.6	29.5	31.1	30.5	29.9	29.2	28.5	28.1	27.9	27.9	27.5	27.4
LPG	Special-purpose vehicle	14.6	16.9	17.2	18.9	21.4	21.3	25.3	25.1	25.6	25.9	25.9	25.9	25.2	24.8
	All types	56.6	55.5	52.7	46.4	43.9	43.7	47.3	45.6	44.5	44.3	43.8	42.8	40.9	41.6
Natural gas	Passenger vehicle	10.2	9.8	9.8	9.2	8.8	8.9	8.9	9.0	9.1	9.0	8.8	8.9	8.9	9.0
	Bus	NO	47.6	45.9	44.9	43.9	43.8	43.3	42.0	42.5	41.9	41.3	39.9	38.3	37.2
	Cargo truck	18.7	18.9	20.2	19.9	20.5	20.1	20.2	21.1	20.6	20.6	21.0	20.9	20.9	20.6
	Special-purpose vehicle	11.1	11.2	12.0	11.8	12.2	11.9	12.0	12.3	12.5	12.7	12.7	12.6	11.8	11.7

Remark: Estimated by dividing the distance traveled on Table 3-41 by number of vehicle on Table 3-42.

Note 1: Due to absence of mileage statistical data, the values until FY2009 are assumed to be the mean value of FY2010-2014.

Table 3-44 Fuel efficiency per vehicle type [km/L (km/m³ for natural gas)]

Fuel	Vehicle type	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Gasoline	Light passenger vehicle	14.2	12.9	12.0	12.6	12.6	12.3	12.6	12.8	13.0	13.3	13.5	13.7	14.0	14.1
	Passenger vehicle (non-hybrid) ¹	10.0	9.2	9.0	9.8	9.9	9.9	9.8	9.9	9.9	10.0	10.1	10.2	10.3	10.4
	Passenger vehicle (hybrid)	NO	NO	NO	IE	IE	IE	16.3	16.1	16.2	15.7	15.5	16.0	16.2	16.5
	Bus ²	4.1	3.9	4.1	4.3	4.3	4.5	5.8	6.0	6.2	6.5	6.7	6.8	7.1	7.3
	Light cargo truck	12.3	11.4	11.1	11.7	11.9	11.9	12.1	12.1	12.0	12.0	12.0	12.1	12.3	12.4
	Small cargo truck ³	8.2	7.7	8.2	8.5	8.5	8.5	9.3	9.3	9.2	9.1	9.0	9.0	9.2	9.3
	Regular cargo truck	4.4	4.2	4.4	4.6	4.9	4.9	IE	IE	IE	IE	IE	IE	IE	IE
Diesel	Special-purpose vehicle	5.1	4.8	5.2	6.4	6.8	7.3	IE	IE	IE	IE	IE	IE	IE	IE
	Passenger vehicle	9.7	7.8	7.0	6.9	7.0	7.0	9.0	9.0	9.0	9.0	9.2	9.3	9.6	10.0
	Bus	3.6	3.4	3.4	3.6	3.6	3.7	3.6	3.6	3.6	3.5	3.5	3.5	3.6	3.6
	Small cargo truck	9.7	10.0	9.7	10.1	10.1	10.0	9.1	8.9	8.9	8.7	8.6	8.6	8.6	8.7
	Regular cargo truck	3.3	3.2	3.4	3.7	3.7	3.8	3.7	3.8	3.8	3.9	3.9	3.9	3.9	3.9
LPG	Special-purpose vehicle	3.0	3.0	3.2	3.8	3.8	3.8	4.0	4.0	4.0	4.1	4.0	4.0	4.0	4.0
	All types	6.0	5.6	5.3	5.4	5.5	5.4	5.4	5.4	5.3	5.3	5.4	5.4	5.5	5.5
Natural gas	All types ⁴	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.2	4.1	4.2	4.2	4.2	4.2	4.1

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

Note 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, MLIT's

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 CH₄ and N₂O emissions. The CO₂ 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 CO₂, CH₄ and N₂O emissions.

e) Category-specific Recalculations

For gasoline hybrid passenger vehicles after FY2003, light passenger vehicles and gasoline passenger vehicles after FY2005, new measurements of raw emission factors for the vehicles were provided by JAMA, and emission factors were revised. Also, the annual distance traveled for FY2016 is revised due to the correction of *Statistics of Motor Vehicle Fuel Consumption*. In response to this revision, the CH₄ and N₂O emissions for the period of FY2003-FY2016 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 CH₄ and N₂O emissions from motorcycles.

b) Methodological Issues

● Estimation Method

The CH₄ and N₂O 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 for motorcycle has been established in 1999, and JAMA has collected the CH₄ and N₂O 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 CH₄ and N₂O 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 : CH₄ and N₂O 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 CH₄ and N₂O 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 3-45 CH₄ and N₂O emission factors of motorcycle in “hot” condition [mg/km]

Vehicle type (displacement)	Emission controlled vehicle ¹⁾		Emission uncontrolled vehicle ²⁾	
	CH ₄	N ₂ O	CH ₄	N ₂ O
Motor-driven cycles class 1 (50cc and under)	13.3	2.64	53	4
Motor-driven cycles class 2 (51cc-125cc)	16.7	0.23		
Mini-sized motorcycles (126cc-250cc)	12.5	0.85		
Small-sized motorcycles (Over 250cc)	22.2	1.09		

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 CH₄ and N₂O 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 3-46 CH₄ and N₂O emission factors for motorcycles in “cold start” condition [mg/start]

Vehicle type (displacement)	Emission controlled vehicle ¹⁾		Emission uncontrolled vehicle ²⁾	
	CH ₄	N ₂ O	CH ₄	N ₂ O
Motor-driven cycles class 1 (50cc and under)	15.8	11.2	33	15
Motor-driven cycles class 2 (51cc-125cc)	18.3	4.2		
Mini-sized motorcycles (126cc-250cc)	30.2	13.7		
Small-sized motorcycles (Over 250cc)	26.1	6.9		

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 Vehicles* by JAMA), 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 (*2007 JAMA Trust Research Report; Detailed Examination in Research Method of Number of Owned Light Two-wheel Vehicles* by Japan Automobile Research Institute (JARI)), 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* by JAMA) and multiplied by use factor by each vehicle type and by each past year (*2006 JAMA Trust Research Report; Research in Contribution Rate of the Emissions from Motorcycles* by JARI), 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 (*Research in Contribution Rate of the Emissions from Motorcycles*), 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 3-47 Activity data of motorcycles

Activity data	Vehicle type (Displacement)	Emission control by regulation	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017			
Distance traveled	Motor-driven cycles class 1 (50cc and under)	Controlled	Million vehicle-km	NO	NO	1,773	4,165	3,910	3,919	3,643	3,182	3,092	3,325	3,248	2,829	2,646	2,415			
		Uncontrolled		10,623	6,268	3,153	753	233	169	112	66	42	29	18	10	6	3			
	Motor-driven cycles class 2 (51cc-125cc)	Controlled		NO	NO	243	1,237	1,940	2,013	2,192	2,540	2,695	2,877	2,992	2,909	2,993	2,962			
		Uncontrolled		2,060	1,853	1,568	686	316	238	172	131	91	61	39	23	14	8			
	Mini-sized motorcycles (126cc-250cc)	Controlled		NO	NO	565	2,664	3,332	3,194	3,127	3,025	3,053	3,141	3,208	3,268	3,277	2,972			
		Uncontrolled		6,111	3,577	2,209	1,055	548	418	330	252	195	147	109	79	56	35			
	Small-sized motorcycles (Over 250cc)	Controlled		NO	NO	317	1,662	2,386	2,637	2,751	2,781	2,952	2,883	3,037	3,471	3,568	3,371			
		Uncontrolled		3,568	3,083	2,505	1,292	779	677	559	448	367	271	212	179	136	93			
	Number of startup	Motor-driven cycles class 1 (50cc and under)		Controlled	Number of Startup	NO	NO	349	739	682	673	626	592	574	577	564	550	513	507	
				Uncontrolled		1,838	1,131	621	134	41	29	19	12	8	5	3	2	1	1	
Motor-driven cycles class 2 (51cc-125cc)		Controlled	NO	NO		31	140	204	209	228	245	259	274	285	325	334	322			
		Uncontrolled	285	255		203	78	33	25	18	13	9	6	4	3	2	1			
Mini-sized motorcycles (126cc-250cc)		Controlled	NO	NO		41	177	217	197	193	195	196	179	183	204	204	174			
		Uncontrolled	361	223		159	70	36	26	20	16	13	8	6	5	4	2			
Small-sized motorcycles (Over 250cc)		Controlled	NO	NO		19	78	106	107	111	111	117	95	87	111	114	72			
		Uncontrolled	187	177		154	60	35	28	23	18	14	9	6	6	4	2			

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 Chapter 1.

e) Category-specific Recalculations

The CH₄ and N₂O emissions from motor-driven cycles for FY2016 were recalculated, since the number of owned vehicle for that year were obtained. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

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

a) Category Description

This section provides the estimation methods for CH₄ and N₂O 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 : CH₄ and N₂O 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 3-48 Default values for railway emission factors

Gas	Unit	Diesel engines	Steam locomotives
CH ₄	kg-CH ₄ /TJ(NCV)	4.15	2
N ₂ O	kg-N ₂ O/TJ(NCV)	28.6	1.5

Source: *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* compiled by ANRE is used as activity data, respectively.

Table 3-49 Activity data used for estimation of emissions from railways

Fuel type	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Diesel oil	1000 kL	356	313	270	248	230	225	218	211	211	205	199	198	189	189
Coal	kt	1.3	1.2	1.7	1.4	1.5	1.7	1.7	1.7	1.6	1.5	1.5	1.5	1.6	1.6

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 CH₄ and -50% to +200% for N₂O) 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 CH₄ and -50% to +200% for N₂O.

● 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 Chapter 1.

e) Category-specific Recalculations

The emissions for FY2016 were recalculated due to a revision of the energy consumption of the *General Energy Statistics*. The emissions from diesel oil for FY2006 through FY2016 were recalculated due to a correction of the calorific value of diesel oil. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

3.2.9.4. Domestic Navigation (1.A.3.d.)**a) Category Description**

This section provides the estimation methods for CH₄ and N₂O 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 : CH₄ and N₂O 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 converted to emission factors per liter using the calorific value for each type of fuel (diesel oil, fuel oil A, B and C).

Table 3-50 Default emission factors for navigation

Gas	Emission factor
CH ₄	7 [kg-CH ₄ /TJ(NCV)]
N ₂ O	2 [kg-N ₂ O/TJ(NCV)]

Source: *2006 IPCC Guidelines* Vol. 2, page 3.50, Table 3.5.3

● **Activity Data**

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

Table 3-51 Activity data used for estimation of emissions from ships [1000 kL]

Fuel type	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Diesel oil	133	208	204	195	189	163	154	149	141	142	157	139	147	147
Fuel oil A	1,602	1,625	1,728	1,324	1,046	946	1,007	969	1,006	994	984	980	1,010	1,004
Fuel oil B	526	215	152	63	25	20	18	16	16	14	12	9	6	6
Fuel oil C	2,446	3,002	3,055	2,873	2,592	2,420	2,482	2,460	2,517	2,487	2,482	2,386	2,361	2,332

- **Completeness**

According to the *2006 IPCC Guidelines* (Vol. 3, page 5.7), CH₄ and N₂O emissions from use of lubricants are very small in comparison to CO₂, 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 default values in the *2006 IPCC Guidelines* are adopted for the emission factors of domestic navigation, the uncertainties indicated in the *2006 IPCC Guidelines* (-50% to +50% for CH₄ and -40% to +140% for N₂O) 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* (-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 CH₄ and -42% to +141% for N₂O.

- **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 Chapter 1.

e) Category-specific Recalculations

The emissions for FY2013 through FY2016 were recalculated due to a revision of the energy consumption of the *General Energy Statistics*. The emissions from diesel oil for FY2006 through FY2016 were recalculated due to a correction of the calorific value of diesel oil. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

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. CO₂ Emissions from Other Sectors and Other (1.A.4., 1.A.5: CO₂)

a) Category Description

This section provides the estimation methods for CO₂ 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 FY2017, CO₂ emissions from this category accounted for 143,401 kt-CO₂, and represented 11.1% of Japan's total GHG emissions (excluding LULUCF). The commercial/institutional (1.A.4.a) accounts for 47.0%, and is the largest subcategory within the "Other sectors" category in FY2017.

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 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.) in accordance with the *2006 IPCC Guidelines*. Please refer to Chapter 7 for further details on the estimation methods.

The CO₂ emissions from biomass are not included in the national totals but are reported in the CRFs 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 3.2.4. b).

● Activity Data

The data given in the *General Energy Statistics* compiled by ANRE 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 3-54, which is the survey results by MOE in FY2014 and FY2015. Please refer to

the Table 3-53 for which category the emissions from mobile or stationary combustion to be allocated in the CRF table.

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 CO₂ emissions from energy consumption for power or steam generation to the sectors generating that power or steam. As such, these CO₂ emissions are added to those from each office in the final energy consumption sector and are reported in 1.A.4.

Table 3-52 Energy consumptions in Other Sectors (1.A.4) (unit: PJ)

Fuel	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Liquid fuels	1,939	2,093	2,200	2,231	1,676	1,568	1,581	1,515	1,423	1,451	1,356	1,299	1,286	1,290
Solid fuels	3	2	1	1	17	17	19	15	12	15	12	12	47	29
Gaseous fuels	418	537	649	731	881	835	835	847	826	814	810	824	839	891
Other fossil fuels	196	219	257	278	263	241	243	242	257	248	246	239	274	273
Biomass	15	18	22	44	53	52	59	62	63	65	73	84	66	69
Total	2,572	2,868	3,129	3,285	2,889	2,714	2,738	2,681	2,582	2,593	2,497	2,457	2,512	2,552

Table 3-53 Correspondence between sectors of Japan's Energy Balance Table and those of the CRF (1.A.4 and 1.A.5)

CRF		General Energy Statistics	
1A4	Other sectors		
		Auto power generation (except for Production, transmission and distribution of electricity [#255330] (until 2015), Agriculture, fishery, mining and construction [#251000] and Manufacturing [#252000])	#255000
1A4a	Commercial/institutional	Auto steam generation (except for Agriculture, fishery, mining and construction [#261000] and Manufacturing [#262000])	#265000
		Final energy consumption; Commercial industry	#650000
		Non-energy and feedstock use; Commercial	#951800
1A4b	Residential	Final energy consumption; Residential	#700000
		Non-energy and feedstock use; Household	#952000
1A4c	Agriculture/forestry/fishing		
		Auto power generation; Agriculture, fishery, mining and construction (agriculture, forestry and fishery)	#251000
		Auto steam generation; Agriculture, fishery, mining and construction (agriculture, forestry and fishery)	#261000
		Final energy consumption; Agriculture, forestry and fishery [#610000]; stationary sources (estimates)	
		Non-energy and feedstock use; Agriculture, fishery, mining and construction (agriculture, forestry and fishery)	#951100
	i Stationary	Final energy consumption; Agriculture [#611100]; mobile sources (estimates)	
		Final energy consumption; Forestry [#611200]; mobile sources (estimates)	
	ii Off-road vehicles and other machinery	Final energy consumption; Fishery, except aquaculture [#611300]; mobile sources (estimates)	
		Final energy consumption; Aquaculture [#611400]; mobile sources (estimates)	
	iii Fishing		
1A5	Other	NO	-

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

Table 3-54 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 combustion	Stationary combustion	Mobile combustion	Stationary combustion	Mobile combustion (ships)	Mobile combustion	Stationary combustion	Mobile combustion (ships)	Mobile combustion	Stationary combustion
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%

Source: Actual condition survey of GHG emissions from non-manufacturing industry, Fiscal year 2014 (MOE)

c) Uncertainties and Time-series Consistency

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 Chapter 1.

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 all years were recalculated.

For the purpose of ensuring time-series consistency and comparability, the reporting category of some sources was revised See 3.2.4. e).

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

3.2.11. CH₄ and N₂O Emissions from Other Sectors and Other (1.A.4., 1.A.5:CH₄ and N₂O)**a) Category Description**

This section provides the estimation methods for CH₄ and N₂O 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 category also provides the estimation methods for determining CH₄ and N₂O 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), CH₄ and N₂O 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 3.2.5. b) (1.A.1).

➤ **Biomass boilers**

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

➤ **Residential**

For Residential (1.A.4.b), CH₄ and N₂O 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 3-21 and Table 3-22 (1.A.1).

➤ *Biomass boilers*

See 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 3-55 CH₄ and N₂O emission factors for residential (1.A.4.b)

Furnace type	Fuel type	CH ₄ Emission factor [kg-CH ₄ /TJ]	N ₂ O Emission factor [kg-N ₂ O/TJ]
Household equipment	Liquid fuels	9.5	0.57
	Solid fuels	290	1.4
	Gaseous fuels	4.5	0.090
	Biomass fuels	290	3.8

Conversion to the GCV basis by multiplying the IPCC default values by 0.95 (liquid, solid and biomass fuels) or 0.9 (gaseous fuels) (*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 *EMEP/EEA air pollutant emission inventory guidebook 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 CH₄ and N₂O emission factors” in the *2006 IPCC Guidelines* vol. 2, page3.50.

Table 3-56 Emission factors of CH₄ and N₂O for off-road vehicles and other machinery in agriculture/forestry/fishing (1.A.4.c)

Fuel	Unit	CH ₄ emission factor	N ₂ O emission factor	Source
Diesel oil, kerosene, fuel oil A used for other than ships	g/t	87	136	<i>EMEP/EEA air pollutant emission inventory guidebook 2016, Non-road mobile sources and machinery, Table 3-1</i>
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	<i>2006 IPCC Guidelines, Vol.2, Table 3.5.3</i>

● **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 3-54 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 (*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 3.2.5. b) (1.A.1).

➤ *Biomass boilers*

See 3.2.5. b) (1.A.2).

➤ *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 3-54), 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 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 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 Chapter 1.

e) Category-specific Recalculations

See 3.2.7. c). However, for the recalculation of “Production, Transmission and Distribution of Electricity” under “Auto power generation” in the *General Energy Statistics*, and the waste incineration for energy purposes and with energy recovery, see 3.2.4. e) (1.A.1).

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

The default emission factors in the *2006 IPCC Guidelines* are used to estimate the CH₄ and N₂O emissions from biomass combustion of stationary sources. As the current emission status may not be reflected, it is necessary to consider establishing country-specific emission factors.

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) 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 3-57 Waste types whose emissions are estimated for waste incineration and energy use
(reported on energy sector: 1.A.)

Category	Waste type		Fuel type to be allocated to CRF	Treatment type	CO ₂	CH ₄	N ₂ O		
1.A.1. (7.4.3.1) ⁷⁾	Municipal solid waste	Plastics	Fossil-fuel derived plastics	Other fossil fuels	* Incinerator -continuous, -semi- continuous -batch type	○ ²⁾	○ ²⁾		
			Biomass-based plastics	Biomass ⁸⁾					
		Paper/ cardboard	Fossil-fuel derived fraction	Other fossil fuels ⁹⁾				○	
			Biogenic fraction	Biomass				NA ¹⁾	
		Nappy (Fossil-fuel derived fraction)		Other fossil fuels				○	
		Textiles	Synthetic textile	Other fossil fuels				○	
			Natural fiber	Biomass				NA ¹⁾	
	Other (biogenic)		Biomass	NA ¹⁾					
	Industrial solid waste	Waste oil	Fossil-fuel derived oil	Other fossil fuels	Incineration with energy recovery	Incinerator	○	○	
			Animal and vegetable oil	Biomass					
		Plastics	Fossil-fuel derived plastics	Other fossil fuels					○
			Biomass-based plastics	Biomass ⁸⁾					NA ¹⁾
		Food waste [Animal and vegetable residues/animal carcasses]		Biomass					○
		Paper/ cardboard	Fossil-fuel derived fraction	Other fossil fuels ⁹⁾					○
			Biogenic fraction	Biomass					IE ⁴⁾
		Wood		Biomass					○
		Textile	Synthetic textile	-					IE ⁵⁾
			Natural fiber	Biomass					IE ⁵⁾
		Sludge	Sewage sludge	-					NA ¹⁾
			Other than sewage sludge	Biomass					○
Specially controlled industrial waste		-	IE ⁵⁾						
1.A.1/2 (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⁾					
	Industrial solid 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⁾					
	Wood		Biomass	○					
	Waste tire	Fossil-fuel derived fraction	Other fossil fuels	○					
Biogenic fraction		Biomass ⁸⁾	NA ¹⁾						
1.A.1/2 (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⁾						
	Refuse Paper and Plastic Fuel (RPF)	Fossil-fuel derived fraction	Other fossil fuels				○		
		Biogenic fraction	Biomass ⁸⁾				NA ¹⁾		

- 1) CO₂ 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 CRF tables.
- 2) CH₄ and N₂O emissions from incineration of municipal solid waste in bulk are estimated by each incineration type and reported as “Other fossil fuels” in the CRF 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 CRF, 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 3-58 Reporting categories on 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 ₂ O	
Waste incineration with energy recovery	MSW	(Unclassified)	Waste incineration with energy recovery	1.A.4.a. Commercial/institutional	○	○	○	
	ISW				○	○	○	
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 & 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 & 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 & steel	○	NO ³⁾	NO ³⁾	
	Gasification		Fuel in iron manufacturing	1.A.2.a. Iron & 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	○	○	○	
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.b. 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	○	○	○	

- 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) CO₂ 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 CRF tables. For detail, see Table 3-57.
- 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) N₂O 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 3-59 shows the greenhouse gas emissions from waste incineration and energy use (reported on energy sector) (1.A.).

Table 3-59 GHG emissions from waste incineration and energy use (reported on energy sector) (1.A.)

Item		Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
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
	b. Petroleum refining	kt-CO ₂	NO	NO	1	6	4	5	6	5	6	5	5	6	4	5
	c. Manufacture of solid fuels and other energy industries	kt-CO ₂	NO	NO	15	240	194	205	242	232	234	NO	24	40	34	44
1.A.2. Manufacturing industries and construction	a. Iron and steel	kt-CO ₂	NO	NO	310	637	379	446	547	487	536	473	579	560	588	624
	b. Non-ferrous metals	kt-CO ₂	119	63	51	17	3	2	2	2	NO	NO	NO	NO	NO	NO
	c. Chemicals	kt-CO ₂	14	64	89	67	66	67	73	72	84	82	65	68	63	65
	d. Pulp, paper and print	kt-CO ₂	NO	56	114	998	1,614	1,663	1,726	1,746	1,771	1,851	1,903	1,950	1,998	2,065
	e. Food processing, beverages and tobacco	kt-CO ₂	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	1,375	1,391	1,324	1,355	1,357	1,453	1,636	1,590	1,711	1,780
g. Other	kt-CO ₂	3,870	4,464	4,425	5,766	5,358	5,236	5,526	5,378	5,624	5,507	5,257	5,648	5,305	5,086	
1.A.4	a. Commercial/institutional	kt-CO ₂	6,679	7,292	9,330	8,234	7,813	6,607	6,440	6,681	7,509	7,323	6,859	6,983	7,865	7,717
Total		kt-CO ₂	10,878	12,431	15,214	17,054	16,805	15,622	15,885	15,957	17,123	16,692	16,327	16,844	17,569	17,385
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
	b. Petroleum refining	kt-CH ₄	NO	NO	1.7E-06	1.8E-05	9.8E-06	1.3E-05	1.6E-05	1.3E-05	1.5E-05	1.3E-05	1.4E-05	1.7E-05	1.2E-05	1.4E-05
	c. Manufacture of solid fuels and other energy industries	kt-CH ₄	NO	NO	IE	IE	IE	IE	IE	IE	IE	NO	IE	IE	IE	IE
1.A.2. Manufacturing industries and construction	a. Iron and steel	kt-CH ₄	NO	NO	NO	7.7E-04	1.4E-03	1.4E-03	1.4E-03	1.3E-03	1.3E-03	1.2E-03	1.4E-03	1.4E-03	1.4E-03	1.6E-03
	b. Non-ferrous metals	kt-CH ₄	3.2E-04	1.8E-04	1.4E-04	7.7E-05	1.5E-05	7.7E-06	7.7E-06	7.7E-06	NO	NO	NO	NO	NO	NO
	c. Chemicals	kt-CH ₄	2.0E-05	1.0E-04	1.5E-04	1.7E-04	1.7E-04	1.8E-04	1.9E-04	1.9E-04	2.2E-04	2.2E-04	1.8E-04	1.9E-04	1.7E-04	1.7E-04
	d. Pulp, paper and print	kt-CH ₄	NO	1.0E-04	2.2E-04	2.7E-03	4.3E-03	4.5E-03	4.6E-03	4.7E-03	4.8E-03	5.0E-03	5.1E-03	5.3E-03	5.5E-03	5.6E-03
	e. Food processing, beverages and tobacco	kt-CH ₄	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	0.23	0.23	0.22	0.22	0.22	0.23	0.26	0.25	0.27	0.28
g. Other	kt-CH ₄	1.8	1.8	2.2	2.9	4.0	4.2	4.2	4.4	4.5	4.8	5.3	5.0	4.9	5.1	
1.A.4	a. Commercial/institutional	kt-CH ₄	0.54	0.54	0.60	0.15	0.15	0.14	0.14	0.17	0.17	0.15	0.15	0.14	0.15	0.15
Total		kt-CH ₄	2.3	2.4	3.0	3.3	4.4	4.6	4.6	4.8	4.9	5.2	5.7	5.4	5.4	5.6
		kt-CO ₂ eq.	59	60	74	81	110	115	114	120	122	129	142	135	134	139
1.A.1. Energy industries	a. Public electricity and heat production	kt-N ₂ O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	b. Petroleum refining	kt-N ₂ O	NO	NO	1.1E-05	1.2E-04	6.3E-05	8.3E-05	1.0E-04	8.3E-05	1.0E-04	8.1E-05	9.0E-05	1.1E-04	8.0E-05	9.1E-05
	c. Manufacture of solid fuels and other energy industries	kt-N ₂ O	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 ₂ O	NO	NO	NO	9.1E-04	1.6E-03	1.6E-03	1.6E-03	1.5E-03	1.5E-03	1.5E-03	1.7E-03	1.6E-03	1.7E-03	1.9E-03
	b. Non-ferrous metals	kt-N ₂ O	2.4E-04	1.3E-04	1.1E-04	5.6E-05	1.1E-05	5.6E-06	5.6E-06	5.6E-06	NO	NO	NO	NO	NO	NO
	c. Chemicals	kt-N ₂ O	8.5E-03	6.8E-03	8.5E-03	4.5E-03	3.7E-03	3.3E-03	3.3E-03	3.0E-03	3.2E-03	2.4E-03	1.7E-03	1.9E-03	1.5E-03	5.8E-03
	d. Pulp, paper and print	kt-N ₂ O	NO	6.6E-04	5.9E-03	2.2E-02	5.4E-02	5.6E-02	5.8E-02	5.6E-02	5.5E-02	5.5E-02	6.1E-02	5.9E-02	6.2E-02	6.5E-02
	e. Food processing, beverages and tobacco	kt-N ₂ O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	f. Non-metallic minerals	kt-N ₂ O	2.7E-03	6.9E-03	1.2E-02	1.7E-02	2.1E-02	2.0E-02	1.9E-02	1.9E-02	1.9E-02	2.0E-02	2.3E-02	2.2E-02	2.4E-02	2.5E-02
g. Other	kt-N ₂ O	5.8E-02	5.1E-02	5.3E-02	6.1E-02	6.6E-02	6.7E-02	6.8E-02	7.0E-02	7.1E-02	7.4E-02	7.9E-02	7.7E-02	7.5E-02	7.7E-02	
1.A.4	a. Commercial/institutional	kt-N ₂ O	1.2	1.3	1.6	1.2	1.1	1.0	1.0	1.0	1.0	1.0	1.0	0.9	1.0	1.0
Total		kt-N ₂ O	1.3	1.4	1.7	1.3	1.2	1.1	1.1	1.1	1.2	1.1	1.1	1.1	1.2	1.2
		kt-CO ₂ eq.	381	421	494	383	368	340	336	330	349	337	338	322	360	362

- 1) Include fossil-fuel derived component only.
CO₂ 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 CRF 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): emissions from coal mining and handling, and oil and natural gas (1.B.2): emissions from the oil and natural gas industries. The main source of emissions from solid fuels is CH₄ 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 FY2017, GHG emissions from fugitive emissions from fuels were 1,278kt-CO₂ eq. and accounted for 0.1% of Japan's total GHG emissions (excluding LULUCF). The emissions have decreased by 75% compared to 1990.

Table 3-60 Emission trends of the fugitive emissions subsector (1.B)

CRF Category		Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017		
1.B.1 Solid Fuels	a. Coal Mining	kt-CH ₄	187.9	93.3	60.5	24.8	22.5	22.1	21.5	21.2	20.9	20.4	20.7	20.1	19.7	20.1		
	b. Solid Fuel Transformation		2.5	2.5	2.0	1.3	1.1	1.0	1.0	0.9	0.9	0.9	0.8	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		1.0	1.1	1.1	1.2	1.1	1.0	1.0	1.0	1.0	0.9	0.9	0.8	0.8	0.8		
	b. Natural Gas		7.0	7.8	8.8	10.7	12.3	11.8	11.1	10.9	10.5	9.8	9.2	9.3	10.0	9.9		
	c. Venting and Flaring		0.3	0.5	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2		
	d. Other (Geothermal Generation)		0.2	0.8	0.7	0.7	0.6	0.5	0.5	0.5	0.5	0.4	0.5	0.4	0.4	0.4		
Total			kt-CH ₄	198.9	105.9	73.4	39.1	37.9	36.7	35.4	34.7	34.0	32.6	32.2	31.5	31.8	32.0	
			kt-CO ₂ eq.	4,973	2,647	1,836	976	947	916	885	867	851	816	806	787	794	801	
1.B.1 Solid Fuels	a. Coal Mining		kt-CO ₂	5.3	2.4	1.6	0.6	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	
	b. Solid Fuel Transformation			NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	
	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			0.03	0.03	0.03	0.04	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02
	b. Natural Gas			0.6	0.7	0.8	1.0	1.2	1.1	1.0	1.0	1.0	0.9	0.9	0.8	0.9	0.9	
	c. Venting and Flaring			81.2	109.1	122.6	164.3	273.9	258.2	221.7	224.0	232.2	221.6	209.8	223.3	245.2	264.7	
	d. Other (Geothermal Generation)			104.4	409.2	386.6	341.9	289.5	241.0	251.2	251.9	256.5	215.1	237.9	200.1	210.5	210.5	
Total		kt-CO ₂		192	521	512	508	565	501	475	477	490	438	449	425	457	477	
1.B.1 Solid Fuels	a. Coal Mining	kt-N ₂ O		NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	
	b. Solid Fuel Transformation			NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	
	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			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	
	b. Natural Gas																	
	c. Venting and Flaring			0.0004	0.0005	0.0004	0.0004	0.0004	0.0004	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
	d. Other (Geothermal Generation)			NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Total				kt-N ₂ O	0.0004	0.0005	0.0004	0.0004	0.0004	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
			kt-CO ₂ eq.	0.11	0.15	0.11	0.11	0.12	0.11	0.10	0.10	0.10	0.09	0.09	0.08	0.08	0.08	
Total of all gases			kt-CO ₂ eq.	5,165	3,169	2,347	1,484	1,512	1,417	1,359	1,345	1,341	1,254	1,255	1,212	1,251	1,278	

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 provides the estimation methods for CH₄ and CO₂ emissions from coal mining, post-mining process, and abandoned mines.

Coal contains CH₄ which was formed during the coalification process. Most will have been naturally

released from the ground surface before mine development, but mining releases the CH₄ remaining in coal beds into the atmosphere. In addition, some of the coal mines still emit CH₄ after they have been abandoned. Also, relatively low-density CO₂ is included in coal in comparison with CH₄, and is emitted to the air through the similar process with the CH₄.

The number of operational coal mines in Japan has decreased and coal production has decreased greatly as well. As a result, the amount of CH₄ emissions from coal mining has decreased year by year.

Furthermore, the coal mining practices have changed recently, resulting in the decreasing trend of CH₄ IEF. Specifically, coal is now mined in more shallow areas. Therefore, emitting less CH₄. 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 CH₄, are re-mined for coal, using the latest technology. This contributes to low CH₄ emissions per amount of coal mined, even if compared with other countries.

b) Methodological Issues

● Estimation Method

➤ CH₄

- Mining Activities

CH₄ 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

CH₄ 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 4.1.1, Fig4.1.1) and by using the Tier 2 method, the CH₄ 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.

$$E = N \times F \times ER \times EF \times CF, \quad EF = (1 + a \times T)^b$$

E : Amount of GHG fugitive emissions from abandoned coal mine [kt/year]

N : Number of abandoned mines which was not submerged [sites]

F : The percentage of mines that release fugitive emissions

ER : GHG emissions from mines before mine closure [m³/year]

EF : Emissions reduction factor

a, b : Parameters determining emission decline curve

T : Time period of mine closure [year]

CF : Gas density [kt/m³] CH₄: 0.67×10⁻⁶

➤ *CO₂*- **Mining Activities**

CO₂ emissions are estimated by multiplying the production amount of coal by CO₂ emission factor.

- **Post-Mining Activities**

CO₂ emissions are estimated by multiplying the production amount of coal by CO₂ emission factor.

- **Abandoned Underground Mines**

The estimation method of CO₂ emissions is similar to that of CH₄ described above, and the CO₂ emission factor is established based on CH₄ emission factor.

● **Emission Factors**➤ *CH₄*- **Mining Activities**

CH₄ emission factor for mining activities is established by dividing the total emissions of CH₄ gas identified in a survey by J-COAL (Japan Coal Energy Center), by the production volume 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, which are established from actual measurements.

Table 3-61 Emission factors for mining activities –underground mines

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Reference
Coal production of underground mines	kt	6,775	5,622	2,364	738	536	575	588	543	528	529	540	470	529	612	Surveyed by J-COAL
CH ₄ total emissions	1000m ³	262	92	57	4.2	2.0	2.1	2.0	1.8	1.8	1.9	2.3	2.4	2.4	2.9	Surveyed by J-COAL
CH ₄ total emissions	kt-CH ₄	176	62	38	2.8	1.3	1.4	1.3	1.2	1.2	1.2	1.5	1.6	1.6	1.9	=CH ₄ [1000m ³] / 1000 × 0.67 [kt/10 ⁶ m ³]
Emission factor	kg-CH ₄ /t	26	11	16	3.8	2.5	2.4	2.2	2.2	2.2	2.3	2.8	3.4	3.0	3.1	CH ₄ total emissions

- **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-CH₄/t] by converting the average value (2.5 [m³/t]) of the default values given in the 2006 IPCC Guidelines with the density of CH₄ (0.67 [kt/10⁶ m³]) 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 4.2.4 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 (*F*), the percentage of mines that release fugitive emissions.

The lower default value (1.3million cubic meter/year/site) indicated in Table 4.1.8 in page 4.27 in the 2006 IPCC Guidelines Vol.2 is used for (*ER*), GHG emissions from mines before mine closure, by taking scale of mine 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.

➤ *CO₂*- *Mining Activities*

CO₂ emission factor for mining activities is established by multiplying CH₄ emission factor (volume basis) by proportion of volume fraction of CO₂ in coalbed gas to that of CH₄ (0.0088), which is obtained by using “*Research Report on Gas Chemical Industry Development, FY1960-64, Reserves in Coal fields*” by Hokkaido Development Agency, and by CO₂ density (1.84kg/m³).

- *Post-Mining Activities*

In the same way as calculated for mining activities, the emissions factors for post-mining activities are established by multiplying CH₄ 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 CH₄ 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 are derived by subtracting the surface mining production from the total coal production as given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* prepared by METI and the data provided by J-COAL.

Table 3-62 Trends in coal production

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total coal production	kt	7,980	6,317	2,974	1,249	1,290	1,206	1,145	1,195	1,247	1,251	1,318	1,265	1,282	1,328
Surface mines		1,205	695	610	511	754	631	557	652	719	721	778	795	753	716
Underground mines		6,775	5,622	2,364	738	536	575	588	543	528	529	540	470	529	612

- *Abandoned Underground Mines*

For activity data, the number of abandoned mines which were not submerged, estimated from the list of abandoned mine in *History of Coal Policy* by J-COAL.

Table 3-63 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 CH₄ which has been emitted from the coal bed during mining in Japan, however there are activities of recovering CH₄ and using it as fuel. Therefore, the net amount of the emissions is estimated by subtracting the recovered value from the total CH₄ emissions. The values of recovery were provided by the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* prepared by METI (1990-1997) and the data provided by J-COAL (since 1998).

Table 3-64 Trends in CH₄ recovery from mining activities

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Recovery	1000 m ³	50,139	11,112	9,810	2,044	988	990	941	733	591	826	448	844	955	482

- **Post-Mining Activities**

The CH₄ 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 CH₄ recovery or flaring has not been implemented.

c) Uncertainties and Time-series Consistency

● **Uncertainties**

For the uncertainties of CH₄ 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 CO₂ emissions during mining activity, the uncertainty of CH₄ emissions and the uncertainty of proportion of volume fraction of CO₂ in coalbed gas to that of CH₄, which is 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 CH₄ 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 CO₂ emission factors during post-mining activities, the uncertainty in CH₄ emission factors and the uncertainty in proportion of volume fraction of CO₂ in coalbed gas to that of CH₄, 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 CH₄ and CO₂, 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 CH₄ emissions and -38% to +301% for CO₂ emissions.

The uncertainties in CH₄ 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 CO₂ emissions from abandoned mines, the uncertainties in CH₄ emissions and the uncertainties in proportion of volume fraction of CO₂ in coalbed gas to that of CH₄, 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 CH₄ 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 by METI 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 by METI 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 CH₄ 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 *Coal Policy History* by J-COAL. The default values in the *2006 IPCC Guidelines* are used for the ratio of gas emitting coal mines, the amount of CH₄ emissions from the coal mine before the closure, and the parameters to determine the decreasing curve of the emissions. Also, the CO₂ emissions from the coal mine before closure are estimated from the CH₄ 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 Chapter 1.

In order to ensure the safety of coal mine workers in Japan, monitoring the concentration of CH₄ and CO in coal mines is ordained by law. Under the law, mining companies must set rules on monitoring management. Mining companies monitor accurately under strict management and checks, and compile relevant reports. Furthermore, national authorities regularly check the monitoring measurements and safety reports.

e) Category-specific Recalculations

There have been no recalculations of emissions from this category.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

3.3.1.1.b. Surface Mines (1.B.1.a.ii.)

a) Category Description

This category provides the estimation methods for fugitive emissions of CH₄ and CO₂ occurring during coal mining and post-mining activities in surface mines. The emissions of CH₄ 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****➤ CH₄****- Mining Activities**

The CH₄ 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 CH₄ 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.

➤ CO₂**- Mining Activities**

CO₂ emissions are estimated by multiplying the production amount of coal by CO₂ emission factor.

- Post-Mining Activities

CO₂ emissions are estimated by multiplying the production amount of coal by CO₂ emission factor.

● Emission Factors**➤ CH₄****- Mining Activities**

The value of 0.804 kg-CH₄/t is used as emission factor for mining activities. It was derived by converting the average (1.2 m³/t) of the default values given in the *2006 IPCC Guidelines*, using the concentration of CH₄ at one atmospheric pressure and 20°C (0.67 kt/10⁶m³).

- Post-Mining Activities

The value of 0.067 kg-CH₄/t is used as emission factor for post-mining activities. It was derived by converting the average (0.1 m³/t) of the default values given in the *2006 IPCC Guidelines*, using the concentration of CH₄ at one atmospheric pressure and 20°C (0.67 kt/10⁶m³).

➤ CO₂**- Mining Activities**

CO₂ emission factor for mining activities is established by multiplying CH₄ emission factor (volume basis) by proportion of volume fraction of CO₂ in coalbed gas to that of CH₄ (0.0088), which is obtained by using “*Research Report on Gas Chemical Industry Development, FY1960-64, Reserves in Coal fields*” by Hokkaido Development Agency, and by CO₂ density (1.84 kg/m³).

- Post-Mining Activities

In the same way as calculated for mining activities, the CO₂ emissions factors for post-mining activities are established by multiplying CH₄ 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* prepared by METI and the data provided by the J-COAL were used as activity data for mining and post-mining activities (see Table 3-62).

c) Uncertainties and Time-series Consistency

- **Uncertainties**

For the uncertainty in CH₄ 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 CO₂ emission factor during mining activities, the uncertainty in CH₄ emission factor and the uncertainty in proportion of volume fraction of CO₂ in coalbed gas to that of CH₄, 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 CH₄ and CO₂ 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 CH₄ and -53% to +201% for CO₂.

For the uncertainty in CH₄ 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 CO₂ emission factor during post-mining activities, the uncertainty in CH₄ emission factor and the uncertainty in proportion of volume fraction of CO₂ in coalbed gas to that of CH₄, 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 CH₄ and CO₂ 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 CH₄ and -38% to +301% for CO₂.

- **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 by METI 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 Chapter 1.

e) Category-specific Recalculations

There have been no recalculations of emissions from this category.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

3.3.1.2. Solid Fuel Transformation (1.B.1.b.)**a) Category Description**

This category provides the estimation methods for CH₄ emissions in the process of manufacturing charcoal in the oven; CH₄ emissions are released due to imperfect combustion of carbon contained wood material which is raw material of charcoal.

b) Methodological Issues● **Estimation Method**

CH₄ emissions from manufacturing charcoal are estimated by multiplying production amount of charcoal by emission factor.

● **Emission Factors**

The default value given in the *Revised 1996 IPCC Guidelines* (Vol.3, page 1.46, Table 1-14) is used since no default value for this category is provided in the *2006 IPCC Guidelines*. Because the production amount of charcoal is available as a statistical data, the emission factor (1000 kg/TJ) of emitted amount per produced amount in NCV is adopted.

● **Activity Data**

The activity data is calculated by multiplying the production amount of charcoal by calorific value. The amount of charcoal production is obtained from *Basic Data for Special Forest Product and Data for Charcoal* by Forestry Agency. For the calorific value, 30 MJ/kg quoted from the *1996 Revised IPCC Guidelines* (Vol.3, page 1.46, Table 1-14) is adopted.

Table 3-65 The Production Amount of Charcoal

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Charcoal Production	t	83,225	82,278	67,428	44,919	37,308	34,449	34,095	31,226	30,263	29,588	27,749	25,865	23,733	23,095

● **Completeness**

CO₂ are also emitted by charcoal production, but the emissions are not estimated since they are bio-derived. The emissions by consuming charcoal are included in “1.A Fuel Combustion”, however the CO₂ emissions are not included in the national totals but are reported in the CRFs as reference in accordance with the *2006 IPCC Guidelines*.

In Japan, the production of briquettes is considered to meet the description of the activity of solid 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 CO₂, CH₄ or N₂O 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*

As for emission factors, the default values given in the *1996 Revised IPCC Guidelines* are used. However, since the uncertainties for emission factors for this category is not provided in the *1996 Revised IPCC Guidelines*, the uncertainties (-67% to +233%, calculated by 95% confidence interval) for CH₄ emission factors for combustion of wood material provided in the *2006 IPCC Guidelines* are substituted.

As for activity data, the uncertainties are evaluated as -50% to +97% by synthesizing the uncertainties for charcoal production (weight base), which are not available in the *Basic Data for Special Forest Product* (Forestry Agency) and then substituted by the uncertainties for coal production, and the uncertainties which are calculated by 95% confidence interval of charcoal calorific value provided in the *2006 IPCC Guidelines* with the error propagation method.

As a result, uncertainties for CH₄ emissions from charcoal production are evaluated as -84% to +252%.

● *Time-series Consistency*

The data source of the charcoal production amount in FY1990, which is the *Data for Charcoal*, is different from the data source 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 *1996 Revised IPCC Guidelines* are used for the CH₄ calorific value and the emission factor throughout the time-series so that the 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 Chapter 1.

e) *Category-specific Recalculations*

There have been no recalculations of emissions from this category.

f) *Category-specific Planned Improvements*

Surveys whether the default emission factors presented in the *1996 Revised IPCC Guidelines* are suitable for Japan's circumstances, and studies of necessity in developing country-specific emission factors are necessary.

3.3.1.3. Others (Uncontrollable combustion and burning coal dumps) (1.B.1.c)

This category provides the estimation methods for CO₂ emissions generated by unintentional coal combustion due to mine fire.

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".

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 provides the estimation methods for fugitive emissions of CO₂, CH₄ and N₂O from the exploratory drilling of oil fields.

In Japan, GHG emissions by the exploratory drilling of oil and natural gas fields are basically only from flaring. Therefore, the fugitive emissions associated with exploratory drilling are included in “1.B.2.c.Flaring.iii Flaring (Combined)”.

“1.B.2.a.i. Exploration of Oil” and “1.B.2.b.1 Exploration of Natural Gas” are reported as “IE”, because the fugitive emissions other than flaring are also conceptionally included in “1.B.2.c.Flaring.iii Flaring (Combined)” since the default emission factors in the *GPG (2000)*, which covers fugitive emissions other than flaring, are used in “1.B.2.c.Flaring.iii Flaring (combined)” as described later.

3.3.2.1.b. Production (1.B.2.a.ii.)

a) Category Description

This category provides the estimation methods for fugitive emissions of CO₂ and CH₄ occur at production of crude oil and in lowering measuring instrument into well at servicing of operating oil fields.

The emissions associated with fugitive emissions during oil production are estimated for offshore and onshore oil field. The emissions from operating oil fields occur in servicing are reported in “1.B.2.b.ii Production of Natural Gas” and not included in this category, because the activity data of number of wells in production is not able to be divided into the numbers of oil producing wells and natural gas producing wells.

b) Methodological Issues

● Estimation Method

The fugitive emissions from oil production are estimated using the Tier 1 method, in accordance with the decision tree in the *2006 IPCC Guidelines* (Vol. 2, page 4.39, Fig.4.2.2).

● Emission Factors

- Production

For emission factors for fugitive emissions from oil production, the default values for fugitive emissions of conventional oil from offshore and offshore oil fields, which are indicated in the *2006 IPCC Guidelines*, are used. As for emission factors for onshore fields, the medians of default values are used.

Table 3-66 Emission factors for fugitive emissions from oil production [kt/10³m³]

		CH ₄	CO ₂	N ₂ O ³⁾
Conventional Oil	Fugitive emissions from offshore fields	5.9×10 ⁻⁷	4.3×10 ⁻⁸	NA
	Fugitive emissions from onshore fields	1.8×10 ⁻³ ¹⁾	1.3×10 ⁻⁴ ²⁾	NA

Source: *2006 IPCC Guidelines* Vol. 2, page 4.50, Table 4.2.4

1) The default value is 1.5×10⁻⁶ - 3.6×10⁻³

2) The default value is 1.1×10⁻⁷ - 2.6×10⁻⁴

3) Excluded from calculations, as the default value is “NA”

- **Servicing**

As the fugitive emissions from the servicing of oil and natural gas wells are reported in “1.B.2.b.ii Production of natural gas”, refer to that section for the emission factors as well.

● **Activity Data**

- **Production**

The amount of crude oil production by offshore and onshore oil field (excluding condensate¹¹) 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 *Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products* and the *Yearbook of Current Production Statistics*. The production amount of natural gas and crude oil from offshore is obtained from *Natural Gas Data Year Book* compiled by the Japan Natural Gas Association.

Table 3-67 Amount of oil production excluding condensate from offshore and onshore oil fields

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Oil production	offshore	1000 kL	175	391	167	76	97	91	78	72	70	82	76	67	67
excluding	onshore	1000 kL	245	232	218	295	243	218	215	209	195	180	164	152	143

- **Servicing**

Because the fugitive emissions from the servicing of oil and natural gas wells are reported in “1.B.2.b.ii Production of natural gas”, please refer to that section also for the activity data.

● **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 1.B.2.b.ii and 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 established in the *2006 IPCC Guidelines* (-100% to +100%) are used for emission factors for oil production, since the default values in the guidelines are used exclusively. For activity data, because the uncertainty of statistics used for source is not obtained, the values established in the *2006 IPCC Guidelines* (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) are used. As a result, the uncertainties for fugitive

¹¹ Light, liquid hydrocarbon that is produced from natural gas wells associated with natural gas production

emissions of CO₂ and CH₄ from oil production are evaluated as -101% to +101% for each.

- **Time-series Consistency**

Consistent values are used for emission factors from FY1990 to the nearest year, using the above-described method. The activity data for oil production are calculated by using the annual data from the *Yearbook of Mineral Resources and Petroleum Products*, the *Natural Gas Data Year Book* and the *Yearbook of Current Production 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 Chapter 1.

e) Category-specific Recalculations

Since the activity data for FY2016 in the *Natural Gas Data Year Book* were revised, the CO₂ and CH₄ emissions in that year were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

As for the fugitive emissions from the servicing of oil and natural gas wells, the correlative relationships between emissions and production volume of crude oil remains unclear when using estimation method in accordance with the *2006 IPCC Guidelines*, and it is likely that the result of the estimating does not reflect the actual status. Therefore, the estimation method in the *GPG (2000)* is adopted. In the future, the background information regarding the *2006 IPCC Guidelines* estimation method will be collected, and if new information is obtained, the adoption of the estimation in the *2006 IPCC Guidelines* will be studied.

3.3.2.1.c. Transport (1.B.2.a.iii.)

a) Category Description

This category provides the estimation methods for fugitive emissions of CO₂ and CH₄ 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.

● *Emission Factors*

The default values given in the *2006 IPCC Guidelines* were used as emission factors.

Table 3-68 Emission factors for transportation of crude oil and condensate [kt/10³m³]

	CH ₄	CO ₂	N ₂ O ¹⁾
Oil Transport/ Tanker Trucks and Rail Cars	2.5×10 ⁻⁵	2.3×10 ⁻⁶	NA
Natural Gas Liquids Transport/ Condensate	1.1×10 ⁻⁴	7.2×10 ⁻⁶	ND

Source: *2006 IPCC Guidelines* Vol. 2, page 4.50 and 4.53, Table 4.2.4

1) 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*, all prepared by METI, are used as activity data for fugitive emissions from transport.

Table 3-69 Production of crude oil and condensate in Japan

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Oil production excluding condensate	1000 kL	420	623	386	370	341	310	293	284	281	265	262	240	219	210
Condensate production		234	243	375	541	633	608	560	541	478	403	365	339	331	336
Oil production (total)		655	866	761	911	973	917	853	824	759	668	626	578	549	546

c) *Uncertainties and Time-series Consistency*

● *Uncertainties*

For the uncertainty of emission factors for CO₂ and CH₄ fugitive emissions from transportation of crude oil and condensate, the values established 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 established 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 statistics provided in sources are not available. As a result, the uncertainties for the CO₂ and CH₄ 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*, all prepared by METI, 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 Chapter 1.

e) *Category-specific Recalculations*

There have been no recalculations of emissions from this category.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

3.3.2.1.d. Refining / Storage (1.B.2.a.iv.)

a) Category Description

This category provides the estimation methods for fugitive emissions of CH₄ occurring when crude oil is refined or stored at oil refineries.

The CO₂ emissions from this source are reported as “NE”. Refining/storage activities exist in Japan and an extremely small amount of CO₂ is considered to be released into the atmosphere from these activities if CO₂ is included in crude oil. Because there are neither actual measurements of the CO₂ content of crude oil nor any default values for emission factors, CO₂ emissions from this source are not estimated.

b) Methodological Issues

● Estimation Method

- 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

For the fugitive emissions from oil storage, a country-specific emission factors can be used. Therefore, the emissions are estimated using these factors.

● Emission Factors

- Oil Refining

With respect to the emission factors for fugitive emissions during the refining process, the amount of CH₄ emitted during the crude oil refining process is considered to be negligible because no fugitive emission of CH₄ 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.

Table 3-70 Emission factor during crude oil refining

Emission factor [kg-CH ₄ /10 ³ m ³]	
Oil refining	2.6×10 ⁻⁶ 1)

Source: *2006 IPCC Guidelines* Vol. 2, page 4.53, Table 4.2.4

1) 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 CH₄ emissions are considered to be very small. If fugitive CH₄ 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 CH₄ emissions would be small.

The Petroleum Association of Japan has conducted experiments relating to the evaporation of CH₄ from tank walls by making the model of floating-roof tank, and based on the result the CH₄ 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-CH₄/year as of 1998) by the amount of the crude oil put into the oil refining industry.

Table 3-71 Assumptions for calculation of emission factor during oil storage

CH ₄ emissions [kt-CH ₄ /year]	Input of crude oil to oil refining industry [10 ³ kL]	Emission factor [kt-CH ₄ /10 ³ kL]
7×10^{-3}	242,861 ¹⁾	2.9×10^{-8}

1) ANRE, *General Energy Statistics*

● 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* compiled by ANRE.

Table 3-72 Amount of crude oil and NGL refined in Japan

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Oil and NGL refined	10 ⁶ m ³	204	241	242	241	224	210	209	197	197	200	189	188	191	184

c) Uncertainties and Time-series Consistency

● Uncertainties

For the uncertainties of emission factors for fugitive emissions of CH₄ 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 CH₄ 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 CH₄ 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 *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 CH₄ 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

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 Chapter 1.

e) Category-specific Recalculations

Since the activity data for FY2013-2016 in the *General Energy Statistics* were revised, the CH₄ emissions in those years were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

3.3.2.1.e. Distribution of Oil Products (1.B.2.a.v.)

Petroleum products are distributed in Japan, and where CO₂ and CH₄ are dissolved, it is conceivable that either or both will be emitted as a result of the relevant activity. The level of CO₂ or CH₄ emitted by the activity is probably negligible in light of the composition of the petroleum products, but because there is no measurement of the CO₂ or CH₄ content in petroleum products, it is not currently possible to calculate emissions. The emissions are reported as “NE” due to the absence of default emission factors.

3.3.2.2. Natural Gas (1.B.2.b.)

3.3.2.2.a. Exploration (1.B.2.b.i.)

This category provides the estimation methods for fugitive emissions of CO₂, CH₄, and N₂O from the explorative drilling of natural gas fields. As well as Exploration of oil (1.B.2.a.i), the emissions in this category are basically only from flaring. Also, it is difficult to distinguish between oil fields and gas fields prior to exploration. Therefore, the emissions are included in 1.B.2.c.Flaring.iii Flaring (combined). In addition, similar to the 1.B.2.a.1 Exploration of Oil, the fugitive emissions other than flaring would be also conceptually included in “1.B.2.c.Flaring.iii Flaring (Combined)”. Therefore, the emissions from this category are reported here as “IE”.

3.3.2.2.b. Production (1.B.2.b.ii.)

a) Category Description

This category provides the estimation methods for fugitive CO₂ and CH₄ emissions from natural gas production and from the lowering work of measuring instruments during the servicing of natural gas wells. The fugitive emissions from natural gas production are estimated by offshore oil fields and onshore oil fields.

b) Methodological Issues

● Estimation Method

The fugitive emissions from the production of natural gas are estimated using Tier 1 method, in accordance with the *2006 IPCC Guidelines* (Vol. 2, page 4.38, Fig. 4.2.1).

For the fugitive emissions related to well servicing, the estimation method of multiplying the amount of crude oil production by emission factors is provided in the *2006 IPCC Guidelines*, however, in Japan, correlation between the amount of crude oil production and the emissions related to well servicing is not clear. Therefore, the Tier1 method provided in the *GPG (2000)* (the estimation method of multiplying the number of production wells by the emission factors), which is considered to be more appropriate for the actual status in Japan, is used

● Emission Factors

- Production

The default values given in the *2006 IPCC Guidelines* are used for the emission factors of fugitive emissions during the production of natural gas.

Table 3-73 Emission factors of fugitive emissions during production of natural gas [kt/10⁶ m³]

		CH ₄	CO ₂	N ₂ O ¹⁾
Natural gas production	Fugitive emissions from offshore field	3.8×10 ⁻⁴	1.4×10 ⁻⁵	NA
	Fugitive emissions from onshore field	2.3×10 ⁻³	8.2×10 ⁻⁵	NA

Source: *2006 IPCC Guidelines* Vol. 2, page 4.48, Table 4.2.4

1) Excluded from calculations, as the default value is "NA".

- Servicing

The default values for fugitive emissions during the servicing of natural gas production wells given in the *GPG (2000)* were used.

Table 3-74 Emission factors during servicing of natural gas production wells [kt/number of wells]

	CH ₄	CO ₂	N ₂ O ¹⁾
Production well (servicing)	6.4×10 ⁻⁵	4.8×10 ⁻⁷	0

Source: *GPG (2000)* Table 2.16

1) Excluded from calculations, as the default value is 0 (zero)

● Activity Data

- Production

The production volume of natural gas from offshore in the *Natural Gas Data Year book* published by the Japan Natural Gas Association 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*, all prepared by METI.

- Servicing

Because it is impossible to statistically differentiate between oil fields and natural gas fields in the time-series, the total number of oil fields and natural gas fields are used for the estimation. As for activity data for fugitive emissions from well servicing, the number of natural gas and oil wells in production provided in *Natural Gas Data Year Book* by the Japan Natural Gas Association is used. As for the latest fiscal year, the values in the previous fiscal year are provisionally used.

Table 3-75 Natural gas production and the number of natural gas and oil wells in production

Item		Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Natural gas production	offshore	10 ⁶ m ³	342	374	350	361	190	191	188	190	196	196	197	190	176	176
	onshore		1,724	1,863	2,149	2,779	3,515	3,364	3,155	3,144	2,981	2,744	2,549	2,525	2,621	2,749
	total		2,066	2,237	2,499	3,140	3,706	3,555	3,343	3,334	3,177	2,940	2,746	2,715	2,797	2,926
Number of gas and oil wells in production		well	1,230	1,205	1,137	1,115	1,065	1,049	1,046	1,047	1,038	1,059	1,046	1,034	1,019	1,019

c) Uncertainties and Time-series Consistency

● Uncertainties

For the uncertainties of emission factors for fugitive emissions of CO₂ and CH₄ from production of natural gas, the values provided in the *2006 IPCC Guidelines* (-100% to +100%) are applied since the default values in the guidelines are used exclusively. As for the activity data, the values established 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 source are not available. As a result, the uncertainties of fugitive emissions of CO₂ and CH₄ from production of natural gas are evaluated to be -101% to +101% for each.

For the emission factors related to servicing of production well, the values established in the *GPG (2000)* (-25% to +25%) are applied since the default values in the guidelines are used exclusively. As for the activity data, the values established in the *2006 IPCC Guidelines* (-25% to +25% of the uncertainties associated with the factor of production facility number) are used, since the uncertainties for statistical data used as source are not available. As a result, the uncertainties of fugitive emissions of CO₂ and CH₄ from servicing of production well are determined to be -35% to +35% for each.

● 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*, all prepared by METI, and on the number of oil/natural gas wells from the *Natural Gas Data Year Book*. 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 Chapter 1.

e) Category-specific Recalculations

Since the activity data for FY2016 in the *Natural Gas Data Year Book* were revised, the CO₂ and CH₄ emissions in that year were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

3.3.2.2.c. Processing (1.B.2.b.iii.)

a) Category Description

This category provides the estimation methods for fugitive CO₂ and CH₄ emissions from the processing of natural gas including adjustment of its constituent elements

b) Methodological Issues

● Estimation Method

The fugitive emissions associated with processing natural gas are estimated using Tier 1 method in accordance with the decision tree in the *2006 IPCC Guidelines* (Vol.2, page 4.38, Fig.4.2.1).

● Emission Factors

For the emission factors for the fugitive emissions during processing of natural gas, the median values between upper limit and lower limit indicated in the *2006 IPCC Guidelines* are used.

Table 3-76 Emission factors during natural gas processing [kt/10⁶ m³]

		CH ₄	CO ₂	N ₂ O ³⁾
Natural gas processing	Fugitive emissions from sweet gas plant	7.55×10 ⁻⁴ ¹⁾	2.35×10 ⁻⁴ ²⁾	NA

Source: *2006 IPCC Guidelines* Vol. 2, page 4.48, Table 4.2.4

1) The default value of CH₄ is 4.8×10⁻⁴ - 10.3×10⁻⁴

2) The default value of CO₂ is 1.5×10⁻⁴ - 3.2×10⁻⁴

3) Excluded from calculations, as the default value is "NA".

● 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*, all prepared by METI, is used as activity data during processing. (Refer to Table 3-75).

c) Uncertainties and Time-series Consistency

● Uncertainties

For the uncertainties of emission factors for fugitive emissions of CO₂ and CH₄ during natural gas processing, the values provided in the *2006 IPCC Guidelines* (-100% to +100%) are applied since the default values in the guidelines are used exclusively. As for the activity data, the values established 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 the statistical data used are not available. As a result, the uncertainties of fugitive emissions of CO₂ and CH₄ during natural gas processing are evaluated to be -101% to +101% for each.

● 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*, all prepared by METI. 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 Chapter 1.

e) Category-specific Recalculations

There have been no recalculations of emissions from this category.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

3.3.2.2.d. Transmission and Storage (1.B.2.b.iv.)

a) Category Description

This category provides the estimation methods for CH₄ 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, and provides the estimation methods for CH₄ 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 CO₂ emissions in this source are reported as “NA”. Approximately 90% of city gas is based on LNG and is free of CO₂. However, domestically produced natural gas from some of Japan’s natural gas strata contains CO₂. Because nearly all of this CO₂ is removed at the natural gas production plants before the gas is sent to pipelines, thus almost no CO₂ in natural gas is emitted from natural gas pipelines, and the natural gas provided by city gas suppliers most likely contains no CO₂. The CO₂ emissions removed at natural gas production plants are included in venting (gas) (1.B.2.c.Venting.ii).

b) Methodological Issues

● **Estimation Method**

CH₄ emissions from transmission of natural gas are estimated by multiplying the sales volume of natural gas by the country-specific emission factors.

CH₄ emissions from storage facilities of natural gas are estimated by multiplying the amount of LNG and natural gas, which are utilized as raw material for city gas, by the country-specific emission factors.

● **Emission Factors**

- **Transmission**

CH₄ 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 CH₄ 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 3-77 and the total values are applied to the emission factors. For the sales volume of 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 3-77 The method of estimating emission factors of natural gas transmission

Fiscal year	Relocation and building work of pipeline	Release of gas used to operate pressure regulators
1990 - 2003	The same value as FY2004 is consistently used.	
2004	Estimated by dividing the actual CH ₄ emissions in FY2004 by the sales volume of natural gas in the same fiscal year.	
2005 - 2007	Estimated by interpolating the emission factor in FY2004 and that in FY2008 which is estimated by the same method as FY2004.	Estimated by interpolating the emission factor in FY2004 and that in FY2011 which is estimated by the same method as FY2004.
2008 - 2010	Estimated by dividing the actual CH ₄ emissions in each fiscal year by the sales volume of natural gas in the same fiscal year.	
2011 -	Estimated by dividing the actual CH ₄ emissions in each fiscal year by the sales volume of natural gas in the same fiscal year.	

As a result of the above estimation, the emission factors in each fiscal year are estimated as shown on the Table 3-78.

Table 3-78 The estimation result of emission factors of natural gas transmission [t-CH₄/10⁶m³]

Item	-2004	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Pipeline relocation & installation	0.220	0.190	0.101	0.100	0.071	0.037	0.073	0.062	0.070	0.115	0.217	0.077
Gas for operating pressure regulators	0.087	0.077	0.048	0.038	0.028	0.018	0.013	0.009	0.005	0.001	0.001	0.001
Total	0.306	0.267	0.148	0.138	0.099	0.056	0.087	0.071	0.075	0.116	0.218	0.078

- Storage

The emission factor is calculated by dividing the CH₄ 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 such as LNG and natural gas. The emission factor calculated using the FY1998 data is 905.41 [kg-CH₄/PJ], while that calculated using the FY2007 data is 264.07 [kg-CH₄/PJ]. The main reason of such change in emission factor is the reduction in CH₄ 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 CH₄ 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 CH₄ 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 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*, all by METI is used for activity data.

Table 3-79 Sales amount of natural gas

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Natural gas sales amount	10 ⁶ m ³	2,067	2,339	2,617	3,329	3,911	3,918	4,020	4,208	3,928	3,790	3,792	3,709	3,806	4,000

- Storage

The amount of LNG and natural gas used as raw material for city gas, provided in the *General Energy Statistics* by ANRE, is used for activity data

Table 3-80 LNG and natural gas used for the feedstock of city gas

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
LNG consumption with city gas production	PJ	464	676	864	1,230	1,439	1,424	1,531	1,574	1,592	1,555	1,567	1,567	1,641	1,665
Natural gas consumption with city gas production	PJ	40	48	61	86	131	127	115	118	112	107	106	103	101	96

c) Uncertainties and Time-series Consistency

● Uncertainties

A country-specific emission factor is used for CH₄ emissions from transmission of natural gas, however, since it is difficult to assess the uncertainties, the established values 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 established values 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 CO₂ and CH₄ from natural gas transmission are assessed to be -100% to +100%.

For the emission factors for fugitive CH₄ 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 established in the *2006 IPCC Guidelines* (-20% to +500%) are applied. As for the activity data, the values established 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 source are not available. As a result, the uncertainties of CH₄ 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, Coal and Coke*, in the *Yearbook of Mineral Resources and Petroleum Products Statistics* and in the *Yearbook of Current Production Statistics* (all by METI).

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 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 Chapter 1.

e) Category-specific Recalculations

Since the activity data for FY2016 in the *General Energy Statistics* were revised, the CH₄ emissions in that year were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

3.3.2.2.e. Distribution (1.B.2.b.v.)

a) Category Description

This category provides the estimation methods for CH₄ emitted 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 3.2.1.b. Methodological issues (Figure 3-4 , Table 3-14, etc.).

The emissions from CO₂ in this source are reported as “NA”. More than 90% of the city gas is based on LNG and is free of CO₂. However, domestically produced natural gas from some of Japan’s natural gas strata contains CO₂. Because nearly all of this CO₂ is removed at the natural gas production plants before the gas is sent to pipelines, the natural gas provided by city gas suppliers most likely contains no CO₂. The emissions of CO₂ removed at natural gas production plants are included in the venting (gas) (1.B.2.c.Venting.ii).

b) Methodological Issues

● **Estimation Method**

CH₄ 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.

● **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. The CH₄ emissions from the city gas pipelines of general gas companies calculated from the actual data by each emission source are shown in Table 3-81. The value of 9.5×10^{-6} kt-CH₄/10⁶ m³, which is obtained by dividing the CH₄ emissions (292 t-CH₄) by the city gas amount sold by general gas companies in the same fiscal year of $30,696 \times 10^6$ m³ (source: *Current Survey of Production Concerning Gas Industry* by ANRE), is used for the emission factor per sales amount.

Table 3-81 CH₄ 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 (ANRE)* to get the amount in volume, and the result is used for the activity data. 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 3-82 The sales amount of city gas

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
The sales amount of city gas	PJ	643	877	1,064	1,419	1,563	1,546	1,644	1,691	1,688	1,667	1,681	1,671	1,738	1,779
Calorific value per volume	MJ/m ³	41.9	41.9	41.1	44.8	44.8	44.8	44.8	44.8	44.8	41.3	41.3	41.2	41.2	41.3
The sales amount of city gas in volume	10 ⁶ m ³	15,367	20,952	25,899	31,684	34,880	34,516	36,705	37,738	37,686	40,370	40,695	40,540	42,168	43,039

c) Uncertainties and Time-series Consistency

● Uncertainties

For emission factor in CH₄ 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 for source, 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 CH₄ 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

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 Chapter 1.

e) Category-specific Recalculations

For FY2013-2016, since the activity data in the *Current Survey of Production Concerning Gas Industry* and the calorific values of city gas in the *General Energy Statistics* were revised, the CH₄ emissions in those years were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There are no major planned improvements in this category.

3.3.2.2.f. Industrial plants and power station / residential and commercial sectors (1.B.2.b.vi)

The conceivable sources of these CH₄ emissions 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), CH₄ emissions from this source are reported as “IE.” Additionally, because CO₂ is basically not included among the city gas constituents, the CO₂ emissions from this source are reported as “NA.”

3.3.2.3. Venting and Flaring (1.B.2.c.)

This section includes fugitive emissions of CO₂ and CH₄ occurring from venting during oil field development, crude oil transportation, refining processes, and product transportation in the petroleum industry, as well as during gas field development, natural gas production, transmission, and processing in the natural gas industry.

It also includes CO₂, CH₄ and N₂O emissions from flaring during the above processes.

3.3.2.3.a. Venting (Oil) (1.B.2.c.Venting.i.)

a) Category Description

This category provides the estimation methods for CO₂ and CH₄ emissions from venting in the petroleum industry.

b) Methodological Issues

● Estimation Method

The emissions from venting in the petroleum industry were calculated using the Tier 1 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 4.39, Fig. 4.2.2) by multiplying the amount of crude oil production by the default emission factors.

● Emission Factors

The default values for conventional oil given in the *2006 IPCC Guidelines* were used for the emission factors of oil field venting.

Table 3-83 Emission factors of oil field venting

		CH ₄	CO ₂	N ₂ O ¹⁾
Oil production/ Conventional oil	Venting [kt/1000 m ³]	7.2×10 ⁻⁴	9.5×10 ⁻⁵	NA

Source: *2006 IPCC Guidelines* Vol. 2, page 4.50, Table 4.2.4

1) Excluded from calculations, as the default value is “NA”

● Activity Data

The production volume of oil in Japan given by METI in its *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke, Yearbook of Mineral Resources and Petroleum Products Statistics* and *Yearbook of Current Production Statistics* is used as activity data of the fugitive emissions from oil field venting. The production of condensate was excluded from the calculation (see Table 3-69).

c) Uncertainties and Time-series Consistency● **Uncertainties**

For the uncertainties in emission factors for CO₂ and CH₄ fugitive emissions from venting (oil), since the default values given in the *2006 IPCC Guidelines* are used for emission factors, the uncertainty values (-50% to +50%) provided in the *2006 IPCC Guidelines* are used. As for activity data, it is unable to evaluate the uncertainties in statistical data used for source, the setting values (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) provided in the *2006 IPCC Guidelines* are used. As a result, the uncertainties in CO₂ and CH₄ fugitive emissions from venting (oil) are evaluated at -52% to +52% for each.

● **Time-series Consistency**

For the emission factors, consistent values as described above are used from FY1990 to the nearest year. The activity data 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*, 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 Chapter 1.

e) Category-specific Recalculations

There have been no recalculations of emissions from this category.

f) Category-specific Planned Improvements

There have been no major planned improvements in this category.

3.3.2.3.b. Venting (Gas) (1.B.2.c.Venting.ii.)**a) Category Description**

This category source deals with CO₂ emissions accompanied by separation and diffusion of CO₂ which is contained in natural gas produced in natural gas production facilities when CO₂ contents does not meet the standard of non-combustion gas content provided by users.

As for other emission source in this category, intentional CO₂ and CH₄ emissions during transmission of natural gas are considered to be included in this category, because their emission factors are provided in the *2006 IPCC Guidelines*. However, the intentional CO₂ emissions from pipeline of natural gas are reported as “NA” in transmission of natural gas (1.B.2.b.iv.) in case of Japan. Therefore, the emissions are not reported. As for CH₄ emissions, the emissions are reported as “IE”, because they are included in emissions from transmission of natural gas (1.B.2.b.iv.).

b) Methodological Issues● **Estimation Method**

For the emissions from this category in FY1990, FY1995 and onward, actual measurement data of CO₂

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 CO₂ 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. (For emission estimating purpose, only emission factors for FY1991-1994 are used.)

Table 3-84 Emission factors of natural gas field venting

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Emission factor	kg-CO ₂ /m ³	0.133	0.117	0.126	0.114	0.124	0.123	0.120	0.119	0.122	0.121	0.124	0.128	0.129	0.140

● *Activity Data*

The total production amount of Minami Nagaoka gas field and Katagai gas field indicated in *Natural Gas Data Year Book* by Japan Natural Gas Association are used for activity data. (For emission estimating purpose, only activity data for FY1991-1994 are used.)

Table 3-85 Production amount of Natural gas from Minami-nagaoka and Katagai gas field

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Minami Nagaoka gas field	10 ⁶ m ³	241	376	571	893	1,719	1,632	1,313	1,308	1,372	1,295	1,172	1,215	1,340	1,340
Katagai gas field	10 ⁶ m ³	191	281	219	336	282	279	346	395	358	369	370	384	421	421
Total	10 ⁶ m ³	432	657	789	1,229	2,001	1,911	1,660	1,704	1,731	1,664	1,542	1,598	1,761	1,761

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 Chapter 1.

e) Category-specific Recalculations

Since the emissions data for FY2016 provided by Japan Petroleum Development Association were revised, the CO₂ emissions in that year were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There have been no major planned improvements in this category.

3.3.2.3.c. Venting (Combined) (1.B.2.c.Venting.iii.)

Statistical data are reported for two categories of petroleum and natural gas in Japan. As a result, fugitive emissions from venting in the combined petroleum and natural gas industries were reported as “IE” since they were accounted for in the emissions from venting in the petroleum industry (1.B.2.c.i) and the natural gas industry (1.B.2.c.ii)

3.3.2.3.d. Flaring (Oil) (1.B.2.c.Flaring.i.)**a) Category Description**

This category provides the estimation methods for CO₂, CH₄, and N₂O from flaring in the petroleum industry.

b) Methodological Issues● **Estimation Method**

The CO₂, CH₄, and N₂O emissions from flaring in the petroleum industry were calculated using the Tier 1 method in accordance with the decision tree of the *2006 IPCC Guidelines*, by multiplying the amount of crude oil production in Japan by the default emissions factors.

● **Emission Factors**

In the absence of actual measurement data or country-specific emission factors in Japan, the default values shown in the *2006 IPCC Guidelines* were used.

Table 3-86 Emission factors for flaring in the oil industry

	Unit	CH ₄	CO ₂	N ₂ O
Flaring (conventional oil)	kt/10 ³ m ³	2.5×10 ⁻⁵	4.1×10 ⁻²	6.4×10 ⁻⁷

Source: *2006 IPCC Guidelines* Vol. 2, p 4.50, Table 4.2.4

● **Activity Data**

For the calculation of activity data for this emission source, the amounts of crude oil production shown in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Natural Resources and Petroleum Products* and the *Yearbook of Current Production Statistics*, all published by METI, are used. The production of condensate is excluded from the calculation (see Table 3-69).

c) Uncertainties and Time-series Consistency● **Uncertainties**

For emission factors for CO₂, CH₄, and N₂O fugitive emissions from flaring (oil), since the default values given in the *2006 IPCC Guidelines* are used for the emission factors, the setting values (-50% to

+50%) provided in the *2006 IPCC Guidelines* are used. As for activity data, it is unable to evaluate the uncertainties in statistical data used for source, the setting values (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) provided in the *2006 IPCC Guidelines* are used. As a result, the uncertainties in CO₂, CH₄, and N₂O fugitive emissions from flaring (oil) are evaluated at -52% to +52% for each.

- ***Time-series Consistency***

For the emission factors, consistent values as described above are used from FY1990 to the nearest year. The activity data of the flaring in oil industry 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*, 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 Chapter 1.

e) Category-specific Recalculations

There have been no recalculations of emissions from this category.

f) Category-specific Planned Improvements

There have been no major planned improvements in this category.

3.3.2.3.e. Flaring (Gas) (1.B.2.c.Flaring.ii.)

a) Category Description

This category provides the estimation methods for CO₂, CH₄, and N₂O from flaring in the natural gas industry.

b) Methodological Issues

- ***Estimation Method***

The CO₂, CH₄, and N₂O emissions associated with flaring in the natural gas industry were calculated using the Tier 1 method in accordance with the decision tree of the *2006 IPCC Guidelines* (Vol. 2, page 4.38, Fig. 4.2.1). The emissions were calculated by multiplying the amount of natural gas production by the emission factors. The total emissions associated with flaring both during gas production and processing were reported as the emissions from flaring in the natural gas industry.

- ***Emission Factors***

The default values for fugitive emissions from flaring in the natural gas industry given in the *2006 IPCC Guidelines* are used.

Table 3-87 Emission factors for flaring in the natural gas industry

		Unit	CH ₄	CO ₂	N ₂ O
Flaring in the natural gas industry	Gas production	kt/10 ⁶ m ³	7.6×10 ⁻⁷	1.2×10 ⁻³	2.1×10 ⁻⁸
	Gas processing/ Sweet gas plant	kt/10 ⁶ m ³	1.2×10 ⁻⁶	1.8×10 ⁻³	2.5×10 ⁻⁸

Source: 2006 IPCC Guidelines Vol. 2, page 4.48, Table 4.2.4

● Activity Data

For the calculation of activity data for this emission source, the amounts of domestic production of natural gas shown in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Natural Resources and Petroleum Products* and the *Yearbook of Current Production Statistics*, all published by METI, were used (see Table 3-75).

c) Uncertainties and Time-series Consistency

● Uncertainties

For the uncertainty of CO₂, CH₄, and N₂O emission factors for flaring (natural gas), the default values given in the 2006 IPCC Guidelines are used for the emission factors exclusively. Therefore, the uncertainty of -25% to +25% in the 2006 IPCC Guidelines is applied. For the activity data, the uncertainty of the statistics used is not clear. Therefore, the value in the 2006 IPCC Guidelines (-15% to +15% of the uncertainties associated with measurement of flow rate (excluding sales volumes)) is used. As a result, the uncertainty of CO₂, CH₄, and N₂O emissions from flaring (natural gas) are evaluated to be -29% to +29% for each.

● Time-series Consistency

For the emission factors, consistent values as described above are used from FY1990 to the nearest year. The activity data of flaring in natural gas industry 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*, 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 Chapter 1.

e) Category-specific Recalculations

There have been no recalculations of emissions from this category.

f) Category-specific Planned Improvements

There have been no major planned improvements in this category.

3.3.2.3.f. Flaring (Combined) (1.B.2.c.Flaring.iii.)

a) Category Description

In Japan, the statistical data are reported for two categories of oil and natural gas. Therefore, the fugitive emissions which can be distinguished of their category are reported in Flaring (Oil) (1.B.2.c.Flaring.i) or in Flaring (Natural gas) (1.B.2.c.Flaring.ii) respectively. In this category, CO₂, CH₄, and N₂O

emissions accompanied by exploration and test before production of oil and natural gas, which are unable to be distinguished of their categories of oil industry or natural gas industry, are reported.

b) Methodological Issues

● Estimation Method

For the fugitive emissions accompanied by exploration and test before production of oil and natural gas, the emission factors, which are established using the crude oil production as activity data, are indicated as default values in the *2006 IPCC Guidelines*.

However, in case of Japan, the correlation between CO₂, CH₄, and N₂O emissions, which are accompanied by exploratory drilling and pre-production testing, and crude oil production, and the correlation between the GHG emissions, which are accompanied by the production during exploration and testing, and the production amount from commercial plants are not clear, thus there is a possibility of deviation between the estimated result and the actual condition, if the estimation method of using the crude oil production as activity data, which is indicated in the *2006 IPCC Guidelines*, is adopted. Therefore, the Tier 1 method in *GPG (2000)*, which is considered to be closer to actual condition, is used in this category. The method used is to multiply the activity data of number of exploratory drilling well or testing well by the default emission factor.

● Emission Factors

The default values indicated in the *GPG (2000)* are adopted.

Table 3-88 Emission factors for exploratory drilling and testing wells [kt/number of wells]

	CH ₄	CO ₂	N ₂ O
Drilling	4.3×10 ⁻⁷	2.8×10 ⁻⁸	0
Testing	2.7×10 ⁻⁴	5.7×10 ⁻³	6.8×10 ⁻⁸

Source: GPG (2000), page 2.86, Table 2.16

● Activity Data

The values described in *Natural Gas Data Year Book* by Japan Natural Gas Association are used for the number of exploratory drilled wells. As for the number of tested wells, it is difficult to grasp statistically, and the tested wells don't always become the succeeded wells. Therefore, the median of the number of wells drilled and the number of wells tested in the *Natural Gas Data Year Book* is used as the number of wells tested. For the most recent year, the data of the previous year are provisionally used.

Table 3-89 Number of wells

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Number of wells drilled	well	8	7	7	10	7	4	2	1	4	5	1	2	2	2
Number of wells succeeded		1	3	4	5	1	2	0	1	2	3	1	1	0	0
Number of wells tested		5	5	6	8	4	3	1	1	3	4	1	2	1	1

c) Uncertainties and Time-series Consistency

● Uncertainties

For the uncertainty of CO₂, CH₄, and N₂O emission factors for flaring (combined), the default values given in the *GPG (2000)* are used for the emission factors exclusively. Therefore, the uncertainty of -25% to +25% in *GPG (2000)* is applied. For the activity data, the uncertainty of the statistics used is not clear. Therefore, the value in the *2006 IPCC Guidelines* (-25% to +25%: uncertainty accompanied with the factor for number of production facilities) is used. As a result, the uncertainty of CO₂, CH₄, and N₂O emissions from flaring (combined) are evaluated to be -35% to +35% for each.

- **Time-series Consistency**

For the emission factors, consistent values as described above are used from FY1990 to the nearest year. The activity data are calculated using the data from the *Natural Gas Data Year Book* 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 Chapter 1.

e) Category-specific Recalculations

Since the activity data for FY2016 in the *Natural Gas Data Year Book* were revised, the CO₂, CH₄ and N₂O emissions in that year were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There have been no major planned improvements in this category.

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 CO₂ and CH₄ emissions in the geothermal power plants, where the CO₂ and CH₄ from the steam production well are emitted from cooling tower 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 CO₂ and CH₄, since any descriptions for estimation methods for this category are not provided in the *2006 IPCC Guidelines*. However, as for CO₂ and CH₄ 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 CO₂ and CH₄ in the produced steam is emitted into the air.

- **Emission Factors**

Mass concentration rate of CO₂ in steam is estimated by using volume concentration of non-condensable gas in steam and volume concentration of CO₂ in non-condensable gas in each geothermal power plant which is provided in *Directory for Geothermal Power Plant Facilities in Japan* by Japan Geothermal Energy Association (JGEA).

Mass concentration rate of CH₄ is estimated by using volume concentration of non-condensable gas in steam in each geothermal power plant which is provided in *Directory for Geothermal Power Plant Facilities in Japan* and concentration of CH₄ in non-condensable gas which is provided in *Geothermal Energy and Greenhouse Gas Emissions* by Geothermal Energy Association.

- **Activity Data**

The amount of steam production in each geothermal power plant is 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 which 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 CO₂ and CH₄ for geothermal power plants in Japan and the trend of the produced amount of steam are indicated in the Table 3-90.

Table 3-90 Emission factor and produced amount of steam of geothermal power plants

Power plant name	Emission factor		Production amount of steam													
	CO ₂ [t-CO ₂ /kt]	CH ₄ [t-CH ₄ /kt]	[kt]													
			1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Matsukawa	12.2	0.025	1,884	1,493	1,708	1,115	1,257	1,083	813	777	745	872	857	666	412	412
Otake	3.1	0.006	1,173	995	995	774	928	817	789	677	770	937	885	867	935	935
Onuma	0.6	0.002	694	682	535	651	628	610	600	590	518	537	521	489	521	521
Onikobe	2.6	0.008	1,018	1,015	1,035	982	896	1,026	1,185	456	348	357	381	334	402	402
Hatchobaru 1	6.5	0.013	2,883	2,366	2,598	2,602	2,937	2,783	2,287	2,468	2,353	2,347	1,887	1,963	2,097	2,097
Hatchobaru 2	5.8	0.011	2,514	2,686	2,532	2,452	2,516	2,215	2,291	1,943	2,219	2,342	2,264	2,209	1,848	1,848
Kakkonda 1	0.3	0.001	3,498	3,126	1,966	2,021	97	1,476	1,535	1,537	1,276	1,374	1,400	1,362	1,455	1,455
Kakkonda 2	0.4	0.001	NO	209	1,823	2,004	467	1,002	1,440	1,521	1,255	1,269	1,225	1,142	1,058	1,058
Suginoi	8.5	0.019	220	284	203	144	157	146	129	139	170	140	129	140	137	137
Mori	28.1	0.053	1,367	1,990	1,981	1,501	1,200	1,065	1,068	888	1,182	1,001	1,105	934	1,015	1,015
Kirishima international hotel	1.1	0.003	48	97	70	NO	NO	NO	30	81	58	68	38	NO	NO	NO
Uenotai	6.5	0.014	NO	1,882	2,070	1,601	1,742	1,801	482	1,480	1,846	1,784	1,717	1,512	1,521	1,521
Yamakawa	5.8	0.012	NO	1,451	1,336	639	802	973	1,026	1,151	1,026	989	702	744	1,031	1,031
Sumikawa	1.4	0.004	NO	3,234	2,846	2,908	2,379	2,593	2,611	2,145	1,853	2,038	2,903	2,903	2,676	2,676
Yanaizunishiyama	68.8	0.130	NO	3,912	3,425	3,197	2,493	1,872	2,229	2,266	2,203	1,626	1,998	1,537	1,691	1,691
Ogiri	0.4	0.001	NO	219	2,373	2,306	2,216	2,117	2,286	2,079	1,983	1,969	2,073	1,928	1,910	1,910
Takigami	1.9	0.004	NO	NO	2,111	2,075	1,993	2,242	2,239	2,358	2,251	2,374	2,087	2,422	2,299	2,299
Hachijojima	18.1	0.041	NO	NO	187	156	164	179	152	171	142	149	151	147	153	153
Kuju	8.5	0.019	NO	NO	10	136	122	129	124	56	26	120	58	108	108	108
Waita	8.5	0.019	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	148	174	174

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 CO₂ and CH₄ 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 Chapter 1.

e) Category-specific Recalculations

Since the activity data for FY2016 in the *Current Status and Trend of Geothermal Power* were revised, the CO₂ and CH₄ emissions in that year were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

There have been no major planned improvements in this category.

3.4. CO₂ transport and storage (1.C.)

CO₂ transport and storage sector provides the CO₂ emissions associated with the carbon dioxide capture and storage (CCS). CCS is the technology or methodology that captures the CO₂ which would be emitted to the atmosphere and stores it underground or under seabed.

This sector consists of three categories; transport of CO₂ (1.C.1): emissions in the stage of CO₂ transport, injection and storage (1.C.2): emissions in the stage of CO₂ injection and storage, and Other (1.C.3). There are five projects of CO₂ injected underground in the past in Japan. CO₂ Emissions in the stage of transport and injection can occur during the period of injection, and CO₂ emissions in the stage of storage can have occurred continuously since CO₂ is injected. Table 3-91 shows the emissions from CO₂ transport and storage (1.C.).

Table 3-91 Past projects of CO₂ underground injection in Japan

Injection site	Period of injection
Kubiki	March 1991 – June 1993
Sarukawa	September 1997 – September 1999
Nagaoka	July 2003 – January 2005
Yubari	November 2004 – October 2007
Tomakomai	April 2016 –

Table 3-92 CO₂ emissions from CO₂ transport and storage (1.C)

IPCC Category		1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1.C.1 Transport of CO ₂	a. Pipelines	NE	NO	NO	NE	NO	NO	NO	NO	NO	NO	NO	NO	NA	NA
	b. Ships	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
1.C.2 Injection and storage	a. Injection	NE	NO	NO	NE	NO	NO	NO	NO	NO	NO	NO	NO	NA	NA
	b. Storage	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

3.4.1. Transport of CO₂ (1.C.1)

3.4.1.1. Pipelines (1.C.1.a.)

This category provides the fugitive emissions of CO₂ in the stage of CO₂ transport by pipeline.

According to the interview to the entities of the projects shown in Table 3-91, the fugitive emissions in the stage of CO₂ 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 three thousand t-CO₂, which is a criterion to include the emissions in the national totals established by the Committee for the Greenhouse Gases Emissions Estimation Methods. Therefore, the emissions from this category are

reported as insignificant NE in the year CO₂ injection was conducted (but reported as NA in the year CO₂ 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 5.

3.4.1.2. Ships (1.C.1.b.)

This category provides the fugitive emissions of CO₂ in the stage of CO₂ 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 provides the fugitive emissions of CO₂ in the stage of liquefied CO₂ transport by a lorry from a plant to an injection site or from a storage tank of liquefied CO₂. It is hard to consider the annual fugitive emissions become larger than three thousand t-CO₂ for following reasons: First, according to the interview to the entities of the projects shown in Table 3-91, 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 six thousand t-CO₂. Therefore, the emissions from this category are reported as insignificant NE. (The emissions are reported as NE in the year CO₂ injection was conducted and reported as NO in the other years.) The treatment of insignificant NE is described in Annex 5.

3.4.2. Injection and Storage (1.C.2)

3.4.2.1. Injection (1.C.2.a.)

This category provides the fugitive emissions of CO₂ in the stage of a compressor or an injection well at an injection site.

According to the interview to the entities of the projects shown in Table 3-91, the fugitive emissions in the stage of injection do not occur basically or the amount is quite small even if the fugitive emissions occur. In addition, the approximate results of emissions estimated using the emission factors shown in Koornneef *et al.* (2008) are less than three thousand t-CO₂, which is a criterion to include the emissions in the national total established by the Committee. Therefore, the emissions from this category are reported as insignificant NE in the year CO₂ injection was conducted (but reported as NA in the year CO₂ 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 5.

3.4.2.2. Storage (1.C.2.b.)

This category provides the fugitive emissions from a storage site.

According to the interview to the entities of the projects shown in Table 3-91, the fugitive emissions from a storage site do not occur basically or the amount is quite small even if the fugitive emissions occur. In addition, the approximate results of emissions estimated using the ratio of stored CO₂ in a storage reservoir to the injected CO₂ shown in the *IPCC (2005)* are less than three thousand t-CO₂,

which is a criterion to include the emissions in the national total established by the Committee. Therefore, the emissions from this category are reported as insignificant NE through all reporting years. The treatment of insignificant NE is described in Annex 5.

3.4.3. Other (1.C.3)

This category provides any other emissions from CCS not reported in transport of CO₂ (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 provides the amount of CO₂ captured for geological storage. Although there is ‘Total amount captured for storage’ in ‘Information item’ of CRF table 1.C, it should be noted that amount of CO₂ captured is subtracted from CO₂ emissions not from 1.C but from categories CO₂ captured.

The amount of CO₂ captured is considered to be nearly equal to that of CO₂ injected in the past projects of geological injection of CO₂ conducted in Japan. Thus, the amount of CO₂ injected that was provided by the entities of the projects is reported as the amount of CO₂ captured in the fiscal years when the injections were conducted. The captured amount is reported in 1.A.1.b Petroleum refining or 2.B.1 Ammonia production in accordance with the source of CO₂ used in each project.

Table 3-93 Amount of CO₂ captured for geological storage

Injection site	Unit	1990	1991	1992	1993	1997	1998	1999	2003	2004	2005	2006	2007	2016	2017	Reported under
Kubiki	kt	0.23	3.93	4.46	1.17	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	2.B.1 Ammonia production
Sarukawa	kt	NO	NO	NO	NO	2.37	4.87	2.71	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	2.B.1 Ammonia production
Yubari	kt	NO	NO	NO	NO	NO	NO	NO	NO	0.04	0.12	0.36	0.37	NO	NO	1.A.1.b Petroleum refining
Tomakomai	kt	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	29.22	110.68	1.A.1.b Petroleum refining

References

1. IPCC, *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, 1997.
2. IPCC, *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, 2000.
3. IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2006.
4. UNFCCC, *UNFCCC Inventory Reporting Guidelines*. (Decision 24/CP.19 Annex I)
5. UNFCCC, *Report of the individual review of the annual submission of Japan submitted in 2012* (FCCC/ARR/2012/JPN), July 2013
6. UNFCCC, *Report of the individual review of the annual submission of Japan submitted in 2013* (FCCC/ARR/2013/JPN), March 2014
7. European Environment Agency, *EMEP/EEA air pollutant emission inventory guidebook 2016*, August 2016.
8. Research Institute of Economy, Trade & Industry, Kazunari Kainou, *Evaluating and Analyzing the Validity of Carbon Emission Factors for Different Fuels*, 2005.
9. Research Institute of Economy, Trade & Industry, Kazunari Kainou, *Recommendation of the Draft Revised Standard Calorific Value and Carbon Emission Factor for Fossil Fuel Energy Sources in Japan*, RIETI Discussion Paper Series 14-J-047, October 2014.
10. Research Institute of Economy, Trade & Industry, Kazunari Kainou, *Interpretation of General Energy Statistics*, April 2012.
11. Environmental Agency Committee for the Greenhouse Gases Emissions Estimation Methods, *GHGs Estimation Methods Committee Report Part 1*, September 2000.
12. Environmental Agency Committee for the Greenhouse Gases Emissions Estimation Methods, *GHGs Estimation Methods Committee Report Part 2*, September 2000.
13. Environmental Agency Committee for the Greenhouse Gases Emissions Estimation Methods, *GHGs Estimation Methods Committee Report Part 3*, September 2000.
14. Environmental Agency, *The Report on Estimation of CO₂ Emissions in Japan*, 1992.
15. Ministry of the Environment, Committee for the Greenhouse Gases Emissions Estimation Methods, *GHGs Estimation Methods Committee Report Part 1*, August 2002.
16. Ministry of the Environment, Committee for the Greenhouse Gases Emissions Estimation Methods, *GHGs Estimation Methods Committee Report Part 2*, August 2002.
17. Ministry of the Environment, Committee for the Greenhouse Gases Emissions Estimation Methods, *GHGs Estimation Methods Committee Report Part 3*, August 2002.
18. Ministry of the Environment, Committee for the Greenhouse Gases Emissions Estimation Methods, *GHGs Estimation Methods Committee Report Part 1*, August 2006.
19. Ministry of the Environment, Committee for the Greenhouse Gases Emissions Estimation Methods, *GHGs Estimation Methods Committee Report Part 2*, August 2006.
20. Ministry of the Environment, *Actual condition survey of GHG emissions from non-manufacturing industry, Fiscal year 2014*, March 2015.
21. Ministry of the Environment, *Actual condition survey of GHG emissions from manufacturing industry, Fiscal year 2014*, March 2015.
22. Ministry of the Environment, *Actual condition survey of GHG emissions from non-manufacturing*

- industry, *Fiscal year 2015*, March 2016.
23. Ministry of the Environment, *General Survey of the Emissions of Air Pollutants*.
 24. Ministry of the Environment, *PRTR Outside Notification Emissions Estimated Data*.
 25. Ministry of Economy, Trade and Industry, *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*.
 26. Ministry of Economy, Trade and Industry, *Yearbook of Mineral Resources and Petroleum Products Statistics*.
 27. Ministry of Economy, Trade and Industry, *Yearbook of Current Production Statistics*
 28. Ministry of Economy, Trade and Industry, *Yearbook of the Current Survey of Energy Consumption*.
 29. Ministry of Economy, Trade and Industry, *Indices of Industrial Production*
 30. Ministry of Economy, Trade and Industry, *Indices of Tertiary Industry Activity*
 31. Ministry of Land, Infrastructure, Transport and Tourism, *Statistical Yearbook of Air Transport*.
 32. Ministry of Land, Infrastructure, Transport and Tourism, *Statistical Yearbook of Motor Vehicle Transport*, and its *Monthly Report*.
 33. Ministry of Land, Infrastructure, Transport and Tourism, *Road Transport Census*.
 34. Ministry of Land, Infrastructure, Transport and Tourism, *Statistical Yearbook of Motor Vehicle Fuel Consumption*
 35. Ministry of Land, Infrastructure, Transport and Tourism, *Airport Management Status Study Report*.
 36. Agency for Natural Resources and Energy, *Current Survey of Production Concerning Gas Industry*
 37. Agency for Natural Resources and Energy, *General Energy Statistics*.
 38. Agency for Natural Resources and Energy, *Structural Survey of Energy Consumption*.
 39. Agency for Natural Resources and Energy, *Electric Power Statistics*.
 40. Forestry Agency, *Basic Data for Special Forest Product*.
 41. Forestry Agency, *Data for Charcoal*.
 42. Automobile Inspection and Registration Information Association, *Statistics of AIRIA/ Number of Motor Vehicle*
 43. Japan Automobile Manufacturers Association, *Survey of Motorcycle Market Trends*
 44. Japan Automobile Manufacturers Association, *Monthly Report Statistics of Vehicles*.
 45. Japan Society for Atmospheric Environment, *Report on Emission Factor Results for Combustion Facilities*, 1997.
 46. Japan Natural Gas Association, *Natural Gas Data Year Book*.
 47. Hokkaido Development Agency, *Research Report on Gas Chemical Industry Development, FY1960-64, Reserves in Coal fields*
 48. Japan Lubricating Oil Society, *Report on the Subsidized Project of Environmental Measures of Lubricants Fiscal Year 2012*, March 2013.
 49. Japan Gas Association website (<http://www.gas.or.jp/en>)
 50. Joris Koornneef, Tim van Keulen, André Faaij, Wim Turkenburg, *Life cycle assessment of a pulverized coal power plant with post-combustion capture, transport and storage of CO₂*, *International Journal of Greenhouse Gas Control*, Volume 2, Issue 4, 448–467, 2008.
 51. IPCC, *IPCC Special Report on Carbon Dioxide Capture and Storage*, 2005.

52. Japan Automobile Manufacturers Association website (<http://www.jama-english.jp/>)
53. Japan Light Motor Vehicle and Motorcycle Association website (<https://www.zenkeijikyo.or.jp/>)
54. Japan Coal Energy Center, *History of Coal Policy*, 2002.
55. Japan Geothermal Energy Association, *Directory for Geothermal Power Plant Facilities in Japan*, 2000.
56. Japan Geothermal Energy Association, *Trend of Geothermal Power in Japan*.
57. Thermal and Nuclear Power Engineering Society, *Current Status and Trend of Geothermal Power*.
58. Geothermal Energy Association, *Geothermal Energy and Greenhouse Gas Emissions*, 2012.
59. Japan Automobile Research Institute, *2007 JAMA Trust Research Report; Detailed Examination in Research Method of Number of Owned Light Two-wheel Vehicles*.
60. Japan Automobile Research Institute, *2006 JAMA Trust Research Report; Research in Contribution Rate of the Emissions from Motorcycles*.
61. Goto, Koike and Suzuki, *Research on Estimation of N₂O Total Emissions of Automobiles, and Generalization and Popularization of the Core Technology of the Reduction Technique*, Final Report of the Global Environment Research Fund FY2002, B-51, 2003.
62. Yoda, Yamashita, Mogi, *Analysis of Nitrous Oxide Emission from Gasoline Vehicles and Study of Measurement Accuracy*, Proceedings of Society of Automotive Engineers of Japan (JSAE) Annual Congress, No.109-10, 3-6, 2010.

Chapter 4. Industrial Processes and Product Use (CRF 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 ₂ O	HFCs	PFCs	SF ₆	NF ₃	
2.A Mineral Industry	2.A.1	Cement Production	○							
	2.A.2	Lime Production	○							
	2.A.3	Glass Production	○							
	2.A.4	Other Process Uses of Carbonates	Ceramics	○						
			Other Uses of Soda Ash	○						
Non-metallurgical Magnesium Production			IE							
Other			○							
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	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	○	○					
			Ethylene Dichloride and Vinyl Chloride Monomer	○	○					
			Ethylene Oxide	○	○					
			Acrylonitrile	○	NA					
Carbon Black			○	○						
Styrene				○						
Phthalic Anhydride			○							
Maleic Anhydride			○							
Hydrogen			○							
2.B.9	Fluorochemical Production	By-product Emissions: Production of HCFC-22				○				
		Fugitive emissions				○	○	○	○	
2.C Metal Production	2.C.1	Iron and Steel Production	Steel	IE	NA					
			Use of Electric Arc Furnaces in Steel Production	○	○					
			Pig Iron	IE	NA					
			Limestone and dolomite use in Iron and Steel Production	○						
			Direct Reduced Iron	NO	NO					
			Sinter	IE	IE					
	Pellet	IE	IE							
	2.C.2	Ferrous Production	IE	○						
2.C.3	Aluminium Production	By-product Emissions	IE			○				
		F-gases Used in Foundries						NO		
2.C.4	Magnesium Production				○		○			
2.C.5	Lead Production	IE								
2.C.6	Zinc Production	IE								
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	Urea-based Catalysts	○						
			NMVOIC Incineration	○						
Road Paving with Asphalt										
Asphalt Roofing										
2.E Electronics Industry	2.E.1	Integrated Circuit or Semiconductor				○	○	○	○	
	2.E.2	TFT Flat Panel Display				○	○	○	○	
	2.E.3	Photovoltaics					IE			
	2.E.4	Heat Transfer Fluid					IE			

Table 4-1 Categories in the industrial processes and product use sector (continued)

Source categories				CO ₂	CH ₄	N ₂ O	HFCs	PFCs	SF ₆	NF ₃				
2.F Product Uses as Substitutes for ODS	2.F.1	Refrigeration and Air- Conditioning	Domestic Refrigeration	manufacturing				○	NO	NO	NO			
				stocks				○	NO	NO	NO			
				disposal				○	NO	NO	NO			
			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
			Transport Refrigeration	manufacturing						IE	NO	NO	NO	
				stocks						IE	NO	NO	NO	
				disposal						IE	NO	NO	NO	
			Industrial Refrigeration	manufacturing						IE	NO	NO	NO	
				stocks						IE	NO	NO	NO	
				disposal						IE	NO	NO	NO	
	Stationary Air-Conditioning (Household)	manufacturing						○	NO	NO	NO			
		stocks						○	NO	NO	NO			
		disposal						○	NO	NO	NO			
	Mobile Air-Conditioning (Car Air Conditioners)	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
					disposal						NO	NO	NO	NO
	2.F.3	Fire Protection	manufacturing						NO	NO	NO	NO		
			stocks						○	NO	NO	NO		
			disposal						NO	NO	NO	NO		
2.F.4	Aerosols	Metered Dose Inhalers	manufacturing						○	NO	NO	NO		
			stocks						○	NO	NO	NO		
			disposal						IE	NO	NO	NO		
		Aerosols	manufacturing							○	NO	NO	NO	
			stocks							○	NO	NO	NO	
			disposal							IE	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 ₂ O from Product Uses	Medical Applications Use During												
2.H Other	2.H.2	Food and Beverages Industry		○										

In FY2017, total GHG emissions from this sector amounted to approximately 99,294 kt-CO₂ eq., accounting for 7.7% of national total emissions (excluding LULUCF) in Japan. The emissions of CO₂, CH₄, and N₂O from this sector have decreased by 36.2% compared to FY1990. The emissions of HFCs, PFCs, SF₆, and NF₃ from this sector have increased by 44.2% 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 CO₂ emissions from cement production (mineral industry) as the clinker production declined, the decrease in N₂O emissions from adipic acid production (chemical industry) as the N₂O abatement equipment came on stream. However, HFC emissions from the product uses as ODS substitutes have largely increased.

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 ₂ O			
	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	NA	NA	CS	CS				
2.D. Non-energy products from fuels and solvent use	D,T1,T2	CS,D	NA	NA	NA	NA		
2.E. Electronic industry								
2.F. Product uses as ODS substitutes								
2.G. Other product manufacture and use					CS	OTH		
2.H. Other	CS		NA	NA	NA	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. Electronic industry	T2	D,CS	T2	D,CS	T2	D,CS	T2	D,CS
2.F. Product uses as ODS substitutes	CS	D,CS	CS	CS				
2.G. Other product manufacture and use			CS	CS	CS,T1,T2	CS,D		
2.H. Other								

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 CO₂ emissions from the calcination of mineral raw material such as CaCO₃, MgCO₃, Na₂CO₃, etc. This section includes GHG emissions from 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 FY2017, emissions from this category were 34,062 kt-CO₂ and represented 2.6% of total GHG emissions (excluding LULUCF). The emissions decreased by 30.8% compared to FY1990.

Table 4-3 CO₂ Emissions from 2.A. Mineral Industry

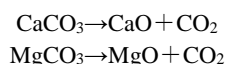
Gas		Units	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017		
CO ₂	2.A.1	Cement production	kt-CO ₂	38,701	42,142	35,086	32,280	28,553	25,308	24,321	24,983	25,625	26,805	26,557	25,936	26,429		
	2.A.2	Lime production	kt-CO ₂	6,674	5,795	5,900	6,646	6,592	5,365	6,285	5,896	5,679	5,767	5,812	5,477	5,504	5,555	
	2.A.3	Glass production	kt-CO ₂	313	283	233	252	173	140	164	168	179	193	194	193	188	194	
	2.A.4	Other process uses of carbonates	Ceramics	kt-CO ₂	930	1,066	981	737	847	896	891	869	964	1,017	1,040	973	879	870
			Other uses of soda ash	kt-CO ₂	119	118	102	78	70	65	63	61	50	45	48	46	43	36
			Other	kt-CO ₂	2,493	1,742	1,617	1,238	1,202	1,005	1,028	1,120	1,167	1,229	1,147	1,113	1,038	977
	Total		kt-CO ₂	49,230	51,146	43,919	41,230	37,436	32,779	32,752	33,097	33,664	35,056	34,798	33,738	33,622	34,062	

4.2.1. Cement Production (2.A.1.)

a) Category Description

CO₂ is emitted by the calcination of limestone, the main component of which is calcium carbonate, during the production of clinker¹, 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 CO₂.

CO₂ emission mechanism of the cement production process



b) Methodological Issues

● Estimation Method

Following the Tier 2 method in the 2006 IPCC Guidelines, the CO₂ emissions from this source was estimated by multiplying the amount of clinker produced by a country-specific emission factor.

CO₂ emissions [t-CO₂] from cement production

= emission factor [t-CO₂/t-clinker] × clinker production [t] × 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 CO₂ 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 CO₂ emitted from cement production were established as follows.

$$EF = EF_{CaO} + EF_{MgO}$$

EF_{CaO} : CaCO₃-origin CO₂ emission factor (established by the following equation)

EF_{MgO} : MgCO₃-origin CO₂ emission factor (established by the following equation)

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)

$$EF_{CaO} = (CaO_{Cl} - CaO_{Cl-Waste}) \times 0.785$$

$$CaO_{Cl-Waste} = \frac{W_{dry} \times CaO_{Waste}}{M}$$

- CaO_{Cl} : CaO content of clinker
 $CaO_{Cl-Waste}$: 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

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

$$MgO_{Cl-Waste} = \frac{W_{dry} \times MgO_{Waste}}{M}$$

- MgO_{Cl} : MgO content of clinker
 $MgO_{Cl-Waste}$: 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 the 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 the 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 the 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 material

Group	Types of waste	Water content	CaO content	MgO content
Incineration residue	Coal ash	7.2 - 14.5%	5.0 - 5.8%	1.0 - 1.1%
	Sewage sludge incineration ash *	10.9 - 15.1%	7.4 - 12.5%	3.5 - 3.8%
	Municipal solid waste incineration ash *	19.2 - 24.6%	10.0 - 26.5%	2.6 - 2.8%
Glass refuse, Concrete refuse, and Ceramics refuse	Glass refuse, Ceramics refuse *	12.1 - 32.7%	17.5 - 31.1%	1.0 - 2.5%
	Concrete refuse *	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 - 11.2%	40.8 - 41.5%	6.1 - 6.5%
	Steelmaking slag	7.7 - 14.1%	34.8 - 40.5%	2.0 - 3.0%
	Nonferrous slag	3.8 - 8.4%	6.4 - 10.0%	1.1 - 1.5%
	Casting sand *	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) *	0.1 - 3.2%	14.5 - 20.7%	0.7 - 0.9%
	Coal ash	1.0 - 3.9%	4.6 - 5.0%	1.0 - 1.1%

* Newly added from FY2009.

Table 4-5 CO₂ emission factors for cement production

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Average CaO content in clinker	%	65.9	65.9	66.0	65.9	65.9	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	1.9	1.7	1.7	2.0	1.8	1.7	1.6	1.6	1.6	1.7
CaO content in clinker excluding waste origin CaO	%	63.3	63.3	63.0	63.9	63.9	64.1	64.1	63.7	64.0	64.1	64.1	64.2	64.1	64.1
CO ₂ /CaO		0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785	0.785
Emission factor	t-CO ₂ /t	0.497	0.497	0.495	0.501	0.502	0.503	0.503	0.500	0.502	0.503	0.503	0.504	0.503	0.503
Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
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
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
MgO content in clinker excluding waste origin MgO	%	1.0	1.0	0.9	1.0	1.0	1.0	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.1
CO ₂ /MgO		1.092	1.092	1.092	1.092	1.092	1.092	1.092	1.092	1.092	1.092	1.092	1.092	1.092	1.092
Emission factor	t-CO ₂ /t	0.010	0.010	0.010	0.011	0.011	0.011	0.011	0.011	0.011	0.012	0.012	0.012	0.012	0.012
Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Combined emission factor	t-CO ₂ /t	0.508	0.508	0.505	0.512	0.513	0.514	0.514	0.511	0.514	0.514	0.515	0.516	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 (Ministry of Economy, Trade and Industry, *Yearbook of Ceramics and Building Materials Statistics*).

Table 4-6 Clinker production

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Consumption of limestone (actual)	kt (dry)	89,366	97,311	81,376	-	-	-	-	-	-	-	-	-	-	-
Clinker production (actual)	kt	-	-	69,528	63,003	55,647	49,195	47,279	48,884	49,883	52,105	51,573	50,307	50,436	51,351
Clinker production (actual) / Consumption of limestone (actual)*		0.853	0.853												
Estimated clinker production after correction**	kt	76,253	83,032	69,528	63,003	55,647	49,195	47,279	48,884	49,883	52,105	51,573	50,307	50,436	51,351

* Clinker Production (actual) / Consumption of Limestone (actual) for FY1990- FY1999 is the average value of FY2000- FY2003.

** Values for FY1990- FY1999 are corrected using estimation, and values for FY2000 and onward are actual.

c) Uncertainties and Time-series Consistency**● Uncertainty**

For the uncertainty of the CO₂ 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

CO₂ emissions from cement production from FY1990 to FY1999 is estimated using estimated activity data and emission factors based on values provided by the 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 Chapter 1.

e) Category-specific Recalculations

Recalculations have been conducted for FY2015, based on updates made to the amount of clinker produced. See Chapter 10 for impact on trend.

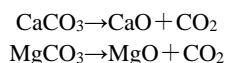
f) Category-specific Planned Improvements

No improvements are planned.

4.2.2. Lime Production (2.A.2.)**a) Category Description**

CO₂ is emitted during the calcination of CaCO₃, MgCO₃ in limestone used as raw material to produce quicklime.

CO₂ generation mechanism of quicklime production process

**b) Methodological Issues****● Estimation Method**

CO₂ emissions are calculated by multiplying limestone consumption by the country-specific emission factor.

CO₂ emissions [t-CO₂] generated by use of raw materials in quicklime production

= emission factor [t-CO₂/t-raw material] × amount of limestone consumed [t-raw material]

● Emission Factors

An emission factor per unit raw material (limestone) (0.428 t-CO₂/t-raw material) provided by the Japan

Lime Association was used.

The Emission factor per unit raw material was calculated by finding the CO₂ 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 (RIETI):

The *Adjusted Price Transaction Table* is a table created from the monetary input table in the Input-Output Table and the consumption data provided in industrial statistics, and is an application of similar estimation methods as in the *General Energy Statistics* (the Energy Balance Table).

In the existing transaction table 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.

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 CO₂ by the production of light calcium carbonate is already deducted in the *Adjusted Price Transaction Table*.

As regards lime production in sugar mills, no emissions occur, since CO₂ emitted from lime production is reabsorbed in the sugar production process. As for lime production during aluminium production, the *Adjusted Price Transaction Table* does not identify any limestone consumption under the aluminium production sector, and therefore production is not confirmed. (Production ended in 2014.)

Table 4-7 Limestone consumption

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Limestone consumption (dry)	kt	15,595	13,540	13,785	15,527	15,401	12,534	14,684	13,775	13,269	13,474	13,579	12,797	12,860	12,978

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, CO₂ emission from lime production has been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

See section 4.2.1. d).

e) Category-specific Recalculations

Recalculations have been conducted for FY2016, based on updates made to limestone consumption data in the *Adjusted Price Transaction Table*. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

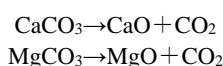
No improvements are planned.

4.2.3. Glass production (2.A.3.)

a) Category Description

Limestone contains CaCO₃ and minute amounts of MgCO₃, and dolomite contains CaCO₃ and MgCO₃. The heating of limestone and dolomite releases CO₂ derived from CaCO₃ and MgCO₃. Similarly, CO₂ 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.

CO₂ generating mechanism of limestone and dolomite use



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 CO₂ and CaCO₃ by 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 CO₂ and MgCO₃ by 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 [Japan Lime Association]). 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.

CaCO₃ → CaO + CO₂	
MgCO₃ → MgO + CO₂	
• Proportion of CaO extractable from limestone: 55.4 %	
	(Median of 54.8% to 56.0%: Japan Lime Association, <i>The Story of Lime</i>)
• Proportion of MgO extractable from limestone: 0.5 % ^b	
	(Median of 0.0% to 1.0%: Japan Lime Association, <i>The Story of Lime</i>)
• 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]
(Sources)	
a. IUPAC “Atomic Weights of the Elements 1999” (http://www.ciaaw.org/pubs/TSAW-1999.pdf)	
b. Japan Lime Association “ <i>The Story of Lime</i> ”	

➤ Dolomite

The emission factor is calculated by adding the value obtained when multiplying the molecular weight ratio of CO₂ and CaCO₃ by 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* [Japan Lime Association]) and the value obtained when multiplying the molecular weight ratio of CO₂ and MgCO₃ by 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* [Japan Lime Association]). 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.

CaCO₃ → CaO + CO₂	
MgCO₃ → MgO + CO₂	
• Proportion of CaO extractable from dolomite: 34.5%	
	(Median value of the 33.1% to 35.85% range given in <i>The Story of Lime</i> [Japan Lime Association])
• Proportion of MgO extractable from dolomite: 18.3%	
	(Median value of the 17.2% to 19.5% range given in <i>The Story of Lime</i> [Japan Lime Association])
• 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]

➤ Soda ash

See 2.A.4.b Other uses of soda ash.

➤ **Other materials**

For barium carbonate (BaCO_3), 0.22t CO_2/t , based on molecular weight ratio of CO_2 to BaCO_3 , is used. For potassium carbonate (K_2CO_3), 0.32t CO_2/t , based on molecular weight ratio of CO_2 to K_2CO_3 , is used. For strontium carbonate (SrCO_3), 0.30t CO_2/t , based on molecular weight ratio of CO_2 to SrCO_3 , is used. For lithium carbonate (Li_2CO_3), 0.60t 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	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Limestone consumption (dry)	kt	66	42	26	31	16	12	17	16	20	23	23	23	22	23
Dolomite consumption (dry)	kt	264	250	203	230	160	126	151	154	164	176	176	174	169	175
Soda ash consumption (dry)	kt	358	320	257	288	210	173	197	201	217	235	236	237	232	237

➤ **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 (JOGMEC)) converted to pure substance mass 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 Ceramics and Building Materials Statistics* (METI) are applied.

For potassium carbonate, domestic demand obtained by subtracting export quantities from import quantities given in the *Trade Statistics of Japan* (the Ministry of Finance) converted to pure substance mass 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 are used for years FY2000 to FY2006, FY2008, and FY2010. For FY2007 and 2009, interpolation was applied. For years FY1900 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* (METI) was applied, and for years from FY2011 and onward extrapolation using demand amounts of SrCO_3 given in the *Mineral Resources Material Flow* (JOGMEC) are applied.

For lithium carbonate, demand amounts of ceramic additives given in the *Mineral Resources Material Flow* (JOGMEC) 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* (JOGMEC)

are applied. For years FY1900 to FY1997, production amounts of plate glass given in the *Yearbook of Ceramics and Building Materials Statistics* (METI) for years FY1900 to FY1997 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, CO₂ emission has been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

See section 4.2.1. d).

e) Category-specific Recalculations

Recalculations have been conducted for all years, based on the addition of emissions from minor CO₂ emitting raw materials such as barium carbonate (BaCO₃) etc. For FY2016 the revision of limestone, dolomite, and soda ash, consumption data in the *Adjusted Price Transaction Table* also contributed to this. 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 CaCO₃ and minute amounts of MgCO₃, and dolomite contains CaCO₃ and MgCO₃. The heating of limestone and dolomite releases CO₂ derived from CaCO₃ and MgCO₃.

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**

The emission factor (440 [kg-CO₂/t]) is calculated by adding the value obtained when multiplying the molecular weight ratio of CO₂ and CaCO₃ by 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 CO₂ and MgCO₃ by 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* [Japan Lime Association]). The emission factor is country-specific. A review of this EF was conducted in 2009, and it was confirmed that it remains valid. (See 4.2.3. b) for details)

➤ **Dolomite**

The emission factor (471 [kg-CO₂/t]) is calculated by adding the value obtained when multiplying the molecular weight ratio of CO₂ and CaCO₃ by 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* [Japan Lime Association]) and the value obtained when multiplying the molecular weight ratio of CO₂ and MgCO₃ by 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* [Japan Lime Association]). The emission factor is country-specific. A review of this EF was conducted in 2009, and it was confirmed that it remains valid. (See 4.2.3. b) for details)

● **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 <i>Adjusted Price Transaction Table</i> (Limestone)	Corresponding sectors in the <i>Adjusted Price Transaction Table</i> (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 Metal Products - metal products for construction use to 2899-09 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

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Limestone consumption															
For Ceramic Products (dry)	kt	442	1,110	1,138	467	575	417	400	434	480	729	906	979	848	787
Dolomite consumption															
For Ceramic Products (dry)	kt	1,561	1,227	1,020	1,128	1,261	1,514	1,519	1,440	1,597	1,479	1,362	1,152	1,074	1,112

c) **Uncertainties and Time-series Consistency**

● **Uncertainty**

See section 4.2.2. 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, CO₂ emission from limestone and dolomite use has been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

See section 4.2.1. d).

e) Category-specific Recalculations

Recalculations have been conducted for FY2015 to FY2016, based on updates made to limestone consumption data in the *Adjusted Price Transaction Table*. Recalculations have been also conducted for FY2016, based on updates made to dolomite consumption data in the *Adjusted Price Transaction Table*. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.2.4.2. Other uses of soda ash (2.A.4.b)

a) Category Description

CO₂ is released during the use of soda ash (Na₂CO₃).

b) Methodological Issues

● **Estimation Method**

CO₂ 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.)

Emission factor for domestic soda ash

$$\begin{aligned}
 &= \text{purity of soda ash (arithmetic mean between the 2 domestic companies)} \\
 &\quad \times \text{molecular weight of CO}_2 / \text{molecular weight of Na}_2\text{CO}_3 \\
 &= 0.995 \times 44.01 / 105.99 \\
 &= 0.413
 \end{aligned}$$

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-CO₂/t-Na₂CO₃]) 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 both limestone and dolomite. For the uncertainty of activity data, the default value of 3% in the *2006 IPCC Guidelines* was used for both limestone and dolomite. As a result, the uncertainty for emissions was estimated as 6% for both limestone and dolomite.

- **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, CO₂ emission from soda ash use has been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

See section 4.2.1. d).

e) Category-specific Recalculations

Recalculations have been conducted for FY2016, based on updates made to soda ash consumption data in the *Adjusted Price Transaction Table*. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.2.4.3. Non-metallurgical magnesium production (2.A.4.c)

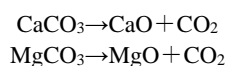
Emissions are included under 2.A.4.d. Other, and are therefore reported as IE.

4.2.4.4. Other (2.A.4.d)

a) Category Description

Limestone contains CaCO₃ and minute amounts of MgCO₃, and dolomite contains CaCO₃ and MgCO₃. The heating of limestone and dolomite releases CO₂ derived from CaCO₃ and MgCO₃.

CO₂ generating mechanism of limestone and dolomite use



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

The emission factor is calculated by adding the value obtained when multiplying the molecular weight ratio of CO₂ and CaCO₃ by 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 CO₂ and MgCO₃ by 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* [Japan Lime Association]). The emission factor is country-specific. A review of this EF was conducted in 2009, and it was confirmed that it remains valid. (See 4.2.3. b) for details)

➤ Dolomite

The emission factor is calculated by adding the value obtained when multiplying the molecular weight ratio of CO₂ and CaCO₃ by 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* [Japan Lime Association]) and the value obtained when multiplying the molecular weight ratio of CO₂ and MgCO₃ by 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* [Japan Lime Association]). The emission factor is country-specific. A review of this EF was conducted in 2009, and it was confirmed that it remains valid. (See 4.2.3. b) for details)

● 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 desulfurization of exhaust gas and production of chemical 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 4-12 Uses and corresponding sectors in the *Adjusted Price Transaction Table*

Uses	Corresponding sectors in the <i>Adjusted Price Transaction Table</i> (Limestone)	Corresponding sectors in the <i>Adjusted Price Transaction Table</i> (Dolomite)
Desulfurization of exhaust gas	063 Mining industry – non-metallic minerals	
Chemical products	2011-01 Chemical Products - chemical fertilizers	2011-01 Chemical Products - chemical fertilizers
	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	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Limestone consumption															
For Flue Gas Desulfurization	kt	1,841	2,139	1,813	2,075	1,922	1,699	1,795	2,008	2,149	2,067	1,741	1,626	1,602	1,535
For Chemical Products (dry)	kt	3,668	1,717	1,772	683	759	531	491	501	481	708	853	894	749	679
Dolomite consumption															
For Chemical Products (dry)	kt	147	96	84	54	47	52	47	35	20	16	12	9	7	7

c) Uncertainties and Time-series Consistency● **Uncertainty**

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, CO₂ emission from limestone and dolomite use has been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

See section 4.2.1. d).

e) Category-specific Recalculations

Recalculations have been conducted for FY2015 to FY2016, based on updates made to limestone consumption data in the *Adjusted Price Transaction Table*. For FY2016, recalculations have been also conducted, based on updates made to dolomite consumption data in the *Adjusted Price Transaction Table*. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.3. Chemical Industry (2.B.)

This category covers CO₂, CH₄, N₂O, HFCs, PFCs, SF₆, and NF₃ emissions from the processes of chemical productions.

This section includes GHG emissions from 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), and Fluorochemical production (2.B.9.).

In FY2017, emissions from this category were 5,595 kt-CO₂ eq. and represented 0.4% of Japan's total GHG emissions (excluding LULUCF). The total emissions of CO₂, CH₄, and N₂O from this category had decreased by 69.4% compared to FY1990. The total of HFCs, PFCs, SF₆, and NF₃ had decreased by 97.5% compared to 1990.

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

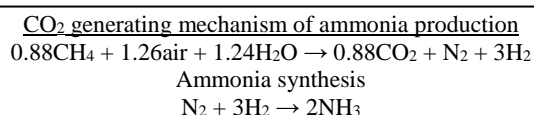
Gas		Units	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017		
CO ₂	2.B.1	Ammonia production	kt-CO ₂	3,418	3,457	3,184	2,167	2,007	1,923	2,123	2,008	1,855	1,934	1,891	1,947	1,658	1,726	
	2.B.5	Carbide production	Silicon carbide	kt-CO ₂	C	C	C	C	C	C	C	C	C	C	C	C	C	
			Calcium carbide	kt-CO ₂	C	C	C	C	C	C	C	C	C	C	C	C	C	
	2.B.6	Titanium dioxide production	kt-CO ₂	102	39	53	59	51	43	62	65	51	60	62	53	58	58	
	2.B.8	Petrochemical and carbon black production	Methanol	kt-CO ₂	56	51	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
			Ethylene	kt-CO ₂	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	191	184	146	130	148	150	169	170	175
			Ethylene oxide	kt-CO ₂	171	191	231	240	191	190	202	202	204	220	214	221	212	227
			Acrylonitrile	kt-CO ₂	440	476	536	509	411	461	524	486	404	364	342	315	319	323
			Carbon black	kt-CO ₂	1,633	1,563	1,590	1,659	1,494	1,308	1,505	1,380	1,261	1,294	1,253	1,161	1,168	1,230
			anhydride	kt-CO ₂	117	124	118	81	59	51	60	55	60	59	58	60	58	61
			Maleic anhydride	kt-CO ₂	123	138	163	114	96	94	102	91	78	89	88	90	91	94
	Hydrogen	kt-CO ₂	6	21	39	34	30	31	34	32	31	28	24	27	29	29		
Total			kt-CO ₂	7,041	7,014	6,810	5,795	5,107	4,872	5,427	5,103	4,652	4,788	4,685	4,591	4,300	4,485	
CH ₄	2.B.5	Carbide production	Silicon carbide	kt-CH ₄	C	C	C	C	C	C	C	C	C	C	C	C		
	2.B.8	Petrochemical and carbon black production	Methanol	kt-CH ₄	0.19	0.17	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	
			Ethylene	kt-CH ₄	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
			Ethylene oxide	kt-CH ₄	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	
			Styrene	kt-CH ₄	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	1.27	1.43	1.45	1.43	1.13	1.13	1.01	1.27
Total			kt-CO ₂ eq.	37.49	37.09	34.15	33.69	31.74	35.83	36.23	35.71	28.14	28.20	25.22	31.79	26.76		
N ₂ O	2.B.2	Nitric acid production	kt-N ₂ O	2.47	2.46	2.57	2.52	1.62	1.54	1.81	1.49	1.53	1.54	1.55	1.40	1.28		
	2.B.3	Adipic acid production	kt-N ₂ O	24.20	24.03	12.56	1.68	2.45	3.49	1.66	1.05	0.51	0.77	0.48	0.38	0.49		
	2.B.4	Caprolactam, glyoxal and glyoxylic acid production	Caprolactam	kt-N ₂ O	4.66	4.93	5.20	3.36	2.47	2.52	2.56	2.48	2.30	1.92	1.26	0.90		
			Glyoxal	kt-N ₂ O	C	C	C	C	C	C	C	C	C	C	C	C		
			Glyoxylic acid	kt-N ₂ O	C	C	C	C	C	C	C	C	C	C	C	C		
	Total			kt-N ₂ O	32.28	32.43	21.30	8.58	7.53	7.92	6.08	5.06	4.34	4.22	3.28	2.68		
Total			kt-CO ₂ eq.	9,620	9,665	6,348	2,558	2,244	2,360	1,813	1,507	1,293	1,259	979	798			
Total of CO ₂ , CH ₄ , and N ₂ O			kt-CO ₂ eq.	16,698	16,716	13,193	8,387	7,383	7,267	7,276	6,646	5,973	6,075	5,689	5,421			
Gas		Units	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017		
HFCs	2.B.9	Fluorochemical production	By-product emissions: Production of HCFC-22	kt-CO ₂ eq.	15,929	21,460	15,688	586	593	50	53	16	18	16	24	30		
			Fugitive emissions	kt-CO ₂ eq.	2	559	296	449	306	234	128	151	120	131	101	83	149	
	Total			kt-CO ₂ eq.	15,930	22,019	15,984	1,035	900	284	181	168	138	147	124	113		
PFCs	2.B.9	Fluorochemical production	Fugitive emissions	kt-CO ₂ eq.	331	914	1,661	1,041	649	459	248	206	148	111	107	115	97	
SF ₆			Fugitive emissions	t	152	197	36	41	54	10	8	6	5	4	3	2		
			Fugitive emissions	kt-CO ₂ eq.	3,471	4,492	821	930	1,229	233	189	132	123	93	62	52		
NF ₃	Fugitive emissions	t	0.2	1.0	7.0	72.1	71.1	66.8	76.9	93.1	76.4	86.4	56.1	23.5				
Total of F-gases			kt-CO ₂ eq.	19,735	27,442	18,587	4,246	4,001	2,124	1,942	2,108	1,723	1,837	1,258	684	752		

4.3.1. Ammonia Production (2.B.1.)

a) Category Description

1) CO₂

In ammonia production, CO₂ is emitted when hydrocarbon feedstock is broken down to make H₂.



2) CH₄

Emission of CH₄ 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, CH₄ was reported as “NE”.

3) N₂O

Emission of N₂O from ammonia production is theoretically impossible, and given that even in actual measurements the emission factor for N₂O is below the limits of measurement, N₂O was reported as “NA”.

b) Methodological Issues

● Estimation Method

CO₂ 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 deducted from emissions. (See section 3.4.4 (I.C.) for details)

● Emission Factors

The same emission factors that are used to calculate CO₂ emissions from the fuel combustion sector (Chapter 3) 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	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Naphtha	GCV	MJ/l	33.63	33.63	33.57	33.55	33.53	33.53	33.53	33.53	33.31	33.31	33.31	33.31	33.31
	CEF	tC/TJ	18.17	18.17	18.17	18.17	18.17	18.17	18.17	18.17	18.17	18.63	18.63	18.63	18.63
LPG	GCV	MJ/kg	50.53	50.63	50.70	50.75	50.73	50.72	50.77	50.76	50.78	50.07	50.09	50.09	50.10
	CEF	tC/TJ	16.54	16.51	16.49	16.48	16.48	16.48	16.47	16.47	16.47	16.38	16.37	16.36	16.36
Off gas	GCV	MJ/m ³	39.35	39.35	44.90	44.90	44.90	44.90	44.90	44.90	46.73	46.73	46.73	46.73	46.73
	CEF	tC/TJ	14.15	14.15	14.15	14.15	14.15	14.15	14.15	14.15	14.15	14.44	14.44	14.44	14.44
Natural gas	GCV	MJ/m ³	42.09	42.39	42.55	42.87	44.71	44.84	44.67	44.74	44.75	40.15	40.15	40.15	40.15
	CEF	tC/TJ	13.90	13.90	13.90	13.90	13.90	13.90	13.90	13.90	13.90	13.97	13.97	13.97	13.97
Coal	GCV	MJ/kg	25.95	25.95	26.60	25.70	25.70	25.70	25.70	25.70	25.97	25.97	25.97	25.97	25.97
	CEF	tC/TJ	24.71	24.71	24.71	24.71	24.71	24.71	24.71	24.71	24.71	24.42	24.42	24.42	24.42
Oil coke	GCV	MJ/kg	35.58	35.58	35.60	29.90	29.90	29.90	29.90	29.90	33.29	33.29	33.29	33.29	33.29
	CEF	tC/TJ	25.35	25.35	25.35	25.35	25.35	25.35	25.35	25.35	25.35	24.50	24.50	24.50	24.50
LNG	GCV	MJ/kg	54.54	54.53	54.52	54.51	54.50	54.49	54.49	54.48	54.47	54.46	54.46	54.46	54.46
	CEF	tC/TJ	13.94	13.95	13.94	13.94	13.95	13.95	13.95	13.95	13.96	13.96	13.95	13.96	13.96
COG	GCV	MJ/m ³	21.51	21.57	21.27	21.42	21.20	21.15	21.32	21.12	20.75	19.12	19.12	19.12	19.12
	CEF	tC/TJ	10.99	10.99	10.99	10.99	10.99	10.99	10.99	10.99	10.99	10.93	10.93	10.93	10.93

(Reference) *General Energy Statistics*, Agency for Natural Resources and Energy

● Activity Data

The fixed units (including weight and volume) for the fuel types in Table 4-16 below, which are from the Ministry of Economy, Trade and Industry’s *Yearbook of the Current Survey of Energy Consumption*, were converted using the calorific values in the Agency for Natural Resources and Energy’s *General Energy Statistics*, and results were used as activity data. Consumption data on some fuel types are confidential.

Table 4-16 Amount of feedstocks used for ammonia production

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Naphtha	kl	189,714	477,539	406,958	92,453	67,062	72,045	70,067	67,646	67,869	71,494	66,079	73,612	18,421	NO
LPG	t	226,593	45,932	5,991	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Off gas	10 ³ m ³	C	230,972	240,200	147,502	151,553	140,783	143,634	126,809	NO	NO	NO	NO	NO	NO
Natural gas	10 ³ m ³	C	100,468	86,873	77,299	50,260	21,773	41,640	41,169	45,808	47,956	51,858	17,498	637	979
Coal	t	C	209,839	726	1,239	802	522	629	879	390	919	787	362	891	483
Oil coke	t	C	273,125	420,862	353,983	336,633	351,594	394,116	365,340	405,557	401,721	426,743	468,684	416,722	462,107
LNG	t	C	46,501	23,395	165,606	162,342	145,699	157,918	161,588	169,109	168,155	127,824	122,453	131,446	122,081
COG	10 ³ m ³	C	35,860	55,333	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

C: Confidential

● **Point to Note**

Fuel consumption in this category has been deducted 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. As a result, the uncertainty of emissions are the following: naphtha -3 - +1%; LPG -3 - +1%; hydrocarbon gas -4 - +3%; natural gas -1 - +1%; coal (steam coal, imported coal) -4 - +3%; petroleum coke -3 - +1%; LNG -1 - +1%; and COG -4 - +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, CO₂ emission from ammonia production has been estimated in a consistent manner throughout the time-series.

d) **Category-specific QA/QC and Verification**

See section 4.2.1. d).

e) **Category-specific Recalculations**

CO₂ emissions were recalculated for FY1990 to FY2012, and FY2016, based on updates made to the carbon emission factors of LNG. For FY2012 and FY2016, the revision of the gross calorific value of LNG also contributed to this. See Chapter 10 for impact on trend.

f) **Category-specific Planned Improvements**

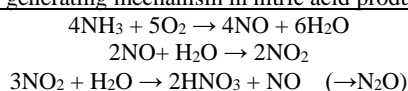
No improvements are planned.

4.3.2. Nitric Acid Production (2.B.2.)

a) **Category Description**

N₂O is emitted when nitric acid (HNO₃) is produced from ammonia.

N₂O generating mechanism in nitric acid production



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 N₂O decomposition, there are catalytic decomposition units in operation.

b) Methodological Issues

● Estimation Method

N₂O 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 N₂O destroyed is currently unavailable, but is reflected in the emission factor.

$$\begin{aligned} & \text{N}_2\text{O emissions [kg-N}_2\text{O]} \text{ from nitric acid production} \\ & = \text{emission factor [kg-N}_2\text{O/t]} \times \text{nitric acid production volume [t]} \end{aligned}$$

● 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 N₂O recovery and destruction into account.

Table 4-17 N₂O emission factors for nitric acid production

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
EFs for nitric acid production	kg-N ₂ O/t	3.50	3.51	3.92	4.18	3.35	3.34	3.58	3.49	3.38	3.55	3.54	3.60	3.59	3.27

● Activity Data

Production amounts of nitric acid are directly provided by the Ministry of Economy, Trade and Industry.

Table 4-18 Amount of nitric acid production

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Nitric acid production	kt	706	701	656	602	484	461	506	426	453	434	437	388	356	355

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 73%. 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 73%.

● Time-series Consistency

Emissions throughout the time series are consistently estimated using the activity data and emission factors provided by the Ministry of Economy, Trade and Industry.

d) Category-specific QA/QC and Verification

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

N₂O is emitted in the adipic acid (C₆H₁₀O₄) production process through the reaction of cyclohexanone, cyclohexanol, and nitric acid.

b) Methodological Issues

● **Estimation Method**

Emissions were estimated using the N₂O generation rates, N₂O 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 N₂O 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 the Ministry of Economy, Trade and Industry by the manufacturer. Relevant data used in estimation is confidential.

● **Point to Note**

From 1990 to 1997, N₂O emissions from adipic acid production increased gradually. However, N₂O 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 due to the low operating rate of N₂O decomposition units caused by mechanical failure 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 N₂O generation rate, N₂O 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

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 Production (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. N₂O 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 five plants producing caprolactam in Japan. Each plant's emission factor fluctuates by year.

- **Activity Data**

Caprolactam production amounts from the *Yearbook of Current Production Statistics – Chemical Industry* compiled by the Ministry of Economy, Trade and Industry were used as activity data.

Table 4-19 Caprolactam production amount

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Caprolactam production	kt	516	546	575	455	365	401	411	392	366	342	266	241	220	223

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 99%. 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 99%.

● **Time-series Consistency**

For the activity data, data from the *Yearbook of Current Production Statistics – Chemical Industry* (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

See section 4.2.1. d).

e) Category-specific Recalculations

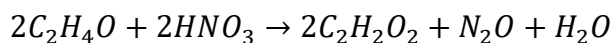
Recalculations have been conducted for FY2004 to FY2016, based on revision of the emission factors. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.4.2. Glyoxal Production (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 N₂O is emitted in the process of oxidation of acetaldehyde. (See below)

**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, and therefore emissions are reported as NO.

● **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 N₂O 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*

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 Production (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 N₂O 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, and therefore emissions are reported as NO.

● ***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 N₂O 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

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 Production (2.B.5.a)****a) Category Description****1) CO₂**

CO₂ is emitted by the reaction of petroleum coke with silica as raw materials in the production of silicon carbide.

CO₂ generating mechanism in the silicon carbide production process

**2) CH₄**

In Japan, silicon carbide is produced in electric arc furnaces, and it is believed that CH₄ is generated from the oxidation of coke, which is used as a reducing agent in silicon carbide production.

b) Methodological Issues**1) CO₂**● **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-CO₂/t]

for silicon carbide production in the 2006 IPCC Guidelines is used.

- **Activity Data**

The activity data for CO₂ 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) CH₄

- **Estimation Method**

Emissions were calculated by multiplying an emission factor based on actual figures obtained in Japan by the energy consumption of electric arc furnaces. This is the same method used for calculating CH₄ emissions in the Fuel Combustion Sector (1.A. Solid Fuels).

- **Emission Factors**

The emission factor of energy consumption in electric arc furnaces (12.8 kg-CH₄/TJ) was determined from CH₄ concentrations in the flue gas, measured dry flue gas amounts per hour, and measured quantity of heat generated per hour. See Chapter 3, 3.2.5 CH₄ and N₂O Emissions from Energy Industry (1.A.1.:CH₄, N₂O)

- **Activity Data**

The activity data for CH₄ 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) CO₂

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) CH₄

The uncertainty of the emission factor, the default value of 10% was applied as provided by the IPCC 2006 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 CO₂ and CH₄ 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, CO₂ and CH₄ emissions from silicon carbide have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

See section 4.2.1. d).

e) Category-specific Recalculations

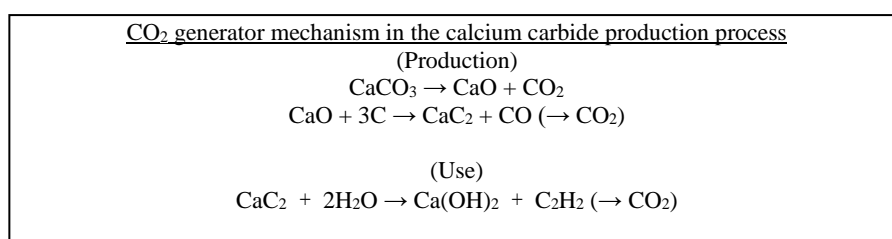
There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.5.2. Calcium Carbide Production and Use (2.B.5.b)**a) Category Description****1) CO₂**

CO₂ 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, CO₂ is generated by the combustion of acetylene, which is generated by reacting calcium carbide with water, and these emissions are reported here.

**2) CH₄**

Byproduct gases (mainly CO) generated in carbide production include a small amount of CH₄, 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**

CO₂ 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 4-20 CO₂ Emission factors for calcium carbide production and consumption (FY1990- FY2007)

Units	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-CO₂/t) for calcium carbide use is also used for FY2008 and onwards.

The calcium carbide production amount used for calculating the CO₂ EF includes not only CaC₂ 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 CaC₂. In Japan, CaC₂ is produced under conditions with excessive CaO. With CaC₂, 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 the Carbide Industry Association are used as the calcium carbide production amount. The data are confidential.

- c) **Uncertainties and Time-series Consistency**

- **Uncertainty**

For the uncertainty of the CO₂ 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**

See section 4.2.1. d).

- e) **Category-specific Recalculations**

There have been no source-specific recalculations.

- f) **Category-specific Planned Improvements**

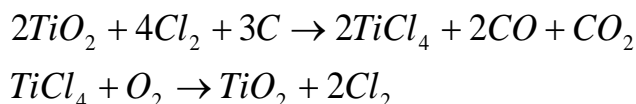
No improvements are planned.

4.3.6. Titanium dioxide Production (2.B.6)

- a) **Category Description**

Titanium dioxide (TiO₂) 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 TiO₂, anatase TiO₂ and rutile TiO₂ (both tetragonal), differ in terms of the crystalline structure, and the anatase TiO₂ is produced by hydrolyzing titanium sulfate and calcination (the sulfate process), or from titanium slag. Rutile TiO₂ is produced through the carbothermal chlorination of synthetic rutile to produce titanium tetrachloride (TiCl₄) and oxidation of the TiCl₄ vapours to TiO₂. (the chloride route)

CO₂ 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.



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.

$$\text{CO}_2 \text{ emissions} = (\text{coke input amount} - \text{carry-over amount}^2) \times \text{carbon content of coke} \times 44/12$$

$$\text{CO}_2 \text{ emission factor} = \text{CO}_2 \text{ emissions} / \text{titanium dioxide production amounts}$$

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 the Japan Titanium Dioxide Industry Association are used)

In the case of Japanese manufacturers, reactions take place under high temperatures such as 1,000 degrees celsius, and therefore the reaction $\text{TiO}_2 + 2\text{Cl}_2 + 2\text{CO} \rightarrow \text{TiCl}_4 + 2\text{CO}_2$ 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 the 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.

² Raw material left over without reacting.

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 *IPCC 2006 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 the 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

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 *2006 IPCC Guidelines* offer a method to calculate CO_2 emissions from calcinating trona ($\text{Na}_2\text{CO}_3 \cdot \text{NaHCO}_3 \cdot 2\text{H}_2\text{O}$), 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 Production (2.B.8.a)****a) Category Description**

CO_2 and CH_4 are emitted during the production of methanol.

b) Methodological Issues**● Estimation Method**

CO₂ and CH₄ 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 CO₂ 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-CO₂/t] (Refer to the 2006 IPCC Guidelines vol. 3 p 3.73, Table 3.12).

The default value for CH₄ from methanol given in the 2006 IPCC Guidelines was used. The emission factor is 2.3 [kg-CH₄/t] (Refer to the 2006 IPCC Guidelines vol. 3 p 3.74).

● Activity Data

Production amounts of methanol (on calendar year basis) given by the Methanol and Formalin Association were used as activity data for CO₂ and CH₄ emissions from methanol production.

Table 4-21 Methanol production amount

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Methanol production	kt	84	75	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

c) Uncertainties and Time-series Consistency**● Uncertainty**

For the uncertainty of the emission factor, the default values from the IPCC 2006 Guidelines of -30 - +30% (CO₂) and -80 - +30% (CH₄) were used. For the uncertainty of activity data, the default values of similar chemical products from the IPCC 2006 Guidelines of -5 - +5% were used. As a result, the uncertainty of CO₂ and CH₄ emissions were estimated as -30 - +30% and -80 - +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, CO₂ and CH₄ emissions from methanol production have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

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 Production (2.B.8.b)**a) Category Description****1) CO₂, CH₄**

CO₂ is emitted in the ethylene production process. CH₄ 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 conversion 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) N₂O

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 N₂O emissions.

b) Methodological Issues● **Estimation Method**

CH₄ and CO₂ 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*.

● **Emission Factors**➤ **CO₂**

The emission factor was set, based on a survey conducted by the Japan Petrochemical Industry Association in 2009 on the CO₂ emission factor from ethylene production.

This country-specific CO₂ EF was established based on CO₂ emissions from decoking, etc and ethylene production data. CO₂ emissions from the energy use of industrial process off gases obtained from the feedstocks are accounted for under '1.A. Fuel combustion,' and therefore there is a difference between the CSEF and the IPCC default value.

This emission factor is confidential.

➤ **CH₄**

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 combusted³), and measured amount of exhaust gas from naphtha cracking furnaces and furnaces heated by re-cycled gas, were

³ The assumption was set based on a flaring efficiency of 98% shown in the IPCC GPG (Table 2.16 note e).

divided by the production amount to calculate emission factors for each company. The weighted average based on production from each company was then applied to establish the emission factor. (Surveyed by the Japan Petrochemical Industry Association) This emission factor is confidential.

- **Activity Data**

Ethylene production amounts from the *Yearbook of Chemical Industries Statistics* compiled by the Ministry of Economy, Trade and Industry were used as activity data for emissions of CH₄ and CO₂ from ethylene production.

Table 4-22 Ethylene production amount

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Ethylene production	kt	5,966	6,951	7,566	7,549	6,520	7,219	6,999	6,474	6,261	6,764	6,687	6,780	6,286	6,459

c) Uncertainties and Time-series Consistency

- **Uncertainty**

The uncertainty for both CO₂ and CH₄ emission factors for ethylene were calculated by finding the 95% confidence interval of emission factors. The estimated uncertainty for both CO₂ and CH₄ 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 CO₂ and CH₄ 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, CO₂ and CH₄ emissions from ethylene production have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

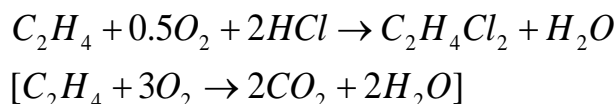
No improvements are planned.

4.3.8.3. 1,2-Dichloroethane and Chloroethylene (2.B.8.c)

a) Category Description

1) CO₂

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 CO₂ from the oxidation of the ethylene. (See the below)



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. CO₂ is emitted through the same chemical reactions as the above in the combined process.

2) CH₄

1,2-dichloroethane passes through washing, refining, and thermolysis processes to become chloroethylene (C₂H₃Cl). A very small amount of CH₄ is contained in the exhaust gases of the reaction, and of the washing and refining processes.

b) Methodological Issues

● Estimation Method

CO₂ 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, CH₄ 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 CH₄ 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

➤ CO₂

A CO₂ emission factor (0.0647 t-CO₂/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 CO₂ emissions across all five plants producing 1,2-dichloroethane and chloroethylene in 2012, by the total chloroethylene production amounts in 2012.

The default value 0.294tCO₂/tVCM also accounts for CO₂ 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.

➤ CH₄

The concentration of CH₄ 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-CH₄/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) No emission factors are set for years

FY2001 and onward.

- **Activity Data**

VCM (Chloroethylene) production amounts from the *Yearbook of Chemical Industries Statistics* compiled by the Ministry of Economy, Trade and Industry were used as activity data for CO₂ emissions

1,2-Dichloroethane production amounts from the *Yearbook of Chemical Industries Statistics* compiled by the Ministry of Economy, Trade and Industry were used as activity data for CH₄ emissions.

Table 4-23 VCM (Chloroethylene) production amount

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
VCM production amount	kt	2,316	2,648	2,976	3,098	2,839	2,958	2,850	2,253	2,009	2,286	2,315	2,616	2,621	2,706

Table 4-24 1,2-Dichloroethane production amount

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1,2-Dichloroethane production	kt	2,683	3,014	3,346	3,639	3,243	3,213	3,155	2,841	2,558	2,733	2,730	3,003	3,012	3,158

c) Uncertainties and Time-series Consistency

- **Uncertainty**

For the uncertainty of the CO₂ and CH₄ emission factors for 1,2-dichloroethane production, the default values of -50 - +20% and -11 - +11% 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 - +21% and -12 - +12%, 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, CH₄ emissions from 1,2-Dichloroethane production have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

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.

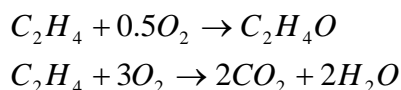
4.3.8.4. Ethylene oxide Production (2.B.8.d)

a) Category Description

1) CO₂, CH₄

Ethylene oxide is produced by reacting ethylene with oxygen over a catalyst, with CO₂ 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.



The CO₂ 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 CH₄ may be emitted through leakage or venting.

b) Methodological Issues

● Estimation Method

➤ CO₂

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. The difference between emissions estimated using an EF which does not reflect recovery, and emissions estimated using an EF which reflects recovery (the actual EF used for this sub-category) is reported under CO₂ from carbonated gas and dry ice production (2.H.2). (See below)

$$E_{CO_2} = EO * EF_1$$

E_{CO₂}: CO₂ emissions from ethylene oxide production

EO: Ethylene oxide production amount per year

EF₁: CO₂ emissions per ethylene oxide production amount (reflecting recovery)

$$R_{CO_2} = EO * EF_2 - E_{CO_2}$$

R_{CO₂}: CO₂ recovery amount from ethylene oxide production processes

EO: Ethylene oxide production amount per year

EF₂: CO₂ emissions per ethylene oxide production amount (without reflecting recovery)

➤ CH₄

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

➤ CO₂

EFs per production amount (recovery reflected: 0.24 t-CO₂/t, recovery not reflected: 0.33 t-CO₂/t) are used. (provided by the 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 not reflecting recovery is lower than the default value of 0.663 t-CO₂/t.

➤ **CH₄**

An EF based on measured data and specific to the manufacturer is used. The CH₄ emission data used to establish the EF is estimated by the manufacturer based on an estimation of CH₄ emissions into the atmosphere, which is further based on the CH₄ 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**

➤ **CO₂**

The ethylene oxide production amounts in the *Yearbook of Current Production Statistics - Chemical Industry* (METI) are used. (Table 4-25)

Table 4-25 Ethylene oxide production amount

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Ethylene oxide production	kt	714	795	961	1,001	795	792	843	842	849	915	894	923	882	945

➤ **CH₄**

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 CO₂ 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 CH₄ 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* (METI) and data from one manufacturer are used throughout the time series. The emission factor is set based on data from the same sources. Therefore, CO₂ and CH₄ emissions from ethylene oxide production have been estimated in a consistent manner throughout the time-series.

d) **Category-specific QA/QC and Verification**

See section 4.2.1. d).

e) **Category-specific Recalculations**

There have been no source-specific recalculations.

f) **Category-specific Planned Improvements**

No improvements are planned.

4.3.8.5. Acrylonitrile Production (2.B.8.e)

a) Category Description

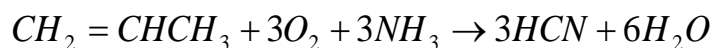
1) CO₂

Acrylonitrile (C₃H₃N) 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 CO₂ by direct oxidation of the feedstock in the ammoxidation process (See below chemical equation 4)

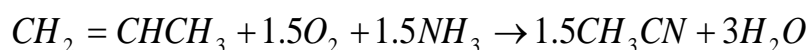
Equation 1: Acrylonitrile reaction



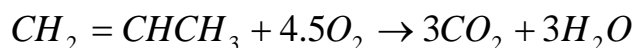
Equation 2: Hydrogen cyanide reaction



Equation 3: Acetonitrile reaction



Equation 4: Feedstock oxidation



2) CH₄

The CH₄ 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 CO₂ emission factor per production (0.73 t-CO₂/t, provided by the Japan Petrochemical Industry Association) is applied for all years. This emission factor is an arithmetic mean of plant-specific CO₂ 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-CO₂/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 Chemical Industries Statistics* compiled by the Ministry of Economy, Trade and Industry were used for activity data.

Table 4-26 Acrylonitrile production amount

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Acrylonitrile production amount	kt	602	652	734	697	563	631	718	665	553	499	468	431	437	443

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 Chemical Industries Statistics*, are used throughout the time series. The emission factor is constant throughout the time series. Therefore, CO₂ emissions from acrylonitrile production have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

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 Production (2.B.8.f)

a) Category Description

1) CO₂, CH₄

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 CO₂ and CH₄ in the tail gas (off gas) emitted from the carbon black production process is released into the atmosphere.

b) Methodological Issues

- **Estimation Method**

- **CO₂**

CO₂ 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.

➤ **CH₄**

CH₄ 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**

➤ **CO₂**

Since it is considered that the CO₂ from natural gas that is used to heat the furnace (secondary feedstock origin) is already accounted for under fuel combustion (1.A.), only CO₂ from the oil and gas used directly as raw material (primary feedstock origin) is accounted for here. A CO₂ emission factor per production (2.06 tCO₂/t) provided by the Carbon Black Association is used. This is established by taking a weighted average of total CO₂ 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.

➤ **CH₄**

In carbon black manufacturing plants in Japan, CH₄ 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 CH₄, and the concentrations of CO, CO₂, and CH₄ 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 CH₄ emission factor can be calculated from the CO₂ emission factor (2.06 t-CO₂/t) as the below. The data is confidential.

$$EF_{CH_4} = 2.06 \text{ [t-CO}_2\text{/t]} \times R \times \frac{0.6 \text{ [wt\%]}}{21.5 \text{ [wt\%]}} \times \frac{16}{44}$$

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 Chemical Industries Statistics* compiled by the Ministry of Economy, Trade and Industry were used for activity data for both CO₂ and CH₄ emissions associated with the manufacturing of carbon black.

Table 4-27 Carbon black production amount

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Carbon black production	kt	793	759	772	805	725	635	730	670	612	628	608	563	567	597

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 CO₂ and CH₄. For the uncertainty of activity data, the default value of 5% given by the *2006 IPCC Guidelines* was used for both CO₂ and CH₄. As a result, the uncertainty of carbon black production emissions was estimated at 55% for both CO₂ and CH₄.

- ***Time-series Consistency***

For activity data, the same source, the *Yearbook of Chemical Industries Statistics*, 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***

See section 4.2.1. d).

- e) ***Category-specific Recalculations***

For FY2016, updates to the *Yearbook of Chemical Industries Statistics* resulted in recalculations of CO₂ and CH₄ emissions. See Chapter 10 for impact on trend.

- f) ***Category-specific Planned Improvements***

No improvements are planned.

4.3.8.7. Styrene Production (2.B.8.g.-)

- a) ***Category Description***

CH₄ is emitted in the styrene production process.

- b) ***Methodological Issues***

- ***Estimation Method***

CH₄ 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 combusted⁴), 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 the Japan Petrochemical Industry Association) This emission factor is confidential.

- ***Activity Data***

Styrene monomer production amounts from the *Yearbook of Chemical Industries Statistics* compiled by the Ministry of Economy, Trade and Industry were used as activity data for CH₄ emissions from styrene production.

⁴ See footnote 1.

Table 4-28 Styrene monomer production amount

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Styrene production	kt	2,227	2,952	3,020	3,375	2,699	3,043	3,019	2,594	2,426	2,539	2,518	2,260	1,952	2,100

c) Uncertainties and Time-series Consistency

● **Uncertainty**

The uncertainty for the CH₄ 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, CH₄ emissions from styrene production have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

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.

4.3.8.8. Phthalic anhydride Production (2.B.8.g.-)

a) Category Description

Phthalic anhydride is used as raw material for plasticizers, synthetic resins, paints, dyes etc. CO and CO₂ 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 CO₂.

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 CO₂ generation rate (mol %) was calculated by assuming that carbon that did not become products or other by-products ultimately become CO₂, 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 CO₂ emissions per production amount, based on the generation rate of CO₂ and products and the molecular weight of each substance. The yield is shown with an upper limit and lower limit in *Petrochemical Processes* (The Japan Petroleum Institute), and therefore EFs are set using the median value.

Table 4-29 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

Source: *Petrochemical Processes* (The Japan Petroleum Institute) (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 4-30 The weighted average EF based on productive capacity of phthalic anhydride

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Weighted average EF	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

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* (Ministry of Economy, Industry and Trade) are used.

Table 4-31 Phthalic anhydride production amount

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Phthalic anhydride production	kt	300	319	288	216	159	137	160	148	162	158	156	159	156	163

c) *Uncertainties and Time-series Consistency*

● *Uncertainty*

For the uncertainty of the emission factor, a 32% 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 32%.

● *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*

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.

4.3.8.9. Maleic anhydride Production (2.B.8.g.-)

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 CO₂ 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 CO₂.

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 CO₂ generation rate (mol %) was calculated by assuming that carbon that did not become products or other by-products ultimately become CO₂, and by using the yield of products or other by-products (mol %) per production process of maleic anhydride (*Petrochemical Processes* (The Japan Petroleum Institute)) The EFs in each production process are calculated from the CO₂ emissions per production amount, based on the generation rate of CO₂ and products and the molecular weight of each substance. The yield is shown with an upper limit and lower limit in *Petrochemical Processes* (The Japan Petroleum Institute), and therefore EFs are set using the median value.

Table 4-32 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

Source: *Petrochemical Processes* (The Japan Petroleum Institute) (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 4-33 The weighted average EF based on productive capacity of maleic anhydride

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Weighted average EF	t-CO ₂ /t	1.20	1.20	1.23	1.11	1.11	1.11	1.11	1.04	1.04	1.04	1.04	1.04	1.04	1.04

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* (Ministry of Economy, Industry and Trade) are used.

Table 4-34 Maleic anhydride production amount

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Maleic anhydride production	kt	103	116	132	103	86	85	93	88	75	86	85	87	88	90

c) Uncertainties and Time-series Consistency

● Uncertainty

For the uncertainty of the emission factor, a 16% 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 17%.

- **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

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.

4.3.8.10. Hydrogen Production (2.B.8.g.-)

a) Category Description

CO₂ 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, CO₂ 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 CO₂ emissions from industrial gas producers was divided by the aggregated production amounts of hydrogen to establish a CO₂ EF per production. Both aggregated values are based on values reported by member companies of the Japan Industrial and Medical Gases Association.

Table 4-35 Emission factors for hydrogen production

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Emission factor	t-CO ₂ / 10 ³ Nm ³	0.82	0.83	0.83	0.88	0.87	0.87	0.87	0.87	0.88	0.87	0.85	0.85	0.84	0.86

- **Activity Data**

The production amounts of hydrogen are for those processes that entail CO₂ emissions, and are based on values reported by member companies of the Japan Industrial and Medical Gases Association.

Table 4-36 Hydrogen production amount

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Hydrogen production	10 ³ Nm ³	7,431	25,116	46,562	37,911	34,330	36,277	38,889	37,437	34,846	32,170	28,394	32,257	34,235	34,095

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 CO₂ 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

See section 4.2.1. d).

e) Category-specific Recalculations

The revision of the emission factors was revised for FY1995 to FY2016 resulting in recalculations. See Chapter 10 for impact on trend.

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) Category Description**

HFC-23 is generated as a by-product of HCFC-22 production.

b) Methodological Issues● **Estimation Method**

Estimating emissions involved 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.

Emissions of by-product HFC-23 associated with the production of HCFC-22

$$\text{Emissions of HFC-23} = \text{Production of HCFC-22 [t]} \times \text{Rate of generation of HFC-23 [\%]} \\ - \text{Amount of recovery and destruction [t]}$$

Table 4-37 Indices related to By-product Emissions of HFC-23: Production of HCFC-22

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production of HCFC-22	t	60,122	81,000	95,271	65,715	60,401	26,682	46,149	45,314	54,388	47,546	51,753	49,121	48,833	52,646
Rate of generation of HFC-23	%	2.13%	2.13%	1.70%	1.90%	2.00%	2.34%	2.01%	1.53%	1.60%	1.41%	1.46%	1.46%	1.38%	1.47%
Emission rate to production of HCFC-22	%	1.79%	1.79%	1.11%	0.06%	0.07%	0.01%	0.01%	0.002%	0.002%	0.002%	0.003%	0.004%	0.003%	0.005%
Emissions	t	1,076	1,450	1,060	40	40	3	4	1	1	1	2	2	2	3
	kt-CO ₂ eq.	15,929	21,460	15,688	586	593	50	53	16	18	16	24	30	24	38

Source: 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, Documents of the first meeting of the Breakout Group on F-gases, FY2013 Committee for the Greenhouse Gas Emissions Estimation Methods

* 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 amounts⁵, 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.

⁵ MITI, Documents of the first meeting of the Group for global warming chemicals, Risk Management Sub-Group, Chemicals Council, 1997.

f) Category-specific Planned Improvements

No improvements are planned.

4.3.9.2. Fugitive Emissions (2.B.9.-)

a) Category Description

HFCs, PFCs, SF₆, and NF₃ are emitted as fugitive emissions during manufacturing. Regarding returned gas cylinders, when residual gas is decomposed and the containment shell is cleaned, 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, SF₆, and NF₃ manufacturing plant in Japan. Recovery, etc is hereby taken into account. The recovery/destruction units are constantly running when the plants are in operation. If any trouble arises in the units, management practices are to stop the plant operation.

The associated indices are given in the table below.

Table 4-38 Fugitive emissions from HFC production

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Emissions	kt-CO ₂ eq.	2	559	296	449	306	234	128	151	120	131	101	83	149	95

Source: 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 (data from Japan Fluorocarbon Manufacturers Association), and data provided by the Ministry of Economy, Trade and Industry, Documents of the first meeting of the Breakout Group on F-gases, FY2013 Committee for the Greenhouse Gas Emissions Estimation Methods

* 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 4-39 Fugitive emissions from PFC production

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Emissions	kt-CO ₂ eq.	331	914	1,661	1,041	649	459	248	206	148	111	107	115	97	78

Source: 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 (data from Japan Chemical Industry Association), Documents of the first meeting of the Breakout Group on F-gases, FY2013 Committee for the Greenhouse Gas Emissions Estimation Methods

* 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 4-40 Indices related to fugitive emissions from SF₆ production

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production of SF ₆	t	1,848	2,392	1,556	2,313	2,647	2,562	2,201	1,993	2,230	2,128	1,997	2,027	2,003	1,680
Emissions	t	152	197	36	41	54	10	8	6	5	4	3	2	2	2
	kt-CO ₂ eq.	3,471	4,492	821	930	1,229	233	189	132	123	93	62	52	50	41

Source: 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 (data from Japan Chemical Industry Association), Documents of the first meeting of the Breakout Group on F-gases, FY2013 Committee for the Greenhouse Gas Emissions Estimation Methods

* 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 4-41 Indices related to fugitive emissions from NF₃ production

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Production of NF ₃	t	6	37	208	1,663	3,353	2,887	3,642	3,612	3,501	4,148	4,660	4,963	4,366	4,649
Emissions	t	0.2	1.0	7.0	72.1	71.1	66.8	76.9	93.1	76.4	86.4	56.1	23.5	25.1	13.6
	kt-CO ₂ eq.	3	17	120	1,240	1,223	1,149	1,323	1,601	1,314	1,486	965	404	432	234

Source: *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* (data from Japan Chemical Industry Association)

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using HFC, PFC, SF₆, and NF₃ shipment amounts⁶ which is thought to be proportional to HFC, PFC, SF₆, and NF₃ production amounts, and the ratio of emissions to the HFC, PFC, SF₆, and NF₃ 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, SF₆, and NF₃, a 2% value from the 2006 IPCC Guidelines was applied.

● Time-series Consistency

See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

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. Metal Industry (2.C.)

This category covers CO₂, CH₄, HFC, PFC and SF₆ emissions from the manufacturing processes of metal products.

This section includes GHG emissions from 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.), and Zinc production (2.C.6.).

In FY2017, emissions from Metal production were 5,988 kt-CO₂ eq. and represented 0.5% of Japan's total GHG emissions (excluding LULUCF). The total emissions of CO₂ and CH₄ from this category had decreased by 21.0% compared to FY1990. The total of HFCs, PFCs and SF₆ had decreased by 29.3% compared to 1990.

⁶ MITI, Documents of the first meeting of the Group for global warming chemicals, Risk Management Sub-Group, Chemicals Council, 1997. All further reference to 'shipment amounts' used for emission estimates for years 1990 to 1994 are from the same source.

Table 4-42 Emissions from 2.C. Metal Industry

Gas				Units	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
CO ₂	2.C.1	Iron and steel production	Use of electric arc furnaces in steel production	kt-CO ₂	356	357	201	242	156	112	160	162	174	144	159	130	141	169
			Limestone and dolomite use in iron and steel	kt-CO ₂	6,888	6,492	6,538	6,255	6,081	5,356	5,941	5,803	5,887	6,037	5,948	5,786	5,660	5,554
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	0.61	0.51	0.59	0.60	0.59	0.60	0.59	0.55	0.55	0.59
			Ferrous alloys production	kt-CH ₄	0.19	0.14	0.13	0.13	0.11	0.11	0.12	0.11	0.13	0.13	0.12	0.12	0.11	0.11
	Total			kt-CH ₄	0.92	0.85	0.80	0.80	0.72	0.62	0.71	0.72	0.72	0.73	0.71	0.67	0.66	0.70
	Total			kt-CO ₂ eq.	23.05	21.34	20.04	20.10	17.89	15.43	17.70	17.96	17.99	18.16	17.68	16.69	16.50	17.43
Total of CO ₂ and CH ₄				kt-CO ₂ eq.	7,267	6,871	6,760	6,517	6,254	5,484	6,118	5,983	6,079	6,199	6,125	5,933	5,818	5,741
Gas				Units	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
HFCs	2.C.4	Magnesium production		kt-CO ₂ eq.	NO	NO	NO	NO	NO	NO	NO	1.00	1.29	1.29	1.29	0.86	1.14	1.43
PFCs	2.C.3	Aluminium production		kt-CO ₂ eq.	203.66	103.55	26.41	21.76	21.59	16.22	15.28	15.24	13.27	9.59	1.91	0.00	0.00	0.00
SF ₆	2.C.4	Magnesium production		t	6.43	5.00	43.00	48.42	27.30	10.00	12.88	8.00	8.00	7.00	8.00	10.00	13.80	10.80
				kt-CO ₂ eq.	146.54	114.00	980.40	1,104.05	622.44	228.00	293.73	182.40	182.40	159.60	182.40	228.00	314.64	246.24
Total of F-gases				kt-CO ₂ eq.	350	218	1,007	1,126	644	244	309	199	197	170	186	229	316	248

4.4.1. Iron and Steel Production (2.C.1.)

4.4.1.1. Steel Production (2.C.1.a)

1) CO₂

Coke oxidizes when it is used as a reduction agent in steel production, and CO₂ is generated. The amount of coke used has been included under consumption of fuel in the Fuel Combustion Sector (1.A.), and the CO₂ generated through the oxidization of coke used as a reducing agent has already been calculated under Fuel Combustion Sector (1.A.).

4.4.1.2. Use of Electric Arc Furnaces in Steel Production (2.C.1.a)

a) Category Description

CO₂ is emitted from carbon electrodes when using electric arc furnaces to make steel. CH₄ is also emitted from electric arc furnaces during iron and steel production.

b) Methodological Issues

1) CO₂

● Estimation Method

CO₂ 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 CO₂. The carbon included in electric furnaces gas given in the *General Energy Statistics* are subtracted from the CO₂ emission in this source since these emissions are included in category 1.A fuel combustion.

● Activity Data

Production of carbon electrodes given in *Yearbook of Ceramics and Building Materials Statistics* compiled by the Ministry of Economy, Trade and Industry, and import and export of carbon electrodes given in *Trade Statistics of Japan*, Ministry of Finance are used.

Table 4-43 CO₂ emissions from carbon electrodes of furnaces

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
#A Import	t	12,341	18,463	11,363	15,075	15,116	11,218	17,321	20,437	20,027	19,960	19,226	18,209	19,773	16,653
#B Domestic production	t	211,933	186,143	184,728	216,061	201,256	169,545	205,081	217,847	197,278	180,322	180,555	151,979	141,193	161,919
#C Export	t	87,108	92,812	107,998	138,409	134,509	116,489	139,757	154,204	135,863	128,435	121,079	103,834	90,664	104,032
#D Electric furnaces gas	t	39,983	14,300	33,201	26,700	39,349	33,709	39,017	39,949	33,898	32,572	35,221	30,848	31,687	28,421
Domestic consumptions (#A + #B - #C - #D)	t	97,184	97,493	54,892	66,028	42,514	30,564	43,629	44,132	47,544	39,274	43,481	35,507	38,614	46,119
CO ₂ emissions	kt-CO ₂ eq.	356	357	201	242	156	112	160	162	174	144	159	130	141	169

2) CH₄

● Estimation Method

Emissions were calculated by multiplying an emission factor based on actual measurements obtained in Japan by the energy consumption of electric arc furnaces. This is the same method used for calculating CH₄ emissions in the Fuel Combustion Sector (1.A. Stationary sources).

● Emission Factors

The emission factor of energy consumption of electric arc furnaces (12.8 kg-CH₄/TJ) was determined by using the data from actual measurement surveys. (See Chapter 3, 3.2.5. and Chapter 4, 4.3.5.1)

● 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	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Electric furnaces	TJ	57,564	55,986	52,457	52,747	47,316	39,753	45,793	47,185	46,195	46,786	46,156	42,919	43,045	46,113

c) Uncertainties and Time-series Consistency

1) CO₂

● Uncertainty

Because all CO₂ 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, CO₂ emissions from electric arc furnaces have been estimated in a consistent manner throughout the time-series.

2) CH₄

● 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 CH₄ 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, CH₄ 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

See section 4.2.1. d).

e) Category-specific Recalculations

Recalculations of CH₄ emissions have been conducted for FY2016, based on updates made to the energy consumption of electric arc furnaces. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.4.1.3. Pig Iron Production (2.C.1.b)

1) CO₂

CO₂ generated from pig iron production is emitted when coke is used as a reduction agent. The amount of coke used has been included under consumption of fuel in the Fuel Combustion Sector (1.A.), and the CO₂ generated through the oxidization of coke used as a reducing agent has already been calculated under Fuel Combustion Sector (1.A.).

2) CH₄

It is theoretically impossible for CH₄ generation in association with pig iron production, and it has been confirmed that CH₄ 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 CaCO₃ and minute amounts of MgCO₃, and dolomite contains CaCO₃ and MgCO₃. The heating of limestone and dolomite releases CO₂ derived from CaCO₃ and MgCO₃.

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**

The emission factor (440 [kg-CO₂/t]) is calculated by adding the value obtained when multiplying the molecular weight ratio of CO₂ and CaCO₃ by 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 CO₂ and MgCO₃ by 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* [Japan Lime Association]). The emission factor is country-specific. (See 4.2.3. b) for details)

➤ *Dolomite*

The emission factor (471 [kg-CO₂/t]) is calculated by adding the value obtained when multiplying the molecular weight ratio of CO₂ and CaCO₃ by 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* [Japan Lime Association]) and the value obtained when multiplying the molecular weight ratio of CO₂ and MgCO₃ by 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* [Japan Lime Association]). The emission factor is country-specific. (See 4.2.3. b) for details)

● *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 <i>Adjusted Price Transaction Table</i> (Limestone)	Corresponding sectors in the <i>Adjusted Price Transaction Table</i> (Dolomite)
Iron and steel/Refining	2611-01 Steel - pig iron to 2611-04 Steel - crude ore (electric furnace)	2611-01 Steel - pig iron to 2631-03 Steel - cast and forged materials (iron)
	2631-02 Steel - cast pipe, -03 - cast and forged materials (iron)	
	2711-01 Non-ferrous metal - copper, -02 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

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Limestone consumption															
For Steel and Refinement (dry)	kt	14,430	13,590	13,619	12,577	12,177	11,000	11,815	11,541	11,663	11,878	11,702	11,455	11,188	10,998
Dolomite consumption															
For Steel and Refinement (dry)	kt	1,144	1,089	1,160	1,530	1,535	1,096	1,576	1,539	1,603	1,720	1,695	1,584	1,565	1,518

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, CO₂ emission from limestone and dolomite use has been

estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

See section 4.2.1. d).

e) Category-specific Recalculations

Recalculations of CO₂ emissions have been conducted for FY2015 to FY2016, based on updates made to limestone consumption data in the *Adjusted Price Transaction Table*. Recalculations have also been conducted for FY2016, based on updates made to dolomite 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. Direct reduced iron production (2.C.1.c)

1) CO₂

CO₂ is 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”.

2) CH₄

CH₄ is generated from the combustion of natural gas or coal when making direct reduced iron. However, there has not been any production of direct reduced iron in Japan, and therefore, it has been reported as “NO”.

4.4.1.6. Sinter Production (2.C.1.d)

1) CO₂

CO₂ generated when making sinter is generated by the combustion of coke fines; these emissions come under the Fuel combustion sector (1.A.). As they are already calculated in this 1.A. sector, they are reported as “IE”.

CO₂ emissions from limestone and dolomite used when making sinter are counted under “4.4.1.4. Limestone and dolomite use in Iron and Steel Production”.

2) CH₄

CH₄ generated when making sinter is all generated by the combustion of coke fines; these emissions come under the Fuel Combustion Sector (1.A.). As they are already calculated in this sector, they are reported as “IE”.

4.4.1.7. Pellet Production (2.C.1.e)

1) CO₂

CO₂ generated when making pellets is generated by the combustion of fine ore; these emissions come

under the Fuel combustion sector (1.A.). As they are already calculated in this 1.A. sector, they are reported as “IE”.

CO₂ emissions from limestone and dolomite used when making pellets are counted under “4.4.1.4. Limestone and dolomite use in Iron and Steel Production”.

2) CH₄

CH₄ generated when making pellets is generated by the combustion of fine ore; these emissions come under the Fuel Combustion Sector (1.A.). As they are already calculated in this sector, they are reported as “IE”.

CO₂ emissions from limestone and dolomite used when making pellets are counted under “4.4.1.4. Limestone and dolomite use in Iron and Steel Production”.

4.4.2. Ferroalloys Production (2.C.2.)

a) Category Description

1) CO₂

Ferroalloys are produced in Japan, and the CO₂ 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 Sector (1.A.), and CO₂ generated as a consequence of the oxidization of coke used as a reduction agent has already been calculated under the Fuel Combustion Sector (1.A.). Residual carbon in the ferroalloys is oxidized when the ferroalloys are used in the production of steel, and are released into the atmosphere as CO₂. Therefore, it has been reported as “IE”.

2) CH₄

Ferroalloys are manufactured in Japan in electric arc furnaces, small-scale blast furnaces, and Thermit furnaces. CH₄ 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

CH₄ emissions from ferroalloy production were calculated by multiplying an emission factor based on actual measurements obtained in Japan by the energy consumption of electric arc furnaces. This is the same method used for calculating CH₄ emissions in the Fuel Combustion Sector (1.A.1. Energy Industries).

● Emission Factors

The value for the emission factor of electric arc furnaces (12.8 kg-CH₄/TJ) was used because these furnaces produce ferroalloys.

● Activity Data

Energy consumption amounts included in the "ferroalloy" category for the iron and steel industries of the *General Energy Statistics* were used.

Table 4-47 Energy consumption for ferroalloy production

Electricity consumption	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Electric furnaces (for Ferroalloys)	TJ	14,456	10,699	10,181	10,072	8,578	8,458	9,510	8,938	10,038	9,956	9,102	9,228	8,507	8,362

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 CH₄ 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, CH₄ emissions from furnaces for ferroalloy have been estimated in a consistent manner throughout the time-series.

d) Category-specific QA/QC and Verification

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) Category Description

1) CO₂

Aluminum refining is conducted in Japan. CO₂ generated in association with aluminum smelting is emitted in conjunction with the oxidization of the anode paste used as a reducing agent. Consumption of coke, the main ingredient in the anode paste has been included in fuel consumption under the Fuel combustion sector (1.A.), and the CO₂ that is generated by the oxidization of coke used as a reducing agent has already been calculated under the Fuel combustion sector (1.A.). Therefore, it has been reported as "IE".

In addition to coke, binder pitch is also used in anodes paste for aluminum refining. All of this pitch is produced from by-product coal tar from coke ovens in Japan, where the coal tar consumption is treated as energy use under the Industry sector of the *General Energy Statistics*. None of it is imported. Therefore, emissions are accounted for under stationary combustion in the energy sector.

2) PFCs

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**

Estimating emissions involved multiplying the production amount of primary aluminum refining by Japan's country-specific emission factors calculated using the equation prescribed in the *2006 IPCC Guidelines*.

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 equation prescribed in the Tier 2 method of the *2006 IPCC Guidelines*, and its associated slope coefficients set by technology, together with the weight fraction of gases was used to determine emission factors, as shown in the table below.

For the years 1990 to 1994, the emission factor for 1995 is used.

Table 4-48 PFC emission factors and aluminum production amounts

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
PFC-14 (CF ₄) EF	kg-PFC-14/t	0.709	0.709	0.482	0.398	0.388	0.390	0.388	0.387	0.386	0.386	0.386	0	0	0
PFC-116 (C ₂ F ₆) EF	kg-PFC-116/t	0.060	0.060	0.041	0.034	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0	0	0
Production of aluminium	t	34,100	17,338	6,500	6,490	6,600	4,930	4,670	4,670	4,075	2,950	588	0	0	0

Source: *Yearbook of Minerals and Non-Ferrous Metals Statistics*, Ministry of Economy, Trade and Industry, *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

● Activity Data

As the activity data for PFC emissions from aluminum refining, the aluminum production amounts given in the *Yearbook of Minerals and Non-Ferrous Metals Statistics* compiled by the Ministry of Economy, Trade and Industry (1995 to 1997), and *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 (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* compiled by the Ministry of Economy, Trade and Industry were used.

c) Uncertainties and Time-series Consistency**● Uncertainty**

For the uncertainty of the emission factor and uncertainty of the activity data, the respective default values of 44% and 2% in the *2006 IPCC Guidelines* were applied. As a result, the uncertainty of the emissions was determined to be 44%.

● Time-series Consistency

See section 4.3.9.1. c)

d) Category-specific QA/QC and Verification

See section 4.3.9.1. d)

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.4.3.2. F-gases used in foundries (2.C.3.-)

Emission from this source was reported as “NO” as it has been confirmed that Japan had no record of the use of SF₆ in aluminum forging processes.

4.4.4. Magnesium Production (2.C.4.)**a) Category Description**

HFCs and SF₆ 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 SF₆ 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 SF₆ used in magnesium foundries. The associated indices are given in the table below.

Table 4-49 Indices related to HFCs and SF₆ emitted from magnesium foundries

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Consumption of HFC-134a	t	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.9	0.9	0.9	0.6	0.8	1.0
Consumption of SF ₆	t	6.4	5.0	43.0	48.4	27.3	10.0	12.9	8.0	8.0	7.0	8.0	10.0	13.8	10.8

Source: *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, Documents of the first meeting of the Breakout Group on F-gases, FY2013 Committee for the Greenhouse Gas Emissions Estimation Methods*

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 SF₆ 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**

See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

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.)

CO₂ 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 1.A.2. Manufacturing industries and construction in the Energy sector, emissions are reported as IE.

4.4.6. Zinc production (2.C.6.)

Similar to lead, CO₂ 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 1.A.2. Manufacturing industries and construction in the Energy sector, emissions are reported as IE.

When Smithsonite (ZnCO₃) which includes carbon in the ore are used as raw material, there is the possibility of CO₂ arising from the ore in the reduction process. However, there are currently no cases of Smithsonite use in Japan.

4.5. Non-energy products from fuels and solvent use (2.D.)

This category covers CO₂ emissions from the use of non-energy products from fuels and solvents. This section includes GHG emissions from the following sources: Lubricant use (2.D.1.), Paraffin wax use (2.D.2.), and Urea used as a catalyst (2.D.3.).

In FY2017, emissions from this category were 2,899 kt-CO₂ eq. and represented 0.2% of Japan's total GHG emissions (excluding LULUCF). The emissions had increased by 34.0% compared to FY1990.

Table 4-50 Emissions from 2.D. Non-energy Products from Fuels and Solvent Use

Gas		Units	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017		
CO ₂	2.D.1	Lubricant use	kt-CO ₂	343	353	350	324	298	302	303	284	259	269	263	243	230	232	
	2.D.2	Paraffin wax use	kt-CO ₂	50	37	36	36	31	30	35	30	27	28	26	25	24	24	
	2.D.3	Other	Urea-based catalysts	kt-CO ₂	NO	NO	NO	0.12	0.52	0.64	0.98	1.57	2.46	3.51	4.60	5.66	6.75	8.03
			NMVOC incineration	kt-CO ₂	1,772	2,057	2,407	2,790	2,790	2,858	2,773	2,763	2,723	2,824	2,640	2,499	2,615	2,635
	Total			kt-CO ₂	2,164	2,447	2,792	3,151	3,119	3,191	3,112	3,079	3,012	3,124	2,933	2,772	2,875	2,899

4.5.1. Lubricant use (2.D.1.)

a) Category Description

CO₂ 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.

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)

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

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* (Agency for Natural Resources and Energy) 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 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* and the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*, 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 4-51 Consumption of engine oil (for types other than total loss types) and grease

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Consumption of engine oil (for types other than total loss types)	TJ	23,449	24,385	24,144	22,298	20,449	20,804	20,768	19,476	17,756	17,788	17,384	15,998	15,168	15,367
Consumption of grease	TJ	3,152	2,503	2,435	2,658	2,530	2,299	2,622	2,573	2,397	2,478	2,486	2,464	2,337	2,164

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 Chemical Industries Statistics*, and 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

See section 4.2.1. d).

e) Category-specific Recalculations

The gross calorific value for grease was revised for FY2013 to FY2016 and resulted in recalculations.

The domestic sales amount of lubricant was revised for FY2016 and also resulted in 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

CO₂ is emitted from the oxidation of paraffin wax during use.

b) Methodological Issues

- **Estimation Method**

Emissions were calculated based on the Tier 1 method given in the *2006 IPCC Guidelines*. (See below)

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

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* (Agency for Natural Resources and Energy) 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 Chemical Industries Statistics*, and 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**

See section 4.2.1. d).

- e) **Category-specific Recalculations**

Recalculations have been conducted for FY2013 to FY2016, based on update made to the gross calorific value of paraffin wax. See Chapter 10 for impact on trend.

- f) **Category-specific Planned Improvements**

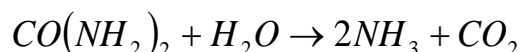
No improvements are planned.

4.5.3. Other (2.D.3.)

4.5.3.1. Urea used as a catalyst (2.D.3.-)

- 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 N₂ and H₂O. By spraying urea aqueous into high temperature exhaust gas, this is hydrolyzed to yield ammonia gas, and CO₂ is emitted as follows.



- b) **Methodological Issues**

- **Estimation Method**

Emissions were calculated based on the *2006 IPCC Guidelines*. (See below)

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

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. This is then multiplied by the ratio of imports to the

domestic total consumption to finally yield the consumption amount of urea-based additives for imports only⁷.

$$AD = N * L * R * D * I$$

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:	Ratio of imports [%]

Table 4-52 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 <i>Statistical Yearbook of Motor Vehicle Transport</i> and <i>Statistical Yearbook of Motor Vehicle Fuel Consumption</i> (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 <i>2006 IPCC Guidelines</i>
Density of diesel oil [t/kL]	0.8831t/kL, based on the <i>Handbook on the General Energy Statistics</i> (RIETI)
Ratio of imports [%]	Ratio of urea imports to (domestic shipment amounts + imports) for each year, based on the <i>Yearbook of Fertilizer Statistics (Pocket Edition)</i> (Ministry of Agriculture, Forestry and Fisheries)

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

See section 4.2.1. d).

e) Category-specific Recalculations

Recalculations have been conducted for FY2013 to FY2016, based on updates made to urea domestic shipment amounts of the *Yearbook of Fertilizer Statistics (Pocket Edition)*, since such data is one of parameters for establishment of activity data. See Chapter 10 for impact on trend.

⁷ Domestically produced urea is from CO₂ recovered from ammonia production processes, and therefore the CO₂ associated with it is already included in 2.B.1. Ammonia production emissions.

f) Category-specific Planned Improvements

No improvements are planned.

4.5.3.2. NMVOC Incineration (2.D.3.-)**a) Category Description**

CO₂ is emitted in the process of NMVOC incineration from facilities etc that use solvents.

b) Methodological Issues● **Estimation Method**

CO₂ 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. CO₂ 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.

$$E_{CO_2} = \sum_i \left(I_i \times C_i \times \frac{44}{12} \right)$$

E_{CO_2} : CO₂ 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 [-]

$$I_i = S_i - E_i - R_i$$

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 CO₂) 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 the Ministry of Environment and other information. From FY2015, an average carbon content for this category (0.64) is used.

● **Activity Data**

Parameters are set as follows:

➤ **NMVOC incineration amounts 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 sales amounts of thinners given in the website of the Japan Paint Manufacturers Association, 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* (Ministry of the Environment, 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 3)

➤ ***Material recycle amounts for use type i***

The material recycle amounts 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 (*1) to the solvent supply amounts for use type i in the year FY2011. This was then multiplied by the growth rate (based on *2) of solvent collection amounts from FY2011. (*1: *Survey on Organic Solvents Use and Emission Treatment*, Japan Solvent Recycling Industry Association, May, 2012, *2: *Survey on Solvent Recycle Amounts*, Japan Solvent Recycling Industry Association)

Table 4-53 Amounts incinerated

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Paints	kt	268	273	338	407	412	391	404	377	411	417	404	417	434	448
Cleaning agents	kt	85	100	90	108	63	67	65	67	44	45	48	46	47	46
Printing solvents	kt	172	195	237	234	232	221	231	235	235	232	220	219	210	205
Chemical products	kt	52	81	132	152	163	173	183	184	179	184	177	187	197	199
Other	kt	198	253	251	335	319	364	354	352	343	366	345	363	383	383

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

See section 4.2.1. d).

e) Category-specific Recalculations

Updates were made to the methods of establishment of domestic supply of solvents. For paint, supply amounts of thinner were added, and for cleansing agents, printing, chemical products, and other use, supply amounts of acetone were added. As a result, recalculations have been conducted for all years. The revision of VOC emissions also contributed to this.

f) Category-specific Planned Improvements

No improvements are planned.

4.5.3.3. Road Paving with Asphalt (2.D.3.-)

Roads in Japan are paved with asphalt, but almost no CO₂ 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.

4.5.3.4. Asphalt Roofing (2.D.3.-)

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 CO₂ 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.

4.6. Electronics industry (2.E.)

This category covers HFC, PFC, SF₆, and NF₃ emissions from the manufacturing of the electronic devices. This section includes GHG emissions from the following sources: Semiconductor (2.E.1.), Liquid Crystals (2.E.2.), Photovoltaics (2.E.3.), and Heat transfer fluid (2.E.4.).

In 2017, emissions from Electronics industry were 2,634 kt-CO₂ eq., and represented 0.2% of Japan's total GHG emissions (excluding LULUCF). The emissions had increased by 38.4% compared to 1990.

Table 4-54 Emissions from 2.E. Electronics Industry

Gas		Units	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
HFCs	2.E.1 Semiconductor	kt-CO ₂ eq.	1	271	283	224	234	150	165	142	122	109	113	113	117	123
	2.E.2 Liquid crystals	kt-CO ₂ eq.	0.001	0.3	1.8	3.0	2.8	2.3	3.0	3.3	2.4	2.4	2.3	1.9	1.9	1.9
	Total	kt-CO ₂ eq.	1	271	285	227	237	152	168	145	124	112	115	115	119	125
PFCs	2.E.1 Semiconductor	kt-CO ₂ eq.	1,423	3,933	6,771	4,594	3,339	2,109	2,214	1,863	1,624	1,556	1,617	1,582	1,721	1,847
	2.E.2 Liquid crystals	kt-CO ₂ eq.	31	87	214	152	83	39	46	59	68	76	90	86	71	84
	Total	kt-CO ₂ eq.	1,455	4,020	6,986	4,746	3,422	2,148	2,261	1,922	1,692	1,631	1,707	1,669	1,792	1,931
SF ₆	2.E.1 Semiconductor	t	13.6	17.5	27.6	23.7	14.4	9.3	9.9	8.6	8.1	8.0	7.7	8.1	8.4	8.8
	2.E.2 Liquid crystals	t	4.8	6.2	38.5	31.2	13.0	8.7	11.8	8.7	7.5	7.4	8.4	8.4	6.9	7.1
	Total	t	18.4	23.8	66.1	54.9	27.4	18.0	21.7	17.3	15.6	15.4	16.0	16.5	15.3	15.9
NF ₃	Total	kt-CO ₂ eq.	419	542	1506	1252	625	410	494	394	356	351	366	375	349	363
	2.E.1 Semiconductor	t	1.6	9.8	5.8	9.4	13.2	10.6	11.1	10.2	10.3	6.4	7.7	8.4	10.6	11.3
	2.E.2 Liquid crystals	t	0.1	0.9	3.8	4.1	1.8	1.3	1.5	1.4	1.2	1.2	1.5	1.3	1.1	1.3
	Total	t	1.7	10.7	9.6	13.5	15.0	11.9	12.6	11.6	11.5	7.6	9.2	9.7	11.8	12.5
Total of All Gases	kt-CO ₂ eq.	30	184	165	232	258	205	217	199	198	131	158	167	203	216	
Total of All Gases		kt-CO ₂ eq.	1,904	5,016	8,941	6,457	4,542	2,916	3,140	2,661	2,370	2,225	2,346	2,326	2,463	2,634

4.6.1. Semiconductor (2.E.1.)

a) Category Description

HFCs, PFCs, SF₆, and NF₃ are emitted from the manufacturing of semiconductors.

b) Methodological Issues

● Estimation Method

The Tier 2a method of the 2006 IPCC Guidelines is used to estimate emissions from semiconductors. These emissions are estimated with purchase of F-gases, process supply rate, use rate of F-gas, removal rate, by-product generation ratio and removal ratio for by-products. Default values are applied for the

use rate of F-gases and the by-product generation rates.

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 “2.B.9. Fluorochemical production – fugitive emissions”.

Japan Electronics and Information Technology Industries Association data are used for F-gases purchased.

<i>F-gas emissions in Semiconductor Manufacturing</i>	
Methods below are applied for each gas:	
(i) HFC-23, PFCs (PFC-14, PFC-116, PFC-218, PFC-c318), SF ₆ , and NF ₃ emissions	
Emissions	= purchased amount of gas × process supply rate × (1 – use rate of gas)
	× (1 – fraction of gas controlled × fraction of gas destroyed)
(ii) By-produced PFC-14 etc emissions	
Emissions	= purchased amount of gas × by-production rate × process supply rate
	× (1 – fraction of gas controlled × 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 4-55 Indices related to emissions of F-gases from manufacturing of semiconductors

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
HFC-23 purchased	t	0.1	47.8	49.4	42.1	73.7	53.8	67.1	68.4	66.7	77.2	86.2	83.2	84.3	
PFC-14 purchased	t	113.3	313.0	299.9	231.5	276.9	208.9	265.3	248.3	222.4	218.1	253.6	285.5	317.1	365.1
PFC-116 purchased	t	75.8	209.5	561.2	393.2	284.9	171.5	194.3	159.9	139.4	117.8	105.5	96.4	102.3	126.1
PFC-218 purchased	t	0.01	0.03	9.91	181.80	180.98	129.47	166.96	137.00	115.48	106.08	117.19	110.90	107.55	130.08
PFC-c318 purchased	t	0.2	0.6	38.6	24.8	40.2	33.3	35.8	36.8	39.7	42.2	52.6	63.3	70.4	106.6
SF ₆ purchased	t	70.1	90.8	131.9	96.8	79.1	60.2	76.7	65.2	63.7	57.6	64.9	68.0	73.4	86.5
NF ₃ purchased	t	8.8	54.4	106.3	406.7	821.8	724.8	860.7	834.5	880.5	905.4	1,055.3	1,232.1	1,310.1	1,597.4
Process supply rate	%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
Use rate of PFC etc	%														
Fraction of PFCs, and SF ₆ destroyed	%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
Fraction of NF ₃ destroyed	%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
CF ₄ etc by-production rate	%														
By-product CF ₄ etc removal rate	%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
HFC emissions	kt-CO ₂ eq.	0.73	270.62	282.71	223.98	234.21	149.81	164.93	142.19	121.63	109.24	112.89	113.08	117.33	123.13
PFC emissions	kt-CO ₂ eq.	1,423.43	3,933.17	6,771.47	4,594.11	3,338.90	2,109.08	2,214.33	1,863.33	1,624.17	1,555.73	1,616.86	1,582.22	1,721.27	1,846.95
SF ₆ emissions	kt-CO ₂ eq.	309.09	399.99	628.71	540.21	328.62	210.92	224.79	196.50	183.55	181.46	174.76	183.97	192.15	199.95
NF ₃ emissions	kt-CO ₂ eq.	27.29	168.28	99.55	161.04	227.29	182.13	190.69	174.82	177.03	109.78	132.01	144.65	183.10	193.74

Source: *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*, and data provided by the Ministry of Economy, Trade and Industry, *Documents of the first meeting of the Breakout Group on F-gases*, FY2013 Committee for the Greenhouse Gas Emissions Estimation Methods

Note: The CF₄ etc by-production rate and By-product CF₄ etc removal rate each include that for C₂F₆.

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 SF₆ shipment amount, and NF₃ production amount data which is thought to be proportional to HFC, PFC, SF₆, and NF₃ 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, SF₆, and NF₃. For the uncertainties of the activity data, 10% was applied for all HFCs, PFCs, SF₆, and NF₃, using the upper limit value in the *2006 IPCC Guidelines*. As a result, the uncertainties of the emissions for HFCs, PFCs, SF₆, and NF₃, were determined to be 100%, 81%, 300%, and 71%, respectively.

● **Time-series Consistency**

See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

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.

4.6.2. Liquid Crystals (2.E.2.)**a) Category Description**

HFCs, PFCs, SF₆, and NF₃ are emitted from the manufacturing of liquid crystals.

b) Methodological Issues● **Estimation Method**

Same methods applied to semiconductors are also applied to emissions from manufacturing of liquid crystals. In principle, default values are applied for the use rate of F-gases and the by-product generation rates. 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.

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 liquid crystals

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
HFC-23 purchased	t	0.0003	0.1	0.7	1.6	1.5	1.1	1.1	1.2	1.0	1.3	1.5	1.1	1.1	1.1
PFC-14 purchased	t	7.5	20.7	47.3	77.8	69.3	51.9	93.7	124.3	121.1	154.5	191.7	177.1	151.8	185.0
PFC-116 purchased	t	0.1	0.4	2.7	9.9	4.1	2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
PFC-c318 purchased	t	0.0	0.0	0.0	0.8	1.9	1.7	1.6	1.9	1.7	1.4	1.8	1.1	1.1	1.1
SF ₆ purchased	t	8.9	11.5	85.3	101.4	146.8	127.1	176.9	129.0	104.1	107.4	126.2	126.6	109.6	116.4
NF ₃ purchased	t	1.3	8.1	106.9	232.2	556.1	532.2	764.1	718.0	668.0	783.8	918.9	808.0	691.9	813.2
Process supply rate	%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
Use rate of PFCs etc	%									40 - 97 %					
Fraction of PFCs, and SF ₆ destroyed	%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
Fraction of NF ₃ destroyed	%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
CF ₄ etc by-production rate	%									0.9 - 7 %					
By-product CF ₄ etc removal rate	%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
HFC emissions	kt-CO ₂ eq.	0.0007	0.27	1.84	2.98	2.83	2.30	3.02	3.28	2.39	2.37	2.26	1.93	1.93	1.91
PFC emissions	kt-CO ₂ eq.	31.35	86.62	214.10	152.03	83.50	39.32	46.50	59.12	68.22	75.63	89.74	86.46	71.21	84.16
SF ₆ emissions	kt-CO ₂ eq.	109.62	141.86	877.24	711.76	295.93	199.39	268.88	197.92	172.05	169.84	191.07	191.25	156.60	162.66
NF ₃ emissions	kt-CO ₂ eq.	2.53	15.61	65.82	70.59	30.83	23.06	26.37	24.24	20.74	21.38	26.19	22.18	19.61	21.94

Source: 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, Documents of the first meeting of the Breakout Group on F-gases, FY2013 Committee for the Greenhouse Gas Emissions Estimation Methods

Note: The CF₄ etc by-production rate and By-product CF₄ etc removal rate each include that for CHF₃.

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, SF₆ shipment, and NF₃ production amount data which is thought to be proportional to HFC, PFC, SF₆, and NF₃ emissions, and extrapolating for these years.

c) Uncertainties and Time-series Consistency

● Uncertainty

See section 4.6.1. c).

● Time-series Consistency

See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

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, and 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 4.7.5. Solvents (2.F.5.), where liquid PFCs etc are collectively captured.

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 includes GHG emissions from 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 2017, emissions from this category were 46,109 kt-CO₂ eq., and represented 3.6% of Japan’s total GHG emissions (excluding LULUCF). The emissions are 10.1 times of 1990.

Table 4-57 Emissions from 2.F. Product uses as substitutes for ODS

Gas		Units	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
HFCs	2.F.1	Refrigeration and air conditioning	kt-CO ₂ eq.	NO	925	2,977	8,876	15,686	17,998	20,483	23,140	26,354	29,008	32,536	35,873	38,903	41,098
	2.F.2	Foam blowing agents	kt-CO ₂ eq.	1	497	484	937	1,510	1,608	1,749	1,923	2,081	2,229	2,373	2,484	2,651	2,801
	2.F.3	Fire protection	kt-CO ₂ eq.	NO	NO	5	7	8	8	8	8	9	9	9	9	10	10
	2.F.4	Aerosols	kt-CO ₂ eq.	NO	1,502	3,117	1,695	931	845	666	634	561	489	503	540	587	600
	2.F.5	Solvents	kt-CO ₂ eq.	NO	NO	NO	6	23	39	60	86	94	109	122	126	130	116
	Total		kt-CO ₂ eq.	1	2,923	6,583	11,522	18,157	20,498	22,967	25,792	29,098	31,844	35,544	39,032	42,280	44,625
PFCs	2.F.5	Solvents	kt-CO ₂ eq.	4,550	12,572	3,200	2,815	1,648	1,420	1,721	1,605	1,583	1,518	1,537	1,517	1,465	1,484
Total of All Gases			kt-CO ₂ eq.	4,551	15,496	9,783	14,336	19,805	21,919	24,687	27,397	30,681	33,362	37,080	40,549	43,745	46,109

4.7.1. Refrigeration and Air Conditioning Equipment (2.F.1.)

4.7.1.1. Domestic Refrigeration Production, Use and Disposal (2.F.1.-)

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

The collected amount of HFCs under regulation was subtracted from 1) fugitive refrigerant ratio from production, 2) fugitive refrigerant ratio from use (including failure of devices), and 3) refrigerant contained at the time of disposal, separately, based on production and shipment amounts and refrigerant contained. Then, all there were combined.

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.

Emissions of HFCs from Domestic Refrigeration

$$\begin{aligned} \text{HFC emissions} = & \text{total refrigerant contained at production} \times \text{fugitive refrigerant ratio at production} \\ & + \sum (\text{number of operated devices containing HFCs} \times \text{refrigerant contained per operated device} \\ & \times \text{fugitive refrigerant ratio from use}) \\ & + \sum (\text{number of disposed devices containing HFCs} \times \text{refrigerant contained per disposed device}) \\ & - \text{collected amount of HFCs} \end{aligned}$$

The associated indices are given in the table below.

Table 4-58 Indices related to emissions of HFCs from domestic refrigeration

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total HFCs charged in the year of production	t	NO	520	590	0.3	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Fugitive refrigerant ratio at production	%	1%	1%	1%	0%	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	34,509	31,471	28,085	24,509	20,984	17,637	14,520	11,691	9,182	7,045
Refrigerant charged per device at production	g	150	150	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%
Number of HFC devices disposed	1,000 devices	NO	NO	177	1,839	3,154	3,445	3,588	3,600	3,456	3,204	2,850	2,451	2,027	1,620
Amount of HFCs collected under law	t/year	—	—	—	52	111	111	111	160	169	189	166	144	138	132
Emissions from manufacturing	kt-CO ₂ eq.	NO	7,436	8,437	0.001	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Emissions from stocks	kt-CO ₂ eq.	NO	5,038	17,811	22,413	18,505	16,876	15,061	13,143	11,253	9,458	7,786	6,269	4,924	3,778
Emissions from disposal	kt-CO ₂ eq.	NO	NO	31,060	246,196	387,517	436,464	460,170	391,114	352,286	279,422	250,686	213,029	148,607	87,154
Emissions	kt-CO ₂ eq.	NO	12,474	57,308	268,609	406,022	453,340	475,231	404,257	363,539	288,880	258,472	219,298	153,531	90,932

Source: 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, Documents of the first meeting of the Breakout Group on F-gases, FY2013 Committee for the Greenhouse Gas Emissions Estimation Methods

Note: Emissions from use and disposal were estimated by summing up the values calculated for each year of the production of devices, and therefore the refrigerant contained per operated device (charge) and refrigerant contained per disposed device cannot be easily provided.

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 all 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 all 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

See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

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. Commercial Refrigeration Production, Use and Disposal (2.F.1.-)**4.7.1.2.a. Commercial Refrigeration****a) Category Description****1) HFCs**

HFCs are emitted from the manufacturing, operation, maintenance, accidents, and disposal of commercial refrigeration.

2) PFCs

Emissions from this source in the “production” category were reported as “NO” as Japan had no record of their use in the production of the products. 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**

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 the devices below, and then aggregated.

centrifugal refrigerating machine, screw refrigerating machine, refrigerator-freezer unit, transport refrigerator-freezer unit, separately placed showcase, built-in showcase, ice making machinery, water fountain, commercial refrigerator-freezer, all-in-one air conditioning system, gas heat pump, chilling unit

Emission factors 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 equipment⁸. (260,000 sample units, conducted from 2007 to 2009).

⁸ For details, refer to *document 1-1 and 1-2 of the 21st meeting of the Group for Prevention of Global Warming, Chemical and Bio Sub-Group, Industrial Structure Council, Ministry of Economy Trade and Industry*, held on March 17, 2009.

Emissions of HFCs from Commercial Refrigeration

Methods below are applied to each type of device and refrigerant

1) manufacturing

Emissions from manufacturing = Σ (number of device produced \times amount of refrigerant contained
 \times fugitive refrigerant ratio from manufacturing)

2) installation

Emissions from operation = Σ (number of device charged refrigerant in place produced
 \times amount of refrigerant contained \times fugitive refrigerant ratio from installation)

3) operation

Emissions from maintenance = Σ (number of devices operated \times amount of refrigerant contained
 \times fugitive refrigerant ratio from operation) - amount collected during servicing

4) disposal

Emissions from disposal = Σ (number of devices disposed \times average amount of refrigerant contained)
- amount collected after use

* In the estimation of emissions from maintenance, 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 4-59 Indices related to emissions of HFCs from commercial refrigeration

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Number of HFC devices produced	1,000 devices	NO	214	374	1,413	1,444	987	1,122	1,198	1,212	1,303	1,250	1,228	1,296	1,350
Average amount of refrigerant charged at production	g/device	372	372	597	3,378	3,533	3,276	3,280	3,360	3,462	3,413	3,539	3,473	3,358	3,329
Fugitive refrigerant ratio at production	%	0.2%	0.2%	0.2%	0.2%	0.1%	0.1%	0.2%	0.2%	0.2%	0.2%	0.1%	0.3%	0.2%	0.2%
Number of devices charged in production place	1,000 devices	NO	9	32	138	199	175	171	190	239	225	260	240	246	249
Average amount of refrigerant during installation	g/device	17,806	17,806	9,221	23,914	26,676	25,955	24,527	24,276	22,826	20,754	20,394	20,073	19,520	18,388
Fugitive refrigerant ratio during installation	%	1%	1%	1%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Number of devices operated	1,000 devices	NO	375	1,957	6,770	10,027	10,847	11,743	12,678	13,616	14,568	15,414	16,134	16,859	17,571
Amount of refrigerant during operation	g/device	1,012	1,012	1,043	4,549	5,632	5,802	5,981	6,192	6,440	6,596	6,799	6,950	7,041	7,074
Fugitive refrigerant ratio during use	%	7.3%	7.3%	7.4%	5.3%	5.6%	5.8%	6.0%	6.1%	6.2%	6.2%	6.3%	6.4%	6.4%	6.3%
Number of devices disposed	1,000 devices	NO	1	23	127	269	325	397	453	512	576	663	748	816	887
Amount of HFCs collected under law during maintenance	t	NO	NO	NO	NO	436	503	548	571	671	682	759	772	861	979
Amount of HFCs collected under law after use	t	NO	NO	NO	183	200	230	269	352	522	689	668	735	952	1,158
Emissions from manufacturing	kt-CO ₂ eq.	NO	3	9	150	234	202	198	220	269	225	256	228	229	209
Emissions from stocks	kt-CO ₂ eq.	NO	40	258	3,415	7,646	9,035	10,524	12,233	14,231	15,850	17,638	18,998	20,150	20,880
Emissions from disposal	kt-CO ₂ eq.	NO	4	51	586	1,931	2,372	2,777	3,141	3,466	3,741	4,739	6,033	7,336	8,319
Emissions	kt-CO ₂ eq.	NO	47	318	4,151	9,810	11,609	13,499	15,594	17,965	19,815	22,633	25,259	27,716	29,408

Source: 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, and data provided by the Ministry of Economy Trade and Industry, Documents of the first meeting of the Breakout Group on F-gases, FY2013 Committee for the Greenhouse Gas Emissions Estimation Methods

* From 2002 onward, “amount of refrigerant” and “fugitive refrigerant ratio from operation” increased because devices became larger with the increase of commercial package AC devices.

* The weighted average GWP for manufacturing in 2017 is 2,372, 2,639 for stocks, and 2,188 for disposal. Emissions are calculated by gas, but are reported as an unspecified mix due to confidentiality reasons.

The 2006 IPCC Guidelines specifies estimation methods for fugitive emissions from refrigerant containers, however, upon consideration of emissions from non-refillable cylinders that are not captured under other sources, they do not exceed 500,000 t-CO₂ eq nor does there exist statistics or survey data that can be used as activity data, thresholds for which estimation should be done as determined by the Committee for Greenhouse Gas Emissions Estimation Methods. It is therefore reported as NE (considered insignificant). (See Annex 5)

Table 4-60 Indices related to emissions of HFCs from commercial refrigeration (railways)

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Number of HFC devices produced *	devices	0	0	30	0	20	0	0	0	0	0	0	0	0	0
Refrigerant HFC charged per device at production *	kg	0	0	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%
Refrigerant HFC charged per device during use *	kg	0	0	3	0	3	3	3	3	3	3	3	3	3	3
Fugitive refrigerant ratio during use	%	0%	0%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%
Number of HFC devices disposed	devices	0	0	0	0	0	10	14	9	13	14	17	21	23	19
Refrigerant stock in device disposed	kg	0	0	0	0	0	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5
Collection rate	%	0	0	0	0	0	30%	31%	29%	34%	34%	32%	38%	39%	38%
Emissions from manufacturing	kt-CO ₂ eq.	NO	NO	0.001	NO	0.0005	NO	NO	NO	NO	NO	NO	NO	NO	NO
Emissions from stocks	kt-CO ₂ eq.	NO	NO	0.080	0.395	0.674	0.665	0.648	0.644	0.644	0.634	0.619	0.600	0.596	0.596
Emissions from disposal	kt-CO ₂ eq.	NO	NO	NO	NO	NO	0.041	0.057	0.038	0.050	0.054	0.068	0.077	0.083	0.069
Emissions	kt-CO ₂ eq.	NO	NO	0.081	0.395	0.675	0.706	0.704	0.682	0.695	0.688	0.687	0.677	0.679	0.666

Source: *Railway Statistical Yearbook*, IPCC default values. * are from manufacturers.

Table 4-61 Indices related to emissions of HFCs from commercial refrigeration (vessels)

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total HFC charge at production by gas *	devices	0	0	0.960	0.8,460	0.16,900	0.17,560	0.16,210	0.27,420	0.38,860	0.45,980	0.32,280	0.25,030	0.54,110	0.48,080
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%
Refrigerant HFC charged per vessel during use *	kg	0	0	10.29.5	10.28.8	10.6,000	10.6,000	10.6,000	10.6,000	10.6,000	10.6,000	10.6,000	10.6,000	10.6,000	10.6,000
Fugitive refrigerant ratio during use	%	0%	0%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%
Refrigerant stock in device disposed by gas	kg	0	0	0	0	0	0.0.0.2	0.0.1	0.0.2	0.0.2	0.0.8	0.1.9	0.1.8	0.2.9	0.4.7
Collection rate	%	0%	0%	0%	0%	0%	30%	31%	29%	34%	34%	32%	38%	39%	38%
Emissions from manufacturing	kt-CO ₂ eq.	NO	NO	0.008	0.066	0.133	0.138	0.127	0.215	0.305	0.361	0.256	0.202	0.432	0.386
Emissions from stocks	kt-CO ₂ eq.	NO	NO	1.163	23.783	52.353	62.463	77.897	95.516	124.812	162.755	176.794	189.264	205.130	218.215
Emissions from disposal	kt-CO ₂ eq.	NO	NO	NO	NO	NO	0.009	0.024	0.102	0.081	0.761	1.842	1.713	2.565	4.110
Emissions	kt-CO ₂ eq.	NO	NO	1.171	23.850	52.485	62.610	78.048	95.833	125.198	163.876	178.892	191.180	208.127	222.712

Source: IPCC default values, *Report on Maritime Affairs* etc. * are from manufacturers.

Table 4-62 Type of HFC and emission factors during use, by type of commercial refrigeration

Type of commercial refrigeration	Type of HFC	Amount of refrigerant	Emission factor *	Share in the number of devices operated (2010)
Small-size refrigerators (built-ins etc)	R-404A, HFC-134a etc	0.1 - 3 kg	2%	40%
Separately installed showcases	R-404A, R-407C etc	20 - 41 kg	16%	3%
Mid-size refrigerators (excluding Separately installed showcases)	R-404A, R-407C etc	2 - 30 kg	13 - 17%	6%
Large-size refrigerators	HFC-134a, R404A etc	300 - 2,300 kg	7 - 12%	0.05%
All-in-one air conditioning systems for buildings	R-410A, R-407C etc	37 kg	3.5%	7%
Other commercial air conditioning devices (excluding All-in-one air conditioning systems for buildings)	R-410A, R-407C etc	3 - 43 kg	3 - 5%	44%

Source: *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 the Ministry of Economy Trade and Industry

* Includes for emissions during servicing, accidents, and breakdowns

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 in production place, and the average amount of refrigerant charged at production from 1995, fugitive refrigerant ratio at production from 1995, average amount of refrigerant during installation from 1995, fugitive refrigerant ratio during installation from 1995, amount of refrigerant during operation from 1995, fugitive refrigerant ratio during use 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 manufacturing. For use, a 5% value based on a 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**

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 the Ministry of Trade and Industry in 2009.

d) Category-specific QA/QC and Verification

See section 4.3.9.1. d).

e) Category-specific Recalculations

Updates to statistics resulted in recalculations of emissions from railway refrigeration for 2016. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.7.1.2.b. Automatic Vending machine Production, Use and Disposal

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 of HFCs from Automatic Vending machines

1) manufacturing

Emissions from manufacturing = Σ (number of device produced \times amount of refrigerant contained \times fugitive refrigerant ratio from manufacturing)

2) accident

Emissions from accident = Σ (number of devices operated \times amount of refrigerant contained \times incidence rate \times average fugitive rate in accident)

3) disposal

(a) until 2001

Emissions from disposal = Σ {number of devices disposed \times amount of refrigerant contained \times (1 - collection rate)}

(b) from 2002 onward

Emissions from disposal = Σ (number of devices disposed \times average amount of refrigerant contained) - 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 4-63 Indices related to emissions of HFCs from automatic vending machines

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Number of HFC devices produced	1,000 devices	NO	NO	272	355	270	173	173	124	30	10	8	7	7	6
Refrigerant charged per device	g	NO	NO	300	220	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%
Number of devices operated	1,000 devices	NO	NO	284	1,999	2,384	2,368	2,279	2,055	1,759	1,530	1,068	748	431	330
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
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
Fugitive refrigerant ratio (fixing)	%	NO	0.009	0.009	0.005	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	213	293	286	347	277	273	299	266	264	196
Emissions	t	NO	NO	0	1	12	17	16	19	15	15	17	15	15	11
	kt-CO ₂ eq.	NO	NO	1	1	22	30	29	34	22	22	24	21	21	16

Source: *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, Documents of the first meeting of the Breakout Group on F-gases, FY2013 Committee for the Greenhouse Gas Emissions Estimation Methods*

* Accidents of devices charged with HFCs almost never occurred in 1999 and 2000, and therefore, were reported as 0. After 2001 onward, the number of accidents are reflected in the estimation.

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

See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

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. Transport Refrigeration Production, Use and Disposal (2.F.1.-)

1) HFCs

Emission was reported as “IE” since HFCs in this category had been included in the total reported in 4.7.1.2.a Commercial Refrigeration (2.F.1.-).

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. 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. Industrial Refrigeration Production, Use and Disposal (2.F.1.-)

1) HFCs

HFCs emissions have been reported as “IE”, as they are included in 4.7.1.2. Commercial Refrigeration (2.F.1.-).

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.

4.7.1.5. Stationary Air-Conditioning (Household) Production, Use and Disposal (2.F.1.-)

a) Category Description

1) HFCs

HFCs are emitted from the manufacturing, operation, and disposals of household stationary air-conditioning devices.

2) PFCs

Emission from this source in the “production” category was reported as “NO” since Japan had no record of their use in production. The emission was also reported as “NO” in the “use” and “disposal”

categories, because it was unlikely that PFCs were used in imported products or refrigerants were refilled.

b) Methodological Issues

● Estimation Method

In accordance with the IPCC Guidelines, emissions of each species of F-gases from 1) manufacturing, 2) operation, 3) disposals are estimated, based on production and shipment amounts and amounts of refrigerants charged. Emission factors are country-specific.

Emissions of HFCs from Stationary Air-Conditioning (Household)

1) manufacturing

Emissions from manufacturing = Σ (number of devices produced \times amount of refrigerant contained \times fugitive refrigerant ratio from manufacturing)

2) operation

Emissions from operation = Σ (number of devices for shipment \times average amount of refrigerant contained \times fugitive refrigerant ratio from operation)

3) disposals

Emissions from disposal = Σ (number of devices disposed \times average amount of refrigerant contained) - amount collected

* 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 4-64 Indices related to emissions of HFCs from stationary air-conditioning (household)

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Number of HFC devices produced	1,000 devices	NO	NO	1,077	3,981	3,970	2,618	3,169	3,155	3,263	3,581	3,076	8,166	8,528	9,055
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
Fugitive refrigerant ratio at production	%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.1%	0.1%	0.1%
Number of devices operated	1,000 devices	NO	NO	1,726	26,091	47,584	53,966	61,540	68,769	75,833	83,349	89,020	94,197	99,157	104,067
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
Fugitive refrigerant ratio during use	%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%	2%
Number of devices disposed	1,000	NO	NO	2	83	351	524	764	1,075	1,456	1,907	2,423	2,990	3,567	4,145
Average refrigerant stock in device disposed	g/device	NO	NO	954	911	870	856	841	827	814	803	796	792	795	796
Amount of HFCs collected under law	t/year	-	-	-	10	67	122	231	264	322	466	508	570	700	892
Emissions from manufacturing	kt-CO ₂ eq.	NO	NO	4	17	20	13	12	10	10	8	7	9	7	6
Emissions from stocks	kt-CO ₂ eq.	NO	NO	72	1,089	1,987	2,253	2,569	2,871	3,165	3,424	3,534	3,549	3,523	3,480
Emissions from disposal	kt-CO ₂ eq.	NO	NO	3	139	511	710	916	1,322	1,833	2,301	2,984	3,767	4,486	5,059
Emissions	kt-CO ₂ eq.	NO	NO	80	1,245	2,517	2,976	3,498	4,204	5,008	5,733	6,524	7,325	8,015	8,546

Source: 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, Documents of the first meeting of the Breakout Group on F-gases, FY2013 Committee for the Greenhouse Gas Emissions Estimation Methods

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

See section 4.7.1.2.a.c).

● Time-series Consistency

See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

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.

4.7.1.6. Mobile Air-Conditioning Production, Use and Disposal (2.F.1.-)

a) Category Description

1) HFCs

HFCs are emitted from manufacturing, operation, breakdowns, accidents, and disposals of mobile 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) breakdowns, 4) accidents and 5) disposals are estimated. Emission factors are country-specific. Emissions from railway and vessel air conditioning are also estimated based on similar methods.

Emissions of HFCs from Mobile Air-Conditioning (Car Air Conditioners)

The below thinking is applied for each type of car:

1) manufacturing

Emissions from manufacturing = Σ (number of devices produced \times amount of refrigerant contained \times fugitive refrigerant ratio from manufacturing)

2) operation

Emissions from operation = Σ (number of cars operated \times amount of refrigerant contained \times fugitive refrigerant ratio from operation)

3) breakdowns

Emissions from maintenance = Σ (number of cars operated \times amount of refrigerant contained \times rate of breakdowns \times fugitive refrigerant ratio from breakdowns)

4) accidents

Emissions from accident = Σ (number of cars in completely destroyed \times amount of refrigerant contained at time of accident)

5) disposal

(a) until 2001

Emissions from disposal = Σ { number of cars disposed \times amount of refrigerant contained \times (1 - collection rate)}

(b) from 2002 onward

Emissions from disposal = Σ (number of cars disposed \times average amount of refrigerant contained) - amount collected

* In the estimation of emissions from operation, the yearly decrease is reflected in the "amount of refrigerant contained."

Relevant indices are shown in Table below.

Table 4-65 Indices related to emissions of HFC-134a from car air conditioners

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Number of cars produced	1,000 devices	0	9,745	9,761	10,407	11,163	7,653	9,292	8,136	9,856	9,613	9,753	9,273	9,205	9,639
Fugitive refrigerant during production	g	4	4	4	3	3	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	64,543	65,375	66,043	67,366	70,406	72,054	72,813	73,272	72,216	72,722
Average refrigerant charged per device	g	700	700	615	548	520	497	497	497	497	497	497	497	497	497
Fugitive refrigerant ratio during use per year per device	g	15	15	15	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%
Fugitive refrigerant ratio from breakdown cars	%	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	207	209	211	216	225	231	233	234	231	233
Average refrigerant charged in completely destroyed cars	g	681	681	610	522	475	461	448	439	426	417	409	404	399	393
Number of cars disposed	1,000 devices	0	116	789	2,058	2,176	2,498	2,895	2,235	2,709	2,835	2,839	2,694	2,666	2,927
Average refrigerant charged at time of disposal	g	676	676	593	522	466	456	444	427	404	412	393	380	370	360
Amount of HFC collected (under law from FY2002)	t/year	-	-	-	531	686	787	898	645	786	785	773	710	682	720
Emissions from manufacturing	kt-CO ₂ eq.	NO	49	49	45	40	13	13	9	11	11	10	10	10	10
Emissions from stocks	kt-CO ₂ eq.	NO	704	1,798	2,331	2,288	2,255	2,222	2,226	2,274	2,276	2,255	2,230	2,166	2,144
Emissions from disposal	kt-CO ₂ eq.	NO	112	669	778	470	503	555	444	442	548	492	449	436	477
Emissions	kt-CO ₂ eq.	NO	865	2,516	3,153	2,798	2,771	2,791	2,679	2,728	2,835	2,757	2,690	2,612	2,631

Source: 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, Documents of the first meeting of the Breakout Group on F-gases, FY2013 Committee for the Greenhouse Gas Emissions Estimation Methods

Table 4-66 Indices related to emissions of HFCs from air conditioners (railways)

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
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%
Fugitive refrigerant ratio during use	%	0%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%	10%
Emissions from manufacturing	kt-CO ₂ eq.	NO	0.003	0.033	0.062	0.078	0.081	0.075	0.065	0.052	0.060	0.059	0.058	0.049	0.063
Emissions from stocks	kt-CO ₂ eq.	NO	0.710	3,224	13,734	23,955	27,336	31,015	34,290	36,833	39,667	42,601	45,451	48,087	51,158
Emissions from disposal	kt-CO ₂ eq.	NO	0.066	0.134	0.091	0.072	0.100	0.191	0.146	0.106	0.060	0.078	0.082	0.047	0.050
Emissions	kt-CO ₂ eq.	NO	0.779	3,391	13,887	24,105	27,516	31,281	34,502	36,991	39,787	42,737	45,591	48,184	51,270

Source: Railway Statistical Yearbook, Yearbook of Railway Car Production Statistics, IPCC default values etc.

Table 4-67 Indices related to emissions of HFCs from air conditioners (vessels)

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
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%
Fugitive refrigerant ratio during use	%	0%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%	15%
Collection rate	%	0%	0%	0%	0%	28%	30%	31%	29%	34%	34%	32%	38%	39%	38%
Emissions from manufacturing	kt-CO ₂ eq.	NO	0.0003	0.004	0.070	0.199	0.200	0.246	0.263	0.223	0.186	0.177	0.153	0.142	0.114
Emissions from stocks	kt-CO ₂ eq.	NO	0.077	0.739	19.384	54.787	66.696	80.925	92.989	103.133	110.083	116.936	121.421	127.563	131.859
Emissions from disposal	kt-CO ₂ eq.	NO	NO	NO	NO	0.036	0.084	0.011	0.030	0.005	0.123	0.283	0.211	0.446	0.557
Emissions	kt-CO ₂ eq.	NO	0.077	0.743	19.454	55.021	66.979	81.182	93.282	103.361	110.393	117.397	121.785	128.151	132.530

Source: IPCC default values, *Report on Maritime Affairs*.

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**

See section 4.7.1.2.b.c).

- **Time-series Consistency**

See section 4.3.9.1. c).

d) *Category-specific QA/QC and Verification*

See section 4.3.9.1. d).

e) *Category-specific Recalculations*

Updates to statistics resulted in recalculations of emissions from railway air conditioning for 2016. See Chapter 10 for impact on trend.

f) *Category-specific Planned Improvements*

No improvements are planned.

4.7.2. Foam Blowing Agents (2.F.2.)

4.7.2.1. Closed Cells (2.F.2.-)

4.7.2.1.a. Urethane Foam (2.F.2.-)

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”.

Urethane-related HFC emissions

HFC emissions

= Amount of HFC used [t] × Leakage during foam blowing [%]

+ Total amount used up to the previous year [t] × Percentage of annual emissions during use [%]

= (Emissions during production) + (Emissions during use)

Table 4-68 Indices related to emissions of HFC from urethane foam

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
HFC-134a use	t	NO	NO	167	224	145	109	66	65	34	28	14	12	NO	NO
HFC-245fa use	t	NO	NO	NO	3,893	3,044	2,440	2,365	2,597	2,613	2,570	2,533	2,230	2,577	2,596
HFC-365mfc use	t	NO	NO	NO	1311	1122	847	900	960	977	921	866	779	794	802
Leakage during foam blowing	%	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%
HFC-134a emissions within the first year after production	t	NO	NO	17	35	15	11	7	7	3	3	1	1	NO	NO
HFC-245fa emissions within the first year after production	t	NO	NO	NO	389	304	244	237	260	261	257	253	223	258	260
HFC-365mfc emissions within the first year after production	t	NO	NO	NO	131	112	85	90	96	98	92	87	78	79	80
HFC-134a emissions during use	t	NO	NO	NO	44	75	82	86	89	92	94	95	96	96	96
HFC-245fa emissions during use	t	NO	NO	NO	86	627	764	874	981	1,097	1,215	1,331	1,445	1,545	1,661
HFC-365mfc emissions during use	t	NO	NO	NO	33	222	273	311	352	395	439	480	519	554	590
HFC-134a emissions	kt-CO ₂ eq.	NO	NO	24	112	128	132	133	137	137	138	138	139	138	138
HFC-245fa emissions	kt-CO ₂ eq.	NO	NO	NO	490	960	1,039	1,144	1,277	1,399	1,516	1,631	1,718	1,857	1,978
HFC-365mfc emissions	kt-CO ₂ eq.	NO	NO	NO	130	266	284	318	355	391	421	450	474	503	532

Source: 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, and data provided by the Ministry of Economy Trade and Industry, Documents of the first meeting of the Breakout Group on F-gases, FY2013 Committee for the Greenhouse Gas Emissions Estimation Methods

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. (Ministry of the Environment, FY2011 PRTR (Pollutant Release and Transfer Register) “Estimation methods for releases from sources not required to report”)

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**

See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

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) 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 the emissions from 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”.

Extruded polystyrene foam-related HFC-134a emissions

HFC-134a emissions =

Amount of HFC-134a used in particular year [t] × Leakage during foam blowing 25%
+ Total amount used in the past up to the previous year [t] × Annual emission rate during use [%]

Table 4-69 Indices related to emissions of HFC-134a from extruded polystyrene foam

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
HFC-134a use	t	NO	NO	NO	26	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Foam productization rate	%	-	-	-	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%
Emissions during production	t	NO	NO	NO	6.50	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
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
Emissions during production	kt-CO ₂ eq.	NO	NO	NO	9.30	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Emission during use	kt-CO ₂ eq.	NO	NO	NO	12.87	13.20	13.20	13.20	13.20	13.20	13.20	13.20	13.20	13.20	13.20
Emissions	kt-CO ₂ eq.	NO	NO	NO	22.17	13.20	13.20	13.20	13.20	13.20	13.20	13.20	13.20	13.20	13.20

Source: 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, Documents of the first meeting of the Breakout Group on F-gases, FY2013 Committee for the Greenhouse Gas Emissions Estimation Methods 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. (Ministry of the Environment, FY2011 PRTR “Estimation methods for releases from sources not required to report”)

c) Uncertainties and Time-series Consistency● **Uncertainty**

See section 4.7.2.1.a. c).

● **Time-series Consistency**

See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

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.-)**4.7.2.2.a. High Expanded Polyethylene Foam (2.F.2.-)****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 the emissions from foam blowing agents used each year was provided by the High Expanded Polyethylene Foam Industry Association.

Table 4-70 Indices related to emissions of HFC-134a from high expanded polyethylene foam

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
HFC-134a use	t	1	346	322	128	100	98	98	98	98	98	98	98	98	98
Emissions	t	1	346	322	128	100	98	98	98	98	98	98	98	98	98
	kt-CO ₂ eq.	1.34	494.78	460.46	183.04	143.00	140.29	140.29	140.29	140.29	140.29	140.29	140.29	140.29	140.29

Source: 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, and data provided by the Ministry of Economy Trade and Industry, Documents of the first meeting of the Breakout Group on F-gases, FY2013 Committee for the Greenhouse Gas Emissions Estimation Methods

Table 4-71 Indices related to emissions of HFC-152a from high expanded polyethylene foam

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
HFC-152a use	t	0.038	14	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Emissions	t	0.038	14	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	kt-CO ₂ eq.	0.005	1.736	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

Source: 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, Documents of the first meeting of the Breakout Group on F-gases, FY2013 Committee for the Greenhouse Gas Emissions Estimation Methods

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**

See section 4.7.2.1.a. c).

● **Time-series Consistency**

See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

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 are emitted by the use of halogen fire extinguishers.

b) Methodological Issues

● **Estimation Method**

HFC-23 and HFC-227ea are used for the productions of fire extinguishers. However, as of 2004, only HFC-227ea is filled in the bottles for fire extinguishing equipment, and each company purchases pre-filled HFC-23 fire extinguisher bottles.

HFCs emission from this category was reported as “NO” by expert judgment since HFC-227ea was a very small amount, 0.0007 [t] (= 700 g) when emission from production in FY2004 was estimated. For use, at the time around 1995, almost no HFC filled fire extinguishers existed on the market, and therefore it is assumed that there was not any use, resulting in NO for 1995 and earlier emissions.

For 1996 and following years, calculations were performed using the following equation and based on the HFC extinguishing agent installations and stocks.

HFC emissions from use of fire extinguishers

$$\text{HFC emissions [t]} = \text{HFC extinguishing agent installations and stocks [t]} \times \text{Emission factor during use}$$

Concerning the emission at the time of disposal of fire extinguishers, it is reported as “NO” because the use of HFC for fire extinguishers has just started, and also the expected lifetime of buildings is 30-40 years, and therefore they are unlikely to be disposed of as of present.

● Emission Factors

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 this category.

Table 4-72 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

● Activity Data

HFC stock amounts provided by the Fire Defense Agency were used as activity data for HFC emissions from fire extinguishing agents use.

Table 4-73 The amounts of the HFC extinguishing agent installations and stocks

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Stocks of HFC-23	t	NO	NO	306	478	501	512	523	528	533	537	546	559	567	573
HFC-23 emissions	t	NO	NO	0.27	0.42	0.44	0.45	0.46	0.46	0.47	0.47	0.48	0.49	0.50	0.50
	kt-CO ₂ eq.	NO	NO	3.99	6.23	6.52	6.67	6.81	6.87	6.94	6.99	7.11	7.29	7.38	7.46
Stocks of HFC-227ea	t	NO	NO	225	392	467	498	522	544	596	640	686	738	754	800
HFC-227ea emissions	t	NO	NO	0.20	0.34	0.41	0.44	0.46	0.48	0.52	0.56	0.60	0.65	0.66	0.70
	kt-CO ₂ eq.	NO	NO	0.64	1.11	1.32	1.41	1.48	1.54	1.69	1.81	1.94	2.09	2.14	2.27
Total emissions	kt-CO ₂ eq.	NO	NO	4.63	7.34	7.85	8.08	8.29	8.42	8.63	8.80	9.06	9.38	9.51	9.72

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 method consistently used from FY1995, based on an emission factor and activity data received from the Fire Defense Agency. For years 1990 to 1994, emissions are reported as NO, in light of the fact that HFC filled fire extinguishers were not in use in 1995.

d) Category-specific QA/QC and Verification

See section 4.2.1. d)

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.7.4. Aerosols (2.F.4.)

4.7.4.1. Metered Dose Inhalers (2.F.4.-)

a) Category Description

HFCs are emitted from the use and disposal 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 produced 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 destructured MDI that were defective products.

F-gas (HFC-134a, HFC-227ea) emissions associated with the manufacturing of MDI

F-gas emissions in year n = Fugitive emissions during manufacturing [t]
 + F-gas potential emissions in year (n - 1) × 50 [%]
 + F-gas potential emissions in year n × 50 [%]
 - amount of disposal of F-gas contained in MDI

Potential emissions of F-gas = F-gas contained in domestic produced MDI + F-gas contained in imported MDI

The associated indices are given in the table below.

Table 4-74 Indices related to emissions of HFC-134a from MDI

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Usage of domestic MDI	t	NO	NO	1.4	0.9	0.9	0.9	1.1	0.8	0.8	0.6	0.9	0.6	0.9	0.6
Usage of imported MDI	t	NO	NO	42.0	70.7	61.9	57.1	57.1	54.0	48.3	46.0	42.4	41.3	39.2	34.2
Amount collected and destroyed	t	NO	NO	0.1	1.9	0.5	0.4	2.5	2.4	0.8	0.7	0.2	3.6	0.4	0.1
Emissions	t	NO	NO	37.2	62.8	61.2	60.0	55.5	54.1	51.3	47.2	44.9	39.3	40.7	37.4
	kt-CO ₂ eq.	NO	NO	53.2	89.7	87.5	85.7	79.4	77.4	73.3	67.5	64.2	56.3	58.2	53.5

Source: 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, and data provided by the Ministry of Economy Trade and Industry, Documents of the first meeting of the Breakout Group on F-gases, FY2013 Committee for the Greenhouse Gas Emissions Estimation Methods

Table 4-75 Indices related to emissions of HFC-227ea from MDI

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Usage of domestic MDI	t	NO	NO	NO	41.0	45.9	27.8	36.0	30.9	25.8	25.1	21.0	23.0	21.4	17.8
Usage of imported MDI	t	NO	NO	3.6	2.1	9.0	1.6	0.4	0.8	0.7	0.7	0.4	18.8	20.2	27.5
Amount collected and destroyed	t	NO	NO	NO	1.2	1.6	0.9	0.8	0.9	0.8	0.8	0.5	0.7	0.2	0.3
Emissions	t	NO	NO	1.8	48.1	46.4	42.8	33.1	34.3	29.8	26.9	23.9	31.7	32.1	43.9
	kt-CO ₂ eq.	NO	NO	5.8	154.7	149.5	137.7	106.7	110.4	96.0	86.7	77.1	102.1	135.0	141.5

Source: 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, and data provided by the Ministry of Economy Trade and Industry, Documents of the first meeting of the Breakout Group on F-gases, FY2013 Committee for the Greenhouse Gas Emissions Estimation Methods

* 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**

See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

See section 4.3.9.1. d).

e) Category-specific Recalculations

Recalculations occurred for 2016 due to the revision of parameter data.

f) Category-specific Planned Improvements

No improvements are planned.

4.7.4.2. Aerosols (2.F.4.-)**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, the amount of emission at the time of “disposal” was reported as “IE” since it is included in the calculation for the “use” category.

HFC emissions associated with the manufacturing of aerosols

$$\begin{aligned} \text{HFC emissions in year } n &= \text{Fugitive emissions during manufacturing [t]} \\ &+ \text{HFC potential emissions in year } (n-1) \times 50 [\%] \\ &+ \text{HFC potential emissions in year } n \times 50 [\%] \end{aligned}$$

$$\begin{aligned} \text{Fugitive emissions during manufacturing} &= \text{HFC consumed during manufacturing in year } n \\ &- \text{HFC potential emissions} \end{aligned}$$

The associated indices are given in the table below.

Table 4-76 Indices related to emissions of HFC-134a from aerosols

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Potential emissions	t	NO	1,300	2,044	604	343	230	200	190	168	168	223	206	236	193
Fugitive emissions during production	t	NO	NO	80	25	13	10	8	7	8	7	12	15	22	35
Emissions in the year produced, during use	t	NO	650	1,022	302	172	115	100	95	84	84	112	103	118	97
Remaining (emissions in the next year)	t	NO	650	1,022	302	172	115	100	95	84	84	112	103	118	97
Emissions	t	NO	1,050	2,137	908	338	297	223	202	187	175	208	230	243	250
	kt-CO ₂ eq.	NO	1,502	3,056	1,299	483	424	319	289	268	250	297	328	347	357

Source: 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, Documents of the first meeting of the Breakout Group on F-gases, FY2013 Committee for the Greenhouse Gas Emissions Estimation Methods etc

* Fugitive emissions from 1992 to 1997 are included in potential emissions.

Table 4-77 Indices related to emissions of HFC-152a from aerosols

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Potential emissions	t	NO	NO	34	1,300	1,416	764	558	502	542	320	353	279	328	276
Fugitive emissions during production	t	NO	NO	1	29	381	494	638	730	464	249	185	109	68	89
Emissions in the year produced, during use	t	NO	NO	17	650	708	382	279	251	271	160	177	140	164	138
Remaining (emissions in the next year)	t	NO	NO	17	650	708	382	279	251	271	160	177	140	164	138
Emissions	t	NO	NO	18	1,217	1,685	1,584	1,299	1,260	986	680	522	425	372	391
	kt-CO ₂ eq.	NO	NO	2.3	150.9	208.9	196.4	161.1	156.2	122.3	84.3	64.7	52.6	46.1	48.5

Source: 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, Documents of the first meeting of the Breakout Group on F-gases, FY2013 Committee for the Greenhouse Gas Emissions Estimation Methods etc

* The production of aerosols using HFC-152a started in 2000.

Table 4-78 Indices related to emissions of HFC-245fa from aerosols

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Potential emissions	t	NO	NO	NO	0.795	0.667	0.318	0.388	2.034	1.094	0.17	1.1	0.275	0	0
Fugitive emissions during production	t	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Emissions in the year produced, during use	t	NO	NO	NO	0.398	0.334	0.159	0.194	1.017	0.547	0.085	0.550	0.138	NO	NO
Remaining (emissions in the next year)	t	NO	NO	NO	0.398	0.334	0.159	0.194	1.017	0.547	0.085	0.550	0.138	NO	NO
Emissions	t	NO	NO	NO	0.547	0.631	0.493	0.353	1.211	1.564	0.632	0.635	0.688	0.138	NO
	kt-CO ₂ eq.	NO	NO	NO	0.5629	0.6499	0.5073	0.3636	1.2473	1.6109	0.651	0.6541	0.7081	0.1416	NO

Source: 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, Documents of the second meeting of the Breakout Group on F-gases, FY2014 Committee for the Greenhouse Gas Emissions Estimation Methods etc

Table 4-79 Indices related to emissions of HFC-365mfc from aerosols

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Potential emissions	t	NO	NO	NO	1.115	0.56	NO	NO	NO	0.274	NO	0.244	0.24	NO	NO
Fugitive emissions during production	t	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Emissions in the year produced, during use	t	NO	NO	NO	0.558	0.280	NO	NO	NO	0.137	NO	0.122	0.12	NO	NO
Remaining (emissions in the next year)	t	NO	NO	NO	0.558	0.280	NO	NO	NO	0.137	NO	0.122	0.12	NO	NO
Emissions	t	NO	NO	NO	0.74	1.018	0.28	NO	NO	0.137	0.137	0.122	0.242	0.12	NO
	kt-CO ₂ eq.	NO	NO	NO	0.5876	0.8083	0.2223	NO	NO	0.1088	0.1088	0.0969	0.1921	0.0953	NO

Source: 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, Documents of the second meeting of the Breakout Group on F-gases, FY2014 Committee for the Greenhouse Gas Emissions Estimation Methods etc

The 2006 IPCC Guidelines specifies estimation methods for HFC-43-10mee emissions from this sub-category, however, emissions do not exceed the 3,000 t-CO₂ eq threshold for estimation, determined by the Committee for Greenhouse Gas Emissions Estimation Methods, and therefore is reported as NE (considered insignificant). (See Annex 5)

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**

See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

See section 4.3.9.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

No improvements are planned.

4.7.5. Solvents (2.F.5.)**a) Category Description**

Liquid HFC-365mfc is used as an industrial dry cleaning solvent by the name of Solkane Dry, and is released into the atmosphere through volatilization etc. HFCs and PFCs are also emitted from the use of solvents for the cleaning of general electronic parts, and semiconductor/liquid crystal manufacturing. The liquid PFCs used were C₅F₁₂ (PFC-41-12) and C₆F₁₄ (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.

HFC-365mfc emissions

= (aggregate number of dry cleaning machines specialized for Solkane Dry use – aggregate number of machines disposed) x average solvent amount used in specialized machines

+ (aggregate number of dry cleaning machines partially using Solkane Dry – aggregate number of machines disposed) x 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 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 4-80 Number of dry cleaning machines using Solkane Dry and average solvent amount used

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Cumulative number of specialized and mixed-use machines	units	0	0	0	12	48	81	121	170	192	216	234	246	259	268
Average solvent use per year (specialized)	kg/unit	0	0	0	673	673	673	673	673	653	678	713	699	692	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. (Average GWP for 2017 is 4,024. Emissions are calculated by gas, but are reported as an unspecified mix due to confidentiality reasons.) 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. The associated indices are given in the table below. 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

See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

See section 4.3.9.1. d).

e) Category-specific Recalculations

For HFC_s, recalculations occurred due to the revision of the average solvent amount used from 2003 onward and revision of the number of dry cleaning machines from 2011 onward. See Chapter 10 for impact on trend.

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 N₂O, PFC, and SF₆ emissions from other product manufacture and use. This section includes GHG emissions from 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.), and Use during Semiconductor/Liquid Crystal Manufacturing (2.G.3.).

In FY2017, emissions from this category were 1,921 kt-CO₂ eq. and represented 0.1% of Japan's total GHG emissions (excluding LULUCF). The total emissions of N₂O from this category had increased by 42.9% compared to FY1990. The total of PFCs and SF₆ had decreased by 82.9% compared to 1990.

Table 4-81 Emissions from 2.G. other product manufacture and use

Gas		Units	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
N ₂ O	2.G.3	Medical applications	kt-N ₂ O	0.93	1.41	1.10	0.86	0.42	0.39	0.32	0.31	0.29	0.25	1.11	0.22	0.22	0.22
		Use during semiconductor/liquid crystal manufacturing	kt-N ₂ O	0.05	0.10	0.15	0.38	0.58	0.48	0.60	0.59	0.74	0.95	0.99	1.13	1.22	1.18
	Total	kt-N ₂ O	0.98	1.51	1.25	1.23	1.00	0.87	0.92	0.91	1.03	1.20	2.10	1.35	1.44	1.40	
	Total	kt-CO ₂ eq.	291	449	371	368	297	259	275	270	308	359	627	402	429	416	
Gas		Units	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
PFCs	2.G.2	Other-Railway silicon rectifiers	t	NO	NO	NO	0.03	0.25	0.34	0.47	0.64	NO	1.11	0.97	0.84	2.24	2.10
	2.G.1	Electrical equipment	t	355.8	460.5	127.6	39.4	36.3	31.2	27.3	31.0	31.5	28.2	26.4	26.8	28.7	27.2
SF ₆	2.G.2	Military applications	t	NO	NO	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
		Accelerators	t	30.8	35.2	34.5	36.8	37.1	36.7	35.0	35.3	36.2	36.3	36.2	37.7	36.9	36.7
	Total	t	386.6	495.6	163.3	77.5	74.6	69.1	63.5	67.5	69.0	65.7	63.8	65.7	66.8	65.2	
Total of F-gases		kt-CO ₂ eq.	8,814	11,300	3,724	1,767	1,704	1,579	1,452	1,545	1,573	1,508	1,464	1,505	1,544	1,505	

4.8.1. Electrical Equipment (2.G.1.)

a) Category Description

SF₆ 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 SF₆ 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 SF₆.

In CRF, the emission was reported as “IE” after including the emission from disposal into the use of electrical equipment.

SF₆ emissions from the production of electrical equipment

SF₆ Emissions from the production = SF₆ purchased [t] × assembly fugitive rate [%]

SF₆ emission from the use of electrical equipment

SF₆ emission from the use

= Stocks of SF₆ × rate of emitted SF₆ into the environment during the use of electrical equipment (0.1%)

SF₆ emission from the inspection of electrical equipment

SF₆ emission from the inspection = actual measurements of SF₆

SF₆ emission from the disposal of electrical equipment

SF₆ emission from the disposal = actual measurements of SF₆

The associated indices are given in the table below.

Table 4-82 Indices related to emissions of SF₆ from electrical equipment

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Emissions during manufacturing	kt-CO ₂ eq.	7,047.27	9,120.00	2,291.17	523.09	423.45	250.80	157.32	168.72	145.92	125.40	136.80	163.43	179.07	141.36
SF ₆ emissions during use, maintenance, and disposal	kt-CO ₂ eq.	1,065.20	1,378.49	618.52	376.32	404.66	460.35	464.91	537.87	572.98	517.35	464.91	446.67	476.31	478.59

Source: *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*, and data provided by the Ministry of Economy, Trade and Industry, *Documents of the first meeting of the Breakout Group on F-gases, FY2013 Committee for the Greenhouse Gas Emissions Estimation Methods*

Due to the lack of data necessary to estimate emissions for the years 1990 to 1994, estimates have been done by using domestic SF₆ shipment amounts which is thought to be proportional to amounts of SF₆ purchased and stocks of SF₆, amounts of SF₆ 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 - +30% was applied for manufacturing and use, and -20 - +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 - +32%, and -22 - +41% for disposal.

● Time-series Consistency

See section 4.3.9.1. c).

d) Category-specific QA/QC and Verification

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.

4.8.2. SF₆ and PFCs from other product use (2.G.2.)**4.8.2.1. Military applications (2.G.2.-)****a) Category Description**

SF₆ is used as an insulating medium in the radar systems of AWACS (Airborne Warning and Control System). When the plane ascends, SF₆ 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, SF₆ is automatically charged into the system from an SF₆ 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.

SF₆ Emissions = Decrease of SF₆ in the container on board the AWACS

+ SF₆ leakage during acquisition/replacement of SF₆ container on AWACS

- SF₆ collected/destroyed – Net increase in AWACS fleet charge

The four-fleet AWACS was officially authorized for use on March 24, 1999, and therefore SF₆ 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

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.-)**a) Category Description**

SF₆ 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 SF₆ 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.

$$\text{SF}_6 \text{ Emissions} = (\text{Number of accelerators}) \times (\text{SF}_6 \text{ use factor}) \times (\text{SF}_6 \text{ charge factor}) \times (\text{SF}_6 \text{ emission factor})$$

The SF₆ use factor, SF₆ charge factor, SF₆ emission factor, and number of accelerators used for estimating emissions are shown below by type of accelerator.

Table 4-83 SF₆ use factor, SF₆ charge factor, SF₆ emission factor by type of accelerator

Item	University and research operated particle accelerators	Industrial particle accelerators	Medical particle accelerators*	Small-scale electron accelerators
SF ₆ use factor	33%	100%	100%	100%
SF ₆ charge factor	2,400kg	1,300kg	0.5kg	400kg **
SF ₆ emission factor	0.07kg/kg	0.07kg/kg	2.0kg/kg	0.07kg/kg

* Among the medical particle accelerators, cyclotrons and synchrotrons are not considered to use SF₆, and therefore are not estimated for.

(Source) 2006 IPCC Guidelines default values excluding the ** value. ** value: Results of interviews with main accelerator manufacturers.

Table 4-84 Number of accelerators by type

Item	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Number of particle accelerators (University/Research facilities)	188	214	212	209	214	219	218	216	231	225	222	241	245	245
Number of particle accelerators (Industrial use)	143	164	145	181	186	181	174	179	184	188	190	193	183	183
Number of particle accelerators (Medical use)	531	641	754	857	922	936	926	986	1,028	1,068	1,081	1,108	1,114	1,114
Number of small-scale (below 1MeV) electron accelerators	243	276	314	282	263	255	218	215	203	201	197	201	196	192

(Source) 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 - +400% uncertainty from the 2006 IPCC Guidelines (particle accelerators - medical use) was applied. A -10 - +10% uncertainty of metal production is taken for the uncertainty of activity

data. As a result, the uncertainty of emissions is -51 - +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

See section 4.2.1. d) .

e) Category-specific Recalculations

The numbers of accelerators were updated for 2016, resulting in recalculations. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

4.8.2.3. Soundproof windows (2.G.2.-)

The 2006 IPCC Guidelines specifies estimation methods for this this sub-category, however, emissions do not exceed the 3000 t-CO₂ eq threshold for estimation, determined by the Committee for Greenhouse Gas Emissions Estimation Methods, and therefore is reported as NE (considered insignificant). (See Annex 5)

4.8.2.4. Adiabatic properties: shoes and types (2.G.2.-)

PFC and SF₆ 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.-)

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.

<p><u>PFC emissions at disposal of railway silicon rectifiers</u></p>

<p>= PFC disposed after use in railway silicon rectifiers - PFC destroyed</p>

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

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. N₂O from product uses (2.G.3.)**4.8.3.1. Medical applications (2.G.3.a)****a) Category Description**

Nitrous oxide is emitted during anesthetics (laughing gas) use. Since 2006, some hospitals have installed N₂O destruction units, and the reductions achieved are reflected in the total emissions. CO₂ is not used as an anesthetic in Japan.

a) Methodological Issues● **Estimation Method**

In relation to emissions of N₂O from use of anesthetics, the actual amount of N₂O shipped as an anesthetic by pharmaceutical manufacturers or importers has been reported for 2005 and preceding years. For 2006 and beyond, the amount of N₂O collected is calculated using the amount of laughing gas used in domestic hospitals equipped with N₂O destruction units for anesthesia, and a destruction rate of 99.9 %. This is subtracted from the N₂O shipped for medical use to yield the amount of N₂O emitted.

Amount of N ₂ O emitted during the use of laughing gas = N ₂ O shipped for medical use – Amount of laughing gas used in hospitals equipped with N ₂ O destruction units × destruction rate
--

● **Emission Factors**

It is assumed that all of the N₂O used as medical gas escapes into the atmosphere, unless collected.

Therefore, no emission factor has been established.

● *Activity Data*

The volume of shipments of N₂O for anesthetics (on calendar year basis) is given in the Ministry of Health, Labour and Welfare's *Statistics of Production by Pharmaceutical Industry*. This is used for 2005 and preceding years, and for 2006 to 2009, the amount of N₂O collected in three, and from 2010 and onward collected in four domestic hospitals equipped with N₂O destruction units is subtracted from the above-mentioned shipment.

Table 4-85 Laughing gas shipment amount and N₂O collected in domestic hospitals

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Laughing gas shipment amount	kg-N ₂ O	926,030	1,411,534	1,099,979	859,389	417,919	389,749	320,110	314,155	292,971	253,218	1,111,265	219,011	219,011	219,011
N ₂ O collected in domestic hospitals	kg-N ₂ O	-	-	-	-	1,454	1,049	914	779	450	509	0	0	0	0

b) Uncertainties and Time-series Consistency

● *Uncertainty*

Because all N₂O 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 volumes of shipments are taken from the *Statistics of Production by Pharmaceutical Industry* in a consistent manner throughout the time series.

c) Category-specific QA/QC and Verification

See section 4.2.1. d).

d) Category-specific Recalculations

There have been no source-specific recalculations.

e) Category-specific Planned Improvements

No improvements are planned.

4.8.3.2. Other (2.G.3.b)

4.8.3.2.a. Use during Semiconductor/Liquid Crystal Manufacturing (2.G.3.b.-)

a) Category Description

N₂O is used as an oxidizing agent to form an insulative oxide film during semiconductor/liquid crystal manufacturing, and the remaining is considered to be released into the atmosphere.

b) Methodological Issues

● *Estimation Method*

Emissions equal all N₂O shipment amounts for semiconductor/liquid crystal manufacturing.

N₂O emissions during semiconductor/liquid crystal manufacturing

= N₂O shipped for semiconductor/liquid crystal manufacturing use

- **Emission Factors**

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

- **Activity Data**

The N₂O shipment amounts for semiconductor/liquid crystal manufacturing reported by the Japan Industrial and Medical Gases Association is used as activity data.

c) Uncertainties and Time-series Consistency

- **Uncertainty**

Because all N₂O 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.

- **Time-series Consistency**

The shipment amounts are taken from what is reported by the Japan Industrial and Medical Gases Association in a consistent manner throughout the time series.

d) Category-specific QA/QC and Verification

See section 4.2.1. d).

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

There is a possibility of over-estimation, since emissions are equal to all N₂O shipment amounts for semiconductor/liquid crystal manufacturing.

4.9. Other (2.H.)

4.9.1. Food and beverages industry (2.H.2.)

The CO₂ recovered, estimated together with the emissions from ethylene oxide production (2.B.8.d) is reported here.

Petroleum refining plants, ammonia production plants, and iron production plants are other sources of supply CO₂ for the production of carbonated gas and dry ice in Japan, however those emissions occurring from petroleum refining plants are reported under the Fuel combustion sector (1.A.), and those emissions occurring from ammonia production plants are reported under ammonia production (2.B.1.), and those emissions occurring from iron production plants are reported under the Fuel combustion sector (1.A.).

Table 4-86 Emissions from the food and beverages industry

Gas		Units	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
CO ₂	2.H.2	Food and beverages industry	kt-CO ₂	64.27	71.54	86.50	90.05	71.55	71.29	75.85	75.81	76.41	82.33	80.44	83.04	79.41	85.07

References

1. IPCC, *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, 1997.
2. IPCC, *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, 2000.
3. IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2006.
4. IUPAC website “*Atomic Weights of the Elements 1999*”.
(<http://www.ciaaw.org/pubs/TSAW-1999.pdf>)
5. Ministry of the Environment press release, July 31, 2000, *Projections of disposal etc of refrigerant CFCs, HCFCs, and HFCs (Reference material 1)*
6. Ministry of the Environment Committee for the Greenhouse Gases Emissions Estimation Methods, *Review of Greenhouse Gases Emissions Estimation Methods Part 2*, August 2002.
7. Ministry of the Environment Committee for the Greenhouse Gases Emissions Estimation Methods, *GHGs Estimation Methods Committee Report Part 1*, August 2006.
8. Ministry of the Environment, *Survey on Management Methods of Halons/Liquid PFCs etc*, 2006.
9. Ministry of the Environment, *Survey on Destruction of Halons/PFCs etc*, 2010.
10. Ministry of the Environment, FY2011 PRTR (Pollutant Release and Transfer Register) “*Estimation methods for releases from sources not required to report*”
11. *Documents of the first meeting of the Breakout Group on F-gases*, FY2013 Committee for the Greenhouse Gas Emissions Estimation Methods (January, 2014)
12. Ministry of the Environment, *Details of the Compilation Results of CFC, HCFC, and HFC Charge and Recovery Amounts for Commercial Refrigeration and Air Conditioning Equipment*
13. Ministry of Economy, Trade and Industry, *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke*.
14. Ministry of Economy, Trade and Industry, *Yearbook of Chemical Industries Statistics*.
15. 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.
16. Agency for Natural Resources and Energy, *General Energy Statistics*.
17. Ministry of Economy, Trade and Industry, *Yearbook of Mineral Resources and Petroleum Products Statistics*.
18. Ministry of Economy, Trade and Industry, *Yearbook of Minerals and Non-Ferrous Metals Statistics*.
19. Ministry of Economy, Trade and Industry, *Yearbook of the Current Survey of Energy Consumption*.
20. Ministry of Economy, Trade and Industry, *Yearbook of Ceramics and Building Materials Statistics*.
21. MITI, *Documents of the first meeting of the Group for global warming chemicals, Risk Management Sub-Group, Chemicals Council*, 1997
22. Ministry of Finance, *Trade Statistics of Japan*.
23. Ministry of Land, Infrastructure, Transport and Tourism, *Statistical Yearbook of Motor Vehicle Transport*
24. Ministry of Land, Infrastructure, Transport and Tourism, *Statistical Yearbook of Motor Vehicle Fuel Consumption*
25. Ministry of Land, Infrastructure, Transport and Tourism, *Railway Statistical Yearbook*.

26. Ministry of Land, Infrastructure, Transport and Tourism, *Yearbook of Railway Car Production Statistics*.
27. Ministry of Land, Infrastructure, Transport and Tourism, *Report on Maritime Affairs*.
28. Ministry of Health, Labour and Welfare, *Statistics of Production by Pharmaceutical Industry*.
29. Ministry of Agriculture, Forestry and Fisheries, *Yearbook of Fertilizer Statistics (Pocket Edition)*
30. Japan Solvent Recycling Industry Association, *Survey on Organic Solvents Use and Emission Treatment* (May, 2012).
31. Japan Solvent Recycling Industry Association, *Survey on Solvent Recycle Amounts*.
32. The Research Institute of Economy, Trade and Industry, *Adjusted Price Transaction Table*.
33. Japan Lime Association, *The Story of Lime*.
34. Carbon Black Association, *Carbon Black Handbook*
35. The Japan Petroleum Institute, *Petrochemical Processes*
36. The Heavy and Chemical Industries News Agency, *Chemicals Handbook*
37. Japan Radioisotope Association, *Statistics on the Radiation in Japan*.
38. Japan Atomic Industrial Forum, *The Nuclear Almanac*.
39. Radiation Application Development Association, *Radiation and Industries No.69, 1996*.
40. Fishing Boat and System Engineering Association of Japan, *Journal of Fishing Boat and System Engineering Association of Japan*.
41. Japan Oil, Gas and Metals National Corporation, *Mineral Resources Material Flow*.
42. Japan Paint Manufacturers Association, *Compilation of Estimation Results of VOC Emissions from Paint*.
43. The Heavy and Chemical Industries News Agency, *Petrochemical Industry of Japan*.

Chapter 5. Agriculture (CRF sector 3)

5.1. Overview of Sector

Greenhouse gas emissions from the agricultural sector are calculated in seven categories: 3A, 3B, 3C, 3D, 3F, 3G, and 3H. In 3A: Enteric Fermentation, CH₄ gas generated and emitted by cattle, buffalo, sheep, goats, horses, and swine as the result of enteric fermentation is reported. In 3B: Manure Management, CH₄ and N₂O generated by treatment of manure excreted by cattle, buffalo, sheep, goats, horses, swine, poultry (hen and broiler), rabbit, and mink are reported. In 3C: Rice Cultivation, CH₄ emissions from paddy fields (continuously flooded and intermittently flooded) cultivated for rice production are reported. In 3D: Agricultural Soils, N₂O emitted directly and indirectly from agricultural soil are reported. Emissions for 3E: Prescribed Burning of Savannas are reported as NO, since Japan has no emission source in this category, while CH₄ and N₂O (as well as CO and NO_x, which is described in Annex 3) emissions from field burning of grains, legumes, root crops, and sugar cane during agricultural activities are reported in 3F: Field Burning of Agricultural Residues. 3G and 3H: Liming and Urea Application, CO₂ emissions by application of limestone and urea to soil are reported.

GHG emissions in the agricultural sector in FY2017 were 33,196 kt-CO₂ eq., comprising 2.6% of total emissions (excluding LULUCF). The value represents a reduction by 10.9% from FY1990.

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

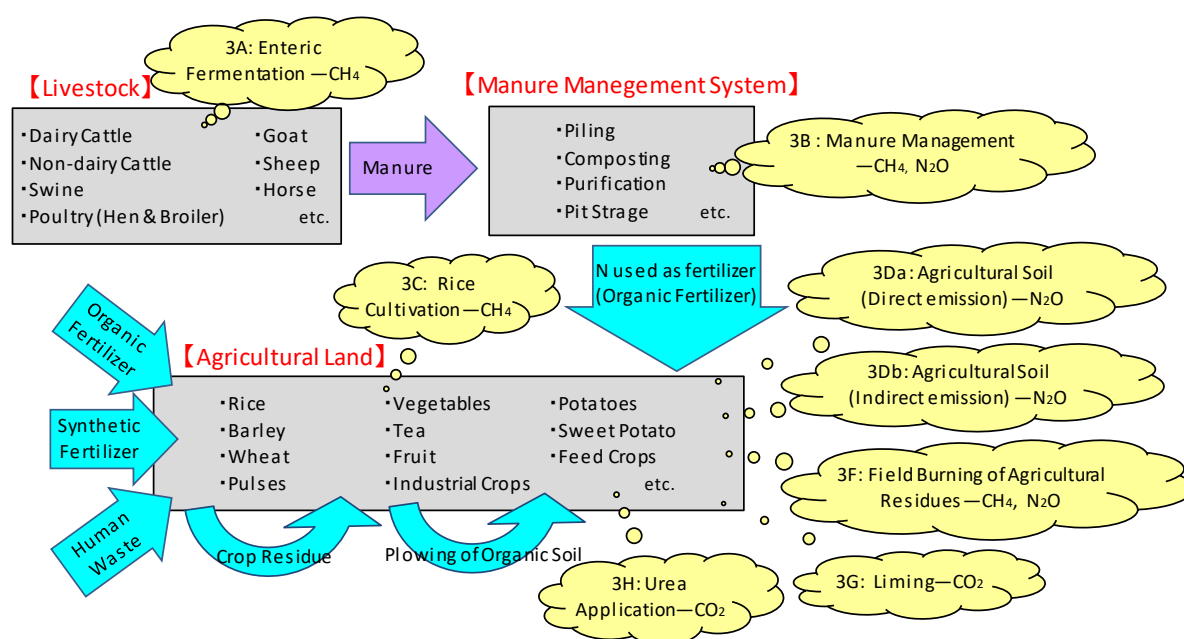


Figure 5-1 Relationships among the categories in the agricultural sector

Table 5-1 Tier of methodology used in Agriculture sector

GREENHOUSE GAS CATEGORIES	CO ₂		CH ₄		N ₂ O	
	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				

D: IPCC default, T1: IPCC Tier1, T2: IPCC Tier2, T3: IPCC Tier3, 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 CH₄. Horses and swine are not ruminants and have monogastric stomachs, but fermentations in their digestive tracts produce a small amount of CH₄, which is released into the atmosphere. These CH₄ emissions are calculated and reported in the Enteric Fermentation (3.A.) section.

GHG emissions from enteric fermentation in FY2017 were 7,283 kt-CO₂ eq., comprising 0.6% of total emissions (excluding LULUCF). The value represents a reduction by 22.1% from FY1990. Main driver of the emission reduction from FY1990 is a reduction of cattle population.

Table 5-2 CH₄ emissions from enteric fermentation

Gas	Livestock species	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
CH ₄	3.A.1.- Dairy cattle	kt-CH ₄	192.4	184.7	171.4	163.2	151.6	149.4	146.1	146.1	143.3	139.6	136.9	136.4	133.4	133.4
	3.A.1.- Non-dairy cattle		163.4	169.4	170.2	162.4	167.1	164.9	157.3	155.7	150.9	146.5	142.0	142.2	142.9	143.4
	3.A.2. Sheep		0.167	0.115	0.097	0.071	0.097	0.113	0.159	0.160	0.129	0.138	0.140	0.140	0.143	0.158
	3.A.3. Swine		15.9	13.9	13.7	13.5	13.9	13.8	13.7	13.6	13.6	13.4	13.2	13.0	13.1	12.9
	3.A.4.- Buffalo		0.011	0.007	0.006	0.005	0.004	0.004	0.004	0.004	0.005	0.005	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
	3.A.4.- Horses		2.1	2.1	1.9	1.6	1.5	1.5	1.3	1.4	1.3	1.3	1.2	1.3	1.3	1.4
Total	kt-CH ₄	374.0	370.3	357.4	340.8	334.2	329.7	318.7	317.0	309.3	301.0	293.6	293.2	291.0	291.3	
	kt-CO ₂ eq	9,351	9,257	8,935	8,520	8,354	8,242	7,967	7,924	7,733	7,525	7,339	7,330	7,275	7,283	

5.2.1. Cattle (3.A.1.)

a) Category Description

This section provides the estimation methods for CH₄ emissions from enteric fermentation in Cattle.

b) Methodological Issues

● Estimation Method

In accordance with decision tree of the *2006 IPCC Guidelines* (Volume 4, Page 10.25, Fig.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 CH₄ conversion factor. However, estimation using amount of dry matter intake has been practiced in Japan on livestock-related research. It is considered that, by applying the results of previous researches, the estimation method using amount of dry matter intake provides more accurate results. For that reason, a technique similar to the Tier 2 method but specific to Japan was used for the calculation of CH₄

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 : CH₄ emissions from enteric fermentation for cattle [kg-CH₄]

EF_i : CH₄ emission factor of enteric fermentation of cattle type i [kg-CH₄/head]

A_i : Cattle population of each cattle type i [head]

As cattle begin to eat coarse feed for real at the age about three months, the calculation of the CH₄ emissions associated with enteric fermentation includes cattle aged three months or older (cattle under three months are excluded from estimation). To reflect the actual situation of emissions in Japan, categorization of cattle is defined as shown in the below Table 5-3, and CH₄ emissions are estimated by type and age.

Table 5-3 Categorization and assumptions underlying calculation of CH₄ emissions associated with enteric fermentation in cattle

Type of cattle		Assumptions for calculation of emissions	Additional information for each animal type		
Dairy cattle	Lactating	—	Lactating cattle.		
	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 <i>Livestock Statistics</i> .	
		3 to 6 months old	Calculation covers 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	1 year old and over	—	Breeding cow excluding dairy breeds. Population of under 1 year old are described in the <i>Livestock Statistics</i> .	
		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	Calculation covers 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	Japanese cattle	1 year old and over	—	Cattle of native breeds in Japan called “Wagyu”, which breeds are served for meat only. Population of under 1 year old are described in the <i>Livestock Statistics</i> .
			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	Calculation covers 3 to 6 months old comprising 4/12 of the population under 1 year old.	
		Dairy breeds	Under 3 months old	Covering 2/12 of the population under 1 year old. Excluded from CH ₄ emission estimation.	Cattle of dairy breeds for meat such as Holsteins. Population of under 2 years old are described in the <i>Livestock Statistics</i> .
			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.	
			3 to 6 months old	Calculation covers 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.			

● Emission Factors

The emission factor for CH₄ 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 CH₄ per dry matter intake. Results of measurements have made clear that it is possible to estimate CH₄ from enteric fermentation in ruminant livestock using the equation given below, which uses dry matter intake as the explanatory variable (Shibata et al. (1993), Reference 42).

$$EF = Y / L_{CH_4} \times Mol_{CH_4} \times Day$$

$$Y = -17.766 + 42.793 \times DMI - 0.849 \times (DMI)^2$$

<i>EF</i>	: CH ₄ emission factor associated with enteric fermentation in cattle [kg-CH ₄ /head]
<i>Y</i>	: Volume of CH ₄ generated per head per day [l/day/head]
<i>L_{CH4}</i>	: Volume of 1 mol CH ₄ [l/mol] (=22.4)
<i>Mol_{CH4}</i>	: Molecular weight of CH ₄ [kg/mol] (=0.016)
<i>Day</i>	: Days in a year [day] (=365 or 366)
<i>DMI</i>	: Dry matter intake [kg/day/head]

Annual emission factors by cattle types were established by applying the dry matter intake to the above equation. The dry matter intake was calculated by substituting fat corrected milk amount, body weight, and daily weight gain by growth into the equation established for each type of cattle in *Japan Feed Standards* compiled by the Japan Livestock Industry Association. The equations to estimate dry matter intake were revised in 2006 for dairy cattle (lactating and non-lactating) and in 2008 for non-dairy cattle (Japanese cattle (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 *Japan Feed 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 over second calving has started after 2015. Therefore, the values of average ages for over second calving for 2015 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 Standards*.

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

Type of cattle		Equation
Dairy cattle	Lactating	After 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 2005: $DMI=2.98120+0.00905 \times W+0.41055 \times FCM$ $FCM=(15 \times FAT/100+0.4) \times MILK$
	Non-lactating	$DMI=0.017 \times W$
	Heifers	$DMI=0.49137+0.01768 \times W+0.91754 \times DG$
Non-dairy cattle	Breeding cows	$DMI=[0.1067 \times W^{0.75}+(0.0639 \times W^{0.75} \times DG)/(0.78 \times q+0.006)]/(q \times 4.4)$ $q=0.4213+0.1491 \times DG$
	Japanese cattle (M)	After 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 2007: $DMI=[0.1124 \times W^{0.75}+(0.0546 \times W^{0.75} \times DG)/(0.78 \times q+0.006)]/\{q \times (1.653-0.00123 \times W)\}$ $q=0.5304+0.0748 \times DG$
	Japanese cattle (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)	$DMI=[0.1291 \times W^{0.75}+\{(1.00+0.030 \times W^{0.75}) \times DG\}/(0.78 \times q+0.006)]/(q \times 4.4)$ $q=(0.859-0.00092 \times W) \times (0.790+0.0411 \times DG)$

W: Weight, FCM: Fat Corrected Milk, FAT: Fat content in milk, MILK: Milk Yield, DG: Daily Gain, q: Energy metabolic rate

Source: Japan Livestock Industry Association, *Japan Feed Standards* (Reference 31)

Table 5-5 Fat content in milk (FAT) and milk yield (MILK) of cattle

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Milk yield	kg/head/day	20.8	22.3	23.5	25.1	25.5	25.7	25.6	25.5	25.8	26.0	26.4	26.9	27.1	27.2
Fat content in milk	%	3.7	3.8	3.9	4.0	4.0	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9

Table 5-6 Weight by cattle (W) [kg head⁻¹]

Type of cattle		1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
Dairy cattle	Lactating	601.0	602.4	625.3	618.5	624.2	625.6	623.3	621.3	619.9	620.1	618.7	617.4	616.8	616.1	
	Non-lactating	601.0	602.4	625.3	618.5	624.2	625.6	623.3	621.3	619.9	620.1	618.7	617.4	616.8	616.1	
	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	1 yr and over	426.6	426.6	487.3	450.9	429.1	429.1	429.1	429.1	429.1	429.1	429.1	429.1	429.1	429.1
		Under 1 yr, over 6 mth	230.2	230.2	279.7	259.3	247.0	247.0	247.0	247.0	247.0	247.0	247.0	247.0	247.0	247.0
		3 to 6 mth	118.4	118.4	127.2	119.3	114.7	114.7	114.7	114.7	114.7	114.7	114.7	114.7	114.7	114.7
	Fattening cattle	Japanese cattle (M): 1 yr and over	574.3	574.3	574.3	572.3	571.0	571.0	571.0	571.0	571.0	571.0	571.0	571.0	571.0	571.0
		Japanese cattle (M): under 1 yr, over 6 mth	273.4	273.4	273.4	274.6	275.4	275.4	275.4	275.4	275.4	275.4	275.4	275.4	275.4	275.4
		Japanese cattle (M): 3 to 6 mth	120.5	120.5	120.5	121.6	122.2	122.2	122.2	122.2	122.2	122.2	122.2	122.2	122.2	122.2
		Japanese cattle (F): 1 yr and over	388.0	388.0	462.5	427.7	406.8	406.8	406.8	406.8	406.8	406.8	406.8	406.8	406.8	406.8
		Japanese cattle (F): under 1 yr, over 6 mth	230.2	230.2	279.7	259.3	247.0	247.0	247.0	247.0	247.0	247.0	247.0	247.0	247.0	247.0
		Japanese cattle (F): 3 to 6 mth	118.4	118.4	127.2	119.3	114.7	114.7	114.7	114.7	114.7	114.7	114.7	114.7	114.7	114.7
		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
Dairy breed: 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		

Table 5-7 Daily Gain by cattle (DG) [kg head⁻¹ day⁻¹]

Type of cattle		1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
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	
	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	
Non-dairy cattle	Breeding	1 yr and over	0.17	0.17	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
		Under 1 yr, over 6 mth	0.70	0.70	0.94	0.86	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81
		3 to 6 mth	0.74	0.74	0.97	0.90	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
	Fattening cattle	Japanese cattle (M): 1 yr and over	0.60	0.60	0.60	0.59	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58	0.58
		Japanese cattle (M): 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
		Japanese cattle (M): 3 to 6 mth	0.86	0.86	0.86	0.86	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
		Japanese cattle (F): 1 yr and over	0.28	0.28	0.27	0.25	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
		Japanese cattle (F): under 1 yr, over 6 mth	0.70	0.70	0.94	0.86	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81
		Japanese cattle (F): 3 to 6 mth	0.74	0.74	0.97	0.90	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
		Dairy breed: over 6 mth	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
		Dairy breed: 3 to 6 mth	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13	1.13

Table 5-8 Dry matter intake by cattle (DMI) [kg head⁻¹ day⁻¹]

Type of cattle		1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
Dairy cattle	Lactating	16.6	17.4	18.2	18.9	18.9	19.0	18.9	18.8	19.0	19.0	19.1	19.4	19.4	19.5	
	Non-lactating	10.2	10.2	10.6	10.5	10.6	10.6	10.6	10.6	10.5	10.5	10.5	10.5	10.5	10.5	
	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	
	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	
Non-dairy cattle	Breeding	1 yr and over	6.6	6.6	7.1	6.6	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	5.5	5.5	6.7	6.2	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9	5.9
		3 to 6 mth	3.4	3.4	3.7	3.5	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
	Fattening cattle	Japanese cattle (M): 1 yr and over	8.4	8.4	8.4	8.3	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7	7.7
		Japanese cattle (M): under 1 yr, over 6 mth	6.8	6.8	6.8	6.8	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2
		Japanese cattle (M): 3 to 6 mth	3.6	3.6	3.6	3.7	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
		Japanese cattle (F): 1 yr and over	5.7	5.7	6.4	6.0	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7	5.7
		Japanese cattle (F): under 1 yr, over 6 mth	4.9	4.9	6.1	5.6	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3
		Japanese cattle (F): 3 to 6 mth	3.0	3.0	3.4	3.2	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0
		Dairy breed: over 6 mth	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
		Dairy breed: 3 to 6 mth	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

Table 5-9 Emission factors associated with enteric fermentation by cattle [kg-CH₄ head⁻¹ yr⁻¹]

Type of cattle		1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
Dairy cattle	Lactating	119.6	122.7	125.0	127.0	127.3	127.5	127.1	127.4	127.4	127.8	127.8	128.8	128.5	128.7	
	Non-lactating	86.3	86.6	89.0	88.2	88.8	89.0	88.7	88.8	88.4	88.4	88.2	88.3	88.0	87.9	
	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	
	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	
Non-dairy cattle	Breeding	1 yr and over	59.0	59.2	63.1	59.3	57.0	57.0	57.0	57.1	57.0	57.0	57.0	57.1	57.0	57.0
		Under 1 yr, over 6 mth	49.8	50.0	60.1	56.3	53.8	53.8	53.8	54.0	53.8	53.8	53.8	54.0	53.8	53.8
		3 to 6 mth	30.4	30.5	33.9	31.8	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5	30.5
	Fattening cattle	Japanese cattle (M): 1 yr and over	73.2	73.4	73.2	72.8	68.5	68.5	68.5	68.7	68.5	68.5	68.5	68.7	68.5	68.5
		Japanese cattle (M): under 1 yr, over 6 mth	61.1	61.3	61.1	61.2	64.5	64.5	64.5	64.7	64.5	64.5	64.5	64.7	64.5	64.5
		Japanese cattle (M): 3 to 6 mth	33.1	33.2	33.1	33.4	30.6	30.6	30.6	30.6	30.6	30.6	30.6	30.6	30.6	30.6
		Japanese cattle (F): 1 yr and over	51.8	51.9	58.1	54.2	51.9	51.9	51.9	52.0	51.9	51.9	51.9	52.0	51.9	51.9
		Japanese cattle (F): under 1 yr, over 6 mth	44.3	44.5	55.3	51.2	48.7	48.7	48.7	48.8	48.7	48.7	48.7	48.8	48.7	48.7
		Japanese cattle (F): 3 to 6 mth	26.9	26.9	31.0	28.7	27.3	27.3	27.3	27.4	27.3	27.3	27.3	27.4	27.3	27.3
		Dairy breed: over 6 mth	75.6	75.8	75.6	75.6	75.6	75.6	75.6	75.8	75.6	75.6	75.6	75.8	75.6	75.6
		Dairy breed: 3 to 6 mth	41.5	41.6	41.5	41.5	41.5	41.5	41.5	41.6	41.5	41.5	41.5	41.6	41.5	41.5

● Activity Data

For activity data of this source, the population of each type of cattle at 1 February in each year, recorded by the MAFF in its *Livestock Statistics* is used.

Table 5-10 Livestock population for cattle (single year) [1000 head]

Type of cattle		1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
Dairy cattle	Lactating	1,082	1,035	971	900	848	830	805	813	798	773	750	752	735	731	
	Non-lactating	332	299	249	231	207	200	195	200	194	185	184	185	179	176	
	Heifer: under 2 yr, over 6 mth	491	445	379	379	334	341	351	328	323	328	328	306	307	316	
	Heifer: 3 to 6 mth	109	99	84	84	74	76	78	73	72	73	73	68	68	70	
	Heifer: under 3 mth	55	49	42	42	37	38	39	36	36	36	36	34	34	35	
Dairy cattle total		2,068	1,927	1,725	1,636	1,500	1,484	1,467	1,449	1,423	1,395	1,371	1,345	1,323	1,328	
Non-dairy cattle	Breeding	1 yr and over	679	646	612	594	651	651	636	614	593	568	553	561	562	574
		Under 1 yr, over 6 mth	17	13	12	14	16	17	16	14	13	14	13	14	18	18
		3 to 6 mth	12	9	8	9	10	11	11	9	9	9	9	9	12	12
		Under 3 mth	6	4	4	5	5	6	5	5	4	5	4	5	6	6
	Fattening cattle	Japanese cattle (M): 1 yr and over	368	412	385	374	414	425	409	405	396	381	368	371	374	379
		Japanese cattle (M): under 1 yr, over 6 mth	125	133	114	119	130	132	127	123	116	115	112	109	110	116
		Japanese cattle (M): 3 to 6 mth	83	89	76	80	87	88	85	82	77	77	75	72	73	77
		Japanese cattle (M): under 3 mth	42	44	38	40	43	44	42	41	39	38	37	36	37	39
		Japanese cattle (F): 1 yr and over	197	265	246	290	322	339	336	343	337	328	313	293	310	312
		Japanese cattle (F): under 1 yr, over 6 mth	102	105	93	89	105	106	101	98	93	91	89	86	81	84
		Japanese cattle (F): 3 to 6 mth	68	70	62	59	70	70	67	65	62	60	59	57	54	56
		Japanese cattle (F): under 3 mth	34	35	31	30	35	35	34	33	31	30	30	29	27	28
		Dairy breed: over 6 mth	805	808	845	789	775	726	671	669	655	639	621	628	626	610
		Dairy breed: 3 to 6 mth	179	180	188	175	172	161	149	149	146	142	138	140	139	136
		Dairy breed: under 3 mth	89	90	94	88	86	81	75	74	73	71	69	70	70	68
Non-dairy cattle total		2,805	2,901	2,806	2,755	2,923	2,892	2,763	2,723	2,642	2,567	2,489	2,479	2,499	2,514	

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*, but 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 Chapter 1.

It was pointed out by implementation of QA activity (QAWG) in FY2016 that ab lactation of dairy cattle is at the age about three months, and CH₄ was actively generated from them. By taking into account it 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 *Japan Feed Standards* (Reference 31). If not available, default data described in the *2006 IPCC Guidelines* are used (e.g. Y_m , C_f and $C_{\text{pregnancy}}$).

As a result, for both dairy cattle and non-dairy cattle, considering the error of CH_4 conversion factor ($Y_m = 6.5\% \pm 1.0\%$), 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.

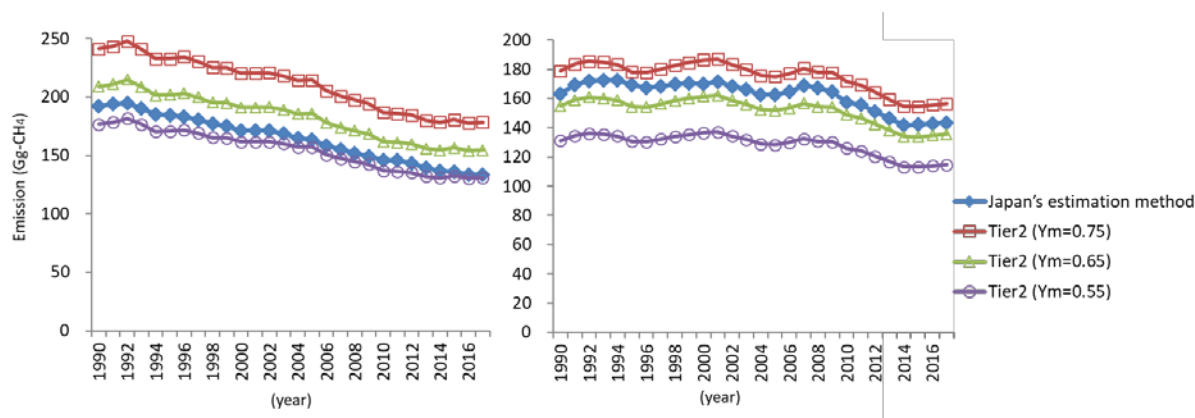


Figure 5-2 Comparison between results of Japan's estimation method and IPCC Tier 2 method
(Left: Dairy cattle, Right: Non-dairy cattle)

e) Category-specific Recalculations

Since the calculation method of body weight for dairy cattle was revised for all years and the calculation method of DMI for non-lactating dairy cattle was revised for years 2005 and before, emissions from all years 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. Buffalo, Sheep, Goats, Horses & Swine (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 buffalo, sheep, goats, horses and swine.

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]

EF : CH_4 emission factor for enteric fermentation of each livestock [kg- CH_4 /head]

A : Livestock 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 CH₄ associated with enteric fermentation in swine, sheep, goats, horses and buffalo

Livestock species	CH ₄ emission factor [kg/year/head]	Reference
Swine	1.4	Established on the basis of results of Mamoru Saito, <i>Methane excretion in fattening pigs and pregnant sows</i> (1988) (Reference 43)
Sheep	8	2006 IPCC Guidelines
Goats	5	
Horses	18.0	
Buffalo	55.0	

● 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 before FY2009 and the “*Status Report regarding Health Management for Livestock Feeding*” by the MAFF from FY2010 onward are used. For swine, population at February 1st 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 before 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 buffalo, sheep, goats, swine, and horses [1000 heads]

Livestock species	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Sheep	21	14	12	9	12	14	20	20	16	17	17	18	18	20
Goats	26	19	22	16	14	14	19	19	19	20	20	17	16	19
Swine	11,335	9,900	9,788	9,620	9,899	9,834	9,768	9,735	9,685	9,537	9,537	9,313	9,346	9,189
Horses	116	118	105	87	81	81	75	75	74	74	69	74	75	76
Buffalo	0.21	0.12	0.10	0.08	0.08	0.08	0.08	0.08	0.09	0.10	0.11	0.11	0.12	0.11

*For swine, data in 2009 and 2014 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 Statistics* 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*, 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 Chapter 1.

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Category-specific Planned Improvements

There are no improvement plans.

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-CO₂ 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 5).

5.3. Manure Management (3.B.)

In livestock manure management process, CH₄ is generated by decomposing organic content in livestock manure with CH₄ fermentation. In addition, CH₄ generated by enteric fermentation dissolved in manure is released by aeration or agitation. In manure management, N₂O is produced mainly by microorganism via nitrification and denitrification processes.

CH₄ and N₂O emissions from manure management in FY2017 are 2,323 kt-CO₂ eq. and 3,916 kt-CO₂ eq., comprising 0.2% and 0.3% of total emissions (excluding LULUCF), respectively. The value represents a reduction by 25.6% for CH₄ and a decrease by 4.8% for N₂O from FY1990. Main driver of the CH₄ emission decrease from FY1990 is a reduction of dairy cattle population, and of the N₂O emission decrease from FY1990 is a reduction for indirect N₂O emission by atmospheric deposition because of a reduction of livestock population.

Table 5-13 CH₄ and N₂O emissions from livestock manure management

Gas	Livestock species	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
CH ₄	3.B.1.- Dairy cattle	kt-CH ₄	106.7	102.8	96.2	94.2	89.4	88.8	86.7	86.6	85.1	83.0	81.5	81.4	79.8	79.8	
	3.B.1.- Non-dairy cattle		4.3	4.5	4.5	5.2	6.1	6.2	6.0	5.9	5.7	5.5	5.4	5.4	5.4	5.4	5.4
	3.B.2. Sheep		0.006	0.004	0.003	0.002	0.003	0.004	0.006	0.006	0.006	0.005	0.005	0.005	0.005	0.005	0.006
	3.B.3. Swine		11.1	9.7	9.1	6.6	5.5	5.1	5.0	5.0	5.0	5.0	4.9	4.9	4.8	4.8	4.7
	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	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.004	0.003	0.003	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		2.3	2.2	2.1	2.4	2.7	2.6	2.6	2.6	2.6	2.6	2.6	2.7	2.7	2.7	2.8
	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	124.8	119.5	112.2	108.7	104.0	102.9	100.5	100.3	98.6	96.2	94.6	94.5	92.9	92.9		
	kt-CO ₂ eq	3,121	2,988	2,804	2,717	2,599	2,573	2,513	2,508	2,465	2,406	2,364	2,362	2,321	2,323		
N ₂ O	3.B.1.- Dairy cattle	kt-N ₂ O	2.1	2.1	2.1	2.4	2.5	2.5	2.5	2.5	2.4	2.4	2.3	2.3	2.3	2.3	
	3.B.1.- Non-dairy cattle		2.8	2.9	2.8	3.0	3.3	3.3	3.1	3.1	3.0	2.9	2.8	2.8	2.8	2.8	
	3.B.2. Sheep		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	
	3.B.3. Swine		3.0	2.6	2.7	3.4	4.0	4.1	4.1	4.1	4.0	4.0	3.9	3.9	3.9	3.8	
	3.B.4.- Buffalo		0.00012	0.00007	0.00006	0.00005	0.00004	0.00005	0.00004	0.00005	0.00005	0.00005	0.00006	0.00006	0.00007	0.00006	
	3.B.4.- Goats		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	
	3.B.4.- Horses		NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	
	3.B.4.- Poultry		1.4	1.4	1.3	1.3	1.3	1.2	1.2	1.2	1.1	1.1	1.1	1.1	1.2	1.2	1.2
	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	
	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	
	3.B.5. Indirect emissions		4.5	4.2	3.9	3.5	3.3	3.2	3.1	3.0	3.0	2.9	2.9	2.9	2.9	3.0	3.0
Total	kt-N ₂ O	13.8	13.2	12.8	13.5	14.3	14.3	14.0	13.8	13.5	13.3	13.1	13.1	13.1	13.1		
	kt-CO ₂ eq	4,114	3,941	3,804	4,013	4,266	4,269	4,158	4,113	4,035	3,967	3,913	3,910	3,912	3,916		
Total of all gases		kt-CO ₂ eq	7,235	6,929	6,608	6,730	6,865	6,842	6,671	6,621	6,501	6,373	6,277	6,272	6,233	6,239	

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 CH₄ and N₂O emissions for manure management from cattle (dairy cattle and non-dairy cattle), swine and poultry (hen and broilers). For grazing animal, CH₄ emissions were reported in this category and N₂O emissions were reported in “3.D.a.3. Urine and dung deposited by grazing animals”.

b) Methodological Issues

● Estimation Method

CH₄ 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 treatment method.

$$E_{CH_4} = \sum (EF_{CH_4-n} \times A_{CH_4-n})$$

E_{CH_4-n} : CH₄ emissions associated with the management of manure excreted by cattle, swine and poultry [g-CH₄]

EF_{CH_4-n} : Emission factor for treatment method n [g-CH₄/g-organic matter];

A_{CH_4-n} : Amount of organic matter contained in manure treated by method n [g-organic matter].

N₂O 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 treatment method.

$$E_{N_2O} = \sum (EF_{N_2O-n} \times A_{N_2O-n}) \times 44 / 28$$

E_{N_2O} : N₂O emission associated with management of manure excreted by cattle, swine and poultry [g-N₂O]

EF_{N_2O-n} : Emission factor for treatment method n [g-N₂O-N/g-N];

A_{N_2O-n} : Amount of nitrogen contained in manure treated by method n [g-N]

● Emission Factors

Emission factors for CH₄ and N₂O associated with Animal Waste Management System (hereafter, AWMS) have been established for each treating method 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 5-14 and Table 5-15 show those emission factors.

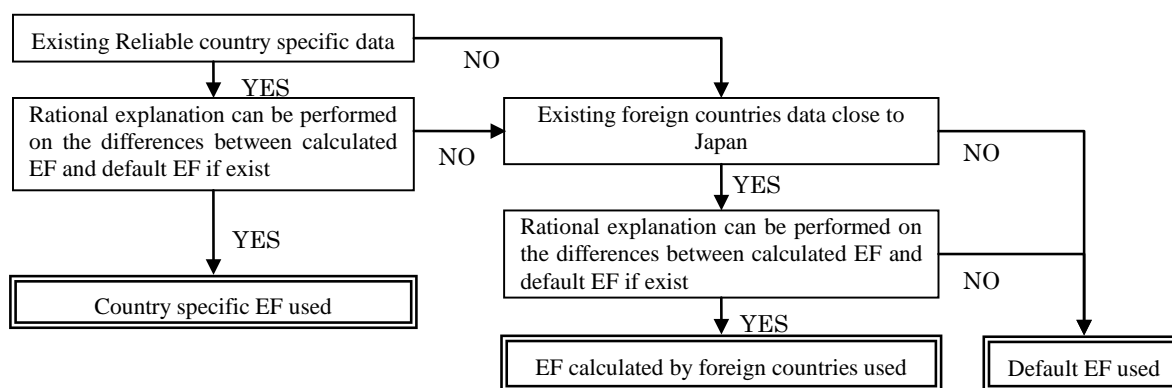


Figure 5-3 Decision tree for determination of EF

Emission factors for CH₄ indicated by “D (default value)” in Table 5-14 and Table 5-15 were calculated by following equation with Bo (maximum methane producing capacity) (Dairy cattle: 0.13, Non-dairy cattle: 0.10, Swine: 0.29) and MCF (methane conversion factor, Table 5-16) in “Asia” indicated in the 2006 IPCC Guidelines. Since MCF for pit storage and composting are described by each temperature in the 2006 IPCC Guidelines, MCF values are calculated with weighted average by regional livestock population and regional MCF decided by the average temperature in each region. Average temperature by region used for development of MCF values is shown in the following Table 5-17. These temperatures were established by the use of 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.

$$EF_{CH_4-n} = Bo \times 0.67 \times MCF$$

EF_{CH_4-n} : Emission factor for treatment method n [g-CH₄/g-organic matter]

Bo : Maximum methane producing capacity [m³-CH₄/kg-organic matter]

0.67 : Conversion factor from volume to weight [kg-CH₄/m³-CH₄]

MCF : Methane conversion factor [%]

For CH₄ 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 (MAFF survey on 2011 (Reference 21)). 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 5-17). 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 (1990: 42% and 2017: 60%).

For “Sun drying” for hen and broiler, emission factors were established on the basis of 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). Detail method is described in the paper by Tsuchiya et al. (2014, Reference 44).

For emission factors of Composting (feces) for hen and broiler, emission factor for swine is applied by expert judgment.

For “Piling”, the most major manure management practice in Japan, Osada et al. (2005, Reference 65) measured actual CH₄ and N₂O 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 (2013, Reference 23).

Shiraishi et al. (2005, Reference 45) measured actual CH₄ and N₂O 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 “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. Detail method is described in the paper by Mori et al. (2015, Reference 66).

Table 5-14 CH₄ Emission factors for each method of treating manure from cattle, swine, hen & broiler
[g-CH₄/g-organic matter]

Treating method	Dairy cattle		Non-dairy cattle		Swine		Hen, broiler	
Pit storage	Table 5-18	J ¹⁰	1.6 %	D ¹	4.9 %	D ¹	-	
Sun drying	0.20 %	J ³	0.20 %	J ³	0.20 %	J ³	0.14 %	J ¹¹
Thermal drying	0 %							Z ⁴
Composting (feces)	0.052 %	D ¹	0.054 %	D ¹	0.080 %	J ⁸	0.080 %	Sw
Piling	3.80 %	J ⁵	0.13 %	J ⁵	0.16 %	J ⁵	Hen: 0.13 %, Broiler 0.02 %	J ¹³
Incineration	0.4 %							O ^{4,2}
Composting (urine)					0.097 %	D ¹		
Composting (feces and urine mixed)	0.052 %	D ¹	0.054 %	D ¹	0.080 %	J ⁸	-	
Purification	0.3%			J ¹⁴	0.91 %	J ¹²		
Methane fermentation (feces)	3.80%	PI	0.13%	PI	0.16%	PI	Hen: 0.13 %, Broiler 0.02 %	PI
Methane fermentation (feces and urine mixed)	Table 5-18	J ⁹	3.5%	DC	3.6%	DC	-	
Pasture, range and paddock	0.076%			J ¹⁰	-		0.14%	SD
Other (feces)	3.80%	M	0.4%	M	0.4%	M	0.4%	M
Other (feces and urine mixed)	3.80%	M	3.5%	M	4.9%	M	-	

* See notation and sources of Table 5-15 below.

Table 5-15 N₂O Emission factors for each method of treating manure from cattle, swine hen & broiler
[g-N₂O-N/g-N]

Treating method	Dairy cattle		Non-dairy cattle		Swine		Hen, Broiler	
Pit storage	0.02%	J ⁹	0 %			D ¹		
Sun drying	2.0 %					D ¹	0.33%	J ¹¹
Thermal drying	2.0 %							D ¹
Composting (feces)	0.25 %				J ⁶	0.16 %	J ⁸	0.16 %
Piling	2.40 %	J ⁵	1.60 %	J ⁵	2.50 %	J ⁵	Hen: 0.54%, Broiler 0.08%	J ¹³
Incineration	0.1 %							O ⁴
Composting (urine)	1.0%					D ¹		
Composting (feces and urine mixed)	1.0%	D ¹	0.25%	J ⁶	0.16%	J ⁸	-	
Purification	2.88 %			J ⁷⁴	2.87%	J ¹²		
Methane fermentation (feces)	2.40 %	PI	1.60 %	PI	2.50 %	PI	Hen: 0.54%, Broiler 0.08%	PI
Methane fermentation (feces and urine mixed)	0.15%	J ⁹	0.15%			DC	-	
Pasture, range and paddock	0.684%			J ¹⁰	-		0.33%	SD
Other (feces)	2.4%	M	2.0%	M	2.5%	M	2.0%	M
Other (feces and urine mixed)	2.88%	M	2.88%	M	2.87%	M	-	

D: Default value of the 2006 IPCC Guidelines

J: Established by data of Japan

O: Established by data of other countries

Z: No emission occurrence because of the mechanism

PI: Application of the value of "Piling"

SD: Application for the value of "Sun drying"

Sw: Application for the value of "Swine"

DC: Estimated from regional EFs of "Dairy cattle" (N₂O: Application for the value of "Dairy cattle")

M: Application of the maximum values of the treating methods for "feces" or "feces and urine mixed"

* Manure excreted by hen and broiler was categorized as feces since it contains a very small amount of urine.

Sources for Table 5-14 and Table 5-15

- 1: 2006 IPCC Guidelines (Reference 1)
- 2: IPCC, *IPCC 1995 Report* (1995) (Reference 2)
- 3: Makoto Ishibashi et al., "Development of technology of reducing GHG on the livestock industry (second report)" (2003) (Reference 46)
- 4: Japan Livestock Technology Association, *GHGs emissions control in livestock Summary*, (2002) (Reference 34)
- 5: Takashi Osada et al., *Greenhouse gas generation from livestock waste composting* (2005) (Reference 65)
- 6: Takashi Osada et al., *Determination of nitrous oxide, methane, and ammonia emissions from a swine waste composting process* (2000) (Reference 67)
- 7: Takashi Osada, *Nitrous Oxide Emission from Purification of Liquid Portion of Swine Wastewater* (2003) (Reference 68)
- 8: *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) (Reference 24)
- 9: MAFF, *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) (Reference 21)
- 10: Akinori Mori and Masayuki Hojito, "Methane and nitrous oxide emissions due to excreta returns from grazing cattle in Nasu, Japan", *Grassland Science* (2015) (Reference 66)
- 11: Idumi Tsuchiya, et al., *Measurement of greenhouse effect gas emissions from drying treatment of poultry manure facility* (2014) (Reference 44)
- 12: MAFF, *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* (2013) (Reference 22)
- 13: MAFF, *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 FY2013* (2014) (Reference 23)
- 14: Makoto Shiraishiet al., "Greenhouse gas emission from the Facility of Cattle Wastewater Treatment with Activated-Sludge process", *Japanese Journal of Zootechnical Science* (2017) (Reference 45)

Table 5-16 MCFs (methane conversion factor) used for calculation of default emission factors

Treating method	MCF	System in the 2006 IPCC Guidelines
Pit storage (non-dairy cattle)	24%	Liquid/ Slurry- Without natural crust (calculated by weighted average)
Pit storage (swine)	25%	Liquid/ Slurry- Without natural crust (calculated by weighted average)
Composting (dairy cattle)	0.6%	Composting - In-vessel (calculated by weighted average)
Composting (non-dairy cattle)	0.8%	Composting - In-vessel (calculated by weighted average)

* For other treating method than the above, MCF values are not established because country-specific emission factors are used.

Source: 2006 IPCC Guidelines, Vol.4 Table10.17 (Reference 1)

Table 5-17 Average temperature by region used for development of MCF values [°C]

Region	Dairy cattle	Non-dairy cattle	Swine
Hokkaido	5.3	6.2	7.4
Tohoku	8.5	11.0	10.1
Kanto	11.9	12.1	14.4
Hokuriku	14.0	14.0	12.7
Tokai	16.0	14.3	15.0
Kinki	15.9	16.0	13.5
Chugoku	14.6	15.0	14.4
Shikoku	16.3	16.1	15.5
Kyusyu and Okinawa	15.8	16.5	16.3

Table 5-18 CH₄ Emission factors for "Pit storage" and "Methane fermentation" for dairy cattle
[g-CH₄/ g-organic matter]

Item	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Pit storage	2.47%	2.44%	2.42%	2.40%	2.39%	2.38%	2.37%	2.37%	2.37%	2.37%	2.37%	2.36%	2.36%	2.36%
Methane fermentation	3.22%	3.17%	3.14%	3.11%	3.08%	3.07%	3.06%	3.06%	3.06%	3.06%	3.05%	3.05%	3.04%	3.03%

Note: These figures are weighted averages of regional emission factors by MAFF survey (Reference 21, No.9 above list) with 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, respectively.

$$A_{CH4-n} = P \times Ex \times Day \times Org \times Mix_n \times MS_n / 1000$$

$$A_{N2O-n} = P \times Nex \times Day \times Mix_n \times MS_n / 1000$$

A_{CH4-n}	: Amount of organic matter excreted [kt]
A_{N2O-n}	: Amount of nitrogen excreted by each type of livestock [kt]
P	: Livestock population [1000 head]
Ex	: Amount of feces and urine excreted per head per day [kg/head/day]
Org	: Organic matter content in feces and urine [%]
Nex	: Nitrogen content of feces and urine excreted per head per day [kg-N/head/day]
Day	: Days in a year [day]
Mix_n	: Proportion of feces and urine separated [%]
MS_n	: Share of each treating method [%]

Total annual 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 proportion of organic matter in feces or urine. Total nitrogen amount was calculated by multiplying the population of each type of animal by the nitrogen content amount of feces or urine excreted per head (Table 5-23, Table 5-24, Table 5-25). The amount of organic matter and nitrogen were allocated to each category of manure management by multiplying the total amount by the percentage of manure treated separately and the percentage per treatment method.

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*" and "*Statistics on Livestock Products Marketing*" are used (see the following Table 5-19) but the data in 2004, 2009 and 2014 are interpolated. For broiler from 1990 to 2008, livestock population described in the "*Statistics on Livestock Products Marketing*" are used. For 2009 onwards, as livestock population are not surveyed in its statistics, livestock population are estimated by using the number of shipment of broiler in the same statistics (see the following Table 5-20). 5-year average (0.170) from FY2004 to FY2008 of "livestock population" / "annual number of shipment", is multiplied by the number of shipment of each year in particular. In addition, days of feeding to shipment are shorter than past. Therefore, 0.919 (=49days/53.3days), ratio of shipment days of present ("*Planning for Breeding Improvement of Poultry*" by MAFF (2015, Reference 19)) and past ("*Questionnaire Survey on Current Breeding Status for Broiler*" by Japan Livestock Technology Association (2008, Reference 35)) is multiplied.

Amount of feces per head per day for dairy cattle is calculated by using the multiple regression equation which is written in "*Japanese Feed Standard*" (Reference 31) 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, Reference 47) 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% by using “*Japanese Feed Standard*” as reference. NI was calculated by dividing Crude Protein (CP) by 6.25. CP were calculated by formulas in “*Japanese Feed Standard*” (Table 5-22) with DMI, milk yield, weight, fat content in milk and daily gain which are same data in ‘3.A. Enteric Fermentation’. KI was set by referring Kume et.al (2010, Reference 69)(Table 5-21).

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, Reference 48)(Table 5-21). DMI and CP used in calculation for nitrogen contents are common to feces and urine.

For “Percentage of manure management by type of animal” and “Proportion of separated and mixed treatment of manure, by type of livestock”, there are two results of surveys in 1997 and 2009. 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 before 1999 and the 2009 survey results were applied after 2009. For 2000 to 2008, interpolation was used (Table 5-26, Table 5-27 and Table 5-28).

Table 5-19 Livestock population for hen [1000 heads]

Livestock species	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Hen	188,786	190,634	186,202	180,697	180,994	179,770	178,546	177,607	174,784	174,806	175,270	175,733	178,900	184,350

* Data of non-surveyed year (in 2009 and 2014) are interpolated.

Source: MAFF, *Livestock Statistics, Statistics on Livestock Products Marketing*

Table 5-20 Livestock population for broiler [1000 heads]

Item	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Livestock Population in statistics (broiler)	142,740	118,123	106,311	103,687	107,141									
Number of Shipment (broiler)				606,898	629,766	634,692	633,799	617,176	649,629	653,999	661,030	666,859	677,332	685,105
Livestock Population used in this inventory (broiler)	142,740	118,123	106,311	103,687	107,141	99,053	98,913	96,319	101,384	102,066	103,163	104,073	105,707	106,920

* From 1990 to 2008, livestock population data in the statistics are used. In 2009 onwards, estimated data by using the number of shipment are used.

Source: MAFF, *Livestock Statistics, Statistics on Livestock Products Marketing*

Table 5-21 Equation to estimate amount of excretion and nitrogen content in excretion for dairy cattle

	Equation
Amount of feces ¹	$F = -8.4753 + 1.8657 \times \text{DMI} + 0.4948 \times \text{NDFom}$ (NDFom : 35%)
Amount of urine ²	$U = -2.2870 + 0.0231 \times \text{NI} + 0.0581 \times \text{KI} - 0.3350 \times \text{MILK}$ (NI = CP / 6.25)
Potassium Intake ³	KI = : 380g/day (Primipara) : 350g/day (2nd calving and over) : 250g/day (Non-lactating) : 220g/day (Heifer: over 6months) : 100g/day (Heifer: 3 to 6months)
Nitrogen content in feces ⁴	$\text{Nf} = 5.01 \times \text{DMI}^{1.2}$ (Lactating) $\text{Nf} = 4.97 \times \text{DMI}^{1.21}$ (Non-lactating • Heifer)
Nitrogen content in urine ⁴	$\text{Nu} = 16.57 \times (\text{CP} / \text{DMI}) \times 100 - 138.6$ (Lactating) $\text{Nu} = 0.24 \times (\text{CP} / 6.25)^{1.14}$ (Non-lactating • Heifer)

Table 5-22 Equation to estimate amount of excretion and nitrogen content in excretion for dairy cattle

	Equation
Lactating	$CP = (CP1 + CP2) \times CFA$ $CP1 = 2.71 \times W^{0.75} / 0.6 \times \text{Correction factor by calving}$ Correction factor by calving: primipara:1.3, 2nd calving:1.15, over 3rd calving:1 $CP2 = (26.6 + 5.3 \times \text{FAT}) \times \text{MILK} / 0.65$ $CFA = 1 + \text{MILK} / 15 \times 0.04$
Non-lactating	$CP = 2.71 \times W^{0.75} / 0.6$
Heifer	$CP = NP / EP$ $NP = FN \times 6.25 + UN \times 6.25 + SP + RP$ $FN = 30 \times \text{DMI} / 6.25$ $UN = 2.75 \times W^{0.5} / 6.25$ $SP = 0.2 \times W^{0.6}$ $RP = 10 \times \text{DG} \times 23.5505 \times W^{-0.0645}$ $EP = 0.51$ (for body weight 120kg and over) $\cdot 0.63$ (for body weight 67~119kg)

F: Feces weight (kg/day), DMI: Dry matter intake (kg/day), NDFom: Natural detergent fiber of organic matter (%), U: Urine weight (kg/day), NI: Nitrogen intake (kg/day), KI: Potassium intake (kg/day), MILK: Milk yield (kg/day), Nf: Nitrogen content in feces (kg/day), Nu: Nitrogen content in urine (kg/day), CP: Crude protein (kg), CFA: Correction factor, W: weight (kg), FAT: Fat content in milk (%), NP: Net protein for preservation and gain for heifer, EP: Conversion efficiency of crude protein to net protein on heifer, FN: metabolic fecal nitrogen for heifer after ablation (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)

Sources for Table 21 and Table 5-22

1: Japan Livestock Industry Association, *Japanese Feed Standard* (Reference 31)

2: Otani et al., "Urine amount of Lactating dairy cow is able to estimate from Intake of Nitrogen and Potassium, and Milk production" (2010, Reference 47)

3: S. Kume et al., "Evaluation of drinking water intake, feed water intake and total water intake in dry and lactating cows fed silage" (2010, Reference 69)

4: Chomei et al., "Prediction and Comparison of Nitrogen Excretions in Dairy and Beef Cattle" (2006, Reference 48)

Table 5-23 Amount of feces and urine excreted (Ex) and nitrogen content by type of livestock (Nex)

Type of livestock		Amount of feces and urine excreted [kg/head/day]		Nitrogen content in feces and urine excreted [g-N/head/day]	
		Feces	Urine	Feces	Urine
Non-dairy cattle	Under two yr.	17.8	6.5	67.8	62.0
	Over two yr.	20.0	6.7	62.7	83.3
	Dairy breed	18.0	7.2	64.7	76.4
Swine	Growing-finishing	2.1	3.8	8.3	25.9
	Breeding	3.3	7.0	11.0	40.0
Hen	Poult	0.059	-	1.54	-
	Adult	0.136	-	Table 5-24	-
Broiler		0.130	-	Table 5-24	-

Source: M, Tsuike et al., *A Computer Program for Estimating the Amount of Livestock Wastes*. (Reference 49)

Table 5-24 Nitrogen content in feces excreted for Hen (adult) and Broiler (Nex)

Type of livestock		Nitrogen content in feces excreted [g-N/head/day]		
		1990~1997	1998~2011	2012~
Hen	Adult	3.28	Interpolation	2.20
Broiler		2.62	Interpolation	1.87

Source: 1990~1997: M, Tsuike et al., *A Computer Program for Estimating the Amount of Livestock Wastes*. (Reference 49)

2012~: Ogino et al., *Estimation of nutrient excretion factors of broiler and layer chickens in Japan* (2016) (Reference 70)

Table 5-25 Organic matter content in feces and urine, by type of livestock (wet base) (Org)

Livestock species	Organic matter content	
	Feces	Urine
Dairy cattle	16%	0.5%
Non-dairy cattle	18%	0.5%
Swine	20%	0.5%
Hen	15%	—
Broiler	15%	—

Source: Japan Livestock Technology Association, *GHGs emissions control in livestock Summary*. (2002) (Reference 34)

Table 5-26 Proportion of separated and mixed treatment of manure, by type of livestock (Mix_n)

Livestock species	Separated			Mixed		
	~1999	2000~2008	2009~	~1999	2000~2008	2009~
Dairy cattle	60%	Interpolation	45.5%	40%	Interpolation	54.5%
Non-dairy cattle	7%	Interpolation	4.8%	93%	Interpolation	95.2%
Swine	70%	Interpolation	73.9%	30%	Interpolation	26.1%
Hen	100%	Interpolation	100%	—	—	—
Broiler	100%	Interpolation	100%	—	—	—

Source: Until 1999: Japan Livestock Technology Association, *GHGs emissions control in livestock Summary*. (2002) (Reference 34),

From 2009 onward: MAFF, *Survey of current status for livestock manure management system* (2009) (Reference 25)

Table 5-27 Percentage of manure management by type of animal
(dairy cattle, non-dairy cattle and swine) (MS_n)

State of Manure (Separated or Mixed)		Treating method	Dairy cattle			Non-dairy cattle			Swine		
			~1999	2000~ 2008	2009~	~1999	2000~ 2008	2009~	~1999	2000~ 2008	2009~
Separated	Feces	Sun drying	2.8%	Interpolation	2.0%	1.5%	Interpolation	0.9%	7.0%	Interpolation	0.7%
		Thermal drying	0%	—	0%	0%	—	0%	0.7%	Interpolation	0.1%
		Composting	9.0%	Interpolation	6.6%	11.0%	Interpolation	8.1%	62.0%	Interpolation	48.2%
		Piling	88.0%	Interpolation	90.1%	87.0%	Interpolation	89.8%	29.6%	Interpolation	49.3%
		Incineration	0.2%	Interpolation	0%	0.5%	Interpolation	—	0.7%	Interpolation	0.6%
		Methane fermentation	—	—	—	—	—	—	—	Interpolation	0.1%
		public sewage	—	—	0%	—	—	—	—	—	—
		Pasturage	—	—	0%	—	—	—	—	—	—
	Other	—	Interpolation	1.3%	—	Interpolation	1.2%	—	Interpolation	1.0%	
	Urine	Sun drying	—	—	0%	—	—	0%	—	—	0%
		Composting (urine)	1.5%	Interpolation	1.7%	9.0%	Interpolation	1.2%	10.0%	Interpolation	5.4%
		Purification	2.5%	Interpolation	5.1%	2.0%	Interpolation	4.4%	45.0%	Interpolation	76.3%
		Pit storage	96.0%	Interpolation	89.6%	89.0%	Interpolation	91.5%	45.0%	Interpolation	15.3%
		Methane fermentation	—	Interpolation	1.9%	—	—	0%	—	Interpolation	0.5%
Public sewage		—	Interpolation	0.8%	—	Interpolation	0.6%	—	Interpolation	0.4%	
Other	—	Interpolation	0.9%	—	Interpolation	2.4%	—	Interpolation	2.1%		
Mixed	Sun drying	4.4%*	Interpolation	1.1%	3.4%*	Interpolation	0.7%	6.0%	Interpolation	0.2%	
	Thermal drying	0%	—	0%	0%	—	0%	0%	—	0%	
	Composting (urine)	18.7%*	Interpolation	22.9%	21.8%*	Interpolation	10.8%	29.0%	Interpolation	21.3%	
	Piling	13.1%*	Interpolation	50.9%	73.2%*	Interpolation	85.6%	20.0%	Interpolation	51.3%	
	Purification	0.3%*	Interpolation	0.2%	0%	—	0%	22.0%	Interpolation	18.5%	
	Pit storage	57.1%*	Interpolation	15.4%	0.6%*	Interpolation	0.1%	23.0%	Interpolation	4.0%	
	Incineration	—	Interpolation	0.1%	—	—	0%	—	—	0%	
	Methane fermentation	—	Interpolation	1.7%	—	—	0%	—	Interpolation	2.0%	
	Public sewage	—	Interpolation	0.1%	—	—	0%	—	Interpolation	0.7%	
	Pasturage	6.5%*	Interpolation	6.5%	1.1%*	Interpolation	1.1%	—	—	0%	
Other	—	Interpolation	1.2%	—	Interpolation	1.6%	—	Interpolation	1.9%		

Source: ~1999: Japan Livestock Technology Association, *GHGs emissions control in livestock Part4*. (1999) (Reference 36)

2009~: MAFF, *Survey of current status for livestock manure management system* (2009) (Reference 25)

*: For dairy cattle and non-dairy cattle, percentage of "Pasturage" are not indicated in Japan Livestock Association data (Reference 36). Therefore, the percentages of "Pasturage" indicated in Reference 25 are applied to all the years 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%.

Table 5-28 Percentage of manure management by type of animal (hen and broiler) (MS_n)

State of Manure (Separated or Mixed)		Treating method	Hen			Broiler		
			~1999	2000~2008	2009~	~1999	2000~2008	2009~
Separated	Feces	Sun drying	30.0%	Interpolation	8.2%	15.0%	Interpolation	2.5%
		Thermal drying	3.0%	Interpolation	2.2%	0%	Interpolation	1.1%
		Composting	42.0%	Interpolation	49.6%	5.1%	Interpolation	19.3%
		Piling	23.0%	Interpolation	36.8%	66.9%	Interpolation	36.7%
		Incineration	2.0%	Interpolation	1.6%	13.0%	Interpolation	30.5%
		Methane fermentation	—	—	—	—	Interpolation	0.1%
		public sewage	—	—	—	—	—	—
		Pasturage	—	—	0%	—	Interpolation	0.1%
	Other	—	Interpolation	1.6%	—	Interpolation	9.9%	

Source: See Table 5-27 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, Reference 65), 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 Format (CRF)*

In the CRF, with regard to nitrogen amount of manure (MMS) from this category, it is required to report emissions by AWMS (“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 management categories and the implementation rates of the management categories have been established for each type of animal. For details, see Table 5-29.

“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 5-29 Correspondence between the Japanese and CRF manure management categories

Sub-categories in Japan		Classification in CRF	Description of treatment	
Manure treatment	Manure management category			
Separate treatment	Feces	Sun drying	Solid storage and dry lot	Dried under sunlight to facilitate handling (for storage and odor prevention).
		Thermal drying	Other system	Dried by heat to facilitate handling.
		Composting	Composting	Fermented for several days to several weeks with forced aeration and agitation in lidded or closed tanks.
		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.
		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.
		Pasture, range and paddock	Pasture, range and paddock	Livestock are fed on a land with vegetation to eat. N ₂ O Emissions are reported in the 'Urine and dung deposited by grazing animals (3.D.a.3.)'.
		Other	Other system	Treated with the method not mentioned above.
	Urine	Liquid composting	Composting	Treated in an aeration storage tank.
		Purification	Aerobic treatment	Separate pollutants using aerobic microbes, such as activated sludge.
		Pit storage	Liquid systems	Stored in a storage tank.
		Methane fermentation	Digesters	Same as above (Methane fermentation).
		Public sewage	—	Same as above (Public sewage).
		Other	Other system	Treated with the method not mentioned above.
Mixed treatment	Sun drying	Solid storage and dry lot	Dried under sunlight to facilitate handling.	
	Thermal drying	Other system	Same as above, Thermal drying.	
	Liquid composting	Composting	Treated in an aeration storage tank.	
	Piling	Composting	Same as above, Piling.	
	Purification	Aerobic treatment	Same as above, Purification.	
	Pit storage	Liquid systems	Stored in a storage tank (e.g. slurry storage).	
	Methane fermentation	Digesters	Same as above (Methane fermentation).	
	Public sewage	—	Same as above (Public sewage).	
	Pasture, range and paddock	Pasture, range and paddock	Same as above (Pasture, range and paddock).	
	Other	Other system	Treated with method not mentioned above.	

c) Uncertainties and Time-series Consistency

● Uncertainties

For the uncertainties of the CH₄ emission factors, Tier 2 values (20%) described in the 2006 IPCC Guidelines were applied. For N₂O emission factors, uncertainty was calculated by synthesis of default uncertainties of each parameter described in the 2006 IPCC Guidelines uncertainty.

For the uncertainties of the activity data, 1% (the standard error for swine given in the *Livestock*

Statistics) was applied to swine, and 9% (the standard error for boiler given in the *Livestock Statistics*) was applied to poultry. For cattle, 1% is adopted, same as “Enteric Fermentation, Cattle”.

As a result, the uncertainties of the emissions for dairy cattle, non-dairy cattle and swine were determined to be -20% to +20% for CH₄ and -71% to +112% for N₂O, and emissions for poultry were determined to be -22% to +22% for CH₄ and -72% to +112% for N₂O.

- **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 Chapter 1. For some country-specific emission factors, there were significant differences between the default emission factors. In the case, the factors of differences were analyzed. QA/QC activities are summarized in Chapter 1.

Country-specific emission factors are used for CH₄ and N₂O 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, CH₄ and N₂O emission factors are low in Japan.

Country-specific emission factors are used for CH₄ and N₂O 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 CH₄, 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 CH₄ emissions. For N₂O, the inferred reason of lower value of the emission factor is the same as CH₄, the Japanese shorter period pit storage doesn't reach to occurrence of scum which is guessed as N₂O source.

For emission factors by piling for poultry, hen's EF is higher than broiler's one. For CH₄, the reason is guessed to be that moisture content of manure for hen is higher than for broiler. Country-specific emissions factors of N₂O by piling 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 emissions factors of N₂O 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.

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 CH₄ emission factor of piling.

e) Category-specific Recalculations

Since the calculation method of amount of excretion and nitrogen content in excretion for dairy cattle

has been revised, the emissions for dairy cattle 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. Buffalo, Sheep, Goats, Horses, Rabbit and Mink (3.B.2., 3.B.4.)

a) Category Description

This section provides the estimation methods for CH₄ and N₂O emissions for manure management from buffalo, sheep, goats, horses, rabbit and mink.

b) Methodological Issues

● *Estimation Method*

CH₄ and N₂O 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).

$$E_{CH_4} = EF_{CH_4} \times P$$

$$E_{N_2O} = \sum (EF_{N_2O-n} \times P \times Nex \times MS_n)$$

E_{CH_4}	: CH ₄ emissions associated with manure management [kg-CH ₄]
E_{N_2O}	: N ₂ O emission associated with livestock manure [kg-N ₂ O]
EF_{CH_4}	: CH ₄ emission factor [kg-CH ₄ head ⁻¹ year ⁻¹]
EF_{N_2O-n}	: N ₂ O emission factor of manure management <i>n</i> [kg-N ₂ O (kg-N) ⁻¹]
P	: Livestock population [head]
Nex	: Nitrogen content in manure [kg-N head ⁻¹]
MS_n	: Percentage of manure management <i>n</i> [%]

● *Emission Factors*

For the emission factors for CH₄, 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 5-30).

For the emission factors for N₂O, the default values given in the *2006 IPCC Guidelines* were used (Table 5-31).

Table 5-30 CH₄ emission factors for sheep, goats, horses, rabbit and mink

Livestock species	Emission factors [kg-CH ₄ head ⁻¹ year ⁻¹]	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 5-31 N₂O Emission factors for buffalo, sheep, goats, horses, rabbit and mink

Manure management category	[kg-N ₂ O-N (kg-N) ⁻¹]
Dry lot	2.0%
Pasture Range and Paddock (buffalo)	2.0%
Pasture Range and Paddock (sheep, goats, horses)	1.0%
Daily Spread	0%
Burned for fuel	0%

Source: Dry lot, Daily Spread: 2006 IPCC Guidelines Vol.4, page 10.62, Table 10.21,
Pasture Range and Paddock: 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 5-32 below).

For N₂O, 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 management category (Table 5-33). For the percentage of manure management category for buffalo, the default values given in the 2006 IPCC Guidelines were used (classification is “Asia”) (Table 5-34). For rabbit and mink, which default values are not described in the 2006 IPCC Guidelines, it is considered by expert judgment that all manure are managed by “Dry lot”. 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 5-32 Livestock population for rabbit and mink [1000 heads]

Livestock Species	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Rabbit	15	16	21	19	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

Source: *Statistical Document for small animals and laboratory animals*, MAFF

Table 5-33 Body weight and N excretion rate for buffalo, sheep, goats, horses, rabbit and mink (Nex)

Livestock species	Body weight [kg]	N excretion rate per weight [kg-N (1000kg-body weight) ⁻¹ day ⁻¹]	N excretion rate [kg-N head ⁻¹ year ⁻¹]
Buffalo	380	0.32	(44.4)
Sheep	48.5	1.17	(20.7)
Goats	38.5	1.37	(19.3)
Horses	377	0.46	(63.3)
Rabbit	-	-	8.1
Mink	-	-	4.59

Source: 2006 IPCC Guidelines Vol.4, Table 10A-9 and Table 10A-6,
2006 IPCC Guidelines Vol.4, page 10.59, Table 10.19

Table 5-34 Percentage of each manure management category for buffalo (MS_n)

Manure management category	Percentage
Lagoons	0%
Liquid /Slurry	0%
Solid Storage	0%
Dry lot	41%
Pasture Range and Paddock	50%
Daily Spread	4%
Digester	0%
Burned for Fuel	5%
Other	0%

Source: 2006 IPCC Guidelines, Vol.4, 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 CH₄, Tier 1 default value (30%) described in the 2006 IPCC Guidelines was applied. For N₂O, 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 CH₄, and -72% to +112% for N₂O 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 Chapter 1.

e) *Category-specific Recalculations*

There have been no source-specific recalculations.

f) *Category-specific Planned Improvements*

There are no improvement plans.

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* by MAFF. However, their population size is small, and each emission was lower than 3000t-CO₂ 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 5).

5.3.4. Indirect N₂O emissions (3.B.5.)

5.3.4.1. Atmospheric Deposition (3.B.5.-)

a) Category Description

This section provides the estimation methods for N₂O indirect emissions caused by atmospheric deposition of nitrogen volatilized as NH₃ and NO_x from livestock manure management.

b) Methodological Issues

● Estimation Method

N₂O emissions have been calculated by Tier 2 method in accordance with decision tree of the 2006 IPCC Guidelines (Vol.4, Page 10.55, Fig. 10.4).

$$E = N_{\text{Volatilization-MMS}} \times EF \times 44/28$$

E	: N ₂ O emissions by atmospheric deposition in the process of livestock manure management [kg-N ₂ O]
$N_{\text{Volatilization-MMS}}$: Nitrogen amount volatilized as NH ₃ and NO _x in the process of livestock manure management [kg (NH ₃ -N+NO _x -N)]
EF	: Emission factor [kg-N ₂ O-N/kg (NH ₃ -N+NO _x -N)]

● Emission Factors

0.010 [kg-N₂O-N/kg-NH₃-N & NO_x-N deposited] (default value, 2006 IPCC Guidelines, Vol.4 Table11.3).

● 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 ($N_{\text{Volatilization-MMS}}$) is calculated using the nitrogen amount included in each manure management system (N_{Bi}) which calculated in the above 5.3.1., and volatilization rate as NH₃ and NO_x from manure in each livestock barn ($Frac_{GASM1i}$) and in each process of treatment ($Frac_{GASM2i}$). The volatilization rate as NH₃ and NO_x from manure are estimated from data described in the “*Estimation of Nitrogen Loading in Japanese Prefectures and Scenario Testing of Abatement Strategies*”, Hojito et al., (2003) (Reference 50) (See Table 5-35). For “Purification”, it is considered that there are not volatilized in treatment process. Indirect N₂O emissions from grazing animal are reported in 3.D.b.1.

$$N_{\text{Volatilization-MMS}} = \sum_i \{ N_{Bi} \times (Frac_{GASM1i} + Frac_{GASM2i}) \}$$

$N_{\text{Volatilization-MMS}}$: Nitrogen amount volatilized as NH ₃ and NO _x in the process of livestock manure management [kg (NH ₃ -N+NO _x -N)]
N_{Bi}	: Nitrogen amount in livestock manure for management system i [kg-N]
$Frac_{GASM1i}$: Volatilization rate as NH ₃ and NO _x in livestock barn for management system i [kg-NH ₃ -N + NO _x -N/kg-N]
$Frac_{GASM2i}$: Volatilization rate as NH ₃ and NO _x in process of treatment for management system i [kg-NH ₃ -N + NO _x -N/kg-N]

Table 5-35 Volatilization rate as NH₃ and NO_x from manure (in livestock barn and in process of treatment)

Livestock species	Treatment		Volatilization rate in livestock barn (Frac _{GASMI})	Volatilization rate in process of treatment (Frac _{GASM2})
	Dairy cattle	Feces	Other than Composting	10.3%
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%
		Other than Purification	14.7%	27.0%
	Urine	Purification	14.7%	0%
		Other than Purification, Pit storage, Methane fermentation	15.8%	24.2%
	Mixed	Purification	14.7%	0%
		Pit storage, Methane fermentation	14.7%	25.0%
Hen and Broiler	Feces	All management	8.4%	51.5%

Source: Established from “*Estimation of Nitrogen Loading in Japanese Prefectures and Scenario Testing of Abatement Strategies*” (Hojito et al. (2003)) (Reference 50)

For buffalo, rabbit, and mink, nitrogen amount volatilized as NH₃ and NO_x from manure were estimated by multiplying total nitrogen amount of manure of each livestock by default volatilization rate described in the 2006 IPCC Guidelines (Other-Solid storage: 12%).

Table 5-36 Nitrogen amount volatilized as NH₃ and NO_x in the process of livestock manure management [kt (NH₃-N+NO_x-N)]

Livestock Species	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Dairy cattle	26.6	26.1	24.6	23.4	21.5	21.0	20.5	20.5	20.2	19.7	19.4	19.5	19.1	19.1
Non-dairy cattle	26.8	27.8	26.8	26.3	27.9	27.6	26.4	26.1	25.2	24.5	23.8	23.7	23.9	24.0
Swine	43.6	38.1	37.0	33.8	33.2	32.4	32.1	32.1	31.9	31.4	31.0	30.7	30.7	30.2
Poultry (Hen, Broiler)	187.6	177.5	157.2	136.3	128.9	121.8	118.1	113.8	111.2	111.5	112.1	113.0	114.5	117.0
Other livestock (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
Total	284.8	269.5	245.7	219.9	211.5	202.9	197.1	192.5	188.5	187.1	186.3	186.9	188.2	190.4

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

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 Chapter 1.

e) Category-specific Recalculations

There have been no source-specific recalculations.

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 from flowing wastewater in 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.)

CH₄ is generated under anaerobic conditions by microbes' activity. Therefore, paddy fields provide favorable conditions for CH₄ 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.

CH₄ emissions from rice cultivation in FY2017 are 13,627 kt-CO₂ eq., comprising 1.1% of total emissions (excluding LULUCF). The value represents an increase by 6.7% from FY1990. Main driver of the emission increase from FY1990 is an increase of amount of organic matter application.

Table 5-37 CH₄ emissions from rice cultivation

Gas	Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
CH ₄	3.C.1.- Continuously flooded	kt-CH ₄	69.8	77.9	72.0	78.2	81.4	78.2	83.8	83.7	82.6	83.3	82.7	79.4	78.6	77.6
	3.C.1.- Intermittently flooded		441.1	466.3	437.9	459.6	484.9	476.3	517.8	503.5	490.4	499.3	494.8	476.9	477.6	467.5
	Total	kt-CH ₄	510.8	544.2	510.0	537.8	566.3	554.5	601.6	587.2	573.0	582.6	577.5	556.3	556.3	545.1
		kt-CO ₂ eq	12,771	13,605	12,749	13,445	14,157	13,863	15,041	14,680	14,325	14,565	14,437	13,908	13,907	13,627

5.4.1. Irrigated (Intermittently Flooded (Single Aeration) and Continuously Flooded) (3.C.1.)**a) Category Description**

This section provides the estimation methods for CH₄ 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 CRF. The diagram below presents the outline.

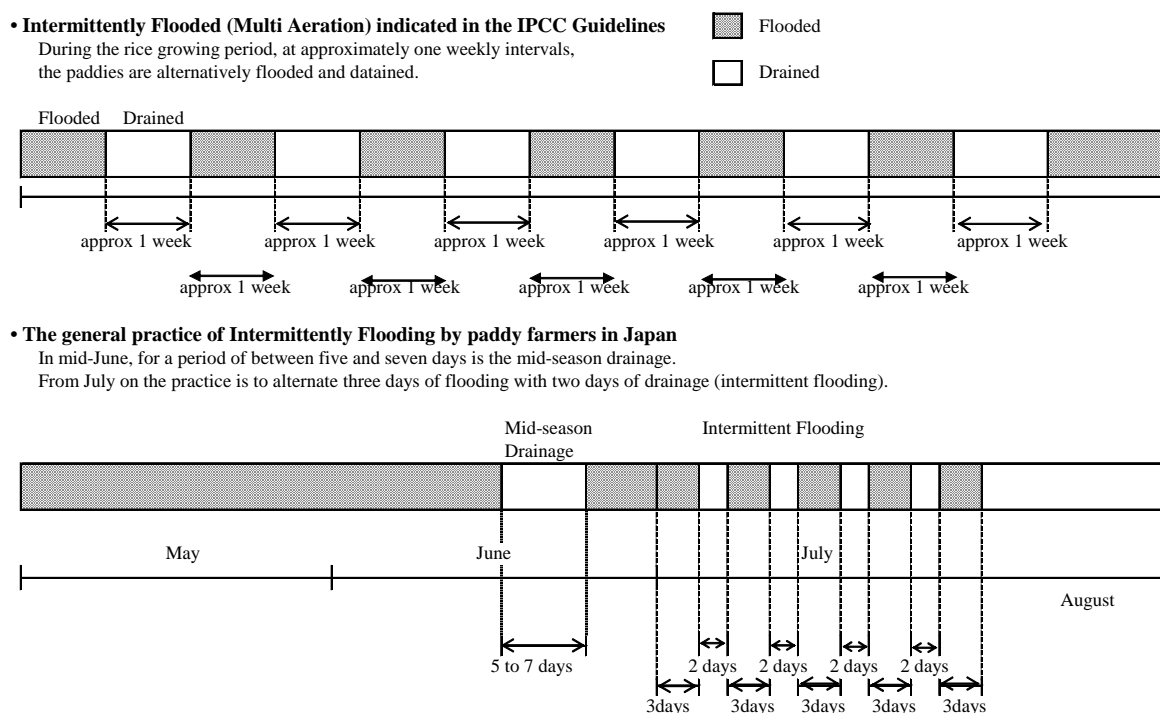


Figure 5-4 Comparison of water management regime in Japan and intermittent flooding (multi aeration) indicated in the 2006 IPCC Guidelines

b) Methodological Issues

● Estimation Method

Based on the calculation method in the 2006 IPCC Guidelines, the emissions were estimated using emission factors established by the calculation using DeNitrification-DeComposition-Rice model (DNDC-Rice model) (Reference 51), which is the mathematical model to estimate change of CH₄ emissions with methods of organic matter application and/or water regime on paddy field, and the following formula determined by its model. The improved model, the DNDC-Rice model is based on the DNDC model and has developed in Japan so as to estimate CH₄ emissions from rice paddy field in Japan. Figure 5-5 is a conceptual scheme of the DNDC-Rice model.

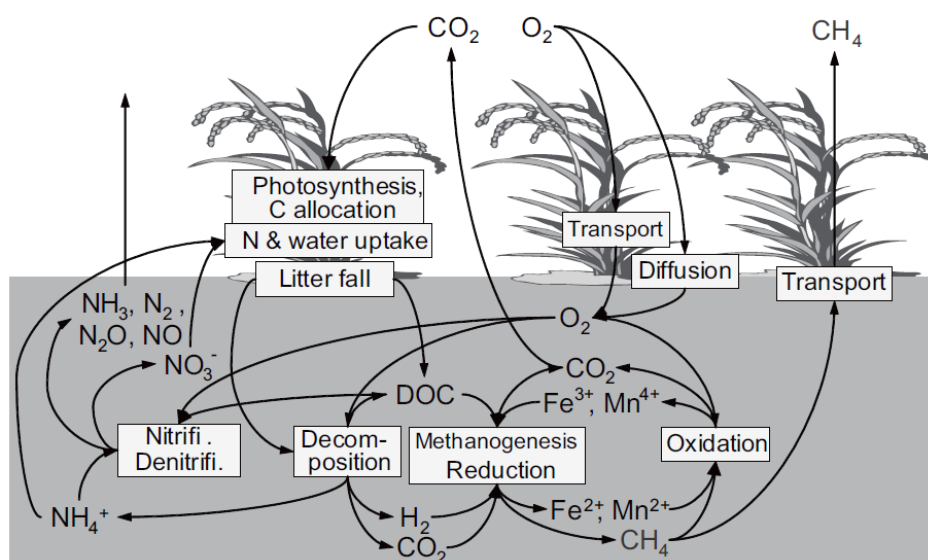


Figure 5-5 Conceptual scheme of the DNDC-Rice model

Reference: Fumoto et al. (2010) (Reference 51)

Tier3 method (DNDC-Rice model) was used to establish emission factor, and modified Tier2 method was used to estimate emissions.

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) (Reference 71), Katayanagi et al. (2017) (Reference 72) and relevant paper.

$$E = \sum_{i,j,k,l} \{ (A_i \times f_{Di,j} \times f_{wi,k} \times f_{ol}) \times EF_{i,j,k,l} \} \times 16/12$$

$$EF = aX + b$$

E	: CH ₄ Emissions from paddy field [kgCH ₄ /year]
i	: Region (7 regions)
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)
A	: Crop area of rice paddy field by region [ha]
f_D	: Proportion of drainage
f_w	: Proportion of water regime
f_o	: Proportion by type of organic matter application
EF	: EFs by region, drainage, water regime, organic matter management method [kgCH ₄ -C/ha/year]
X	: Amount of organic matter [tC/ha/year]
a	: Slope (estimated by regression formula with CH ₄ emissions calculated by the DNDC-Rice model and amount of organic matter)
b	: Intercept (estimated by regression formula with 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) (Reference 26), 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 the *Fourth Basic Survey on Infrastructure Development of Land Use* (MAFF) (Reference 27)
- 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) (Reference 73) which were divided the whole Japan to 136 regions in accordance to 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) (Reference 74), application amount of compost and crop residue (e.g. rice straw) plowed into soil by each prefecture in 1981 to 2010 were estimated. In other words, the average amount of crop residues plowed into soil such as rice straw were estimated by multiplying crop residue amount estimated from crop residue from prefecture harvest statistics of rice (and second crop such as wheat and fertilizer feed crops) by percentage plowed into the soil, then, by dividing the value by the rice cropping area. For amount of compost application, the average application amount by each year were estimated by the survey results of “*Basis Survey of Soil Environment*” by MAFF and “*Survey of Greenhouse Gas Emissions from Soils and Soil Carbon Sequestration*” by Research council on Soil function for global warming countermeasures (2013, Reference 37), etc.

Using the DNDC-Rice model and the above input data, CH₄ 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 compost¹, rice straw only, compost only, non-organic matter). Taking into account statistical significant difference of their results, CH₄ 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

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 (*fo*) is not available, its scenario is not used for inventory emission estimation.

equation (linear function) to predict CH₄ 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 CH₄ emissions flux estimated non-organic application scenario.

Total amount of organic matter application in region level were aggregated by prefecture which was estimated by the method described by Yagasaki and Shirato (2014). In addition, to induce amount of organic matter application (X) which are used in estimation in the inventory, their total amount and proportion of organic matter management (Table 5-43) were used. 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 5-38, and Table 5-39 below, respectively.

Table 5-38 Amount of organic matter application by region (X) [t-C/ha]

Item		1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Rice straw	Hokkaido	1.68	2.16	2.39	2.74	2.50	2.31	2.74	2.68	2.50	2.50	2.56	2.45	2.40	2.44
	Tohoku	1.83	2.25	2.62	2.66	2.52	2.60	2.85	2.59	2.46	2.52	2.54	2.41	2.37	2.32
	Hokuriku	2.97	2.99	3.41	2.36	2.35	2.43	3.60	3.34	2.31	2.37	2.33	2.27	2.40	2.23
	Kanto	1.76	2.09	2.54	2.56	2.44	2.48	2.58	2.44	2.34	2.41	2.36	2.16	2.19	2.16
	Tokai and Kinki	2.29	2.65	2.87	2.97	2.82	2.83	3.06	2.83	2.75	2.84	2.70	2.68	2.73	2.67
	Chugoku and Shikoku	1.96	2.51	2.72	2.74	2.71	2.50	2.90	2.71	2.58	2.59	2.48	2.45	2.55	2.55
	Kyusyu and Okinawa	1.39	1.50	1.65	1.57	1.95	1.75	1.96	1.53	1.75	1.77	1.72	1.67	1.72	1.71
Compost	Hokkaido	1.24	0.61	0.68	1.79	2.72	2.32	2.22	2.61	2.49	2.15	2.15	2.15	2.15	2.15
	Tohoku	1.24	0.61	0.67	1.78	2.70	2.30	2.18	2.52	2.41	2.15	2.15	2.15	2.15	2.15
	Hokuriku	1.23	0.61	0.67	1.78	2.71	2.31	2.20	2.58	2.47	2.15	2.15	2.15	2.15	2.15
	Kanto	1.38	0.74	0.73	2.14	3.23	2.73	2.57	2.99	2.85	2.50	2.49	2.49	2.49	2.49
	Tokai and Kinki	1.25	0.61	0.68	1.80	2.75	2.34	2.22	2.61	2.48	2.16	2.16	2.16	2.16	2.16
	Chugoku and Shikoku	1.33	0.67	0.71	1.94	2.90	2.49	2.37	2.77	2.65	2.31	2.31	2.33	2.33	2.34
	Kyusyu and Okinawa	1.60	0.95	0.85	2.82	4.49	3.82	3.58	4.33	4.11	3.67	3.70	3.73	3.77	3.75

Table 5-39 CH₄ emission factors in each segment [kg-CH₄-C/ha/year]

Item		1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017		
Poorly drained field, Continuously flooded	Rice straw	Hokkaido	571	701	765	859	793	743	859	843	794	795	811	780	766	778	
		Tohoku	664	775	875	886	849	871	936	867	833	847	854	819	807	795	
		Hokuriku	805	810	909	664	660	679	953	892	653	666	655	642	673	634	
		Kanto	235	276	331	333	318	324	335	319	306	316	309	284	288	284	
		Tokai and Kinki	492	562	606	627	598	600	644	599	583	600	574	570	579	566	
		Chugoku and Shikoku	464	573	615	619	613	571	650	611	587	589	568	561	581	580	
		Kyusyu and Okinawa	185	198	216	206	252	229	254	202	228	231	224	218	224	224	
		Compost	Hokkaido	452	279	298	600	855	746	717	823	792	698	698	698	698	698
	Tohoku		505	337	355	651	897	790	757	848	820	748	748	748	748	748	
	Hokuriku		401	254	270	529	745	652	627	715	689	613	613	613	613	613	
	Kanto		188	109	108	282	416	355	335	387	370	326	325	325	325	325	
	Tokai and Kinki		284	157	170	394	582	500	478	554	530	466	466	466	466	466	
	Chugoku and Shikoku		341	210	218	460	651	570	546	624	600	534	534	537	538	539	
	Kyusyu and Okinawa		211	131	119	358	562	481	450	542	515	462	465	469	474	471	
	No-amendment		Hokkaido	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	
		Hokuriku	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	
		Tokai and Kinki	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	
		Kyusyu and Okinawa	16	16	16	16	16	16	16	16	16	16	16	16	16	16	
		Poorly drained field, Intermittently flooded	Rice straw	Hokkaido	571	701	765	859	793	743	859	843	794	795	811	780	766
	Tohoku			637	747	846	856	820	842	906	838	805	818	825	790	779	767
	Hokuriku			605	609	691	488	486	501	727	677	479	490	481	471	496	464
	Kanto			212	249	298	300	286	292	302	287	275	284	278	256	260	256
	Tokai and Kinki			399	457	493	510	486	488	525	487	473	488	466	463	471	460
	Chugoku and Shikoku			416	518	556	560	554	515	589	553	530	533	512	506	525	524
	Kyusyu and Okinawa			162	173	188	180	219	199	220	176	198	201	195	190	195	194
Compost	Hokkaido			452	279	298	600	855	746	717	823	792	698	698	698	698	698
	Tohoku		480	314	332	624	868	762	730	819	792	720	720	720	720	720	
	Hokuriku		271	150	163	377	555	479	458	531	509	447	447	447	447	447	
	Kanto		170	99	98	254	374	319	301	348	333	293	293	292	293	293	
	Tokai and Kinki		227	122	133	318	473	406	387	450	430	377	377	377	377	377	
	Chugoku and Shikoku		302	180	187	412	589	514	492	565	543	481	481	484	484	486	
	Kyusyu and Okinawa		183	116	106	308	481	412	386	464	441	396	399	402	406	404	
	No-amendment		Hokkaido	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	
Hokuriku			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	
Tokai and Kinki			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	
Kyusyu and Okinawa			19	19	19	19	19	19	19	19	19	19	19	19	19	19	
One day drained field, Continuously flooded			Rice straw	Hokkaido	333	417	458	519	476	444	518	508	477	477	488	467	459
	Tohoku			492	576	653	661	633	649	699	646	621	631	637	610	601	592
	Hokuriku			608	612	692	493	490	506	728	678	484	495	486	476	501	469
	Kanto			156	182	218	219	209	213	220	210	201	208	203	187	190	187
	Tokai and Kinki			225	258	279	289	275	276	297	275	268	276	264	262	266	260
	Chugoku and Shikoku			184	232	250	252	249	231	265	248	238	239	229	227	235	235
	Kyusyu and Okinawa			155	166	180	172	211	191	212	169	190	193	187	182	188	187
	Compost	Hokkaido		256	145	157	352	516	446	427	495	475	415	415	415	415	415
		Tohoku	371	242	256	482	670	588	563	632	611	556	556	556	556	556	
		Hokuriku	280	160	173	384	559	484	464	535	514	452	452	452	452	452	
		Kanto	126	75	75	186	272	233	220	253	242	214	214	213	214	214	
		Tokai and Kinki	125	65	71	178	268	229	218	254	243	212	212	212	212	212	
		Chugoku and Shikoku	131	74	77	183	266	230	220	254	244	215	215	216	216	217	
		Kyusyu and Okinawa	176	109	99	300	471	403	377	455	432	387	390	393	398	395	
		No-amendment	Hokkaido	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	
	Hokuriku		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	
	Tokai and Kinki		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	
	Kyusyu and Okinawa		12	12	12	12	12	12	12	12	12	12	12	12	12	12	

Table 5-39 CH₄ emission factors in each segment [kgCH₄-C/ha/year] (Continued)

Item		1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017			
One day drained field, Intermittently flooded	Rice straw	Hokkaido	229	289	318	360	330	307	360	353	331	331	339	324	318	324		
		Tohoku	349	412	469	475	454	467	504	465	445	453	457	437	431	424		
		Hokuriku	441	444	502	357	355	366	529	492	351	358	352	344	363	340		
		Kanto	115	134	160	161	154	156	162	154	148	153	149	138	140	138		
		Tokai and Kinki	101	116	126	130	124	124	134	124	121	124	119	118	120	117		
		Chugoku and Shikoku	98	125	135	136	135	124	144	134	128	129	124	122	127	127		
		Kyusyu and Okinawa	88	94	103	98	120	109	121	96	109	110	107	104	107	106		
		Compost	Hokkaido	175	96	105	242	359	309	296	344	330	287	287	287	287	287	
			Tohoku	259	163	173	342	482	421	402	454	438	397	397	397	397	397	
	Hokuriku		201	114	124	277	405	350	335	388	372	327	327	327	327	327		
	Kanto		93	57	56	137	199	171	161	186	178	157	157	157	157	157		
	Tokai and Kinki		56	29	32	80	121	103	98	114	109	95	95	95	95	95		
	Chugoku and Shikoku		69	37	39	98	144	124	118	137	131	115	116	116	116	117		
	Kyusyu and Okinawa		100	62	56	171	269	230	215	260	247	221	223	225	227	225		
	No-amendment		Hokkaido	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	
		Hokuriku	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		
		Tokai and Kinki	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		
		Kyusyu and Okinawa	7	7	7	7	7	7	7	7	7	7	7	7	7	7		
		4 hour drained field, Continuously flooded	Rice straw	Hokkaido	300	376	413	468	430	400	468	459	430	430	440	422	414	421
				Tohoku	451	532	605	612	586	601	649	598	574	584	589	563	555	546
	Hokuriku			578	582	659	469	467	481	693	646	461	471	463	453	477	446	
	Kanto			208	242	288	289	277	282	291	277	267	275	269	248	252	248	
	Tokai and Kinki			240	275	296	307	292	293	316	293	285	294	281	279	283	277	
	Chugoku and Shikoku			250	313	337	339	336	312	357	335	321	322	310	306	317	317	
	Kyusyu and Okinawa			185	198	216	206	253	229	255	202	228	232	225	219	225	224	
	Compost			Hokkaido	230	130	140	317	466	402	385	447	429	374	374	374	374	374
				Tohoku	336	214	227	442	620	543	519	585	565	512	512	512	512	512
Hokuriku			266	152	165	365	532	460	441	509	489	430	430	430	430	430		
Kanto			169	103	102	247	358	307	291	334	320	283	282	282	282	283		
Tokai and Kinki			137	73	80	191	285	244	233	271	259	227	227	227	227	227		
Chugoku and Shikoku			179	104	108	248	357	311	297	342	328	290	290	292	292	293		
Kyusyu and Okinawa			211	130	118	360	567	484	454	547	519	465	469	473	478	475		
No-amendment			Hokkaido	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	
	Hokuriku		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		
	Tokai and Kinki		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		
	Kyusyu and Okinawa		13	13	13	13	13	13	13	13	13	13	13	13	13	13		
	4 hour drained field, Intermittently flooded		Rice straw	Hokkaido	166	210	231	263	241	224	263	257	241	241	247	236	232	236
				Tohoku	316	374	427	432	413	424	458	422	404	412	415	397	391	384
Hokuriku				390	392	445	315	313	323	468	436	309	316	310	303	320	299	
Kanto				143	167	199	200	191	195	201	192	184	190	186	171	174	171	
Tokai and Kinki				135	154	167	173	164	165	178	165	160	165	158	157	159	156	
Chugoku and Shikoku				173	217	233	235	233	216	248	232	222	223	214	212	220	219	
Kyusyu and Okinawa				109	117	128	122	150	136	151	120	135	137	133	129	133	132	
Compost				Hokkaido	126	69	75	176	261	225	215	251	240	209	209	209	209	209
				Tohoku	232	144	154	309	438	382	365	412	398	360	360	360	360	360
		Hokuriku	175	97	106	243	358	309	295	342	328	288	288	288	288	288		
		Kanto	115	69	68	170	248	213	201	231	221	195	195	195	195	195		
		Tokai and Kinki	76	40	44	107	160	137	131	152	145	127	127	127	127	127		
		Chugoku and Shikoku	123	71	74	171	248	215	206	237	227	201	201	202	202	203		
		Kyusyu and Okinawa	125	76	69	214	337	288	270	325	309	276	279	281	284	282		
		No-amendment	Hokkaido	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	
Hokuriku			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		
Tokai and Kinki			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		
Kyusyu and Okinawa			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 5-40 to Table 5-43 were used respectively.

Table 5-40 Area of paddy fields by region (A) [kha]

Region	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Hokkaido	146	163	135	119	115	115	115	114	113	113	112	111	108	107
Tohoku	525	539	456	444	419	421	429	406	414	419	419	415	414	413
Hokuriku	258	260	221	218	211	211	213	213	213	215	216	214	213	212
Kanto	386	390	336	331	320	320	322	323	324	324	323	322	321	318
Tokai	117	116	95	91	88	87	88	88	88	87	86	85	85	84
Kinki	145	148	122	117	111	111	111	111	111	111	110	108	107	106
Chugoku and Shikoku	236	232	187	182	176	176	178	176	175	175	173	170	167	165
Kyusyu and Okinawa	246	251	207	206	196	196	202	202	203	203	201	199	196	195
Total	2,058	2,098	1,758	1,708	1,637	1,637	1,657	1,632	1,641	1,647	1,639	1,623	1,611	1,600

* On the estimation, Tokai and Kinki regions are aggregated as one region

Source: *Statistics of Cultivated and Planted Area* (MAFF)

Table 5-41 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%

Source: MAFF, “*Forth basic survey on infrastructure development of land use*” (Reference 27)

Table 5-42 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%

Source: Research council on soil function for global warming countermeasures, “*Survey of Greenhouse Gas Emissions from Soils and Soil Carbon Sequestration*” (Reference 37)

Table 5-43 Proportion of organic matter management in Japan (f_O)

Item	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Straw amendment	60%	60%	60%	60%	65%	61%	57%	62%	65%	64%	64%	64%	64%	64%
Various compost amendment	20%	20%	20%	20%	18%	23%	26%	22%	23%	27%	27%	27%	27%	27%
No-amendment	20%	20%	20%	20%	17%	16%	17%	16%	12%	9%	9%	9%	9%	9%

Source: 1990-2007: MAFF, “*Basic Survey of Soil Environment*” (Reference 26)

2008-2012: Research council on Soil function for global warming countermeasures, “*Survey of Greenhouse Gas Emissions from Soils and Soil Carbon Sequestration*” (Reference 37)

After 2013: MAFF, “*the Project of Basic Survey on Greenhouse Gas Emissions from Agricultural Land Soils*” (Reference 28)

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 Chapter 1.

Comparison of CH₄ 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) (Reference 75), Fumoto et al. (2010) (Reference 51), and Katayanagi et al. (2016) (Reference 71).

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 CH₄ emission was strongly and significantly correlated with the observations ($r=0.861$), reflecting the variations caused by differences among the sites and the treatments.

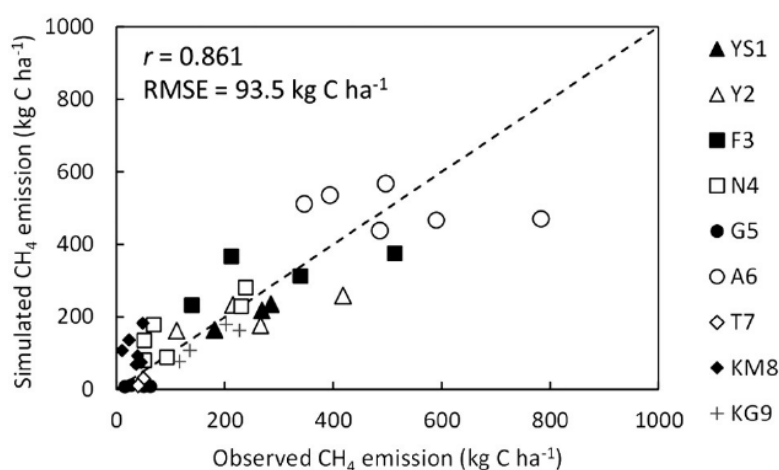


Figure 5-6 Comparison of annual methane emission between values observed and values simulated by the DNDC-Rice model

Source: Quoted from Figure 3 in Katayanagi et al. (2016) (Reference 71)

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 discussed in the Agriculture Breakout Group on the Committee of GHG Emission Estimation Methods.

e) *Category-specific Recalculations*

There have been no source-specific recalculations.

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. Rainfed & Deep Water and Other (3.C.2., 3.C.3., 3.C.4.)

As indicated in the *World Rice Statistics 1993–94*, IRRI (International Rice Research Institute), rainfed and deep water paddy fields do not exist in Japan. Therefore, this category has been reported as “NO”.

Just as indicated in the *World Rice Statistics 1993-94*, IRRI, a possible source of emissions for other paddy field is upland rice field, but since upland rice field are not flooded, like the soil of fields, they are aerobic. The bacteria that generate CH₄ are obligatory anaerobic bacterium, and unless the soil is maintained in an anaerobic state, CH₄ will not be emitted. As generation of CH₄ is not feasible, this category was reported as “NA”.

5.5. Agricultural Soils (3.D.)

This section provides the estimation methods for N₂O direct emissions from soils (by applied inorganic fertilizers, organic fertilizers, grazing livestock manure, crop residue, mineralization by soil carbon loss, and plowing of organic soil), and for N₂O indirect emissions (by atmospheric deposition, and nitrogen leaching and run-off).

N₂O emissions from agricultural soils in FY2017 are 5,408 kt-CO₂ eq., comprising 0.4% of total emissions (excluding LULUCF). The value represents a reduction by 24.0% 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.

Table 5-44 N₂O emissions from agricultural soils

Gas	Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017		
N ₂ O	3.D.a. Direct emission	1. Inorganic N fertilizers	kt-N ₂ O	6.2	5.3	5.0	4.8	3.7	3.6	4.2	4.0	4.1	4.2	4.1	4.1	4.1		
		2. Organic N fertilizers		5.3	5.1	4.8	4.3	4.5	4.2	4.3	4.2	4.2	4.2	4.3	4.3	4.3	4.3	
		3. Manure by grazing animal		0.2	0.2	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
		4. Residues		2.4	2.3	2.5	2.3	2.2	2.0	2.0	2.0	2.0	2.0	2.0	1.9	1.9	1.9	1.9
		5. Mineralization		1.4	1.3	1.3	1.3	1.3	1.3	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2	1.2
		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.b. Indirect emission	1. Atmospheric deposition	2.7	2.5	2.3	2.2	2.0	1.9	2.1	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	
		2. N leaching and run-off	5.4	5.1	4.8	4.5	4.2	4.0	4.2	4.2	4.2	4.2	4.2	4.2	4.1	4.1	4.1	
	Total		kt-N ₂ O	23.9	22.2	21.3	19.9	18.3	17.5	18.6	18.2	18.3	18.4	18.2	18.2	18.1	18.1	
			kt-CO ₂ eq	7,121	6,604	6,344	5,936	5,468	5,228	5,552	5,436	5,439	5,494	5,433	5,426	5,388	5,408	

5.5.1. Direct Soil Emissions (3.D.a.)

Application of inorganic fertilizers, organic fertilizers, and grazing livestock manure, or plowing of crop residues into soil generates ammonium ions in the soil. The soil emits N₂O in the process of oxidizing the ammonium ions into nitrate-nitrogen under aerobic conditions. N₂O is also emitted via denitrification of nitrate. In addition, N₂O is generated by decomposition of organic matter in mineral soil and plowing of organic soil because of nitrification and denitrification of nitrogen.

5.5.1.1. Inorganic N Fertilizers (3.D.a.1.)

a) Category Description

This section provides the estimation methods for N₂O emissions by the application of inorganic synthetic fertilizers (synthetic fertilizers).

b) Methodological Issues

● Methodology for Estimating Emissions / Removals of GHGs

N₂O emissions were calculated by Tier2 method, using country-specific emission factors in accordance

with decision tree of the 2006 IPCC Guidelines (Vol. 4, p11.9, Fig.11.2).

In addition, estimation method for N₂O emission reduction from agricultural soil using synthetic fertilizer with nitrification inhibitor is also established.

$$E = \sum_{ij} (F_{SNij} \times EF_{1ij}) \times 44 / 28$$

E	: N ₂ O emissions associated with the application of synthetic fertilizer in agricultural soil (crop field) [kg-N ₂ O]
F_{SNij}	: Nitrogen amount of synthetic fertilizer j applied to agricultural soil for crop type i [kg-N]
EF_{1ij}	: Emission factor of synthetic fertilizer j for crop type i [kg-N ₂ O-N/kg-N]
i	: Crop type
j	: Fertilizer type (with or without nitrification inhibitor)

● Emission Factors

Emission factors were established based on actual data measurement conducted in Japan. Emission factors of the application of synthetic fertilizer with nitrification inhibitor were established by multiplying their country-specific emission factor by N₂O reduction rate.

Emission factors for N₂O associated with the application of synthetic fertilizers and organic fertilizers were defined as the same value, because there was no significant difference between emission factors of synthetic fertilizers and organic fertilizers, analyzing data for N₂O emissions from agricultural fields in Japan.

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 N₂O emissions. The emission factor of rice is adopted as a default value within the 2006 IPCC Guidelines and its validity has been internationally confirmed.

N₂O emission reduction rate using synthetic fertilizer with nitrification inhibitor was decided as 26%, the lower limit of N₂O reduction rate using fertilizer with dicyandiamide (26-36%) described in Akiyama et al. (2010) (Reference 76). 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 in paddy rice field, synthetic fertilizer with nitrification inhibitor is never used. Therefore, EF with nitrification inhibitor for paddy rice was not developed.

Table 5-45 N₂O emission factor for synthetic fertilizer to agricultural soil

Crop type	Emission Factor without nitrogen inhibitor [kg-N ₂ O-N/kg-N]	Emission Factor with nitrogen inhibitor [kg-N ₂ O-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)]

Source: Akiyama et al., *Direct N₂O emissions and estimate of N₂O emission factors from Japanese agricultural soils*. (2006) (Reference 77)

Akiyama et al., *Estimations of emission factors for fertilizer-induced direct N₂O emissions from agricultural soils in Japan: Summary of available data* (2006) (Reference 78)

Akiyama et al., *Evaluation of effectiveness of enhanced-efficiency fertilizers as mitigation options for N₂O and NO emissions from agricultural soils: meta-analysis*, *Global Change Biology* (2010) (Reference 76)

● Activity Data

Total nitrogen amount of synthetic fertilizer described in “*Yearbook of Fertilizer Statistics (Pocket Edition)*” (Reference 38) 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 5-46).

In addition, considering emission factors above, 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 by the amounts of synthetic fertilizers applied per unit area for each crop type based on the results of studies (Reference 39) in Japan. Total synthetic fertilizer is apportioned to each crop type in accordance with the corresponding application amount for each crop type.

$$F_{SNi} = (F_T - F_{FRST}) \times \frac{(RA_i \times RF_i \times 10)}{\sum (RA_n \times RF_n \times 10)}$$

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 of crop field for crop type i [ha]

RF_i : Nitrogen amount of synthetic fertilizer per area of crop field for crop type i [kg-N/10a]

RA_n : Area of crop field by each crop type [ha]

RF_n : Nitrogen amount of synthetic fertilizer per area of crop field by each crop type [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 (*Research Report on Methodologies for Quantification of GHG Emission Reduction in FY 2000* (Reference 39)). 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 the 2000 study (Reference 39) were applied uniformly for these crops in all the years.

Because of the influence of the transition of recommended rate of fertilizer application by local governments and other factors, fertilizer application amounts for tea change from year to year. 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) (Reference 52) and the ratio of synthetic fertilizer and organic fertilizer applied to tea according to the 2000 study (Reference 39) 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 5-49). For paddy rice, the data of synthetic fertilizer application amount for each year in “*Yearbook of Fertilizer Statistics (Pocket Edition)*” 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 N fertilizer applied (agricultural soil)" is from surveyed data by MAFF, and 13% which is an average nitrogen content in production from major manufacturers was applied for emission estimation. In addition, since synthetic fertilizer with nitrification inhibitor was not used for paddy rice nor feed crops, they were excluded from estimation.

Table 5-46 Nitrogen amount of synthetic fertilizer applied to soil [t-N]

Item	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total N amount of synthetic N fertilizer	611,955	527,517	487,406	471,190	360,056	350,135	409,590	387,201	396,783	409,918	394,629	394,629	394,629	394,629
N amount of synthetic N fertilizer applied (forest soil)	288	248	229	222	157	165	193	182	187	193	186	186	186	186
N amount of synthetic N fertilizer applied (agricultural soil)	611,667	527,269	487,177	470,968	359,899	349,970	409,397	387,019	396,596	409,725	394,443	394,443	394,443	394,443

* This amount includes synthetic fertilizer with nitrification inhibitor.

Source: Total: *Yearbook of Fertilizer Statistics (Pocket Edition)* (References 38)

Applied to forest: Estimated on the basis of Forestry Agency Survey

Table 5-47 Nitrogen amount of synthetic fertilizer with nitrification inhibitor [t-N]

Item	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
N amount of synthetic N fertilizer with nitrification inhibitor	0	0	4,030	4,290	4,160	5,980	4,940	5,850	5,070	7,800	4,550	5,070	5,070	5,070

Source: Estimated from MAFF data and nitrogen contents (13%)

Table 5-48 Amount of synthetic fertilizers application per area by each type of crop (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

Source: Association for Advancement of Agricultural Science, *Research Report on Methodologies for Quantification of GHG Emission Reduction in FY 2000* (References 39)

Table 5-49 Amount of synthetic fertilizers application per area (rice and tea) [kg-N/10a]

Item	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Amount of synthetic N fertilizers application per area (rice)	9.65	8.71	7.34	6.62	6.47	5.80	5.95	5.93	6.04	6.10	5.97	5.97	5.97	5.97
Amount of synthetic N 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

Source: Rice: *Yearbook of Fertilizer Statistics (Pocket Edition)* (References 38)

Tea: Nonaka (2005) (References 52)

Research Report on Methodologies for Quantification of GHG Emission Reduction in FY 2000 (Reference 39)

Table 5-50 Area of cropping by each type of crop [kha]

Crop type	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Vegetables	620.1	564.4	524.9	476.3	469.5	468.7	465.4	460.4	457.9	453.4	452.1	448.9	444.1	441.7
Paddy rice (for grain)	2,055.0	2,106.0	1,763.0	1,702.0	1,624.0	1,621.0	1,625.0	1,574.0	1,579.0	1,597.0	1,573.0	1,505.0	1,478.0	1,465.0
Fruit	346.3	314.9	286.2	265.4	254.7	250.7	246.9	243.5	240.3	237.0	233.8	230.2	226.7	222.9
Tea	58.5	53.7	50.4	48.7	48.0	47.3	46.8	46.2	45.9	45.4	44.8	44.0	43.1	42.4
Potatoes	115.8	104.4	94.6	86.9	84.9	83.1	82.5	81.0	81.2	79.7	78.3	77.4	77.2	77.2
Pulse	256.6	155.5	191.8	193.9	199.7	197.5	189.0	186.2	180.2	178.5	181.0	187.6	187.7	187.9
Feed crops	1,096.0	1,013.0	1,026.0	1,030.0	1,012.0	1,008.0	1,012.0	1,030.0	1,029.0	1,012.0	1,019.0	1,072.0	1,082.0	1,084.9
Sweet potato	60.6	49.4	43.4	40.8	40.7	40.5	39.7	38.9	38.8	38.6	38.0	36.6	36.0	35.6
Wheat	366.4	210.2	236.6	268.3	265.4	266.2	265.7	271.7	269.5	269.5	272.7	274.4	275.9	273.7
Coarse cereal (incl. buckwheat)	29.6	23.4	38.4	45.9	49.1	47.5	49.7	58.1	62.6	62.9	61.4	59.7	62.2	64.5
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
Industrial crops	142.9	124.5	116.3	110.3	107.5	106.4	104.8	101.9	100.2	98.5	97.8	98.8	99.3	100.3
Tobacco	30.0	26.4	24.0	19.1	16.8	15.8	15.0	13.0	9.0	8.9	8.6	8.3	8.0	7.6
Upland rice	18.9	11.6	7.1	4.5	3.2	3.0	2.9	2.4	2.1	1.7	1.4	1.2	0.9	0.8

Source: Potatoes: MAFF, *Vegetable Production and Shipment Statistics*, Tobacco: Survey of Japan Tobacco Inc., Mulberries: MAFF Survey, Other crops: MAFF, *Statistics of Cultivated and Planted Area* (Note: "Industrial crops" is subtracted the area of "Tobacco" from estimated value from total area of tea, rapa, 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 (31%) described 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 31%.

● *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 Chapter 1. Comparison with Japan's EF and the default EF in the IPCC Guidelines is described in the section 'Emissions factors' above.

e) *Category-specific Recalculations*

There have been no source-specific recalculations.

f) *Category-specific Planned Improvements*

There are no improvement plans.

5.5.1.2. Organic Fertilizer (3.D.a.2.)

a) *Category Description*

This section provides the estimation methods for N₂O emissions by application of organic fertilizer

(livestock and other composting and barnyard manure).

b) Methodological Issues

● Estimation Method

Emissions of N₂O have been calculated by Tier2 method in accordance with decision tree of the 2006 IPCC Guidelines (Vol.4, p.11.9, Fig.11.2).

$$E = \sum_i (N_{ONi} \times EF_{1i}) \times 44 / 28$$

E	: N ₂ O emissions from the application of organic fertilizers to agricultural soils [kg-N ₂ O]
N_{ONi}	: Nitrogen amount of organic fertilizer applied to agricultural soil for crop type i [kg-N]
EF_{1i}	: Emission factor of organic fertilizer for crop type i [kg-N ₂ O-N/kg-N]

● Emission Factors

The same country specific emission factor used for synthetic fertilizer is used. (Table 5-45)

● 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).

$$N_{ON} = N_{AM} + N_{SEW} + N_{FU} + N_{COMPsub} + N_{OOA}$$

N_{ON}	: Nitrogen amount in organic fertilizers applied to soil
N_{AM}	: Nitrogen amount in livestock manure applied to soil
N_{SEW}	: Nitrogen amount in sewage sludge applied to soil
N_{FU}	: Nitrogen amount in human waste applied to soil
$N_{COMPsub}$: Nitrogen amount in composting sub-material applied to soil (rice straw, rice husk, wheat straw)
N_{OOA}	: Nitrogen amount in other organic fertilizers applied to soil (fish residue, soybean oil residue, canola oil residue, etc.)

➤ Nitrogen amount in livestock manure applied to soil (N_{AM})

Amount of nitrogen in livestock manure applied to agricultural soil (N_{AM}) was calculated by subtracting the amount of nitrogen included in grazing cattle manure (N_{PRP}), nitrogen in livestock manure volatilized as N₂O (excluding grazing cattle) (N_{N2O}), nitrogen in manure volatilized as NH₃ and NO_x (excluding grazing cattle) ($N_{NH3+NOx}$), nitrogen eliminated by “incineration” and “purification” ($N_{inc+pur}$), and nitrogen in manure disposed directly as waste ($N_{disposal}$) from the total nitrogen in livestock manure ($N_{Total-AW}$).

$$N_{AM} = N_{Total-AW} - N_{PRP} - N_{N2O} - N_{NH3+NOx} - N_{inc+pur} - N_{disposal}$$

N_{AM}	: Nitrogen amount in livestock manure applied to soil [kg-N]
$N_{Total-AW}$: Total amount of nitrogen excreted by livestock [kg-N]
N_{PRP}	: Amount of nitrogen included in grazing cattle manure [kg-N]
N_{N2O}	: Nitrogen in livestock manure volatilized as N ₂ O (excluding grazing cattle) [kg-N]
$N_{NH3+NOx}$: Nitrogen in manure volatilized as NH ₃ and NO _x (excluding grazing cattle) [kg-NH ₃ -N +

NO_x-N] $N_{inc+pur}$: Nitrogen eliminated by “incineration” and “purification [kg-N] $N_{disposal}$: Amount of nitrogen in manure disposed directly as waste [kg-N]

For the amount of nitrogen included in grazing livestock manure (N_{PRP}), nitrogen in livestock manure volatilized as N₂O (excluding grazing livestock) (N_{N2O}) and nitrogen eliminated by “Incineration” and “Purification ($N_{inc+pur}$), the amount calculated in 3.B. Manure management were used.

Nitrogen in manure disposed directly as waste ($N_{disposal}$) includes manure sent to landfill after treatment (“Treated disposal”) and manure sent directly to landfill without treatment (“Direct final disposal”). The amount of treated disposal manure is negligible and its treatment method is unknown. Therefore, treated disposal manure was included in the calculation of the direct final disposal manure.

The amount of nitrogen in manure disposed directly as waste ($N_{disposal}$) was calculated as equation below.

$\frac{\text{Nitrogen content in livestock manure disposed in the direct final disposal } (N_{disposal})}{= \text{Total amount of direct final disposal and treated final disposal} \times \text{Average nitrogen contents in manure}}$

For the total amounts of direct final disposal and treated disposal, data shown in the *Report of the Research on the State of Wide-range Movement and the Cyclical Use of Wastes* were used. Average nitrogen contents in manure were calculated from total nitrogen amount in manure and total manure amount.

The livestock manure that was not applied to agricultural soils but disposed directly was included in the estimation of “7.2.1. Emissions from Managed Landfill Sites (5.A.1.)”

Table 5-51 Nitrogen amount in livestock manure applied to agricultural soil (N_{AM}) [t-N]

Item	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total nitrogen amount in animal manure ($N_{Total-AW}$)	773,189	738,112	686,632	639,241	629,322	612,550	595,301	585,962	574,067	566,214	559,930	560,858	562,304	565,795
Nitrogen amount in manure for grazing animal (N_{PRP})	13,235	13,100	12,142	11,371	11,185	11,298	10,924	10,934	10,710	10,591	10,190	10,468	10,430	10,592
Amount of N ₂ O-N released from manure (excluding Incineration and Purification) (N_{N2O})	4,578	4,528	4,431	4,840	5,221	5,260	5,095	5,048	4,935	4,832	4,745	4,749	4,739	4,754
Amount of NH ₃ -N and NO _x -N released from manure (excluding grazing animal) ($N_{NH3+N_{NOx}}$)	265,769	253,031	229,586	199,629	188,252	179,992	174,691	170,698	166,567	165,228	164,398	164,961	166,070	168,218
Nitrogen eliminated by Incineration and purification ($N_{inc+pur}$)	68,702	60,012	60,437	75,297	86,818	87,582	86,437	85,283	85,141	84,320	83,799	83,482	83,793	83,117
Nitrogen amount in manure disposed directly as waste ($N_{disposal}$)	312	299	270	250	255	320	237	241	280	289	297	285	293	281
Nitrogen amount in livestock manure applied to agricultural soil (N_{AM})	420,594	407,142	379,767	347,854	337,592	328,099	317,917	313,758	306,433	300,954	296,501	296,913	296,978	298,834

➤ **Nitrogen amount in sewage sludge applied to soil (N_{SEW})**

Nitrogen amount in sewage sludge applied to soil (N_{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 (N_{FU})**

Nitrogen amount of human waste (N_{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 ($N_{COMPsub}$)**

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 5-59).

➤ **Nitrogen amount in other organic fertilizers applied to soil (N_{OOA})**

Nitrogen amount in other organic fertilizers (fish residue, soybean oil residue, canola oil residue, etc.) applied to soil (N_{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 5-52 Amount of sludge and other organic fertilizer [kt]

Item	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Animal derived Fertilizers	384.1	389.4	341.0	262.7	291.9	271.2	268.3	259.8	302.6	298.3	268.2	268.2	268.2	268.2
Fish residue	111.5	88.6	89.0	73.9	81.6	70.0	62.2	52.1	55.4	60.0	51.7	51.7	51.7	51.7
Bone meal	113.1	134.2	112.8	11.4	20.6	21.3	16.7	17.6	19.4	16.2	18.5	18.5	18.5	18.5
Other animal derived	159.5	166.6	139.2	177.5	189.7	179.9	189.4	190.1	227.7	222.1	198.1	198.1	198.1	198.1
Plant derived fertilizers	635.9	725.7	982.4	494.8	972.1	643.2	1,064.3	1,190.9	1,079.2	1,203.7	1,455.4	1,455.4	1,455.4	1,455.4
Soybean oil residue	3.5	4.7	28.9	1.1	41.0	36.1	209.5	138.5	134.4	167.7	265.0	265.0	265.0	265.0
Canola oil residue	451.0	437.2	620.7	241.0	299.9	228.0	221.4	396.3	347.9	288.4	399.5	399.5	399.5	399.5
Other plant derived	181.4	283.8	332.8	252.7	631.2	379.1	633.5	656.1	596.9	747.6	790.9	790.9	790.9	790.9
Sludge	787.3	935.2	817.7	1,287.4	1,377.1	1,295.0	1,395.6	1,361.5	1,329.3	1,355.5	1,292.9	1,292.9	1,292.9	1,292.9

Source: Yearbook of Fertilizer Statistics (Pocket Edition) (References 38)

Table 5-53 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%

Source: Other than sludge: Yearbook of Fertilizer Statistics (Pocket Edition) (References 38),

Sludge: Established from Japan Sewage Works Association data (References 40)

Table 5-54 Nitrogen amount in organic fertilizers applied to agricultural soil [t-N]

Item	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
From livestock manure (N_{AM})	420,594	407,142	379,767	347,854	337,592	328,099	317,917	313,758	306,433	300,954	296,501	296,913	296,978	298,834
From sewage sludge (N_{SEW})	21,257	25,250	22,078	34,760	37,183	34,965	37,682	36,759	35,892	36,599	34,907	34,907	34,907	34,907
From human waste (N_{FU})	10,394	4,747	2,116	874	1,702	457	427	369	351	286	273	231	204	204
From composting sub-material ($N_{COMPsub}$)	18,316	15,514	11,485	11,217	9,927	9,270	8,864	8,443	8,803	8,879	7,700	6,816	6,774	6,797
From other organic fertilizers (N_{OOA})	57,128	60,790	71,314	43,685	69,006	51,743	76,006	79,927	77,593	83,796	96,378	96,378	96,378	96,378
Total (Nitrogen amount applied to agricultural soil as organic N fertilizer) (N_{ON})	527,688	513,443	486,760	438,391	455,410	424,533	440,897	439,256	429,072	430,514	435,758	435,245	435,241	437,119

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

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

N_{ONi} : Nitrogen amount of organic fertilizer applied to agricultural soil for crop type i [t-N]

N_{ON} : Total nitrogen amount in organic fertilizers applied to agricultural soil [t-N]

RA_i : Area of crop field for crop type i [ha]

RF_i : Nitrogen amount of organic fertilizer per area of crop field for crop type i [kg-N/10a]

RA_n : Area of crop field by each crop type [ha]

RF_n : Nitrogen amount of organic fertilizer per area of crop field by each crop type [kg-N/10a]

For nitrogen amount of 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) (Reference 52) and the ratio of synthetic fertilizer and organic fertilizer applied to tea according to the 2000 study (Reference 39) were used to estimate the amounts of organic fertilizer applied and time-series data were prepared (see Table 5-49). Organic fertilizer application amount per unit area by each crop type except tea is based on the data on the survey in 2000 (reference 39) as same as synthetic fertilizer. Cultivated area by each crop type is same as synthetic fertilizers.

Table 5-55 Amount of nitrogen as organic fertilizers application per area for tea [kg-N/10a]

Item	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Amount of 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

Source: Total amount of synthetic and organic fertilizers: Nonaka (2005) (Reference 52)

Research Report on Methodologies for Quantification of GHG Emission Reduction in FY 2000 (Reference 39)

Table 5-56 Amount of nitrogen as organic fertilizers application per area by each type of crop (excluding 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

*The value of paddy rice was substituted for upland rice.

Source: *Research Report on Methodologies for Quantification of GHG Emission Reduction in FY 2000* (Reference 39)

c) Uncertainties and Time-series Consistency

● Uncertainties

For the emission factors, uncertainty (31%) described in the reference of EFs, Akiyama et al. (2006), was applied. For activity data for livestock manure, 9% for population of broiler given in the *Livestock Statistics* was applied as substitution. For activity data for others, 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 32%.

- ***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 Chapter 1.

e) Category-specific Recalculations

Since the calculation method of amount of excretion and nitrogen content in excretion for dairy cattle have been revised, the emissions for dairy cattle for the whole time-series were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

The same emission factor has been used for inorganic and organic fertilizers. Thus, the possibility to establish separate emission factors for these two types of fertilizer is under consideration.

5.5.1.3. Urine and dung deposited by grazing animals (3.D.a.3.)

a) Category Description

This section provides the estimation methods for N₂O emissions from urine and dung deposited by grazing animals.

b) Methodological Issues

The method for calculating CH₄ and N₂O 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.a.4.)

a) Category Description

This section provides the estimation methods for N₂O emissions by crop residue plowed into soil.

b) Methodological Issues

- ***Estimation Method***

Basically, the N₂O emissions were calculated by using the *2006 IPCC Guidelines*. For Emission factors, default EF described in the *2006 IPCC Guidelines* 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*.

$$E = EF \times A \times 44/28$$

E	: N ₂ O emissions for crop residue [kg-N ₂ O]
EF	: N ₂ O EF for crop residue [kg-N ₂ O-N/kg-N]
A	: Nitrogen amount plowed into soils as crop residue [kg-N]

- **Emission Factors**

0.01 [kg-N₂O-N/kg-N] (Default, 2006 IPCC Guidelines)

- **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 calculated from each prefecture data was used. The nitrogen content of this crop was calculated by multiplying the aforementioned data by nitrogen content in crop residue (kg-N/t) calculated from Date (1988, Reference 53). In addition, below-ground were calculated from production, dry matter fraction of harvested product, ratio of below-ground residues to production, N content of below-ground residues. For the ratio of below-ground residues to production ($Frac_{BGR-P}$), 27% indicated by Ogawa K. et al. (1988, Reference 54) was used. For dry matter fraction of harvested product (DRY), 0.89 of default value indicated in the 2006 IPCC Guidelines was used.

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

A_{Rice}	: Nitrogen amount plowed into soils as crop residue [t-N] (Rice)
$Residue$: Amount plowed into soils as crop residue (rice straw and chaff) [t]
N_{AG}	: N contents of above-ground residues [kg-N/kg]
P	: Production amount of rice [t]
DRY	: Dry matter fraction of harvested product
$Frac_{BGR-P}$: Ratio of below-ground residues to production 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 plowed into soils as crop residue [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]
$Area$: Cultivated area of tea [ha]

Table 5-57 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) (Reference 55), Kinoshita et al. (2005) (Reference 56), Tachibana et al. (1996) (Reference 57)
Medium pruning	Once in five years	19.4	Ohta et al. (1996) (Reference 58)
Leaf fall	Annual	11.5	Hoshina et al.(1982) (Reference 55)

➤ **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 production calculated from Matsumoto (2000, Reference 59) by annual crop production (by MAFF, *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* (Reference 30) was used for sugar beets, potato, Japanese radish and onion, and the data of Owa (1996) (Reference 60) 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 production, the value for a similar type of crop was used. The same values were adopted for all fiscal years.

$$A_{Vegetable} = P \times (1 - Frac_{Remove} - Frac_{burnt} \times CF) \times N_R$$

$A_{Vegetable}$: Nitrogen amount plowed into soils as crop residue (Vegetables, Sugarcane, Sugarbeet) [t-N]
P	: Production amount [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 5-58 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 (R_{BG-BIO}) for main crops

Crop type	Fraction of above-ground residue removed (Frac _{Remove})	Fraction burnt on field (Frac _{burnt})	Combustion factor (CF)	Ratio of above-ground residues (R _{BG-BIO})
Vegetables	47%	7%	0.80 ^{*4}	-
Sugarbeet	47% ^{*1}	7% ^{*1}	0.80 ^{*4}	-
Sugarcane	47% ^{*1}	7% ^{*1}	0.80 ^{*4}	-
Green manure crops	0% ^{*2}	0% ^{*2}	-	Non-legume hay:0.80 Sorghum: 0.24 ^{*9}
Feed crops	100% ^{*3}	0% ^{*3}	-	
Wheat, barley, rye and oats	Table 5-60	Table 5-60	0.90 ^{*5}	Wheat: 0.24 Barley: 0.22 Rye: 0.25 ^{*10} Oats: 0.25
Pulse	13%	12%	0.80 ^{*4}	0.19 ^{*6}
Maize, tubers and roots, other crops	47% ^{*1}	7% ^{*1}	0.80 ^{*4}	Maize: 0.22 Tubers and roots: 0.20 ^{*7} Other crops: 0.22 ^{*8}

(Reference) Frac_{Remove(T)}, Frac_{burnt(T)}: Research Council on Soil Function for Global Warming Countermeasures, "Survey of Greenhouse Gas Emissions from Soils and Soil Carbon Sequestration" (Reference 37)
CF, R_{BG-BIO(T)}: 2006 IPCC Guidelines

*1: Value of vegetables, *2: all residue are plowed into soil, *3: all above-ground biomass removed as for feed, *4: Value of maize and/or sugarcane, *5: Value of wheat, *6: Value of Soybean, *7: Value of potato, *8: Value of grains, *9: Average value between maize and oats, *10: Substituted by oats

Table 5-59 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% ^e Chaff: 0.423% ^e	-	Wet weight
Rice (below ground)	-	0.9% ^{z*3}	Dry weight
Vegetables	Japanese radish: 0.093% ^{b,d} Chinese cabbage: 0.071% ^d Cabbage: 0.183% ^a Lettuce: 0.164% ^d Onion: 0.019% ^{b,d}		Wet weight
Sugar beet		0.095% ^{b,d}	
Sugarcane		0.548% ^c	
Green manure crops and Feed crops	Non-legume hay: 1.5% ^z Sorghum: 0.7% ^z	Non-legume hay: 1.2% ^z Sorghum: 0.6% ^z	
Wheat	0.43% ^a	0.9% ^z	
Barley	Two-row: 2.14% ^a Six-row: 0.31% ^a	1.4% ^z	Dry weight
Rye	0.50% ^z	1.1% ^z	
Oats	0.70% ^z	0.8% ^z	
Maize	1.64% ^a	0.7% ^z	
Soybean	0.65% ^a	0.8% ^z	
Adzuki beans	0.84% ^a	1.0% ^{z*1}	
Potatoes	2.42% ^a	1.4% ^{z*2}	

<Reference>

a: Matsumoto N., *Development of Estimation Method and Evaluation of Nitrogen Flow in Regional Areas* (2000) (Reference 59)

b: Hokkaido Government, *Hokkaido Fertilizer Recommendations 2010*. (2010) (Reference 30)

c: *Document of Kagoshima prefectural Institute for Agricultural Development*

d: Owa N., *New Trends in Technology for Efficient Use of Nutrients – Nutritional Balance of Crops in Japan* (1996) (Reference 60)

e: Date N., "Handbook for Organic Fertilizers and Microbial Materials", 1988 (Reference 53)

z: 2006 IPCC Guidelines

*1: Substituted by dry bean, *2: Substituted by potato

*3: Substituted by wheat

➤ **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 5-58 and Table 5-59 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 5-60. 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.

$$A = \sum_T \left\{ \left[AG_{DM(T)} \times N_{AG(T)} \times (1 - Frac_{Remove(T)}) + (Area_{(T)} - Area_{burnt(T)} \times CF) \times Frac_{Renew(T)} \times (AG_{DM(T)} \times 1000 + Crop_{(T)}) \times R_{BG-BIO(T)} \times N_{BG(T)} \right] \right\}$$

$$Area_{burnt(T)} = Area(T) \times Frac_{burnt(T)}$$

A	: Nitrogen amount plowed into soils as crop residue [t-N]
$Area_{(T)}$: Crop area of crop T [ha]
$Area_{burnt(T)}$: Crop 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 production of crop T [kg/ha]
$R_{BG-BIO(T)}$: 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 5-60 Proportion removed from field and burned in field for wheat, barley, rye and oats [%]

Item	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Proportion removed from field	32.1	32.1	32.1	32.1	34.0	35.9	37.8	39.8	40.2	41.0	41.0	37.9	40.2	38.5
Proportion burned in field	13.5	13.5	13.5	13.5	12.5	11.6	10.6	9.5	9.2	8.8	8.3	8.0	7.7	7.7

*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 Chapter 1.

At the Break Out 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 data for rice straw and rice chaff plowed into soil in FY2015 and 2016 were updated, the emissions in FY2015 and 2016 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.a.5.)**a) Category Description**

This section estimates N₂O emissions by nitrogen mineralization in loss of carbon oxidized by organic matter in mineral soil.

b) Methodological Issues**● Estimation Method**

When using the estimation method in the *2006 IPCC Guidelines*, amount of carbon loss in organic matter in mineral soil, which is a part of activity data, cannot be figured out in Japan. Therefore, it was calculated by country-specific method by using the cultivation area of a mineral soil, and the N₂O emission per area (background N₂O emission of agricultural land).

$$E = EF \times A \times 44/28$$

<i>E</i>	: N ₂ O emissions by mineralization of nitrogen in mineral soils [kg-N ₂ O]
<i>EF</i>	: N ₂ O emission factor by mineralization of nitrogen in mineral soils per ha [kg-N ₂ O-N/ha]
<i>A</i>	: Area of plowed mineral soil [ha]

● Emission Factors

N₂O emission factor of background in agricultural soils in Japan (0.65 kgN₂O-N/ha) indicated by Akiyama et al. (2006, Reference 78), which is the scientific paper used in “5.5.1.1. Inorganic N Fertilizers (3.D.a.1.)”, was used as basis of EF, and N₂O emissions by atmospheric deposition and crop residue were subtracted from the background EF.

Nitrogen amount deposited as NH₃+NO_x on agricultural soils in Japan is decided by expert judgment

on the basis of domestic case studies as 10kgN/ha. For nitrogen amount plowed into soils as crop residue per area, 32kgN/ha calculated in “5.5.1.4. Crop Residues (3.D.a.4.)” above are used. 0.10kgN₂O-N/ha + 0.32kgN₂O-N/ha (emission factors are 1% of atmospheric deposition amount and 1% of crop residue) which were emitted from its deposition and crop residue plowed into soil were subtracted as double counting from background EF. Finally, 0.23 (=0.65 -0.10 -0.32) kgN₂O-N/ha was used as the corrected emission factor.

● *Activity Data*

The area of plowed mineral soil was established by multiplying the cultivated areas of paddy fields and common upland fields, obtained from the *Statistics of Cultivated and Planted Area* (MAFF), by the percentage of organic soils (peat soil and muck soil) in paddy fields and common upland fields in Japan. Lands of mineral soil converted to paddy field and upland field are estimated in LULUCF sector. For detail, see estimation method described in LULUCF sector (6.6.1 b) 2) “Activity Data” below).

Table 5-61 Intended areas of mineral soil in Agriculture sector [kha]

Item	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Intended paddy field	2,612	2,549	2,469	2,386	2,344	2,334	2,325	2,303	2,295	2,288	2,279	2,268	2,252	2,236
Intended upland field	1,162	1,117	1,095	1,112	1,123	1,127	1,131	1,128	1,128	1,126	1,122	1,117	1,115	1,107

c) *Uncertainties and Time-series Consistency*

● *Uncertainties*

For the emission factors, uncertainty (31%) described 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 31%.

● *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 Chapter 1.

e) *Category-specific Recalculations*

Since the estimation method for mineral soil area associated with land use conversion in LULUCF sector was changed, the emissions for whole time-series were recalculated. See Chapter 10 for impact on trend.

f) *Category-specific Planned Improvements*

It is planned to discuss the subtraction method for double count of N₂O emissions from the EF of Akiyama et al. (2006)

5.5.1.6. Plowing of Organic Soil (3.D.a.6.)

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 N₂O 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 : N₂O emission associated with the plowing of organic soil [kg-N₂O]

EF : N₂O emission factor for plowing of organic soil [kg-N₂O-N/ha]

A : Area of plowed organic soil [ha]

● Emission Factors

For paddy cultivation in organic soils, it is known that N₂O emission in paddy field is lower than the one in upland field. In Japan, Nagata (2006, Reference 61) observed N₂O emissions for paddy 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-N₂O-N/ha/year] by deducting emission for applied fertilizer (estimated from country-specific emission factor of fertilizers (0.31% [kg-N₂O-N/kg-N]) indicated in Table 5-45 above). For the upland field of organic soil, some observation results exist (Nagata 2006, Nagata (2009, Reference 62)), but there is not much difference from the default of temperate region (8 [kg-N₂O-N/ha/year]) indicated in 2006 IPCC Guidelines. Therefore, default value is used for upland field. For grassland, same default value (8 [kg-N₂O-N/ha/year]) is used.

● Activity Data

For the area of plowed organic soil, same method indicated in “5.5.1.5. Mineralization/Immobilization Associated with Loss/Gain of Soil Organic Matter (3.D.a.5.)” above was used.

For annual renewal ratio of grassland, a report of a study result by Hatano (2017, Reference 63) 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 because of no survey for the period. The averages from 2006 to 2010 were used for 2016. Annual plowed area is calculated by multiplying the annual renewal ratios by organic soil areas of grassland.

Table 5-62 Annual renewal ratio of grassland

	Before 2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	After 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%

Note: Hatano (2017) “Survey on actual situation of grassland management for feed” (Reference 63)

Table 5-63 Intended areas of organic soil in the agriculture sector [kha]

Item	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Intended paddy field	161.9	161.3	160.6	159.9	159.7	159.7	159.6	159.5	159.7	160.0	160.2	160.2	160.2	160.4
Intended upland field	24.7	24.4	24.2	24.0	24.0	24.0	23.9	23.9	23.9	23.9	23.9	23.9	23.9	24.0
Intended grassland (Hokkaido)	1.2	1.2	1.2	1.2	1.2	1.5	1.2	1.4	1.5	1.3	1.6	1.7	1.2	1.2
Intended grassland (other area)	0.005	0.004	0.004	0.004	0.003	0.004	0.006	0.010	0.043	0.026	0.014	0.009	0.004	0.003

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 Chapter 1.

e) *Category-specific Recalculations*

Since the estimation method for organic soil area associated with land use conversion in LULUCF sector was changed, the emission from all years were recalculated. See Chapter 10 for impact on trend.

f) *Category-specific Planned Improvements*

No improvement plans.

5.5.2. Indirect Emissions (3.D.b.)

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 N₂O generated by microbe activity on the deposited nitrogen compounds was calculated.

N₂O 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.b.1.)

a) *Category Description*

This section provides the estimation methods for N₂O indirect emissions caused by atmospheric

deposition of nitrogen compounds volatilized as NH₃ and NO_x from synthetic fertilizers applied to soil, organic fertilizers applied to soil, and the grazing livestock manure applied to soil.

b) Methodological Issues

● Estimation Method

N₂O emissions have been calculated in accordance with decision tree of the 2006 IPCC Guidelines (Vol. 4, Page 11.20, Fig11.3).

$$E = EF \times A \times 44/28$$

<i>E</i>	: N ₂ O emissions from atmospheric deposition [kg-N ₂ O]
<i>EF</i>	: N ₂ O Emission factor for atmospheric deposition [kg-N ₂ O-N/ kg-NH ₃ -N+NO _x -N volatilized]
<i>A</i>	: Total nitrogen amount volatilized as NH ₃ and NO _x from synthetic fertilizers, organic fertilizers, and grazing livestock manure [kg-NH ₃ -N+NO _x -N]

● Emission Factors

0.01 [kg-N₂O-N/kg-NH₃-N & NO_x-N volatilized] (default value, 2006 IPCC Guidelines, Vol.4 Table11.3).

● Activity Data

As described in the following equation, the activity data are composed of the “nitrogen amount volatilized as NH₃ and NO_x from inorganic fertilizers applied to soil, organic fertilizers applied to soil, and the grazing livestock manure applied to soil. The “nitrogen amount volatilized NH₃ and NO_x in process of livestock manure management” are reported in 3.B.5.

$$A = N_{FERT} \times Frac_{GASF} + N_{ON} \times Frac_{GASM3} + N_{PRP} \times Frac_{GASM4}$$

<i>A</i>	: Total N amount volatilized as NH ₃ and NO _x from synthetic fertilizers, organic fertilizers, and grazing livestock manure [kg-NH ₃ -N+NO _x -N]
<i>N_{FERT}</i>	: N amount for inorganic fertilizers applied to agricultural soil [kg-N]
<i>Frac_{GASF}</i>	: Percentage of volatilization as NH ₃ and NO _x from inorganic fertilizers applied to agricultural soil [(kg-NH ₃ -N + NO _x -N)/kg-N]
<i>N_{ON}</i>	: N amount for organic fertilizers applied to agricultural soil [kg-N]
<i>Frac_{GASM3}</i>	: Percentage of volatilization as NH ₃ and NO _x from nitrogen contained in livestock manure and human waste applied to agricultural soils [(kg-NH ₃ -N + NO _x -N)/kg-N]
<i>N_{PRP}</i>	: N amount in grazing livestock manure [kg-N]
<i>Frac_{GASM4}</i>	: Fraction of volatilization as NH ₃ and NO _x from livestock manure during treatment [(kg-NH ₃ -N + NO _x -N)/kg-N]

➤ N amount volatilized as NH₃ and NO_x from inorganic fertilizers applied to soil (N_{FERT} × Frac_{GASF})

“N amount of synthetic fertilizer applied to agricultural soil (in Table 5-46)” calculated in the Inorganic N Fertilizers (3.D.a.1.) was used for the amount of fertilized nitrogen (N_{FERT}), and the default value, indicated in Table 5-64, given in the 2006 IPCC Guidelines was used for the percentage of volatilization (Frac_{GASF}).

Table 5-64 Proportion of nitrogen volatilized from synthetic fertilizers and organic fertilizers as ammonia

or nitrogen oxides

	Value	Unit
Frac _{GASF}	0.10	kg-NH ₃ -N + NO _x -N/kg of synthetic fertilizer nitrogen applied
Frac _{GASM}	0.20	kg-NH ₃ -N + NO _x -N/kg of nitrogen excreted by livestock

Source: 2006 IPCC Guidelines Vol. 4, Table 11.3

➤ *N amount volatilized as NH₃ and NO_x from organic fertilizers applied to agricultural soil (N_{ON}×Frac_{GASM3})*

For nitrogen amount in organic fertilizers applied to agricultural soil (N_{ON}), the data described in the “Organic N Fertilizers (3.D.a.2.)” were used. For proportion of nitrogen volatilized as NH₃ and NO_x (Frac_{GASM3}), default value (Frac_{GASM}=0.20) of the 2006 IPCC Guidelines indicated in Table 5-64 above was used.

➤ *N amount volatilized as NH₃ and NO_x from grazing livestock manure (N_{PRP}×Frac_{GASM4})*

For the nitrogen amount in grazing livestock manure (N_{PRP}), the calculated data in 3.B. were used. For proportion of nitrogen volatilized as NH₃ and NO_x (Frac_{GASM4}), default value (Frac_{GASM}=0.20) of the 2006 IPCC Guidelines indicated in Table 5-64 was used.

Table 5-65 Amount of nitrogen that volatilizes as ammonia and nitrogen oxides from synthetic fertilizers, livestock manure, and human waste [t (NH₃-N+NO_x-N)]

Item	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
From inorganic N fertilizers applied to soil (N _{FERT} ×Frac _{GASF})	61,167	52,727	48,718	47,097	35,990	34,997	40,940	38,702	39,660	40,973	39,444	39,444	39,444	39,444
From organic N fertilizers (N _{ON} ×Frac _{GASM3})	105,538	102,689	97,352	87,678	91,082	84,907	88,179	87,851	85,814	86,103	87,152	87,049	87,048	87,424
From grazing livestock manure (N _{PRP} ×Frac _{GASM4})	2,647	2,620	2,428	2,274	2,237	2,260	2,185	2,187	2,142	2,118	2,038	2,094	2,086	2,118
Total (nitrogen amount volatilized as ammonia and nitrogen oxides (A))	169,351	158,035	148,498	137,049	129,309	122,163	131,304	128,740	127,616	129,194	128,634	128,587	128,579	128,987

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 Chapter 1.

e) Category-specific Recalculations

Since the calculation method of amount of excretion and nitrogen content in excretion for dairy cattle have been revised, the emissions for dairy cattle 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 ratios of volatile nitrogen compounds has been conducted.

5.5.2.2. Nitrogen Leaching and Run-off (3.D.b.2.)

a) Category Description

This section provides the estimation methods for N₂O emissions from Nitrogen Leaching and Run-off.

b) Methodological Issues

● **Estimation Method**

N₂O emissions were calculated according to the decision tree in the *2006 IPCC Guidelines* (Vol. 4, Page 11.20, 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 ₂ O emissions from N leaching and run-off [kg-N ₂ O]
EF	: N ₂ O Emission factor for N leaching and run-off [kg-N ₂ O-N/kg-N]
A	: Total nitrogen amount for N leaching and run-off from synthetic fertilizers, organic fertilizers, etc. [kg-N]

● **Emission Factors**

0.0075 [kg-N₂O-N/kg-N] (default value, *2006 IPCC Guidelines*).

● **Activity Data**

As described the formula below, activity data was composed of each nitrogen amount of leaching and run-off by synthetic fertilizers, organic fertilizers, grazing livestock manure, crop residue, and carbon loss by mineralization. Each AD was calculated by multiplying the default value of proportion of leaching and run-off given in the *2006 IPCC Guidelines* (0.30 [kg-N/kg-N]) by the amount of nitrogen calculated in 3.D.a.1. to 3.D.a.5. above.

$$A = (N_{FERT} + N_{ON} + N_{PRP} + N_{CR} + N_{SOM}) \times Frac_{LEACH}$$

A	: Total nitrogen amount for N leaching and run-off from inorganic fertilizers, organic fertilizers, etc. [kg-N]
N_{FERT}	: Nitrogen amount in inorganic fertilizers applied to agricultural soil [kg-N]
N_{ON}	: Nitrogen amount in organic fertilizers applied to agricultural soil [kg-N]
N_{PRP}	: Nitrogen amount in grazing livestock manure [kg-N]
N_{CR}	: Nitrogen amount in crop residue plowed into soil [kg-N]
N_{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] (=0.30) (default value in the <i>2006 IPCC Guidelines</i> (Vol.4 Table 11.3))

Table 5-66 Total nitrogen amount for N leaching and run-off from synthetic fertilizers, organic fertilizers, etc. [t (NH₃-N+NO_x-N)]

Item	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
From inorganic N fertilizers applied to soil ($N_{\text{FERT}} \times \text{Frac}_{\text{LEACH}}$)	183,500	158,181	146,153	141,291	107,970	104,991	122,819	116,106	118,979	122,918	118,333	118,333	118,333	118,333
From organic N fertilizers ($N_{\text{ON}} \times \text{Frac}_{\text{LEACH}}$)	158,306	154,033	146,028	131,517	136,623	127,360	132,269	131,777	128,722	129,154	130,728	130,573	130,572	131,136
From grazing livestock manure ($N_{\text{PRP}} \times \text{Frac}_{\text{LEACH}}$)	3,971	3,930	3,642	3,411	3,355	3,389	3,277	3,280	3,213	3,177	3,057	3,140	3,129	3,178
From crop residue ($N_{\text{CR}} \times \text{Frac}_{\text{LEACH}}$)	45,299	44,717	47,719	43,955	41,525	38,834	37,750	37,521	38,290	38,276	37,328	36,916	35,332	36,160
From mineralization ($N_{\text{SOM}} \times \text{Frac}_{\text{LEACH}}$)	71,075	69,165	67,138	65,483	64,686	64,500	64,334	63,815	63,645	63,457	63,222	62,914	62,537	62,089
Total (nitrogen amount by leaching and run-off) (A)	462,151	430,026	410,680	385,657	354,159	339,075	360,449	352,499	352,848	356,982	352,667	351,877	349,903	350,895

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 Chapter 1.

e) Category-specific Recalculations

Since the calculation method of amount of excretion and nitrogen content in excretion for dairy cattle have been revised, the 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 Savannas (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 CH₄ and N₂O into the atmosphere. CH₄ and N₂O

emissions from this source are calculated and reported in this category.

CH₄ and N₂O emissions from Field Burning of Agricultural Residues in FY2017 are 67 kt-CO₂ eq. and 21 kt-CO₂ eq., comprising 0.005% and 0.002% of total emissions (excluding LULUCF), respectively. The value represents a reduction by 47.3% and 47.3% for CH₄ and N₂O from FY1990, respectively.

Table 5-67 CH₄ and N₂O emissions from field burning of agriculture residues

Gas	Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017		
CH ₄	3.F.1. Cereals	Wheat	kt-CH ₄	0.38	0.22	0.27	0.31	0.28	0.26	0.24	0.22	0.21	0.20	0.19	0.18	0.18		
		Barley		0.15	0.09	0.08	0.08	0.08	0.07	0.07	0.06	0.06	0.06	0.05	0.05	0.05	0.05	
		Maize		0.08	0.07	0.06	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.04
		Rice		1.96	2.05	1.38	1.03	0.76	0.71	0.70	0.70	0.66	0.75	0.68	0.56	0.57	0.57	
		Other cereals		0.06	0.05	0.08	0.09	0.09	0.09	0.09	0.11	0.12	0.12	0.12	0.12	0.11	0.12	0.12
	3.F.2. Pulses	Soybeans		0.47	0.22	0.40	0.43	0.48	0.47	0.45	0.44	0.42	0.42	0.42	0.43	0.46	0.49	0.49
		Other pulses		0.35	0.27	0.22	0.19	0.17	0.16	0.16	0.16	0.15	0.16	0.16	0.16	0.14	0.12	0.12
	3.F.3. Tubers and roots	Potatoes		0.23	0.20	0.18	0.17	0.17	0.16	0.16	0.16	0.16	0.16	0.16	0.15	0.15	0.15	0.15
		Sugarbeet		0.14	0.14	0.14	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.12	0.11
		Other tubers and roots		0.20	0.17	0.15	0.13	0.13	0.13	0.12	0.12	0.12	0.12	0.12	0.11	0.11	0.11	0.11
	3.F.4.	Sugarcane		0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
	3.F.5.	Vegetables		0.95	0.87	0.81	0.74	0.72	0.72	0.72	0.71	0.71	0.70	0.69	0.69	0.69	0.68	
	Other	Other crops		0.08	0.06	0.05	0.04	0.04	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02
	Total			kt-CH ₄	5.1	4.4	3.8	3.4	3.1	3.0	2.9	2.9	2.8	2.9	2.8	2.7	2.7	2.7
				kt-CO ₂ eq	127	111	96	86	78	76	74	73	71	72	70	67	67	67
N ₂ O	3.F.1. Cereals	Wheat	kt-N ₂ O	0.010	0.006	0.007	0.008	0.007	0.007	0.006	0.006	0.005	0.005	0.005	0.005	0.005	0.005	
		Barley		0.004	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.001	
		Maize		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	0.001	0.001
		Rice		0.051	0.053	0.036	0.027	0.020	0.018	0.018	0.018	0.017	0.019	0.018	0.015	0.015	0.015	
		Other cereals		0.002	0.001	0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
	3.F.2. Pulses	Soybeans		0.012	0.006	0.010	0.011	0.012	0.012	0.012	0.011	0.011	0.011	0.011	0.011	0.012	0.013	0.013
		Other pulses		0.009	0.007	0.006	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.003	0.003
	3.F.3. Tubers and roots	Potatoes		0.006	0.005	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004
		Sugarbeet		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	0.003
		Other tubers and roots		0.005	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
	3.F.4.	Sugarcane		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
	3.F.5.	Vegetables		0.025	0.023	0.021	0.019	0.019	0.019	0.019	0.018	0.018	0.018	0.018	0.018	0.018	0.018	0.018
	Other	Other crops		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	0.001	0.001
	Total			kt-N ₂ O	0.13	0.12	0.10	0.09	0.08	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07
				kt-CO ₂ eq	39	34	30	26	24	23	23	22	22	22	22	21	21	21
Total of all gases			kt-CO ₂ eq	166	145	126	112	102	99	96	95	93	94	92	88	88	88	

b) Methodological Issues

● Estimation Method

CH₄ and N₂O 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 : CH₄ and N₂O emissions from field burning of agriculture residues [t-CH₄ or t-N₂O]

A : Area burnt [ha]

M_B : Mass of fuel available for combustion [t/ha]

C_f : Combustion factor

G_{ef} : Emission factor [g-CH₄/kg or g-N₂O/kg]

● Emission Factors

CH₄: 2.7 [g-CH₄/kg (dry matter)] (default value in the *2006 IPCC Guidelines*)

N₂O: 0.07 [g-N₂O/kg (dry matter)] (default value in the *2006 IPCC Guidelines*)

● Activity Data

Parameters used in estimation are indicated in the Table 5-68 below. For proportion of burned residue and combustion factor, same values to estimate N₂O emissions for crop residue were used. For rice,

since data of the amount of burning rice straw and rice chaff on crop field (Table 5-69) is available, mass of fuel available for combustion (M_B) was not multiplied in estimation.

The proportion 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 calculated from each prefecture data as shown in Table 5-60 above.

Table 5-68 Proportion of burned residue on agricultural field, $M_B \times C_f$ and Combustion factor

Crop	Proportion of burned residue	$M_B \times C_f$	Combustion Factor (C_f)
Rice	---	---	0.80
Pulse	12% *1	10 *3	---
Vegetable, Sugarbeet, Maize, Tuber crops (e.g. potato), Buckwheat, Canola seed, Konjac, Rush grass, Tabaco	7% *2	10 *3	---
Sugarcane	7% *2	6.5	---
Wheat, Barley, Ray, Oats	See Table 5-60	4 *4	---

Reference: Proportion burned: Research Council on Soil Function for Global Warming Countermeasures, "Survey of Greenhouse Gas Emissions from Soils and Soil Carbon Sequestration" (Reference 37)

$M_B \times C_f$: 2006 IPCC Guidelines

*1: value of pulse, *2: value of vegetable, *3: value of maize, *4: value of wheat

For rice, amount of burning rice straw and rice chaff on crop field is surveyed by MAFF (Table 5-69). 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* by MAFF.

Table 5-69 Amount of burning rice straw and rice chaff on crop field [kt]

Item	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Rice straw	438.2	536.9	429.1	276.6	183.9	163.5	149.3	187.0	149.4	183.4	161.7	144.2	152.8	152.8
Rice chaff	581.3	528.3	291.3	260.3	209.9	206.0	212.9	179.2	195.6	206.6	193.9	147.5	142.6	142.6
Total	1,019.5	1,065.2	720.4	536.9	393.8	369.4	362.2	366.2	345.0	390.0	355.6	291.7	295.4	295.4

Source: 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 Chapter 1.

e) Category-specific Recalculations

Since the data for rice straw and rice chaff plowed into soil in FY2015 and 2016 were updated, the emission in FY2015 and 2016 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvement plans.

5.8. Liming (3.G.)

a) Source/Sink Category Description

CO₂ are released into the air by application of limestone (CaCO₃) fertilizer and/or dolomite (CaMg(CO₃)₂) fertilizer via hydrogen carbonate ions (HCO₃⁻) which is released in soil water. This category deals with CO₂ emissions from their agricultural lime application.

CO₂ emissions from this category in FY2017 were 363 kt-CO₂, comprising 0.03 % of total emissions (excluding LULUCF). The value represents a decrease by 34.1% from FY1990.

Table 5-70 CO₂ emissions from agricultural lime application

Gas	Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
CO ₂	3.G.-Limestone	kt-CO ₂	550	303	332	231	304	270	242	246	369	379	362	362	362	362
	3.G.-Dolomite	kt-CO ₂	0.3	0.5	0.5	0.6	1.7	0.6	1.0	1.1	0.6	1.1	1.0	1.0	1.0	1.0
	Total	kt-CO ₂	550	304	333	231	306	270	243	247	370	380	363	363	363	363

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, Figure 11.4).

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

E : Annual CO₂ emissions from agricultural lime application [t-CO₂/yr]

$M_{\text{Limestone}}$: Annual amount of calcic limestone [t/yr]

M_{Dolomite} : Annual amount of dolomite [t/yr]

$EF_{\text{Limestone}}$: Emission factor of calcic limestone [t-C/t]

EF_{Dolomite} : Emission factor of dolomite [t-C/t]

● Emission Factors

Limestone (CaCO₃): 0.12 [t-C/t] (default value, *2006 IPCC Guidelines*).

Dolomite (CaMg(CO₃)₂): 0.13 [t-C/t] (default value, *2006 IPCC Guidelines*).

● Activity Data

➤ Annual amount of limestone and dolomite applied to cropland

These data were calculated by adding up lime production and import quantities as listed in *the Yearbook of Fertilizer Statistics (Pocket Edition)* published by the Association of Agriculture and Forestry Statistics. 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 (CaCO₃), and all of the “Magnesium carbonate fertilizer” and 74% of “Mixed magnesium fertilizer” as dolomite (CaMg(CO₃)₂).

Table 5-71 Amount of limestone and dolomite applied to agricultural soils [kt]

Item	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Applied Limestone	1,250	689	755	524	691	613	550	558	839	860	822	822	822	822
Applied Dolomite	0.7	1.1	1.1	1.4	3.5	1.2	2.0	2.4	1.3	2.2	2.0	2.0	2.0	2.0

Source: Estimated from the data described in “Yearbook of Fertilizer Statistics (Pocket Edition)”

c) Uncertainties and Time-series Consistency

● Uncertainty Assessment

For uncertainty of the emission factor, default values (50%) described in the 2006 IPCC Guidelines was applied. For activity data, 1% for area of paddy fields given in the *Statistics of Cultivated and Planted Area* was applied as substitution. As a result, the uncertainties of the emissions were determined to be 50%.

● Time-series Consistency

Emissions are estimated by using consistent estimation methods and data sources.

d) Source-/Sink-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 Chapter 1.

e) Category-specific Recalculations

There have been no source-specific recalculations.

f) Source-/Sink-specific Planned Improvements

There are no improvement plans.

5.9. Urea application (3.H.)

a) Source/Sink Category Description

CO₂ are released into the air by application of urea ((NH₃)₂CO) fertilizer via hydrogen carbonate ions (HCO₃⁻) which is released in soil water. This category deals with estimation and reporting for this CO₂ emissions. Since estimation of urea production in Japan in Industrial Processes sector includes CO₂ emission in use phase, this category estimates CO₂ emissions from use phase of imported urea fertilizer.

CO₂ emissions from this category in FY2017 were 189 kt-CO₂, comprising 0.01 % of national total emissions (excluding LULUCF). The value represents an increase by 222 % from FY1990.

Table 5-72 CO₂ emissions from urea fertilizer

Gas	Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
CO ₂	3.H. Urea fertilization	kt-CO ₂	59	56	110	179	134	120	160	168	150	198	189	189	189	189

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, 11.33, Figure11.5).

$$E = (M \times EF) \times 44/12$$

E : Annual CO₂ emissions from urea fertilizer [t-CO₂/yr]
M : Annual amount of imported urea fertilizer [t/yr]
EF : Emission factor of urea fertilizer [t-C/t]

- **Emission Factors**

0.20 [t-C/t] (default value, 2006 IPCC Guidelines).

- **Activity Data**

These data were calculated by deducting “amount of domestic urea production for fertilizer” from “total demand of urea fertilizer” described in *the Yearbook of Fertilizer Statistics (Pocket Edition)* published by the Association of Agriculture and Forestry Statistics.

Table 5-73 Amount of imported urea fertilizer [kt]

Item	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Amount of imported urea fertilizer	80	76	149	244	183	164	218	229	205	270	258	258	258	258

Source: 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 Chapter 1.

- e) **Category-specific Recalculations**

There have been no source-specific recalculations.

- f) **Category-specific Planned Improvements**

There are no improvement plans.

5.10. Other carbon-containing fertilizers (3.I.)

Since there are no other sources to be reported in this category, this category is reported as “NO”.

5.11. Other (3.J.)

Since there are no other sources as “Other”, this category is reported as “NO”.

References

1. IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2006.
2. IPCC, *IPCC 1995 Report: Agricultural Options for Mitigation of Greenhouse Gas Emissions*, 747-771, 1995.
3. International Rice Research Institute, *World Rice Statistics 1993-94*.
4. Environmental Agency Committee for the Greenhouse Gases Emissions Estimation Methods, *Review of Greenhouse Gases Emissions Estimation Methods Part 1*, September 2000.
5. Ministry of the Environment Committee for the Greenhouse Gases Emissions Estimation Methods, *Review of Greenhouse Gases Emissions Estimation Methods Part 3*, August 2002.
6. Ministry of the Environment Committee for the Greenhouse Gases Emissions Estimation Methods, *Review of Greenhouse Gases Emissions Estimation Methods*, February 2006.
7. Ministry of the Environment, Environmental Regeneration and Material Cycles Bureau, *Report of the research on the state of wide-range movement and cyclical use of wastes (the volume on cyclical use)*.
8. Ministry of the Environment, Environmental Regeneration and Material Cycles Bureau, *Waste Treatment in Japan*.
9. Japan Meteorological Agency, *Climate Charts of Japan*.
10. Ministry of Agriculture, Forestry and Fisheries of Japan, *Statistics on Milk and Dairy Products*.
11. Ministry of Agriculture, Forestry and Fisheries of Japan, *Livestock Statistics*.
12. Ministry of Agriculture, Forestry and Fisheries of Japan, *Statistics of Livestock Production Costs*.
13. Ministry of Agriculture, Forestry and Fisheries of Japan, *Statistics on Livestock Products Marketing*.
14. Ministry of Agriculture, Forestry and Fisheries of Japan, *Statistics of Cultivated and Planted Area*.
15. Ministry of Agriculture, Forestry and Fisheries of Japan, *Crop Statistics*.
16. Ministry of Agriculture, Forestry and Fisheries of Japan, *Vegetable Production and Shipment Statistics*.
17. Ministry of Agriculture, Forestry and Fisheries of Japan, *Status Report regarding Health Management for Livestock Feeding*.
18. Ministry of Agriculture, Forestry and Fisheries, Agricultural Production Bureau, Livestock Industry Department, Livestock Production and Feed Division, *Statistical Document of Horse*.
19. Ministry of Agriculture, Forestry and Fisheries of Japan, "Planning for Breeding Improvement of Poultry", 2015.
20. Ministry of Agriculture, Forestry and Fisheries of Japan, *Statistical Document for small animals and laboratory animals*.
21. Ministry of Agriculture, Forestry and Fisheries of Japan, *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 FY2011*, 2012.

22. Ministry of Agriculture, Forestry and Fisheries of Japan, *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*, 2013.
23. Ministry of Agriculture, Forestry and Fisheries of Japan, *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 FY2013*, 2014.
24. 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), Project Title: *Discussions on Greenhouse Gas Emissions Estimation Method for Livestock Manure Management by taking Japan's Climate Conditions into account*.
25. Ministry of Agriculture, Forestry and Fisheries of Japan, Agricultural Production Bureau, Livestock Industry Department: *Survey of current status for livestock manure management system*, 2009.
26. Ministry of Agriculture, Forestry and Fisheries of Japan, “*Basic Survey of Soil Environment*”.
27. Ministry of Agriculture, Forestry and Fisheries of Japan, “*Forth Basic Survey on Infrastructure Development of Land Use*”.
28. Ministry of Agriculture, Forestry and Fisheries of Japan, “*the Project of Basic Survey on Greenhouse Gas Emission Estimation from Agricultural Land Soil*”.
29. Okinawa prefecture, *Survey Result of Feeding Livestock and Poultry*.
30. Hokkaido Government, Department of Agriculture, *Hokkaido Fertilizer Recommendations 2010*, 2010.
31. Japan Livestock Industry Association, *Japanese Feed Standard*.
32. Livestock Improvement Association of Japan. INC, *Record of Dairy Herd Performance Test*.
33. Japan Livestock Industry Association, *Statistical Document of Livestock Breeding*.
34. Japan Livestock Technology Association, *GHGs emissions control in livestock Summary*, March 2002.
35. Japan Livestock Technology Association, “*Questionnaire Survey on Current Breeding Status for Broiler*”, 2008.
36. Japan Livestock Technology Association, *GHGs emissions control in livestock Part4*, March 1999.
37. Research Council on Soil Function for Global Warming Countermeasures, “*Survey of Greenhouse Gas Emissions from Soils and Soil Carbon Sequestration*”.
38. Association of Agriculture and Forestry Statistics, *Yearbook of Fertilizer Statistics (Pocket Edition)*.
39. Association for Advancement of Agricultural Science, *Research Report on Methodologies for Quantification of GHG Emission Reduction in FY 2000*
40. Japan Sewage Works Association data
41. Japan Tabaco Inc. data

42. Masaaki Shibata, Fuminori Terada, Mitsunori Kurihara, Takehi Nishida and Kazuo Iwasaki, "*Estimation of Methane Production in Ruminants*", Japanese Journal of Zootechnical Science, 64(8), 790-796, 1993.
43. Mamoru Saito, *Methane Excretion in Fattening Pigs and Pregnant sows*, Japanese Journal of Zootechnical Science, 59(9), 779-778, 1988.
44. Idumi Tsuchiya, Hideo Etsue, Hiroshi Dougan, Takuma Sakamoto, Mitsuyoshi Ishida, Sanki Hasegawa and Takashi Osada, "*Measurement of greenhouse effect gas emissions from drying treatment of poultry manure facility*", Japanese Journal of Zootechnical Science, 85(1), 61-69, 2014.
45. Makoto Shiraishi, Takashi Osada, Takeshi Mizuki and Kenji Takatori, "*Greenhouse gas emission from the Facility of Cattle Wastewater Treatment with Activated-Sludge process*", Japanese Journal of Zootechnical Science, 88(4), 479-490, 2017.
46. Makoto Ishibashi, Jyunya Hashiguchi, Morihiro Koga, "*Development of technology of reducing GHG on the livestock industry (second report)" the experiment and study of environmental safeguards on the livestock industry*, Annual Report of the Kumamoto Prefectural Agricultural Research Center Animal Husbandry Research Institute, 2003.
47. Fumihiro Otani, Masahiro Amari, Masumi Tagusari, Shinichi Kume "*Urine amount of Lactating dairy cow is able to estimate from Intake of Nitrogen and Potassium, and Milk production*", Result information of Institute of Livestock and Grassland Science, NARO, 2010.
48. Yousuke Choumei, Fuminori Terada and Hiroyuki Hirooka "*Prediction and Comparison of Nitrogen Excretions in Dairy and Beef Cattle*", Japanese Journal of Zootechnical Science, 77(4), 485-494, 2006.
49. Mikinori Tsuiki and Yasuo Harada, "*A Computer Program for Estimating the Amount of Livestock Wastes*", J. JASS, 13(1), 17-23, 1997.
50. Masayuki Hojito, Atsuo Ikeguchi, Kazunori Kohyama, Kazuhiro Shimada, Akifumi Ogino, Shin-ichiro Mishima and Koichi Kaku, "*Estimation of Nitrogen Loading in Japanese Prefectures and Scenario Testing of Abatement Strategies*", Japanese Journal of Soil Science and Plant Nutrition, 74(4) 467-474, 2003.
51. Tamon Fumoto, Tetsuji Yanagihara, Takashi Saito and Kazuyuki Yagi "*Process-modeling approach toward estimation of greenhouse gas emissions from crop lands*", Journal of the Japanese Society of Soil Physics, 114, 49-52, 2010.
52. Kunihiro Nonaka, "*Nitrogenous environmental load in tea fields and fertilizer application technology for the reduction of the environmental load*", Tea Research Journal, 100, 29-41, 2005.
53. Noboru Date, "*Handbook for Organic Fertilizers and Microbial Materials*", Rural Culture Association Japan, 1988.
54. Kazuo Ogawa, Yutaka Takeuchi and Masahiro Katayama, "*Biomass Production and the Amounts of Absorbed Inorganic Elements by Crops in Arable lands in Hokkaido, and its evaluation*", Research Bulletin of the Hokkaido National Agricultural Experiment Station, 149, 57-91, 1988.
55. Tsuguo Hoshina, Shuji Kozai and Yoshio Honjo, "*Decomposition of Tea Organic Residues in Soil and Re-absorption of the Nitrogen by Tea Plant*", Tea Research Journal, 55, 30-36, 1982.
56. Tadataka Kinoshita, Masaki Tsuji, "*Nitrogen Balance in "Tencha" Tea Field*", Tea Research Journal,

- 100, 52-54, 2005.
57. Naoaki Tachibana, Toshihisa Ikeda and Katsuhiko Ikeda, “Changes in Nitrogen Uptake with Aging and Under Heavy Application of Nitrogen in Tea Plants”, Japanese Journal of Crop Science, 65(1), 8-15, 1996.
 58. Mitsuru Ohta, Mitsui Iwahashi, Akio Morita, “Decomposition of Organic Matter derived from Pruned Branches and Nitrogen Loss in a Renewal Tea Field after First Crop of Tea”, Tea Research Journal, 84 (supplement), 130-131, 1996.
 59. Naruo Matsumoto, *Development of Estimation Method and Evaluation of Nitrogen Flow in Regional Areas*, Bulletin of National Institute for Agro-Environmental Sciences, 18, 81-152, 2000.
 60. Naoto Owa, “New Trends in Technology for Efficient Use of Nutrients – Nutritional Balance of Crops in Japan” 1996 Sixth Kanto-Tokai Agricultural Study Session on Soil Management Technologies for Agricultural Production in Harmony with Environment; National Agriculture and Bio-oriented Research Organization, 1996.
 61. Osamu Nagata, Ryoji Samejima, “Effect of land use change in Ishikari peatland on greenhouse gas emission”, *New Research Results: Hokkaido Region*, 115-121, 2006.
 62. Osamu Nagata, Tomoko Sugito, Shohei Kobayashi, and Ryoji Sameshima, “Nitrous oxide emissions following the application of wheat residues and fertilizer under conventional-, reduced-, and zero-tillage systems in central Hokkaido, Japan”, *Journal of Agricultural Meteorology*, 65(2), 151-159, 2009.
 63. Ryusuke Hatano, “Report of survey on actual management of grasslands forage cropping areas in Japan”, Project Report of Livestock Industry Promotion by Japan Racing Association in FY2016, 2017.
 64. Yusuke Takata, Makoto Nakai and Hiroshi Obara, *Digital soil map of Japanese croplands in 1992*, Japanese Journal of Soil Science and Plant Nutrition, 80, 5, 502-505, 2009.
 65. Takashi Osada, Yasuyuki Fukumoto, Tadashi Tamura, Makoto Shiraihi, Makoto Ishibashi, “Greenhouse gas generation from livestock waste composting”, Proceedings of the Fourth International Symposium on Non-CO₂ Greenhouse Gases (NCGG-4), Science, Control, Policy and Implementation, Millpress, Rotterdam, 105-111, 2005.
 66. Akinori Mori and Masayuki Hojito, “Methane and nitrous oxide emissions due to excreta returns from grazing cattle in Nasu, Japan”, *Grassland Science*, 61(2), 109-120, 2015.
 67. Takeshi Osada, Kazutaka Kuroda, Michihiro Yonaga, “Determination of nitrous oxide, methane, and ammonia emissions from a swine waste composting process”, *Journal of Material Cycles and Waste Management*, 2(1), 51-56. 2000.
 68. Takashi Osada, “Nitrous Oxide Emission from Purification of Liquid Portion of Swine Wastewater”, *Greenhouse Gas Control Technologies - 6 International Conference*, Volume I, J. Gale and Y. Kaya (Eds.), 1299-1304. 2003.
 69. S. Kume, K. Nonaka, T. Oshita, and T. Kozakai “Evaluation of drinking water intake, feed water intake and total water intake in dry and lactating cows fed silages”, *Livestock Science*, 128(1-3), 46-51, 2010.
 70. Akifumi Ogino, Hitoshi Murakami, Takahiro Yamashita, Motohiro Furuya, Hirofumi Kawahara, Takako Ohkubo, Takashi Osada, “Estimation of nutrient excretion factors of broiler and layer chickens in Japan”, *Animal Science Journal*, 88(4), 659-668, 2016.

71. Nobuko Katayanagi, Tamon Fumoto, Michiko Hayano, Yusuke Takata, Tsuneo Kuwagata, Yasuhito Shirato, Shinji Sawano, Masako Kajiura, Shigeto Sudo, Yasushi Ishigooka, Kazuyuki Yagi, “*Development of a method for estimating total CH₄ emission from rice paddies in Japan using the DNDC-Rice model*”, *Science of the Total Environment*, 547, 429–440, 2016.
72. Nobuko Katayanagi, Tamon Fumoto, Michiko Hayano, Yasuhito Shirato, Yusuke Takata, Ai Leon, Kazuyuki Yagi, “*Estimation of total CH₄ emission from Japanese rice paddies using a new estimation method based on the DNDC-Rice simulation model*”, *Science of the Total Environment*, 601–602, 346–355, 2017.
73. Michiko Hayano, Tamon Fumoto, Kazuyuki Yagi, and Yasuhito Shirato, “*National-scale estimation of methane emission from paddy fields in Japan: Database construction and upscaling using a process-based biogeochemistry model*”. *Soil Science Plant Nutrition*, 59(5), 812–823, 2013.
74. Yagasaki, Y., and Y. Shirato, “*Assessment on the rates and potentials of soil organic carbon sequestration in agricultural lands in Japan using a process-based model and spatially explicit land-use change inventories – Part 1: Historical trend and validation based on nation-wide soil monitoring*”, *Biogeosciences*, 11(16), 4429–4442, 2014.
75. Kazunori Minamikawa, Tamon Fumoto, Masayuki Itoh, Michiko Hayano, Shigeto Sudo, Kazuyuki Yagi, “*Potential of prolonged midseason drainage for reducing methane emission from rice paddies in Japan: a long-term simulation using the DNDC-Rice model*”, *Biology and Fertility of Soils*, 50(6), 879–889, 2014.
76. Hiroko Akiyama, Xiaoyuan Yan, and Kazuyuki Yagi, “*Evaluation of effectiveness of enhanced-efficiency fertilizers as mitigation options for N₂O and NO emissions from agricultural soils: meta-analysis*”, *Global Change Biology*, 16(6), 1837–1846, 2010.
77. Akiyama, H., Yagi, K., and Yan, X., “*Direct N₂O emissions and estimate of N₂O emission factors from Japanese agricultural soils*”, In program and Abstracts of the International Workshop on Monsoon Asia Agricultural Greenhouse Gas Emissions, March 7-9, 2006, Tsukuba, Japan, pp. 27, 2006.
78. Hiroko Akiyama, Xiaoyuan Yan, and Kazuyuki Yagi, “*Estimations of emission factors for fertilizer-induced direct N₂O emissions from agricultural soils in Japan: Summary of available data*”, *Soil Science and Plant Nutrition*, 52, 774–787, 2006.

Chapter 6. Land Use, Land-Use Change and Forestry (CRF 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 land-use change. Japan classifies its national land into six categories—forest land, cropland, grassland, wetlands, settlements, and other land—and subdivides each of them into two subcategories by distinguishing them on the basis of the occurrences of land conversion in a certain period, in accordance with the *2006 IPCC Guidelines*; a default value of 20 years was used when distinguishing the land conversion. 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), carbon stock changes in harvested wood products (HWP) in forest land, direct N₂O emissions from N fertilization in forest land, CH₄ and N₂O emissions from drainage of organic soils, N₂O emissions from nitrogen mineralization resulting from change of land use or management of mineral soils, indirect N₂O emissions from managed soils, and non-CO₂ emissions from biomass burning. Tiers of methodology used in this sector are shown in Table 6-1. In this chapter, above- and below- ground biomass are referred to collectively as “living biomass”, and dead wood and litter collectively as “dead organic matter”.

Japan’s total land area as of FY2017 is about 37.8 million ha, which represents an increase by 0.06% over the FY1990 value. The increase results from reclamation by drainage and soil filling of sea areas¹. The dominant land use type is forest land, which covers about 24.88 million ha, followed by cropland, which covers about 4.27 million ha. In addition, grassland, wetlands, settlements, and other land cover about 0.95 million ha, 1.35 million ha, 3.86 million ha, and 2.49 million ha, respectively. Japan includes the land territory in the LULUCF estimation and reporting and does not include sea area which the *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands (Wetlands Guidelines)* provides some methodologies.

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 a temperate, humid climate zone. Some islands in the southern part of Japan belong to a subtropical climate zone, and the northern part of Japan is located in a cool-temperate climate zone. The average annual temperature and precipitation in Tokyo, the capital city of Japan located in the temperate, humid climate zone, are 15.4 degrees Celsius and 1,528.8mm; those in Sapporo, Hokkaido prefecture, located in the cool-temperate climate zone, are 8.9 degrees Celsius and 1,106.5 mm; and those in Naha, Okinawa prefecture, located in the subtropical climate zone, are 23.1 degrees Celsius and 2,040.8 mm, respectively.²

¹ Statistical reports on the land area by prefectures and municipalities in Japan
<<http://www.gsi.go.jp/kokusaikoryu/kokusaikoryu-e30092.html>>

² The average annual temperatures and precipitation are the average of the years between FY1981 and 2010. See National Astronomical Observatory, *2012 Chronological Scientific Tables* (Tokyo: Maruzen Inc., 2019) pp.184-185 and pp.196-197. With respect to the degrees of latitude, see Geographical Survey Institute, *Degrees of Latitudes and Longitudes of Japan’s Northernmost, Southernmost, Easternmost and Westernmost Points*
<<http://www.gsi.go.jp/KOKUJYOHO/center.htm>>.

The LULUCF sector contains both sources and sinks; however, in Japan, it has been a net sink continuously since FY1990. Net removals in FY2017 were 57,458 kt-CO₂; this accounts for 4.4% of the total national emissions (excluding LULUCF). The net removals in FY2017 also represent a decrease of 8.0% below the FY1990 value and an increase of 5.4% over the FY2016 value. Net removals in Japan had increased until FY2003, but have been decreasing continuously since 2003. The key drivers for the rise in removals since FY1990 until FY2003 were increase of removals in forest land and decrease of emissions resulting from land conversion because of decrease of areas of land conversion. The subsequent decreasing trends were due to decrease of removals in forest land. See descriptions in each category for further information on reasons of trends.

This chapter is divided into 16 sections. Sections 6.2. and 6.3. describe the method of determining land-use categories and the method of determining areas (data base and estimation method of determining areas). Section 6.4. describes general parameters for estimating carbon stock changes from land-use conversion. Sections 6.5. to 6.10. explain the estimation methods of carbon stock changes in each land-use category. Section 6.11. describes estimation method of carbon stock changes in Harvested Wood Products (HWP). In addition, GHG emissions in the LULUCF sector resulting from other than carbon stock changes are described in sections 6.12 to 6.16.

Table 6-1 Methodological tiers used in the LULUCF sector

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	CO ₂		CH ₄		N ₂ O	
	Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
A. Forest land	T1,T2,T3	CS,D	T1	D	T1,T2	CS,D
B. Cropland	T1,T2,T3	CS,D	T1	D	T1,CS	CS,D
C. Grassland	T1,T2,T3	CS,D	T1	D	T1,CS	CS
D. Wetlands	T1,T2	CS,D	NO,NA,NE	NA	NO,NA,NE	NA
E. Settlements	T2	CS,D	NO,NA	NA	NO,NA	NA
F. Other land	T2	CS,D	NO	NO	T1	D
G. Harvested wood products	T2,T3	CS,D				

D: IPCC default, T1: IPCC Tier1, T2: IPCC Tier2, T3: IPCC Tier3, CS: country-specific method or emission factor

6.2. Land-use definitions and the classification systems used and their correspondence to the land use, land-use change and forestry categories

In accordance with the 2006 IPCC Guidelines, all lands in Japan are classified into 6 land-use categories. In Japan, as shown in Table 6-2, lands are allocated in each land-use categories on the basis of the definitions in existing statistics. Area of each land-use category is identified by using value indicated in land classification in existing statistics. Lands which are not be classified into the above five land use categories is defined as “Other Land”, which the area of is determined by deducting the total area of five land use categories from total national land. As for forest land, cropland and grassland, country-specific subcategories are determined (forest land: forests with standing trees (intensively managed forests / semi-natural forests) / forests with less standing trees / bamboo; cropland: rice fields / upland fields / orchards / cultivation abandoned agricultural land; grassland: pasture land / grazed meadow land/ wild land). In addition, the definition of country-specific subcategory for forest land, which was established by Japan, is shown in Table 6-3.

Table 6-2 Criteria for land-use category allocation and sources of data and information to determine area

IPCC Land use category	Criteria for land-use category allocation	Sources of data and information to determine area
Forest	Forests under Forest Law Article 5 and 7.2.	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 <i>Forestry Status Survey</i> [-2004] and the <i>National Forest Resources Database</i> [2005-] (Forestry Agency). ³
Cropland	Rice fields, upland fields, orchards and cultivation abandoned agricultural land	Rice fields, upland fields and orchard according to <i>Statistics of Cultivated and Planted Area</i> by the MAFF. Cultivation abandoned agricultural land according to <i>World Census of Agriculture and Forestry</i> by the MAFF.
Grassland	Pasture land, grazed meadow land, and wild land ⁴ . (excluding pasture land and grazed meadow land)	Pasture land according to <i>Statistics of Cultivated and Planted Area</i> by the MAFF, grazed meadow land (excluding when it is included in forest land) according to <i>World Census of Agriculture and Forestry</i> by the MAFF, and wild land according to <i>Land Use Status Survey</i> by the MLIT.
Wetlands	Lands covered with water (such as dams), rivers, and waterways.	Lands covered with water, rivers, and waterways according to <i>Land Use Status Survey, Survey of Forestry regions</i> by the MLIT. Among them, the lands that are subject to revegetation activities (e.g. green areas along rivers and erosion control sites, a part of urban parks) are allocated to settlements.
Settlements	Urban areas that do not constitute forest land, cropland, grassland or wetlands. Urban green areas are all wooded and planted areas that do not constitute forest land.	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 <i>Land Use Status Survey</i> 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 11-11).
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 <i>Statistical Reports on the Land Area by Prefectures and Municipalities in Japan</i> by the Geospatial Information Authority of Japan (GSI).

MAFF: Ministry of Agriculture, Forestry and Fisheries; MLIT: Ministry of Land, Infrastructure, Transport and Tourism

Table 6-3 Definitions of forest subcategories

Forest subcategories	Definitions
Forest with standing trees	Forest that does not fall under "forest with less standing trees" and has a tree crown cover of standing trees 30% or higher (including young stands with the degree of stocking ⁵ of 3 or higher even though the tree crown cover is less than 30%). Even if the tree crown cover of standing trees is less than 30%, forest in which the sum of the crown covers of both standing trees and bamboo is 30% or higher, while dominated by standing trees, is also included
Intensively managed forest	Forest land that is subject to artificial regeneration such as tree planting and seeding, and in which no less than 50% of the volume (or the number) of standing trees are of tree species subject to artificial regeneration.
Semi-natural forest	Forest with standing trees which is not classified as intensively managed forests
Forest with less standing trees	Forest in which the sum of the tree crown covers of both standing trees and bamboo is less than 30 percent.
Bamboo	Forest, other than "forest with standing trees", in which a tree crown cover of bamboo (excluding bamboo grasses) is 30% or higher. Even if the tree crown cover of bamboo is less than 30%, forest in which the sum of the crown covers of both standing trees and bamboo is 30% or higher with bamboo being dominated is also included.

Reference: Forestry Agency of Japan, *Forest Status Survey* (March, 2007) *partially modified

In accordance with *2006 IPCC Guidelines*, each land use category is further classified into "Land remaining Land" and "Land converted to Land" depending on its history of land-use conversion; each

³ The *Forestry Status Survey* and the *National Forest Resources Database* use the same definitions and survey methods for forests, and these two data bases have time-series consistency.

⁴ Its present status is mainly wild grassland (including perennial pasture land, degenerated pasture land, and areas abandoned after cultivation and becoming wild).

⁵ The degree of stocking is the ratio of actual volume to the expected volume of the forest stand, multiplied by 10.

area is calculated by estimation based on existing statistics. Among them, the areas of land converted to forest land are estimated based on data of the areas of afforestation and reforestation under Article 3, paragraph 3, of the Kyoto Protocol, which are determined by utilizing orthophotos taken at the end of 1989 and recent satellite images, in addition to existing statistics. The areas of forest land converted to other land-use categories are estimated based on data of the areas of deforestation determined in the same way as afforestation and reforestation, in addition to data of the *World Census of Agriculture and Forestry* and the Forestry Agency's records. For detailed information on the methods of determining the areas of afforestation, reforestation and deforestation, see section 11.4.2.3. in Chapter 11. In addition, Land-use categories that cannot be directly determined from existing statistics are determined using estimation measures such as allocation of areas of land conversion by means of the ratio of actual land areas for each land-use category.

6.3. Approaches for estimating land areas and land-use database used for the inventory preparation

6.3.1. Survey methods and due dates of major land area statistics

Table 6-4 shows the survey methods and due dates of major land area statistics.

Table 6-4 Survey methods and due dates of major land area statistics

Name of the statistics / census		Survey method	Survey due date	Frequency	Presiding ministry
Forest Status Survey		Complete count survey	March, 31 st	Approximately 5 years (Before 2004)	MAFF (Forestry Agency)
National Forest Resources Database		Complete count survey	April, 1 st	Every year (Since 2005)	MAFF (Forestry Agency)
Statistics of Cultivated and Planted Area (Survey of cropland area)	[Cropland area]	Ground measurement survey (sample)	July, 15 th	Every year	MAFF
	[Expansion area and converted area of cropland]	Tabular survey (using documents from relevant agencies and aerial photographs, etc.)	July, 15 th in the previous year until July, 14 th		
World Census of Agriculture and Forestry		Complete count survey	[by 2000] August, 1 st [from 2005] February, 1 st	[by 2000] Every 10 years, [from 2005] every 5 years	MAFF
Land Use Status Survey		Complete count Survey	---	Every year	MLIT
Statistical Reports on the Land Area by Prefectures and Municipalities in Japan		Complete count Survey	October, 1 st	Every year	GSI

Details for urban green facilities are shown in Table 11-11.

MAFF: Ministry of Agriculture, Forestry and Fisheries; MLIT: Ministry of Land, Infrastructure, Transport and Tourism

6.3.2. Land area estimation methods

Some land areas cannot be directly determined from existing statistics; therefore, they are estimated using the following methods:

- Interpolation
- Allocation of areas of land conversion by means of the ratio of actual land areas for each land-use category

- Allocation of areas of land conversion by means of the ratio of converted land areas for a certain year

Please refer to each related section for more detailed explanations about estimation method in individual area.

- **Interpolation**

- **Method**

The areas of forest land before 2004 were surveyed at an interval of approximately five years, and it was difficult to directly determine the areas of forest land in the unsurveyed years. Therefore, they were estimated by interpolation by means of linear expressions based on the areas in the surveyed years.

- **Land-use category**

4.A.2. Land converted to Forest land (FY1991- 1994, 1996- 2001 and 2003- 2004).

- **Allocation of areas of land conversion by means of the ratio of actual land areas for each land-use category**

- **Method**

In Japan, it is difficult to obtain the areas of upland field converted to forest land, orchard converted to forest land and pasture land converted to forest land directly from existing statistics, since those are collectively reported as arable land. Therefore, these land areas were estimated by multiplying the arable land converted to forest land by the ratios of actual land areas for each of the land-use categories (upland field, orchards and pasture land).

- **Land-use category**

4.A.2. Land (Cropland and Grassland) converted to Forest land

4.B.2. Land (Forest land, Grassland, Wetlands and Other land) converted to Cropland

4.C.2. Land (Forest land, Cropland, Wetlands and Other land) converted to Grassland

4.E.2. Land (Cropland and Grassland) converted to Settlements

4.F.2. Land (Cropland and Grassland) converted to Other land

- **Allocation of areas of land conversion by means of the ratio of converted land area for a certain year**

- **Method**

In Japan, it is difficult to directly obtain annual land areas of cropland, grassland, settlements and other land converted to wetlands, respectively. Therefore, with the assumption that the annual land ratios of cropland, grassland, settlements and other land converted to wetlands to land converted to wetlands in FY1998 is constant, the ratio are multiplied by the areas of land converted to wetlands in each year to obtain the area of respective land use category converted to wetlands.

- **Land use category**

4.D.2. Land (Cropland, Grassland, Settlements and Other land) converted to Wetlands

6.3.3. Land-use transition matrix

Land use transition matrix to determine land use conversion has been produced annually since FY1990 until now, for six land use categories whose areas are identified in accordance with the description in section 6.2 and in the beginning part of section 6.3. Land use conversion made in FY1990 and in

FY2017 are shown in the following Table 6-5 and Table 6-6 individually. In addition, land use matrix produced by accumulating land conversion between each land use category, from FY1990 to FY2017, is shown in Table 6-7. In Japan, all lands are managed lands and land without management does not exist; therefore, the columns for lands without management are shaded in gray.

Table 6-5 Land-use transition matrix for Japan in FY1990

(kha)

After Conversion \ Before Conversion	Forest land	Cropland	Grassland	Wetlands	Settlements	Other land	Total
Forest Land	24,945.3	5.34	0.75	0.31	14.76	3.66	24,970.1
Cropland	2.71	4,807.0	0.90	0.02	21.35	2.16	4,834.1
Grassland	0.67	0.004	1,029.8	0.007	3.19	0.36	1,034.0
Wetlands	NO	0.34	0.12	1,308.4	IE	IE	1,308.9
Settlements	0.82	IE	NO	0.002	3,169.7	IE	3,170.5
Other land	0.82	0.21	0.01	0.1	IE	2,455.0	2,456.1
Total	24,950.3	4,812.9	1,031.6	1,308.8	3,209.0	2,461.2	37,773.7

Table 6-6 Land-use transition matrix for Japan in FY2017

(kha)

After Conversion \ Before Conversion	Forest land	Cropland	Grassland	Wetlands	Settlements	Other land	Total
Forest Land	24,876.3	0.18	0.46	0.18	5.47	0.60	24,883.2
Cropland	0.04	4,260.5	0.51	0.02	8.48	2.31	4,271.9
Grassland	0.13	0.005	949.7	0.003	1.82	0.23	951.9
Wetlands	NO	NO	NO	1,347.9	IE	IE	1,347.9
Settlements	0.02	IE	NO	0.001	3,847.2	IE	3,847.2
Other land	NO	5.07	0.35	0.0	IE	2,489.8	2,495.3
Total	24,876.5	4,265.8	951.0	1,348.1	3,863.0	2,493.0	37,797.4

Table 6-7 Land-use transition matrix for FY1990-FY2017

(kha)

2017 \ 1990	Forest Land (managed)	Forest Land (unmanaged)	Cropland	Grassland (managed)	Grassland (unmanaged)	Wetlands (managed)	Wetlands (unmanaged)	Settlements	Other land	Total unmanaged land	Initial area
Forest Land (managed)	24,766.6		27.0	12.0		15.8		209.3	50.5		25,081.2
Forest Land (unmanaged)											
Cropland	35.4		4,206.0	22.7		1.3		370.4	65.4		4,701.3
Grassland (managed)	12.5		1.1	914.4		0.3		57.4	8.9		994.6
Grassland (unmanaged)											
Wetlands (managed)	0.1		1.1	0.4		1,326.3		IE	IE		1,327.9
Wetlands (unmanaged)											
Settlements	32.3		IE	NO		0.1		3,225.9	IE		3,258.3
Other land	29.5		30.6	1.5		4.4		IE	2,368.1		2,434.1
Total unmanaged land											
Final area	24,876.5		4,265.8	951.0		1,348.1		3,863.0	2,493.0		37,797.4
Net change	-204.7		-435.5	-43.6		20.2		604.7	58.9		0.0

Note: The areas described as "IE" are included in "Other lands remaining the same land-use category" which could be used for adjustment with total area of national land.

6.4. Parameters for estimating carbon stock changes from 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 6-8a to Table 6-11) to prevent the reiteration of indicating these parameters in each subsequent section. The method of establishing some parameters, calculation method, and ground for establishing them are shown in “Note”. Please refer to each section specified in Note. In case that notation “-” is used in table instead of describing numbers and description is separately made, please also refer to “Note” since the case may be under examination.

As for parameter whose value is indicated as “0”, there are following three cases: in accordance with the 2006 IPCC guidelines, default value, “0”, is applied; carbon stock changes but no calculation methodology exists; it is assumed “0” under the assumption that there is no change. For details, please refer to “Note”.

Table 6-8a Living biomass stocks for each land-use category before and immediately after conversion

Land use category		Biomass stock or Carbon stock	Note	
Before conversion	Forest land	100.3 [t-d.m./ha] (FY2017)	Calculated by utilizing the values of biomass stocks in land of deforestation under Article 3, paragraph 3, of the Kyoto Protocol, which are provided from the NFRDB. In addition, the values before FY2007 are substituted by the average value between FY2008 and FY2012. (Reference values [t-d.m./ha]: FY1990:113.4, FY2005:113.4, FY2008:135.1, FY2009:108.3, FY2010:99.8, FY2011:100.6, FY2012: 123.2, FY2013: 98.5, FY2014: 99.1, FY2015: 99.5, FY2016: 99.9)	
	Cropland	Rice field	0	Biomass stocks are assumed to be “0”.
		Upland field	0	Biomass stocks are assumed to be “0”.
		Orchard	IE	Included in cropland remaining cropland.
	Grassland	13.50 [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	Biomass stocks are assumed to be “0”.		
Immediately after conversion	All land uses	0	Biomass stocks are assumed to be “0”.	

Table 6-8b Living biomass growth increments for each land-use category after conversion

Land use category		Biomass growth increment	Note	
After conversion	Forest land	3.0 [t-C./ha/yr]	Removals in this land are directly estimated based on the implied removal factor of AR activity under the Kyoto Protocol. The average value between FY2008 and FY2010 are applied to all reporting years.	
	Cropland	Rice field	0	Biomass stocks are assumed to be “0”.
		Upland field	0	Biomass stocks are assumed to be “0”.
		Orchard	IE	Included in cropland remaining cropland.
	Grassland	2.70 [t-d.m./ha]	Default value (Table 6.4: One fifth of the value 13.5 at “warm temperate wet”, the 2006 IPCC Guidelines)	
	Settlements	-	See section 6.9.2.b)1)	
Wetlands and other land	0	Biomass growth increment are assumed to be “0”.		

Table 6-9 Carbon stocks of dead wood for each land-use category before and after conversion

Land-use Category		Carbon Stock	Note
Before Conversion	Forest land	14.70[t-C/ha] (FY2017)	Calculated from carbon stocks in dead wood in all forests. In addition, the values before 2004 are substituted by the value of FY2005.(Reference values [t-C/ha]: FY1990: 15.08, FY2005: 15.08, FY2008: 15.02, FY2009: 14.99, FY2010: 14.97, FY2011: 14.95, FY2012: 14.93, FY2013:14.86, FY2014: 14.81, FY2015:14.77, FY2016: 14.77)
	Cropland, grassland, wetlands, settlements, other land	0	Default value (Section 5.3.2 etc. in Volume 4 of the 2006 IPCC Guidelines, Tier.1)
Immediately after conversion	All land uses	0	Default value (Section 5.3.2 etc. in Volume 4 of the 2006 IPCC Guidelines, Tier.1) Carbon stocks immediately after conversion are assumed to be "0".
After conversion	Forest land	13.01 [t-C/ha]	Average carbon stocks per unit area in 20-year-old forests obtained by the CENTURY-jfos model
	Cropland, grassland, wetlands, other land	0	Default value (Section 5.3.2 etc. in Volume 4 of the 2006 IPCC Guidelines, Tier.1)
	Settlements	0	Default value (Section 8.3.2 in Volume 4 of the 2006 IPCC Guidelines, Tier 1)

Table 6-10 Carbon stocks of litter for each land-use category before and after conversion

Land-use Category		Carbon Stock	Note
Before Conversion	Forest land	7.31 [t-C/ha] (FY2017)	Calculated from carbon stocks in litter in all forests. In addition, the values before 2004 are substituted by the value of FY2005. (Reference values [t-C/ha]: FY1990: 7.24, FY2005: 7.24, FY2008: 7.26, FY2009: 7.27, FY2010: 7.28, FY2011: 7.28, FY2012: 7.29, FY2013: 7.29, FY2014:7.29, FY2015:7.30, FY2016: 7.33)
	Cropland, grassland, wetlands, settlements, other land	0	Default value (Section 5.3.2 etc. in Volume 4 of the 2006 IPCC Guidelines, Tier.1)
Immediately after conversion	All land-uses	0	Default value (Section 5.3.2 etc. in Volume 4 of the 2006 IPCC Guidelines, Tier.1) Carbon stocks immediately after conversion are assumed to be "0".
After conversion	Forest land	5.637 [t-C/ha]	Average carbon stocks per unit area in 20-year-old forests obtained by the CENTURY-jfos model
	Cropland, grassland, wetlands, other land	0	Default value (Section 5.3.2 etc. in Volume 4 of the 2006 IPCC Guidelines, Tier.1)
	Settlements	-	See section 6.9.2.b)2)

Table 6-11 Carbon stocks of soil for each land-use category before and after conversion (in mineral soils)

Land-use Category		Carbon Stock	Note	
Before conversion	Forest land	85.48 [t-C/ha] (FY2017)	Value of soil carbon stocks at 0-30 cm depth one year before the inventory year. National average value calculated by the CENTURY-jfos model. In addition, the value in FY2005 is applied to the years before 2004. (Reference values [t-C/ha]: FY1990: 85.07, FY2005: 85.07, FY2008: 85.14, FY2009: 85.12, FY2010: 85.17, FY2011: 85.20, FY2012: 85.30, FY2013: 85.31, FY2014:85.34, FY2015:85.36, FY2016:85.69)	
	Cropland	Rice field	71.38 [t-C/ha]	Value of soil carbon stocks at 0-30 cm depth. Data provided from Dr. Makoto Nakai, National Institute for Agro-Environmental Sciences (Unpublished) * These carbon stocks were not applied to “cropland converted to grassland” and “grassland converted to cropland”.
		Upland field	86.97 [t-C/ha]	
		Orchard	77.46 [t-C/ha]	
		Cropland (average)	76.46[t-C/ha]	
	Grassland	134.91 [t-C/ha]		
	Wetlands	88.00 [t-C/ha]	Default value (2006 IPCC Guidelines Table 2.3, Wetland soils/ Warm temperate).	
	Settlements	-	Under investigation	
Other land	-	This value is determined depending on land conversion status.		
After conversion	Forest land	82.907 [t-C/ha]	Value of soil carbon stocks at 0-30 cm depth. Average carbon stocks per unit area in 20-year-old forests obtained by the CENTURY-jfos model.	
	Cropland	IE	Included in cropland remaining cropland.	
	Grassland	IE	Included in grassland remaining grassland.	
	Wetlands	-	Under investigation	
	Settlements	-	These values are determined depending on land conversion status.	
	Other land	-		

* All carbon stocks in mineral soils before conversion to forest land are regarded as 80 t-C/ha due to expert judgment.

6.5. Forest land (4.A.)

Forests absorb CO₂ from the atmosphere by photosynthesis, fix carbon as organic substances, and store these substances for a given period. In contrast, forests emit CO₂ due to the effects of events such as logging and natural disturbances.

All forests in Japan are managed forests, and they consist of intensively managed forests, semi-natural forests, bamboo, and forests with less standing trees. Japan’s forest land area in FY2017 was about 24.9 million ha—about 65.8% of the total national land area. The net removal in this category in FY2017 was 60,854 kt-CO₂ (excluding 25.25kt-CO₂ eq. of CH₄ and N₂O emissions resulting from biomass burning, 0.82 kt-CO₂ eq. of N₂O emission resulting from N fertilization in forest land, and 155.6kt-CO₂ eq. of N₂O emission from nitrogen mineralization resulting from change of land use or management of mineral soils). Although this represents an increase of 3.9% over the FY2016 value, it has decreased by 23.0% compared to FY1990 value, and the net removal has been on a long-term decreasing trend. This declining trend in removals in recent years is due to the maturity of Japanese forests. In this section, forest land is divided into two subcategories: “Forest land remaining Forest land (4.A.1.)” and “Land converted to Forest land (4.A.2.)”, and they are described separately in the following subsections.

Table 6-12 Emissions and removals in forest land resulting from carbon stock changes

Gas	Category	Carbon pool	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
CO ₂	4.A. Forest land	Total	kt-CO ₂	-79,074	-87,612	-90,642	-92,665	-80,790	-75,893	-76,419	-78,135	-77,698	-70,006	-68,292	-63,120	-58,572	-60,854	
		Living Biomass	kt-CO ₂	-73,015	-79,832	-83,665	-87,554	-76,892	-72,718	-73,893	-76,222	-76,250	-68,874	-67,332	-62,246	-57,737	-59,982	
		Dead Wood	kt-CO ₂	-2,860	-3,803	-2,837	-1,082	-140	401	894	1,329	1,644	1,821	1,864	1,846	1,781	1,660	
		Litter	kt-CO ₂	-2,697	-2,352	-1,774	-1,078	-802	-672	-577	-500	-452	-414	-385	-372	-355	-350	
		Mineral soil	kt-CO ₂	-503	-1,625	-2,367	-2,950	-2,956	-2,904	-2,843	-2,742	-2,640	-2,538	-2,439	-2,348	-2,260	-2,183	
		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	-72,384	-84,278	-88,209	-90,790	-79,133	-74,458	-75,004	-76,757	-76,358	-68,709	-67,055	-61,949	-57,466	-59,814	
		Living Biomass	kt-CO ₂	-68,097	-77,381	-81,877	-86,176	-75,677	-71,668	-72,858	-75,214	-75,270	-67,922	-66,423	-61,387	-56,926	-59,217	
		Dead Wood	kt-CO ₂	-1,791	-3,270	-2,447	-782	127	633	1,124	1,552	1,861	2,028	2,063	2,034	1,959	1,827	
		Litter	kt-CO ₂	-2,233	-2,122	-1,605	-948	-686	-571	-478	-404	-358	-324	-299	-290	-278	-278	
		Mineral soil	kt-CO ₂	-263	-1,505	-2,280	-2,883	-2,897	-2,852	-2,792	-2,692	-2,491	-2,395	-2,306	-2,221	-2,146		
		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	-6,690	-3,334	-2,433	-1,875	-1,657	-1,436	-1,415	-1,377	-1,340	-1,297	-1,237	-1,171	-1,106	-1,041	
		Living Biomass	kt-CO ₂	-4,918	-2,451	-1,789	-1,378	-1,215	-1,050	-1,035	-1,007	-980	-952	-908	-859	-812	-765	
		Dead Wood	kt-CO ₂	-1,070	-533	-389	-300	-267	-233	-229	-223	-217	-208	-198	-188	-178	-166	
		Litter	kt-CO ₂	-464	-231	-169	-130	-116	-101	-99	-97	-94	-90	-86	-82	-77	-72	
		Mineral soil	kt-CO ₂	-239	-119	-87	-67	-60	-52	-51	-50	-49	-46	-44	-42	-40	-37	
		Organic soil	kt-CO ₂	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

6.5.1. 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 the past 20 years as of FY2017. The net removal in this subcategory in FY2017 was 59,814kt-CO₂ (excluding GHG emissions other than carbon stock changes). This represents a decrease of 17.4% below the FY1990 value and an increase of 4.1% over the FY2016 value. Net removals in forest land remaining forest land have been decreasing continuously since 2003. This long-term declining trend in removals is due to the maturity of Japanese forests. Nonetheless, removals per year fluctuate because annual quantity of harvesting domestic timber is changed depending on increase and decrease of demand on the domestic timber due to economic trends.

Five carbon pools in bamboo in forest land remaining forest land are all reported as “NA” because annual growth and death of bamboo trunk in established bamboo are 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.

It is said that annual growth and death of bamboo trunk are almost equivalent in bamboo forests which reach the constant density in general. FAO conducted a survey (2007) on bamboo resources in 1990, 2000, and 2005 in several Asian and African countries. They reported that the carbon stock changes per unit area for five years (2000-2005) in each country had remained the same. The result of the survey supported the assumption that annual growth and death of bamboo trunk are almost equivalent.

With respect to forests with less standing trees, carbon stock changes in living biomass are estimated, and those 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).

The carbon stock changes in dead organic matter in forest land remaining forest land were net removals during 1990–2008 and net emissions since 2009. The change in the trend is due to the age classes of the intensively managed forests where thinning and harvesting are cyclic, causing annual variations in the contributions to the dead wood pool. Concretely speaking, tree thinning in forests planted in 1960s was

implemented in 1990s, and transition of carbon stocks from living biomass to dead organic matter was promoted. However, quantity of tree thinning decreased afterwards; hence, the carbon stock gains transmitted to dead organic matter were decreased, and carbon stock losses due to decomposition of the transmitted dead organic matter were increased. The carbon stock losses in the dead organic matter exceed the carbon stock gains in the pool in 2009. As a result, the carbon stock changes were net removal from 1990 to 2008, and net emissions since 2009.

b) Methodological Issues

1) Carbon stock changes in Living Biomass in “Forest land remaining Forest land”

● Estimation Method

In accordance with the decision tree provided in the 2006 IPCC Guidelines, carbon stock changes in living biomass in all forest land are estimated by the Tier 2 stock difference method using the country specific values of the amount of biomass accumulation. In this method, the carbon stock change in the living biomass pool is estimated by calculating the difference between the absolute amounts of carbon stocks in the pool at two points of time⁶.

$$\Delta C_{LB} = \sum_k \left\{ (C_{t_2} - C_{t_1}) / (t_2 - t_1) \right\}_k$$

ΔC_{LB} : Annual change in carbon stocks in living biomass [t-C/yr]

t_1, t_2 : Time points of carbon stock measurement

C_{t_1} : Total carbon in biomass calculated at time t_1 [t-C]

C_{t_2} : Total carbon in biomass calculated at time t_2 [t-C]

k : Type of forest management

The carbon stocks in living biomass are calculated by multiplying the stand volume of each tree species by wood density, the biomass expansion factor, the root-to-shoot ratio and the carbon fraction of dry matter. These parameters except the carbon fraction are determined for each tree species.

$$C = \sum_j \left\{ [V_j \times D_j \times BEF_j] \times (1 + R_j) \times CF \right\}$$

C : Carbon stock in living biomass [t-C]

V : Merchantable volume [m³]

D : Wood density [t-d.m./m³]

BEF : Biomass expansion factor for conversion of merchantable volume

R : Root-to-hoot ratio

CF : Carbon fraction of dry matter [t-C/t-d.m.]

j : Tree species

Since Japan calculates the carbon stock change of living biomass in the total forest land in this manner, the carbon stock change of living biomass in forest land remaining forest land is obtained by subtracting

⁶ Japan, as described below, estimates carbon stocks in living biomass using data from the National Forest Resources Database which is developed based on Forest Register's data from prefectures or Regional Forest Offices of National Forests. When they update Forest Registers' data, the prefectures and Regional Forest Offices revise basic information like tree species or areas to represent the correct status of forest. There are circumstances in which prefectures or Regional Forest Offices revise Forest Registers' data like tree species or areas when they update them so that the correct status of forests can be reflected. In this circumstance, modification of carbon stock changes in living biomass is implemented in order to obtain correct carbon stock change values. Without the modification, difference between carbon stock without revision at time point t_1 and carbon stock with revision at time point t_2 under the stock change method would not reflect the correct carbon stock changes.

the carbon stock change in land converted to forest land from the total change. For the method of estimating carbon stock change in land converted to forest land, see section 6.5.2.b)1).

● **Parameters**

➤ **Volume**

The Forestry Agency has developed the National Forest Resources Database (NFRDB) in order to estimate GHG emissions/removals from forests. The data in the NFRDB are based on the information on areas, tree species and forest ages from the “Forest Registers” prepared by prefectures or Regional Forest Offices.

Merchantable volumes are estimated by multiplying the areas for each tree species and forest age in the NFRDB by merchantable volumes per area for each tree species and forest age in yield tables. Source of data for the volumes per area are shown in Table 6-13 below. With respect to estimating the volumes of Japanese cedar, Hinoki cypress and Japanese larch in private forests, which are major tree species of intensively managed forests in Japan, the volumes per area reported in new yield tables, reflecting the latest survey results, are applied.

$$V = \sum_{m,j} (A_{m,j} \cdot v)$$

V : Merchantable volume [m³]

A : Area [ha]

v : Merchantable volume per area [m³/ha]

m : Age class or forest age

j : Tree species

Table 6-13 Yield tables used to estimate merchantable volume

Tree species			Yield tables	
			Private Forest	National Forest
Intensively managed forests	Conifer	Japanese cedar, Hinoki cypress, Japanese larch	New yield tables	Yield tables developed by Regional Forest Offices
		Other conifer	Yield tables developed by prefectures	
	Broad leaf			
Semi-natural forests				

- **Forest Registers and yield tables developed by prefectures or Regional Forest Offices**

When forest plans are established for private and national forests (all forest lands are divided into 158 planning areas, and forest plans are established each year for 1/5 [about 30] of them), field surveys are implemented in these forests to develop a Forest Register which includes data on area, forest age, volume by tree species and so on. When forest plans are established (private forests: by each prefecture, national forests: by Regional Forest Offices of National Forests), the Forest Registers are updated to reflect the change in volume due to growth, cutting and disturbances. In general, the volume data described in the Forest Registers are estimated based on land area data and yield tables, which provide stand growth in the case that typical forest practices are implemented for each region, tree species and site class (yield tables show the relationship between forest age or age class and volume per area).

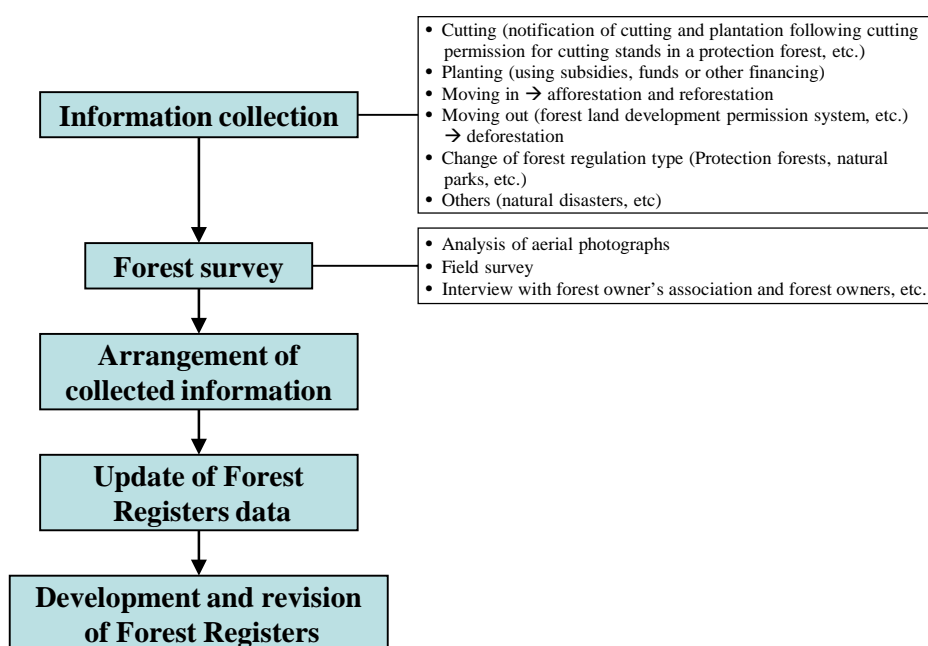


Figure 6-1 Procedures for developing Forest Registers

- ***New yield tables (Japanese cedar, Hinoki cypress, Japanese larch)***

In 2006, the Forestry and Forest Products Research Institute developed new yield tables for Japanese cedar, Hinoki cypress and Japanese larch based on the results of a field survey over the country. The area of these three tree species covers 82% of intensively managed forests in private forests.

The new yield tables for Japanese cedar were established for 7 regions, those for Hinoki cypress for 4 regions and those for Japanese larch for 2 regions.

➤ ***Biomass expansion factor and Root-to-shoot ratio***

The biomass expansion factors (BEF) and root-to-shoot ratios (R) were set based on the results of a biomass survey on dominant tree species, and existing research reports which were implemented by the Forestry and Forest Products Research Institute (Table 6-14).

BEFs were calculated for two age classes (20 years and below / 21 years and above) and for each tree species, because it was identified that BEFs differed between young forests and mature forests. On the other hand, R values were established only for tree species, because the root-to-shoot ratio was not correlated with forest age.

➤ ***Wood density***

Wood density (D) data were set based on the results of biomass survey on dominant tree species and existing research reports which were implemented by the Forestry and Forest Products Research Institute (Table 6-14). These D values were established only for tree species, because wood density was not correlated with forest age.

➤ ***Carbon fraction of dry matter***

The country specific value set based on Japan's research result was adopted as the carbon fraction (CF) of dry matter (Table 6-14).

Table 6-14 Biomass expansion factor, root-to-shoot ratio, wood density for tree species and carbon fraction

		BEF [-]		R [-]	D [t-d.m./m ³]	CF [t-C./t-d.m]	Note
		≤ 20	> 20				
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		
	Sakhaline 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		
	Sakhaline 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	
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 popular	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	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 prefecture	
		1.40	1.26	0.26	0.624	Applied to prefectures other than above	

BEF: Biomass expansion factor (20 = age class)

R: Root-to-shoot ratio

D: Wood density

CF: Carbon Fraction

● Activity Data (Area)

➤ Determining the forest area

Forest areas of 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 from the National Forest Resource Database (NFRDB) since FY2005 and onward. Data

from FY1991 to FY1994, FY1996 to FY2001, and FY2003 to FY2004 are estimated by linear interpolation. 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 are estimated from “other conifer” and “other broad leaf” area divided by the area ratio in FY1995.

Table 6-15 Classifications in Forest Status Survey (before 2004)
and National Forest Resource Database (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		Japanese lime
	Ginkgo		Linden
	Exotic conifer trees		Kalopanax
Other needle leaf	Paulownia		
		Exotic broad leaf trees	
		Other broad leaf	

➤ Obtaining the land area of “Forest land remaining Forest land”

This land area is estimated by subtracting the cumulative total area of land converted to forest land during the past 20 years from the total area of forest land in the year subject to estimation. All areas of land converted to forest land are assumed to be intensively managed forests. For the activity data of land converted to forest land, see section 6.5.2.b)1).

Table 6-16 Area of forest land remaining forest land within the past 20 years

Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Forest land remaining Forest land	kha	24,501.8	24,673.4	24,712.8	24,866.5	24,857.2	24,850.4	24,870.1	24,874.4	24,868.3	25,085.8	25,030.7	24,827.2	24,734.1	24,806.7
Intensively managed forests	kha	9,839.3	10,132.1	10,167.3	10,210.9	10,196.5	10,200.9	10,188.9	10,186.9	10,180.6	10,153.6	10,142.0	10,122.9	10,051.2	10,070.6
Semi-natural forests	kha	13,354.5	13,220.3	13,195.2	13,315.7	13,333.5	13,349.6	13,360.8	13,359.5	13,355.2	13,369.3	13,380.7	13,401.4	13,389.2	13,426.2
Cut-over forests and lesser stocked forests	kha	1,159.0	1,171.0	1,197.4	1,186.0	1,170.8	1,142.8	1,161.7	1,169.0	1,170.8	1,400.6	1,355.6	1,150.0	1,146.9	1,155.2
Bamboo	kha	149.0	150.0	152.9	154.0	156.4	157.1	158.6	159.1	161.7	162.3	152.4	153.0	146.8	154.8

Source: Forest Status Survey, National Forest Resources Database (Forestry Agency)

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

● Estimation Method

In accordance with the decision tree provided in the 2006 IPCC Guidelines, these pools are estimated by the Tier 3 method.

Carbon stock changes in pools of dead wood, litter and mineral soils are estimated by multiplying average carbon stock changes per unit area per forest management type by the land area of each forest

management type.

$$\Delta C_{dls} = \sum_{k,m,j} \left\{ A_{k,m,j} \times (d_{k,m,j} + l_{k,m,j} + s_{k,m,j}) \right\}$$

ΔC_{dls} : Annual change in carbon stocks in dead wood, litter and soil [t-C/yr]

A : Area [ha]

d : Average carbon stock change per unit area in dead wood [t-C/ha/yr]

l : Average carbon stock change per unit area in litter [t-C/ha/yr]

s : Average carbon stock change per unit area in soil [t-C/ha/yr]

k : Type of forest management

m : Age class or forest age

j : Tree species

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, it is not thought probable that the trouble would be taken to do drainage and plant trees on land with organic soil not suitable for the growing of forestry tree species, when forestry management have been at severe condition during some decades. Moreover, there are many cases where areas with organic soil have a precious natural environment, and the change of the land configuration or character are being regulated in these places by law and regulations. In addition, when we consulted with persons who have demonstrable expertise in forest soil environments, it was confirmed that they have never heard of such cases of soil drainage in forest lands with organic soils in Japan. Given the above, it is thought that soil drainage in forest land with organic soils is not implemented in Japan; therefore the emissions for this category are reported as “NO”.

● **Parameters**

Average carbon stock changes per unit area for dead wood, litter and soils are calculated by the CENTURY-jfos model, which was modified from the CENTURY model (Colorado State University) to be applicable to Japanese climate, soil, and vegetation conditions.

➤ **Key Assumptions and Parameters for the CENTURY-jfos Model**

Since it is thought that the amounts of tree growth and stable soil carbon stocks were thought to vary depending on climatic or locational conditions, the data of climatic values and soil carbon stocks were aggregated for each tree species in each prefecture (Table 6-17). It was assumed that forests have continually existed and been routinely utilized, and that their soil carbon stocks have been in a nearly steady state. Next, the parameters in the CENTURY-jfos model were adjusted. First, the growth parameters of above-ground biomass were adjusted so that the model be fitted to the growth in the yield tables in association with climatic values calculated per prefecture and per tree species. Second, the parameters were adjusted so that soil carbon stocks after the 60-year cutting age after a spinup of 3,000 years be fitted to the parameters for each of the prefectures and tree species calculated by Morisada *et al.* (2004). The methodologies of adjusting each parameter are in accordance with Sakai *et al.* (2010).

Tuning of the CENTURY-jfos Model

The Forestry and Forest Products Research Institute adjusted the CENTURY model in order to apply it to the Japanese forest environment. That is, forests were classified by predominant tree species (Japanese Cedar, Hinoki Cypress, Pine species, Japanese Larch, Sakhaline Fir, Sakhaline Spruce, broad leaf trees, and other conifer trees), and the geographical distribution of the tree species and soil types underneath were identified for each prefecture. The climate conditions to run the model were prepared from the mesh climate data provided by the Meteorological Agency of Japan (Japan Meteorological Agency, 2002). The model was adjusted with parameters on tree growth so that the tree growth in the model conformed to yield tables, and it was also tuned so that its output of carbon stocks in soil conformed to actual values based on field surveys for each prefecture and tree species (Table 6-17). The model after these modifications was named as the CENTURY-jfos model. After the tuning, carbon stocks in dead wood, litter and soil, and their stock changes were calculated by the CENTURY-jfos for different types of forest management such as management with thinning or without thinning.

Average annual carbon stock changes per unit area in dead wood, litter and soil are calculated for 1 – 19 age classes (for 100 years) for each type of forest management by means of CENTURY-jfos in order to estimate carbon stock changes in these carbon pools using the same activity data as for living biomass.

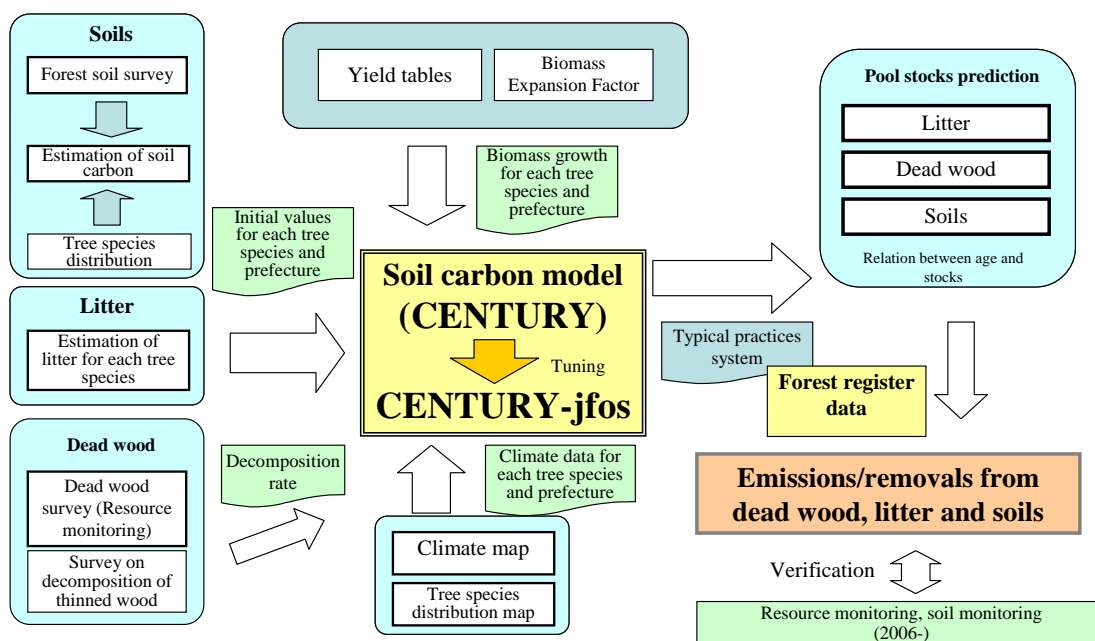


Figure 6-2 Estimation of emissions/removals in dead wood, litter and soils

Table 6-17 Standard soil carbon stocks used for the CENTURY-jfos model

(t-C/ha [30 cm depth])

Prefecture No.	Prefecture	Tree Species							
		Japanese Cedar	Hinoki Cypress	Pine species	Japanese Larch	Sakhaline Fir	Sakhaline Spruce	Broad Leaf Trees	Other Conifer Trees
1	Hokkaido	98.0	NA	95.0	91.0	88.0	93.7	91.0	83.5
2	Aomori	92.1	NA	94.3	83.3	109.1	NA	89.0	89.8
3	Iwate	89.5	93.6	92.7	93.9	98.1	NA	91.3	93.3
4	Miyagi	86.1	70.8	78.5	90.3	110.9	NA	82.8	80.5
5	Akita	81.1	NA	72.4	81.0	108.5	NA	82.6	79.6
6	Yamagata	83.2	79.7	68.0	81.0	97.4	NA	74.4	76.9
7	Fukushima	84.3	83.7	81.1	89.3	108.6	NA	81.4	85.0
8	Ibaraki	84.3	83.4	97.6	NA	NA	NA	91.2	90.8
9	Tochigi	83.0	86.1	91.6	100.6	133.4	NA	93.1	96.4
10	Gunma	88.7	88.3	93.9	95.1	98.1	NA	86.5	93.9
11	Saitama	81.3	82.4	96.2	106.8	NA	NA	85.8	94.7
12	Chiba	93.9	85.7	65.6	NA	NA	NA	84.6	76.4
13	Tokyo	79.2	81.6	85.7	94.7	NA	NA	63.9	84.3
14	Kanagawa	91.9	99.8	89.8	NA	NA	NA	94.9	99.1
15	Niigata	83.9	51.3	63.4	86.7	133.0	NA	85.3	86.9
16	Toyama	90.3	NA	72.5	88.5	106.0	NA	94.5	100.2
17	Ishikawa	82.7	80.2	70.2	NA	133.4	NA	86.6	74.3
18	Fukui	88.7	85.8	79.8	NA	NA	NA	90.1	80.6
19	Yamanashi	93.0	93.9	98.0	99.3	NA	NA	93.9	95.6
20	Nagano	102.1	100.5	96.0	108.4	106.0	NA	97.9	103.3
21	Gifu	100.5	94.8	79.1	99.6	107.8	NA	95.8	93.9
22	Shizuoka	94.6	96.7	69.1	90.7	NA	NA	90.0	93.7
23	Aichi	91.2	85.0	60.1	NA	NA	NA	78.5	77.2
24	Mie	92.1	84.4	63.8	97.1	NA	NA	78.7	80.5
25	Shiga	83.5	73.0	59.6	NA	NA	NA	79.5	65.8
26	Kyoto	74.0	67.4	63.3	NA	NA	NA	66.4	64.6
27	Osaka	78.9	74.0	60.9	NA	NA	NA	67.5	66.0
28	Hyogo	88.3	71.8	53.0	123.6	NA	NA	63.4	61.9
29	Nara	79.6	69.8	65.5	NA	NA	NA	73.4	69.4
30	Wakayama	72.1	70.5	58.2	NA	NA	NA	62.8	69.9
31	Tottori	73.8	74.9	75.6	121.2	NA	NA	72.3	75.4
32	Shimane	69.0	66.6	61.2	77.3	NA	NA	64.6	63.2
33	Okayama	80.3	73.7	51.4	121.2	NA	NA	65.2	63.6
34	Hiroshima	74.0	71.8	54.0	71.2	NA	NA	65.0	58.7
35	Yamaguchi	64.9	60.9	49.3	NA	NA	NA	55.2	54.8
36	Tokushima	72.9	63.7	63.6	NA	NA	NA	66.7	63.7
37	Kagawa	57.7	61.9	56.6	NA	NA	NA	57.2	57.7
38	Ehime	80.1	75.1	63.2	85.4	NA	NA	67.4	74.1
39	Kochi	81.4	76.1	73.8	NA	NA	NA	74.1	76.2
40	Fukuoka	97.3	88.9	77.5	NA	NA	NA	86.5	88.3
41	Saga	83.6	83.0	69.1	NA	NA	NA	79.6	82.9
42	Nagasaki	82.9	84.5	82.6	NA	NA	NA	78.9	84.5
43	Kumamoto	108.7	96.0	79.3	NA	NA	NA	93.5	95.6
44	Oita	109.9	100.5	108.3	130.3	NA	NA	99.1	101.4
45	Miyazaki	106.1	102.0	93.7	NA	NA	NA	98.0	99.6
46	Kagoshima	108.4	102.4	75.7	NA	NA	NA	90.8	97.0
47	Okinawa	58.5	NA	58.9	NA	NA	NA	58.0	58.5

● Activity Data (Area)

Forest area data provided by the NFRDB were used for the estimation as activity data input to CENTURY-jfos model. In addition, areas of organic soils in forest land were estimated as reference values 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, bamboo and forests with less standing trees are reported as “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 12% for the total removals by forest land remaining forest land. Uncertainty estimates regarding the major parameters in this category are shown in Table 6-18.

Table 6-18 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		22	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 <i>2006 IPCC Guidelines</i> 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.

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 Chapter 1.

e) *Category-specific Recalculations*

● *Correction in accordance with revision of AR area*

Areas of intensively managed forests in forest land remaining forest land was recalculated because areas of afforestation and reforestation (AR areas), which is used as original data for determining areas of forests converted from other land-use, were revised. Following the revision, carbon stock changes in

living biomass, dead organic matter and mineral soils in this category were recalculated for all years. For details in the revision of estimation method of AR and D areas, please see the Chapter 11, 11.5.1.7, “Review of AR and D areas”.

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

None.

6.5.2. 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 removal in this subcategory in FY2017 was 1,041 kt-CO₂. This represents a decrease of 84.4% below the FY1990 value and a decrease of 6.0% below the FY2016 value. Removals since 1990 have been in consistent decreasing trend. The reason of the consistent decrease trend is inferred that the number of proprietors of forestry business who newly expand their areas for planting trees has decreased because profitability of forestry business in Japan has declined.

b) Methodological Issues

1) Carbon stock change in Living Biomass in “Land converted to Forest land”

● **Estimation Method**

In the Tier 2 method, the annual carbon stock change in land converted to forest land (ΔC_{LF}) is to be estimated by summing the loss of carbon stock due to conversion (ΔC_L) and the change of carbon stock accumulated after conversion (ΔC_F). However, it is difficult to extract removals occurred on land converted to forest land directly from the data of the NFRDB because it deals with the stock change of living biomass of both forest land remaining forest land and land converted to forest land after land conversion collectively. On the other hand, it can be assumed that forest land subjected to AR activities under Article 3, paragraph 3, of the Kyoto Protocol and land converted to forest land have similar nature. Therefore, ΔC_F was estimated by multiplying the area of converted land by the carbon stock change per unit area due to AR activities. The ΔC_F value is reported all together under rice field converted to forest land in the CRF. ΔC_L was estimated and reported for each land-use category. For conversions from rice field, upland field, wetlands, settlements and other land, where carbon stocks of living biomass are assumed as 0, the carbon losses are reported as “NA”.

$$\Delta C_{LF} = \Delta C_L + \Delta C_F$$

$$\Delta C_L = \sum_i \{A_i \times (B_a - B_{b_i}) \times CF\}$$

$$\Delta C_F = A_{LF} \times IEF_{AR}$$

ΔC_{LF} : Annual carbon stock change in land converted to forest land [t-C/yr]

ΔC_L : Annual carbon stock change at the land conversion [t-C/yr]

ΔC_F : Carbon stock change in the converted land within 20 years since conversion [t-C/yr]

i : Land-use category before conversion

A_i : Annual increase of land area that has been converted from land-use type i to forest [ha/yr]

- B_a : Dry matter weight per unit area immediately after conversion to forest [t-C/yr]
 $B_{b,i}$: Dry matter weight per unit area before conversion from land-use type i to forest [t-C/yr]
 A_{LF} : Area of converted forest land within 20 years [ha]
 IEF_{AR} : Average carbon stock change per unit area due to AR activities (equal to the implied removal factor) [t-C/ha/yr]
 CF : Carbon fraction of dry matter [t-C/t-d.m.]

● **Parameters**

➤ **Per unit area removals of Afforestation and Reforestation activities**

The average value of carbon stock change per unit area due to AR activities between FY2008 and FY2010 (3.0 t-C/ha/yr) was applied to all reporting years, and for AR area and amount of removal, confirmed values in first commitment period of Kyoto Protocol were fixed.

➤ **Biomass stock in each Land-Use Category**

The parameter of grassland before conversion, shown in Table 6-8a, is used.

● **Activity Data (Area)**

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 annually converted areas from each land-use category are described below.

➤ **Total area of “Land converted to Forest land”**

It is logically presumed that the areas of land converted to forest land include AR areas, forest land restored from degraded land by natural succession, and land whose land-use categories are changed to forest land due to other reasons. However, it does not occur in general in Japan that forest land restored from degraded land by natural succession usually would be determined as “Forests under Forest Law Article 5 and 7.2” as indicated in Table 6-2. Therefore, such areas are classified as remaining land categories. Hence, it is regarded that the areas of land converted to forest land are similar to the AR areas, and that the areas are determined in accordance with the concept of “overlap” described as a time series consistency and recalculation approach on section 5.3.3.1 in Volume 1 of the 2006 IPCC Guidelines, by using the AR areas and areas of forested cropland reported in the *Statistics of Cultivated and Planted Area*. Since the AR areas are identified in detail by utilizing orthophotos taken at the end of 1989 and satellite images taken from FY2005 onwards, the annual areas of land converted to forest land in and after 2005 were regarded as the same as the areas obtained by utilizing the method of estimating annual AR areas in KP-LULUCF and the annual AR areas were used. For further information on determining AR areas, see section 11.4.2.3 in Chapter 11.

The annual AR areas before FY2005 are not directly obtained from orthophotos interpretation. Thus, the area of land converted to forest land before FY2005 are estimated separately from FY1990 to FY2004 and FY1971 to FY1989 respectively taking into account available information.

- **From FY1990 to FY2004**

The annual areas of land converted to forest land from FY1990 to FY2004 are calculated by simply dividing the total AR area of FY 2005 (=total land converted to forest area for the period from FY1990 to FY2005), by numbers of years from FY1990 to FY2004.

- **From FY1971 to FY1989**

The annual areas of land converted to forest land before FY1990 are calculated by using forest area and

deforestation area obtained from statistics provided by the *World Census of agriculture and Forestry* (MAFF). The *Statistics of Cultivated and Planted Area* (MAFF) was also used as an anxious data for obtaining land use category level information. In concrete terms, the areas are calculated by the following procedures.

1. Forest area change from FY1970 to FY1980 and FY1980 to FY1990 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 are calculated by using the 10 years total deforestation area obtained from the statistics and the changed areas of forest calculated in Step 1;
3. The difference between the total afforestation area on agriculture land in 10 years (calculated from the *Statistics of Cultivated and Planted Area* (MAFF)) and the total area of land converted to forest land of 10 years calculated in Step 2 is assumed as the afforestation area on the land other than agricultural land;
4. The ratios of the 10-year cumulative afforestation area on agricultural land and on non-agriculture lands for the periods from FY1970 to FY1979 and FY1980 to FY1989 are calculated. Annual afforestation areas on non-agricultural land area calculated by multiplying the estimated ratio above to the annual afforestation area on agriculture land obtained from statistics.

➤ **Areas of “Cropland and Grassland converted to Forest Land”**

The areas of cropland converted to forest land before FY2004 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 dividing the areas of forested by planting on arable land, also provided by the *Statistics of Cultivated and Planted Area*, by means of the existing area ratios of upland fields, orchards and pasture land.

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 in the *Statistics of Cultivated and Planted Area* and those of forested by planting on grazed meadow reported in *A Move and Conversion of Cropland*.

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, by the annual AR area obtained by utilizing the method of estimating AR areas in KP-LULUCF.

➤ **Areas of “Wetlands, Settlements or Other land converted to Forest land”**

The areas of wetlands, settlements, and other land converted to forest land cannot be obtained directly from statistics for the years before FY2004. Therefore, 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.

The areas of wetlands, settlements or other land converted to forest land since FY2006 were respectively estimated by multiplying the percentage of the number of plots interpreted as conversion from wetlands, settlements or other land to forest land in the total number of AR plots, by the annual AR area obtained by utilizing the method of estimating AR areas in KP-LULUCF.

Table 6-19 Area of land converted to forest land (single year)

Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Land converted to Forest land	kha	5.01	5.01	5.01	5.01	4.40	3.60	3.60	2.53	2.53	1.02	1.02	0.72	0.72	0.18
Cropland converted to Forest land	kha	2.71	1.22	1.08	0.57	2.55	1.74	1.74	1.14	1.14	0.55	0.55	0.18	0.18	0.04
Rice field	kha	0.92	0.47	0.41	0.17	0.84	0.57	0.60	0.33	0.33	0.16	0.15	0.05	0.05	0.01
Upland field	kha	1.31	0.57	0.51	0.31	1.35	0.92	0.90	0.64	0.64	0.31	0.32	0.11	0.11	0.02
Orchard	kha	0.49	0.19	0.15	0.09	0.37	0.25	0.24	0.17	0.17	0.08	0.08	0.027	0.03	0.01
Grassland converted to Forest land	kha	0.67	0.31	0.28	0.17	0.67	0.97	0.97	0.98	0.98	0.29	0.29	0.39	0.39	0.13
Wetlands converted to Forest land	kha	NO	NO	NO	NO	0.01	NO	NO	0.03	0.03	0.01	0.01	NO	NO	NO
Settlements converted to Forest land	kha	0.82	1.74	1.83	2.13	0.80	0.59	0.59	0.31	0.31	0.13	0.13	0.09	0.09	0.02
Other land converted to Forest land	kha	0.82	1.74	1.83	2.13	0.37	0.30	0.30	0.07	0.07	0.04	0.04	0.05	0.05	NO

(Reference): Forestry Status Survey, National Forest Resources Database (Forestry Agency)

Table 6-20 Area of Land converted to forest land within the past 20 years

Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Land converted to Forest land	kha	448.5	223.5	163.2	125.6	111.9	97.5	96.1	93.6	91.2	87.2	83.2	78.9	74.6	69.8
Cropland converted to Forest land	kha	121.9	57.7	40.6	30.0	31.9	29.9	29.0	27.7	27.1	26.2	25.4	24.3	23.3	22.2
Rice field	kha	53.8	23.7	15.9	11.0	11.0	10.8	10.4	9.9	9.5	9.1	8.7	8.3	7.8	7.4
Upland field	kha	46.8	23.7	17.7	14.0	15.8	14.6	14.2	13.7	13.6	13.3	13.0	12.5	12.1	11.6
Orchard	kha	21.4	10.3	6.9	4.9	5.1	4.6	4.3	4.1	4.0	3.8	3.7	3.5	3.4	3.2
Grassland converted to Forest land	kha	19.3	11.6	9.0	7.3	8.2	8.1	8.4	8.8	9.4	9.4	9.3	9.4	9.5	9.3
Wetlands converted to Forest land	kha	NO	NO	NO	NO	0.03	0.03	0.03	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Settlements converted to Forest land	kha	153.6	77.1	56.8	44.2	36.5	30.6	30.3	29.6	28.5	27.0	25.5	23.9	22.2	20.4
Other land converted to Forest land	kha	153.6	77.1	56.8	44.2	35.2	28.9	28.4	27.4	26.1	24.5	22.9	21.2	19.5	17.7

(Reference): Forestry Status Survey, National Forest Resources Database (Forestry Agency)

2) Carbon Stock Changes in Dead Organic Matter and Soils in “Land converted to Forest land”

● Estimation Method

Carbon stock changes in dead wood, litter and mineral soils were calculated under the assumption that these carbon stocks change linearly over 20 years from those in land-use categories other than forest land to those in forest land. The calculation was implemented by applying the average carbon stocks obtained by the CENTURY-jfos model. Emissions from organic soils in this category were reported as “NO” in the same manner as forest land remaining forest land.

$$\Delta C_{LF\ i} = A_i \times (C_{after} - C_{before\ i}) / 20$$

$\Delta C_{LF\ i}$: Annual change in carbon stocks in dead wood, litter or soils in land-use category i converted to forest land [t-C/yr]

A_i : Area of land-use category i being converted to forest land within the past 20 years [ha]

C_{after} : Average carbon stocks per unit area in land-use category after conversion (forests) [t-C/ha]

$C_{before\ i}$: Average carbon stocks per unit area in land-use category i before conversion [t-C/ha]

i : Land-use category (cropland, grassland, wetlands, settlements, or other land)

● Parameters

Parameters for each carbon pool in Table 6-9 (dead wood), Table 6-10(litter) and Table 6-11 (soil) 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 (Area)**

- **Total areas of “Land converted to Forest land”**

See Table 6-20.

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 12% 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 Chapter 1.

e) Category-specific Recalculations

- **Correction in accordance with revision of AR area**

As it was mentioned in 6.5.1.e), areas of forest land converted from other land-use categories due to the correction of AR area were recalculated. Accordingly, carbon stock changes in living biomass, dead organic matter and mineral soils in this category were recalculated from FY1990 to FY2016.

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

- **Carbon Stock Changes in Soils in “Cropland and Grassland converted to Forest Land”**

The areas converted to forest land from upland fields, orchards and pasture land are estimated by multiplying the total areas converted from cropland to forest land by each area ratio of upland fields, orchards and pasture land. However, this estimation method may not represent the actual condition of these areas. Hence, improvement of the validity of the estimation method and land-area identification is an issue to be examined in the future.

6.6. 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 cultivation abandoned agricultural land.

In FY2017, Japan’s cropland area was about 4.27 million ha, which is equivalent to about 11.3% of the national land. The area of organic soil in cropland is about 0.217 million ha. The emissions from this category in FY2017 were 4,522 kt-CO₂ (excluding 34.9 kt-CO₂ eq. of non-CO₂ emissions from drained organic soils and drainage ditches, 6.0 kt-CO₂ eq. of N₂O emissions resulting from nitrogen

mineralization resulting from change of land use or management of mineral soils, and 21.0 kt-CO₂ eq. of CH₄ and N₂O emissions resulting from biomass burning); this represents a decrease of 61.4% below the FY1990 value and a decrease of 6.0% below the FY2016 value.

In this section, cropland is divided into two subcategories, “Cropland remaining Cropland (4.B.1.)” and “Land converted to Cropland (4.B.2.)”, and describes them separately in the following subsections.

Table 6-21 Emissions and removals in cropland resulting from carbon stock changes

Gas	Category	Carbon pool	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
CO ₂	4.B. Cropland	Total	kt-CO ₂	11,718	5,485	72	2,302	10,475	8,003	5,504	5,918	4,965	3,681	4,436	4,337	4,811	4,522
		Living Biomass	kt-CO ₂	1,380	466	227	245	365	332	297	289	297	219	213	243	239	201
		Dead Wood	kt-CO ₂	296	59	18	33	54	43	43	42	42	23	23	19	19	10
		Litter	kt-CO ₂	142	28	9	16	26	21	21	20	20	11	11	9	9	5
		Mineral soil	kt-CO ₂	8,249	3,292	-1,806	392	8,416	5,994	3,532	3,956	2,994	1,814	2,574	2,450	2,929	2,688
		Organic soil	kt-CO ₂	1,653	1,640	1,624	1,617	1,614	1,613	1,612	1,611	1,612	1,614	1,615	1,615	1,615	1,618
	4.B.1. Cropland remaining Cropland	Total	kt-CO ₂	10,116	5,141	-40	2,119	10,148	7,775	5,289	5,709	4,723	3,559	4,313	4,231	4,705	4,456
		Living Biomass	kt-CO ₂	280	245	157	121	128	177	154	151	127	144	137	179	174	168
		Dead Wood	kt-CO ₂	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
		Mineral soil	kt-CO ₂	8,249	3,292	-1,806	392	8,416	5,994	3,532	3,956	2,994	1,814	2,574	2,450	2,929	2,688
		Organic soil	kt-CO ₂	1,588	1,603	1,609	1,606	1,604	1,604	1,603	1,602	1,602	1,602	1,602	1,602	1,601	1,600
	4.B.2. Land converted to Cropland	Total	kt-CO ₂	1,602	345	111	184	327	228	215	209	242	122	123	106	107	65
		Living Biomass	kt-CO ₂	1,100	221	69	124	238	155	142	139	170	75	76	64	64	32
		Dead Wood	kt-CO ₂	296	59	18	33	54	43	43	42	42	23	23	19	19	10
		Litter	kt-CO ₂	142	28	9	16	26	21	21	20	20	11	11	9	9	5
		Mineral soil	kt-CO ₂	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
		Organic soil	kt-CO ₂	64	36	15	11	10	9	9	9	11	13	13	14	14	18

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

a) Category Description

This subcategory deals with carbon stock changes in cropland, which has remained as cropland during the past 20 years. The emissions from this subcategory in FY2017 were 4,456 kt-CO₂ (excluding GHG emissions other than carbon stock changes); this represents a decrease of 55.9% below the FY1990 value and a decrease of 5.3% below the FY2016 value. Carbon stock changes in mineral soils have greatly contributed to the increase/decrease trend of emissions/removal amount in this category. CO₂ emissions from mineral soils in FY2017 were 2,688 kt-CO₂; a 67.4% decrease compared to FY1990 and a 8.2% decrease compared to FY2016.

From FY1990 to FY2003, the emissions had a decreasing trend and even reached removal. However, after turning back to emissions in FY2004, emissions have been increasing continuously, while temporal decrease can be seen. Then, an increase has been continuously shown with transitory emission decrease at a time. It is considered that the time-series variability is mainly caused by annual changes of amount of carbon input into soils (especially, carbon input of compost) and climate (especially, temperature). Carbon stock changes have been estimated by using a modeling method, explained below; therefore, the changes at the national level were affected by the sum of measurement result of each local area. It is considered that the variability in Hokkaido prefecture, which holds more than 25% of upland field in Japan, have a relatively large influence on the carbon stock changes at the national level, because the year-to-year variability in upland field was especially larger than among three categories of cropland. Roughly to say, the overall carbon fluctuation tends to be roughly linked to the trend of the compost

manure input to soil, and One tendency can be seen that variations in crop yields act as finer annual fluctuations.

Carbon stock changes in living biomass are estimated for the carbon stock change in perennial tree crops (fruit trees) according to the *2006 IPCC Guidelines*.

Carbon stock changes in dead organic matter are estimated as zero (0) by applying the Tier 1 method, which assumes 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”.

Carbon stock changes in mineral soils in rice field, upland field and orchard were estimated by applying Tier 3 model (Roth C, Rothamsted Carbon Model) .On-site CO₂ emissions from drained inland organic soils in rice fields and upland fields were estimated. Off-site CO₂ emissions via waterborne carbon losses from drained inland organic soils in rice fields and upland fields were estimated.

CO₂ emission from organic soils in orchards and in cultivation abandoned agricultural land were reported as “NO” because tillage and drainage of organic soils in orchard and in cultivation abandoned agricultural land were not implemented. The area of cropland remaining croplands within the past 20 years was shown in Table 6-22. Besides, this area contained both land of mineral soils and organic soils.

Table 6-22 Areas of cropland remaining cropland within the past 20 years

Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Cropland remaining Cropland	kha	4,597	4,464	4,417	4,386	4,353	4,346	4,339	4,317	4,313	4,305	4,295	4,280	4,258	4,228
Rice fields	kha	2,768	2,707	2,628	2,545	2,503	2,494	2,484	2,462	2,454	2,446	2,438	2,426	2,412	2,395
Upland fields	kha	1,186	1,141	1,119	1,136	1,147	1,150	1,154	1,152	1,152	1,150	1,146	1,142	1,139	1,131
Orchards	kha	426	372	328	318	311	308	306	303	300	296	293	289	284	280
Cultivation abandonment area	kha	217	244	343	386	392	394	396	401	407	412	418	423	423	423

b) Methodological Issues

1) Carbon Stock Changes in Living Biomass in “Cropland remaining Cropland (Orchard)”

● Estimation Method

As for living biomass, only perennial woody species are targeted for estimation. Therefore, carbon stock changes in living biomass only in orchards are estimated by applying the Tier 2 estimation method (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 orchards are calculated by multiplying cultivation area of each orchard tree by dry matter biomass weight per tree, planting density, and carbon fraction of dry matter. The carbon stocks in above- and below ground biomass were calculated by using the root-to-shoot ratio. These parameters except the carbon fraction are determined for each type of orchard tree.

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

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

*10/1000 is for unit conversion

- ΔC : Carbon stock change in living biomass of Orchard [t-C/yr]
 C_t : Total Carbon 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*

According to Tier 2 method described in the *2006 IPCC Guidelines*, 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 (change of cultivation area)*

Changes of cultivation area were estimated for 15 major orchard trees by each prefecture by subtracting cultivation area in the previous year from these in the current year. The cultivation area for 15 major orchard trees was identified by existing statistics (*the Statistics of Cultivated and Planted Area* by the MAFF). As for fruit trees other than 15 major orchard trees, the cultivation area was also identified by existing statistics. 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 activity data (area) used for estimation in living biomass includes area of orchard land converted from other land-use.

2) *Carbon Stock Changes in Soils in “Cropland remaining Cropland”*

● *Estimation Method*

➤ *Carbon stock changes in mineral soils*

Japan uses a Tier 3 method to estimate soil organic C stock changes in agriculture land (cropland and managed grassland) by calculating carbon stock changes of soil over time based on the Rothamsted Carbon Model (Roth C).

Figure 6-3 is conceptual diagram of Roth C. Roth C is a soil carbon dynamic model validated by using long-term field experiments (Coleman and Jenkinson, 1996). In order to apply the model to Japanese agricultural conditions, the model was tested against long-term experimental data sets in Japanese agricultural lands. 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, the model required modification for Andosols and paddy soils by taking unique mechanisms of soil C dynamics in these soils into account. 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). 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).

Since the land use data used for the model estimation (grid based data set) and used for the official land classification in GHG inventory (statistical data) are not very consistent, the GHG inventory do not use the carbon stock change calculation results directly from the Roth C model, but use Roth C to calculate the average C stock change rates per hectare in each prefecture and in each sub-category (rice field, upland crop fields, orchards and managed grassland). The carbon stock changes (t-C/year) were calculated by multiplying the average carbon stock changes in each year by land use subcategory (rice fields, upland fields, orchards and pastoral land) calculated by the Roth C model by the mineral soil area of each prefecture obtained from existing statistics.

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 or not land conversion. The estimation equation is as follows:

$$\Delta C_{national} = \sum_{i,j} (\Delta SOC_{i,j} \times A_{i,j})$$

$\Delta C_{national}$: Carbon stock changes in mineral soils [t-C/yr]

SOC : Carbon stock changes in mineral soils per unit area [t-C/ha], 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

➤ *CO₂ emissions from organic soils*

For estimating CO₂ emissions from organic soils, emissions from plowing organic soils (on-site emissions), and emissions from water-soluble carbons (off-site emissions) were estimated; These estimations include the estimations in organic soils in other land converted to crop land.

- *On-site CO₂ emissions from organic soils*

On-site CO₂ emissions from organic soils in rice fields and upland fields were estimated by applying Tier 1, 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 can be used. The estimation equation is as follows:

$$\Delta C_{OS} = \sum_c (A \times EF)_c$$

ΔC_{OS} : Carbon stock changes in organic soils (emissions) [t-C/yr]

A : Area of organic soils [ha]

EF : CO₂ emission factor [t-C/ha/yr]

c : Climate zone

- *Off-site CO₂ emissions via waterborne carbon losses from drained inland organic soils*

Off-site CO₂ 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 the *Wetlands guidelines*. The estimation equation is as follows:

$$CO_2 - C_{DOC} = \sum(A \times EF_{DOC})$$

$$EF_{DOC} = DOC_{FLUX_NATURAL} \times (1 + \Delta DOC_{DRAINAGE}) \times F_{rac_{DOC-CO_2}}$$

$CO_2 - C_{DOC}$: Annual off-site CO₂-C emissions due to DOC loss from drained organic soils [t-C/yr]

A : Land area of drained organic soils in land-use subcategory [ha]

EF_{DOC} : Emission factors for annual CO₂ 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

$Frac_{DOC-CO_2}$: Conversion factor for proportion of DOC converted to CO₂ following export from site

● Parameters

➤ Assumption and parameters necessary for mineral soil modeling

As shown in Figure 6-3, soil carbon is divided into five compartments with different decomposition rates and the amount change of soil carbon is calculated monthly; input parameters are 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 other activity data (carbon input from crop residue and organic manure). To apply the model to nationwide estimation, input data was determined using the existing statistical material, map data and questionnaire survey with the resolution of 1km mesh for weather, 100m mesh for soil property and land use data, and amount of carbon input was adjusted by prefecture and by land use subcategory (rice fields, upland fields, orchards, pasture land).

The weather, soil property and land use data are available as spatially explicit data set, while carbon input from crop residue and organic manure are calculated by statistical data and survey data available based on public administration boundary basis. In addition, as for the input amount of crop residue, the amount of crop residue to be returned to soil is calculated by multiplying various factor by the crop yields obtained from statistical data by each prefecture. However, since the input amount of organic manure can not be obtained from statistical data by land use subcategory, the questionnaire survey results by crops (rice, upland crops, vegetables, fruit trees, tea, feedstuff, pasture grass) for FY1980, FY1985, FY1990, FY1995, FY2000, FY2010 are used.

The model is implemented at the national scale using the input data, and the soil carbon stock amount per unit area are calculated monthly with a standard mesh (100 m × 100 m). The sum of the monthly values is the value of that year and the difference from the previous year is the amount of soil carbon change (t-C/ha/year) per unit area for that year. By overlapping with soil carbon change per unit area per standard mesh and the administrative boundary data, soil carbon change amount (t-C/ha/year) per unit area by prefecture and by land use subcategory (rice fields, upland fields, orchard, pasture land) were obtained.

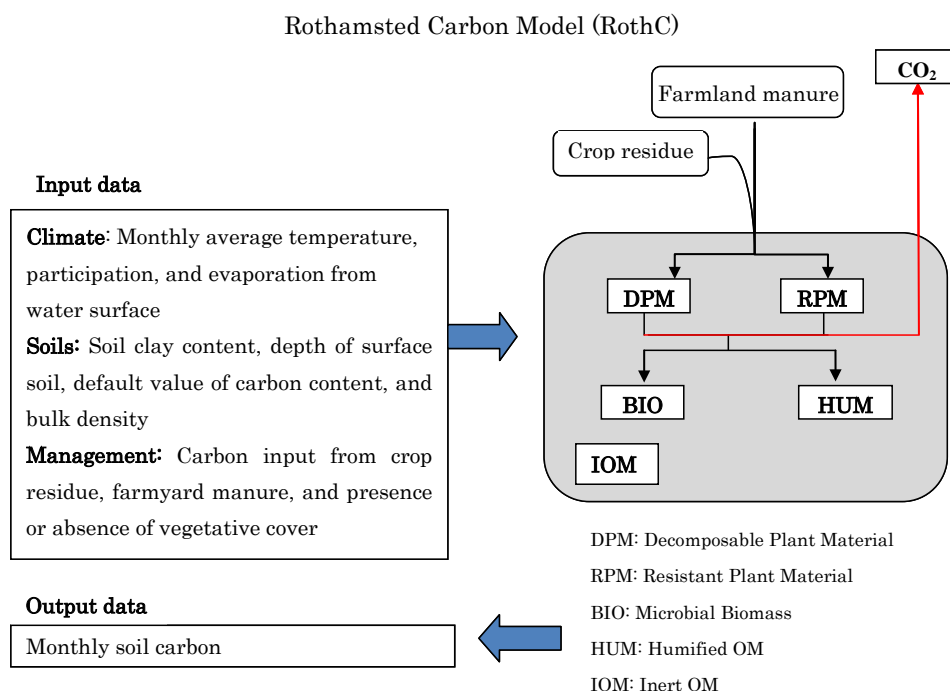


Figure 6-3 Roth C model

➤ **CO₂ emission factors from organic soils (on-site)**

The following CO₂ emission factors from organic soils in rice fields and upland fields were applied to the estimation.

Table 6-23 CO₂ emission factors resulting from cultivation of organic soils

Type of land use	Climate zone	Emission factors [t-C/ha/yr]	Reference
Rice field	Cold temperate	1.55	Measured data ¹⁾
	Warm temperate	1.55	Data measured for cold temperate was applied. ²⁾
Upland field	Cold temperate	4.18	Measured data
	Warm temperate	10.0	Default value (2006 IPCC Guidelines, Table 5.6)

- 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.

➤ **CO₂ emissions factors from organic soils (off-site)**

Tier 1 default parameters described in the *Wetlands guidelines* were applied to the estimation.

Table 6-24 Default DOC emission factors for drained organic soils

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

Wetlands guidelines: Table 2.2

● **Activity Data (Area)**

➤ **Area of mineral soils**

Areas of mineral soils in cropland applied for Roth C model were estimated from the reported area in

the *Statistics of Cultivated and Planted Area*, divided as Rice field (only the area with rice really planted), upland field (including the area divided into rice field with other crops planted and with no crops) and orchards; and the areas of organic soils in each divided area (Table 6-25) is subtracted. As for calculation, this Roth C model is widely applied for area which was recorded once as cropland since FY1970 (was regarded as cropland); therefore, the area includes area (mineral soils) of land converted to cropland.

➤ **Area of organic soils**

Since information on areas of organic soils in agricultural land in FY1992 and FY2001 is available, the time-series organic soil area was calculated by implementing the following 1 to 3 for each year;

1. Calculating area of organic soil in agricultural land (rice field, upland field, orchard) for FY1992 and FY2001;
2. Adding area of organic soil of agricultural land converted from other land-use to 1;
3. Subtracting area of organic soil of land converted from agricultural land from 1;

The total organic soil area of agricultural land converted from other land-use within 20 years were reported in cropland converted from land category, and the organic soil area other than those were reported in cropland remaining cropland category. In addition, organic soil area in FY1992 through FY2001 were calculated by interpolation of area of FY1992 and FY2001 by means of linear expression.

The organic soil area in converted agricultural land is basically calculated by multiplying the total land use area for each land use category, by the organic soil rate in the original land use category. However, as for the conversion from wetlands, the ratio of organic soil in land converted from wetlands was set as 0%, because organic soil did not exist in the soil map around the reclaimed wetland that falls into this activity.

As for the conversion from agricultural land, organic soil area were estimated for each land-use (rice field, upland field, orchard) for each land conversion site, by multiplying organic soil ratio in converted land that occurred between FY1992 and FY2001, by the total area of land converted to other land use.

This estimation has been conducted for each prefecture. The estimated areas of organic soils are as follows (sum of area of cropland remaining cropland and area of cropland converted from other land-use). The areas of cultivated organic soil in the Agriculture sector (see section 3.D.a.6) are reported as the active mass actually cultivated in organic soil of agricultural land, and includes all areas of organic soil for rice field and upland field and the renewal ratio (3%) of pasture lands, while organic soils for orchard, grazed meadow and wild land are not included. As for estimation of emissions from organic soils in the LULUCF sector, the values used as activity data are the same area values as in the agricultural sector, but in the CRF of the LULUCF sector, total organic soil area are reported regardless of tillage or drainage. Hence, the areas of organic soil in cropland reported under LULUCF sector (see Table 6-25) were not the same as the areas reported under the Agriculture sector.

Table 6-25 Areas of organic soils in cultivated cropland

Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total	kha	222.2	219.6	217.8	216.8	216.6	216.5	216.5	216.4	216.6	216.7	216.8	216.7	216.6	216.9
Rice field	kha	161.9	161.3	160.6	159.9	159.7	159.7	159.6	159.5	159.7	160.0	160.2	160.2	160.2	160.4
Upland field	kha	24.7	24.4	24.2	24.0	24.0	24.0	23.9	23.9	23.9	23.9	23.9	23.9	23.9	24.0
Orchard	kha	1.4	1.2	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9
Cultivation abandonment area	kha	34.1	32.6	32.2	32.0	32.0	32.1	32.1	32.1	32.1	32.0	31.8	31.8	31.6	31.7

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 mineral soil, 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 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 31% 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 Chapter 1.

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.Y & Taniyama.I, 2003, Shirato et al., 2004, Shirato.Y & Yokozawa.M., 2005, Takata.Y et al., 2011, Shirato.Y, 2011 listed in this chapter.

e) *Category-specific Recalculations*

● *Correction in accordance with revision of D area*

Areas of deforestation (D area) is used for determining each land use area converted from forest land. Since the method of estimating D area from the satellite image interpretation results were revised, areas of cropland remaining cropland were recalculated for all years. For more details on correction of estimation methodology of areas of deforestation, please see Chapter 11, 11.5.1.7 in NIR "Review of AR areas and D areas".

- ***Correction in accordance with the revision of organic soil area***

Since the estimation method of organic soil area in rice fields and upland fields were modified, CO₂ emissions (on-site and off-site) and carbon stock changes in mineral soils for all years were recalculated.

- ***Correction in accordance with the revision of cultivation area of fruit trees***

In addition to 15 main perennial crops, planted area of minor perennial crops were included in the total orchard area. With this correction, the carbon stock changes in living biomass in cropland remaining cropland for all years were recalculated.

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

As tier 3 approach, Roth C model is used for estimating carbon stock change in mineral soils. For more detail explanations of outcomes of the estimation and the fluctuating factor of input values, further analysis will be continued.

6.6.2. 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 FY2017 is 37.5 kha, which represents 0.1% of the national total area.

The emissions from this subcategory in FY2017 were 65 kt-CO₂ (excluding GHG emissions other than carbon stock changers); this represents a decrease of 95.9% below the FY1990 value and a decrease of 38.8% below the FY2016 value. Since FY1990, the emissions had decreased, with some annual variability. Increasing and decreasing of areas where converted cropland from forest, which has higher carbon stock, have an influence on the annual variability.

With respect to living biomass, its carbon stock change as a result of land-use conversion from other land use to cropland is estimated. This process includes both temporary loss of living biomass in the land before and followed gains of living biomass after conversion. However, gains in carbon stocks in rice fields land and upland fields were set as zero. Gains in carbon stocks in orchards were estimated in cropland remaining cropland in a lump and was reported as “IE”.

With respect to dead organic matter, Japan used the CENTURY-jfos model to estimate carbon stocks in dead organic matter in forest land, and then estimated carbon stock changes in forest land converted to cropland. Carbon stock changes in cropland converted from land-uses other than forest land were reported as “NA” assuming that the emissions would not occur.

In regard to carbon stock changes in mineral soils, the carbon stock changes in cropland converted from forest land, grassland and wetlands were estimated in the tier 3 model in a lump for the whole cropland area, and so reported as “IE”. CO₂ emissions (on-site and off-site) from organic soils in cropland converted from land-use categories were estimated in rice field and upland field converted from grassland.

b) Methodological Issues

1) Carbon stock changes in Living Biomass in “Land converted to Cropland”

● Estimation Method

The Tier 2 method is applied for forest land converted to cropland using the country specific value of the amount of biomass accumulation. The Tier 1 method is applied for land uses other than forest land converted to cropland using default values.

$$\Delta C = \Delta C_i + \Delta C_j$$

$$\Delta C_i = A (CR_a - CR_i) \times CF$$

$$\Delta C_j = A \times CR_j \times CF$$

ΔC : Annual carbon stock change in the converted land [t-C/yr]

ΔC_i : Annual carbon stock change at the time of land conversion [t-C/yr]

ΔC_j : Annual carbon stock change in the converted land after conversion [t-C/yr]

i : Land use before conversion

j : Land use after conversion

A : Area of converted land for the current year [ha]

CR_a : Dry matter biomass weight per unit area immediately following conversion [t-d.m./ha/yr], default value=0

CR_i : Dry matter biomass weight per unit area before land was converted from land-use type i [t-d.m./ha/yr]

CR_j : Change of dry matter biomass weight per unit area accumulated after conversion [t-d.m./ha/yr]

CF : Carbon fraction of dry matter [t-C/t-d.m.]

● Parameters

➤ Biomass stock in each Land-Use Category

The values shown in Table 6-8a and Table 6-8b are used for the estimation of biomass stock changes upon land-use conversion and subsequent changes in biomass stock due to biomass growth in the 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 forest land converted to other land-use categories

It was assumed that the areas of forest land converted to other land-use categories (cropland, grassland, wetlands, settlement and other land) were consistent with the area of deforestation (D area) reported under Article 3, paragraph 3, of the Kyoto Protocol. Thus, the area of forest land converted to cropland was estimated by allocating the D area. Since the D survey by satellite image has been conducted since FY2005, the applied method to calculate the D area for FY1970 to FY2004 and for post FY2005 are as follows, respectively.

- From FY1990 to FY2004

In the period from FY1990 to FY2004, annual conversion areas from forest land to other land-use categories were identified by surveys on D areas (For further information on determining the D areas,

see section 11.4.2.3 in Chapter 11). With respect to the areas before 1989, the areas were obtained from statistics provided by the *World 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 from the ratio between the D areas since FY1990 and the areas converted from forests provided by the *World Census of Agriculture and Forestry* and the Forestry Agency's records, and multiplying the areas converted from forests since FY1970 by the adjustment factor.

To estimate areas of forest land converted to each land-use category, ratios of conversion from private forests area to other land-use categories resulting from forest land development, based on the Forestry Agency's records was set. And then, total conversion areas from forest land were multiplied by the ratios of conversion. The ratios are regarded as applicable to the total forests because conversion from private forests to other land-use categories accounts for 90% of the total areas of conversion from forest land.

- *After FY2005*

The areas of forest land converted to cropland, grassland, wetlands, settlements and other land were estimated by multiplying the D area by the land ratios of forest land converted to each land-use category. Both the ratio and the area were determined by the D survey. For further information on determining the D areas, see section 11.4.2.3 in Chapter 11.

➤ *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. 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.

It should be noted that the area presented in the CRF "Table 4.B Sectoral background data for land use, land-use change and forestry – Cropland" is not the annually converted area in FY2017 but the sum of annually converted areas during the past 20 years.

Table 6-26 Area of land converted to cropland (single year)

Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Land converted to Cropland	kha	5.9	2.2	1.8	1.0	1.6	0.8	0.8	0.9	4.6	4.4	3.5	1.8	1.1	5.3
Forest land converted to Cropland	kha	5.3	1.1	0.3	0.6	1.0	0.8	0.8	0.8	0.8	0.4	0.4	0.4	0.4	0.2
Rice field	kha	0.009	0.01	0.002	0.0004	0.1	0.04	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1
Upland field	kha	3.9	0.8	0.3	0.5	0.7	0.6	0.5	0.5	0.5	0.2	0.2	0.2	0.2	0.1
Orchard	kha	1.4	0.3	0.1	0.1	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.04	0.04	0.02
Grassland converted to Cropland	kha	0.004	0.05	0.03	0.06	0.01	0.009	0.001	0.002	0.001	0.001	0.007	0.007	0.004	0.005
Wetlands converted to Cropland	kha	0.34	0.03	0.07	NO	0.47	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
Other land converted to Cropland	kha	0.2	1.1	1.3	0.4	0.1	0.05	0.04	0.1	3.8	4.0	3.1	1.5	0.7	5.1
Rice field	kha	0.2	1.0	1.3	0.3	0.1	0.05	0.03	0.1	3.7	3.7	2.7	1.2	0.5	3.2
Upland field	kha	0.02	0.03	0.02	0.1	0.01	0.001	0.01	0.01	0.1	0.3	0.3	0.2	0.2	1.5
Orchard	kha	0.01	0.01	0.01	0.02	0.002	0.0001	0.002	0.001	0.03	0.1	0.1	0.1	0.1	0.4

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 the value of carbon stock in dead organic matter in forest land obtained by the CENTURY-jfos model. All carbon stocks in dead organic matter in the subcategory are assumed oxidized and emitted as CO₂ 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.

$$\Delta C_{DOM} = \sum_i \{ (C_{after\ i} - C_{before\ i}) \times A \}$$

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]

A : Area of converted land within the year of conversion [ha]

i : type of dead organic matter (dead wood or litter)

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 thus reported as “NA”. 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 reported as “NA”, 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.

● Parameters

Average carbon stocks in dead wood and litter in forest land before conversion are shown in Table 6-9 and Table 6-10. In addition, it is assumed that they become zero immediately after conversion, and will not accumulate after conversion.

● Activity Data (Area)

Annually converted areas to cropland are used for estimating carbon stock changes in dead organic matter in land converted to cropland.

3) Carbon Stock Changes in Soils in “Land converted to Cropland”

● Estimation Method

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 6.6.1.b) 2). Therefore, carbon stock in mineral soils in cropland converted from other land use was reported as “IE”. CO₂ emissions (on-site and off-site) from organic soils was estimated in rice field and in upland field converted from other land use. For detailed information on the emission factors and activity data, see section 6.1.1. The areas of land converted to cropland are shown in Table 6-27 below.

Table 6-27 Area of land converted to cropland within the past 20 years

Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Land converted to Cropland	kha	215.4	158.1	110.8	61.6	45.1	37.4	32.3	29.6	30.5	33.0	33.3	32.9	33.0	37.5
Forest land converted to Cropland	kha	125.9	117.1	95.9	48.6	30.3	23.0	18.4	16.2	13.7	13.0	12.3	11.6	11.2	10.7
Rice field	kha	11.4	7.2	0.9	0.4	0.5	0.5	0.6	0.7	0.7	0.8	0.9	1.0	1.2	1.2
Upland field	kha	76.4	77.1	67.1	34.9	22.1	16.8	13.5	11.8	10.0	9.4	8.8	8.2	7.8	7.4
Orchard	kha	38.0	32.7	27.9	13.3	7.7	5.7	4.4	3.7	3.0	2.8	2.5	2.3	2.2	2.0
Grassland converted to Cropland	kha	33.7	15.8	1.2	1.0	1.0	1.0	1.0	1.0	0.9	0.7	0.5	0.5	0.4	0.4
Wetlands converted to Cropland	kha	11.0	3.2	1.7	1.2	1.2	1.1	0.7	0.7	0.6	0.6	0.6	0.6	0.6	0.6
Settlements converted to Cropland	kha	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Other land converted to Cropland	kha	44.8	22.0	12.0	10.8	12.5	12.3	12.1	11.7	15.2	18.7	19.9	20.3	20.9	25.9
Rice field	kha	23.2	13.2	10.7	9.4	11.1	11.0	10.8	10.4	13.8	17.1	18.2	18.4	18.7	21.9
Upland field	kha	11.5	6.0	1.0	1.1	1.1	1.0	1.0	1.0	1.1	1.2	1.3	1.5	1.7	3.2
Orchard	kha	10.1	2.8	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.5	0.8

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 18% for the entire emission from the land converted to cropland.

● *Time-series Consistency*

Although the methods to estimate the area of forest land converted to other land-use categories are different between FY1990-2004 and post FY2005 as described in section 6.6.2.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 Chapter 1.

e) *Category-specific Recalculations*

● *Correction in accordance with revision of D area*

Since the method of estimating D area, which is used for estimating the areas of cropland converted from forest land were revised, carbon stock changes in living biomass and dead organic matter in this category were recalculated for all years.

See Chapter 10 for impact on trend.

f) *Category-specific Planned Improvements*

● *Methods of Obtaining Data of the area of “Grassland converted to Cropland”*

Statistical data on the area of land converted from grassland to cropland are limited to land converted from grassland (pasture land) to cropland (rice field), so the carbon stock changes in these areas have not been estimated. Therefore, the methods to detect the following area data of conversion need to be developed.

- from pasture land to upland field
- from pasture land to orchard
- from grazed meadow to rice field
- from grazed meadow to upland field
- from grazed meadow to orchard

● **Estimation Method of Soil Carbon Stock Change upon “Land converted to Cropland”**

The estimation method will be considered when new data and information are obtained.

6.7. Grassland (4.C)

Grassland is generally covered with perennial pasture and is used mainly for harvesting fodder or grazing. In FY2017, Japan’s grassland area was about 0.95 million ha, which is equivalent to about 2.5% of the national land. The area of organic soil in the grassland is about 0.055 million ha. The carbon stock changes in this category in FY1990 was 1,053 kt-CO₂ emissions, 95 kt-CO₂ removals in FY2016, and 157 kt-CO₂ removals in FY2017 (excluding 2.2 kt-CO₂ eq. of non-CO₂ emissions from drained organic soils and drainage ditches, 2.2 kt-CO₂ eq. of N₂O emissions resulting from nitrogen mineralization resulting from change of land use or management of mineral soils).

In this section, grassland is divided into two subcategories, “Grassland remaining Grassland (4.C.1.)” and “Land converted to Grassland (4.C.2.)”, and describes them separately in the following subsections.

Table 6-28 Emissions and removals from grassland resulting from carbon stock changes

Gas	Category	Carbon pool	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
CO ₂	4.C. Grassland	Total	kt-CO ₂	1,053	684	41	-1,026	-1,031	-134	32	250	-25	-95	87	-39	-95	-157
		Living Biomass	kt-CO ₂	101	9	-13	42	218	137	125	77	108	111	114	74	75	56
		Dead Wood	kt-CO ₂	42	9	3	20	59	51	51	35	35	44	44	31	30	25
		Litter	kt-CO ₂	20	4	1	10	29	25	25	17	17	21	21	15	15	12
		Mineral soil	kt-CO ₂	862	633	20	-1,126	-1,366	-384	-198	87	-221	-303	-130	-199	-244	-278
		Organic soil	kt-CO ₂	29	29	29	29	29	36	28	34	36	32	38	39	29	28
	4.C.1. Grassland remaining Grassland	Total	kt-CO ₂	881	658	48	-1,098	-1,338	-349	-171	120	-187	-273	-94	-161	-217	-251
		Living Biomass	kt-CO ₂	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
		Litter	kt-CO ₂	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Mineral soil	kt-CO ₂	862	633	20	-1,126	-1,366	-384	-198	87	-221	-303	-130	-199	-244	-278
		Organic soil	kt-CO ₂	20	25	28	28	28	34	27	32	34	31	36	38	27	27
	4.C.2. Land converted to Grassland	Total	kt-CO ₂	172	27	-7	72	307	215	202	130	162	178	181	122	122	94
		Living Biomass	kt-CO ₂	101	9	-13	42	218	137	125	77	108	111	114	74	75	56
		Dead Wood	kt-CO ₂	42	9	3	20	59	51	51	35	35	44	44	31	30	25
		Litter	kt-CO ₂	20	4	1	10	29	25	25	17	17	21	21	15	15	12
		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
		Organic soil	kt-CO ₂	9	4	2	1	1	2	1	1	2	1	2	2	1	1

6.7.1. Grassland remaining Grassland (4.C.1)

a) Category Description

In this category carbon stock changes in grassland remaining grassland during the past 20 years are reported, divided into three subcategories: “pasture land”, “grazed meadow” and “wild land”.

The carbon stock changes in this subcategory were 881 kt-CO₂ emissions in FY1990, 217 kt-CO₂ removals in FY2016 and 251 kt-CO₂ removals in FY2017 (excluding GHG emissions other than carbon stock changes).

The emissions had been decreasing since FY1990, and turned to be removals in 2000s and hit a peak in removals in FY2008. However, the removals have been on a decreasing trend since FY2009 up to now, although minor fluctuations have been repeatedly interrupted.

This high variability was largely due to carbon stock changes in mineral soils (In particular, input amount of compost).

As major impact factors on this high variabilities through time-series, input amount of carbon and yearly temperature fluctuations are considered. Amount of manure application has been on an increasing trend especially in 2000s, though the trend remained flat in following years. 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 CO₂ emissions resulting from tillage and drainage of organic soils and off-site CO₂ emissions via waterborne carbon losses from drained inland organic soils in pasture land were estimated by applying Tier 1 method.

CO₂ emission from organic soils in grazed meadow was reported as “NO” because the tillage 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.

Table 6-29 Areas of grassland remaining grassland within the past 20 years

Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Grassland remaining Grassland	kha	710.6	856.9	951.0	978.4	970.5	968.6	966.7	928.9	927.3	924.7	931.0	929.3	915.8	923.1
Pasture land	kha	325.6	496.0	584.1	601.9	594.1	592.2	590.3	588.9	587.3	584.7	581.0	579.3	575.8	573.1
Grazed meadow	kha	105.0	100.9	96.8	96.5	96.4	96.4	96.4	96.4	96.4	96.3	96.3	96.3	96.3	96.3
Wild land	kha	280.0	260.0	270.0	280.0	280.0	280.0	280.0	243.6	243.6	243.7	253.7	253.7	243.7	253.7

b) Methodological Issues

1) Carbon Stock Changes in Soils in “Grassland remaining Grassland”

● Estimation Method

➤ Carbon stock changes in mineral soils

Carbon stock change in mineral soils in pasture land was estimated by using the Tier 3 modeling method same as 6.6.1.b)2) cropland remaining cropland (4.B.1)

➤ ***On-site CO₂ emissions resulting from cultivation in organic soils***

With respect to CO₂ 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 cropland remaining cropland.

➤ ***Off-site CO₂ emissions via waterborne carbon losses from drained inland organic soils***

Off-site CO₂ 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 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).

➤ ***CO₂ emission factors from organic soils (EF)***

Because there is little research data on CO₂ 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 CO₂ 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 6.6.1.b)2). 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 11.4.2.7.a.in Chapter 5 in this NIR). 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 (*World 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 6.6.1, 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 6-30 Area of organic soil in grassland remaining grassland

Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Grassland remaining Grassland	kha	46.0	52.2	56.7	57.5	57.4	57.4	57.3	55.5	55.4	55.3	55.7	55.5	54.9	55.3
Pasture land	kha	28.2	35.4	39.4	39.8	39.8	39.7	39.6	39.5	39.5	39.4	39.2	39.1	39.0	38.8
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
Wild land	kha	13.2	12.2	12.7	13.2	13.2	13.2	13.2	11.4	11.4	11.4	11.9	11.9	11.4	11.9

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 CO₂ 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 Chapter 1.

e) *Category-specific Recalculations*

● *Correction in accordance with revision of D area*

Areas of deforestation (D area) is used for determining each land use area converted from forest land. Since the method of estimating D area from the satellite image interpretation results were revised, areas of grassland remaining grassland were recalculated for all years.

● *Correction in accordance with the revision of organic soil area*

Since the estimation method of organic soil area in pasture land were modified, CO₂ emissions (on-site and off-site) for all years were recalculated.

See Chapter 10 for impact on trend.

f) *Category-specific Planned Improvements*

As Tier 3 approach, Roth C model is used for estimating carbon stock change in mineral soils. For more detail explanations of outcomes of the estimation and the fluctuating driver of input values, further analysis will be continued.

6.7.2. 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 carbon stock changes in this category in FY2017 was 94 kt-CO₂ ; this represents a decrease of 44.9% below the FY1990 value and a decrease of 22.3% below the FY2016 value. With respect to living biomass, its carbon stock changes as a result of land-use conversion from other land use to grassland are estimated. The carbon stock changes include both temporary loss of living biomass in the land before and subsequent gain after conversion.

With respect to dead organic matter, Japan used the CENTURY-jfos model to estimate carbon stocks in dead organic matter in forest land, and then estimated carbon stock changes in forest land converted to grassland. Carbon stock changes in grassland converted from land-uses other than forest land were reported as “NA” or “NO” because suitable knowledge for estimating carbon stocks for the land-use categories was not available, or because it was assumed that no carbon stock change occurred, respectively.

Carbon stock changes in soils as a result of land-use conversion from other land use to grassland were estimated. With respect to carbon stock changes in mineral soils, the carbon stock changes in grassland converted from forest land, cropland, wetlands and other land were estimated together for the whole grassland, and reported in grassland remaining grassland (“IE” in land converted to grassland). CO₂ emissions from organic soils in pasture land converted from cropland were estimated. CO₂ emission in forest land converted to grassland were reported as “NO” because conversion of organic soil area from forest land to grassland was not implemented in general in Japan. CO₂ emissions from organic soils in grassland converted from wetlands and Other land were reported as “IE” because the emissions were included in those in grassland remaining grassland.

Carbon stock changes in each carbon pool in settlements converted to grassland are reported as “NO” because the land conversion from settlements to grassland is not implemented in general in Japan.

b) Methodological Issues

1) Carbon stock changes in Living biomass in “Land converted to Grassland”

● Estimation Method

The Tier 2 method was applied to estimate forest land and cropland (rice fields) converted to grassland (pasture lands) using country specific and provisional values of the amount of biomass accumulation. The Tier 1 method was used for land uses other than forest land and cropland (rice fields) converted to grassland (pasture lands) using default value. The equations are given in section 6.6.2.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 6-8a and Table 6-8b 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 6-31) 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 6-32).

➤ Area Converted from Forestland

As described in 6.6.2.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 6.6.2.b)1). Areas of settlements converted to grassland are reported as “NO” because land conversion from settlements to grassland does not occur.

It should be noted that the area presented in the CRF “Table 4.C Sectoral background data for land use, land-use change and forestry – Grassland” is not the annually converted area in FY2017 but the sum of annually converted areas during the past 20 years.

Table 6-31 Area of land converted to grassland (single year)

Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Land converted to Grassland	kha	1.8	0.8	1.1	2.1	2.1	1.6	1.6	1.2	1.1	1.3	1.2	1.1	1.2	1.3
Forest land converted to Grassland	kha	0.8	0.2	0.1	0.4	1.1	0.9	0.9	0.6	0.6	0.8	0.8	0.6	0.6	0.5
Cropland converted to Grassland	kha	0.9	0.6	1.0	1.7	0.8	0.7	0.7	0.6	0.4	0.3	0.3	0.4	0.5	0.5
Wetlands converted to Grassland	kha	0.12	0.01	0.03	NO	0.20	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
Other land converted to Grassland	kha	0.01	0.01	0.01	0.04	0.003	0.0003	0.004	0.003	0.05	0.15	0.14	0.13	0.11	0.35

Table 6-32 Area of land converted to grassland within the past 5 years

Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Land converted to Grassland	kha	11.6	5.1	5.1	7.0	9.8	9.7	9.3	8.7	7.6	6.8	6.4	5.8	5.8	6.1
Forest land converted to Grassland	kha	4.7	1.4	0.5	0.5	2.9	3.8	4.4	4.6	4.2	3.9	3.8	3.4	3.4	3.2
Cropland converted to Grassland	kha	6.5	3.4	4.5	6.2	6.4	5.7	4.6	3.8	3.2	2.6	2.2	1.9	1.9	2.0
Wetlands converted to Grassland	kha	0.3	0.1	0.03	NO	0.2	0.2	0.2	0.2	0.2	NO	NO	NO	NO	NO
Settlements converted to Grassland	kha	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other land converted to Grassland	kha	0.1	0.2	0.04	0.3	0.3	0.1	0.1	0.02	0.1	0.2	0.3	0.5	0.6	0.9

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

6.6.2.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”⁷, for the same reasons as described in section 6.6.2.b)2).

● Parameters

The average carbon stocks in dead wood and litter in forest land before conversion are shown in Tables 6-9 and 6-10. 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 CO₂ 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 sum of annually converted areas from other land-use categories to grassland for the past 20 years was regarded as the area of land converted to grassland during the past 20 years. The areas are shown in Table 6-33.

Table 6-33 Areas of land converted to grassland within the past 20 years

Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Land converted to Grassland	kha	321.0	164.7	60.6	28.7	27.2	26.6	26.4	26.3	26.0	26.4	26.8	27.2	27.6	27.9
Forest land converted to Grassland	kha	182.6	106.4	35.1	7.1	6.8	6.6	6.8	7.0	7.1	7.8	8.4	8.8	9.3	9.6
Cropland converted to Grassland	kha	70.6	38.5	23.9	20.7	19.4	19.0	18.8	18.5	18.0	17.7	17.5	17.3	17.2	16.8
Wetlands converted to Grassland	kha	1.7	1.6	1.0	0.4	0.5	0.4	0.3	0.3	0.3	0.3	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
Other land converted to Grassland	kha	66.1	18.2	0.5	0.6	0.6	0.6	0.6	0.5	0.6	0.6	0.7	0.8	0.9	1.3

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 section 6.6.1.b)2). 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 in mineral soil was reported regardless of whether or not land conversion has been occurred and carbon stock in pasture land converted from other land use was reported as “IE” since it was included in carbon stock in pasture land remaining pasture land. CO₂ 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 6.6.1.b)2).

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 20% for the entire removal

⁷ Cropland in the Japanese statistics includes pasture land which falls into grassland.

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 6.6.1.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 Chapter 1.

e) Category-specific Recalculations

● ***Correction in accordance with revision of D area***

Since the method of estimating D area, which is used for estimating the areas of grassland converted from forest land were revised, carbon stock changes in living biomass and dead organic matter in this category were recalculated for all years.

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

● ***Method of Obtaining Data of the “Areas of Cropland converted from Other Land-use Categories to Grassland”***

The method used to obtain data on the area converted to grassland needs to be improved. For example, currently, the area of lands converted from forest land to grassland is estimated by multiplying the summed areas of forest land converted to cropland and grassland by the ratio of grazing land to the summed area. However, this estimation method may not represent the actual status of these areas. Therefore, the validity of the estimation method needs to be reviewed, and, if necessary, a new method of obtaining the area data should be developed.

● ***Method of Obtaining Data of the “Area of Cropland converted to Grassland”***

The area of Cropland converted to Grassland cannot be obtained from statistics except for the land-use conversion from cropland (rice field) to grassland (pasture land). For this reason, the estimates of the carbon stock changes in this land-use category may not fully reflect the actual conditions. Therefore, the methods used to detect the following area data need to be developed.

- from upland field to pasture land
- from orchard to pasture land
- from rice field to grazed meadow
- from upland field to grazed meadow
- from 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.

6.8. 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, flooded land, and other wetlands. However, emissions and removals from other wetlands are not reported in Japan.

In FY2017, 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 FY2017 were 47 kt-CO₂ emissions; this represents a decrease of 48.2% below the FY1990 value and a decrease of 2.6% below the FY2016 value.

In this section, wetlands is divided into two subcategories, “Wetlands remaining Wetlands (4.D.1.)” and “Land converted to Wetlands (4.D.2.)”, and describes them separately in the following subsections.

Table 6-34 Emissions and removals in wetlands resulting from carbon stock changes

Gas	Category	Carbon pool	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
CO ₂	4.D. Wetlands	Total	kt-CO ₂	90	358	426	40	86	113	107	52	60	24	24	48	48	47	
		Living Biomass	kt-CO ₂	65	257	305	28	64	80	74	36	44	16	17	33	33	32	
		Dead Wood	kt-CO ₂	17	69	82	8	14	22	22	11	11	5	5	10	10	10	
		Litter	kt-CO ₂	8	33	39	4	7	11	11	5	5	2	2	5	5	5	
		Mineral soil	kt-CO ₂	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA
		Organic soil	kt-CO ₂	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA
	4.D.1. Wetlands remaining Wetlands	Total	kt-CO ₂	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA
		Living Biomass	kt-CO ₂	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA
		Dead Wood	kt-CO ₂	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA
		Litter	kt-CO ₂	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA	NO,NENA
		Mineral soil	kt-CO ₂	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA
		Organic soil	kt-CO ₂	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA	NENA
	4.D.2. Land converted to Wetlands	Total	kt-CO ₂	90	358	426	40	86	113	107	52	60	24	24	48	48	47	
		Living Biomass	kt-CO ₂	65	257	305	28	64	80	74	36	44	16	17	33	33	32	
		Dead Wood	kt-CO ₂	17	69	82	8	14	22	22	11	11	5	5	10	10	10	
		Litter	kt-CO ₂	8	33	39	4	7	11	11	5	5	2	2	5	5	5	
		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

6.8.1. Wetlands remaining Wetlands (4.D.1)

a) Category Description

This subcategory deals with carbon stock changes in wetlands which have remained as wetlands during the past 20 years.

For carbon stock change in organic soil managed for peat extraction, as a result of the domestic survey, it is found out that although 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” under the revision of the UNFCCC Guidelines. “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”. “Other wetlands remaining other wetlands” are reported as “NA” because the activity is not defined at the present time in Japan.

Table 6-35 Areas of wetlands remaining wetlands within the past 20 years

Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Wetlands remaining Wetlands	kha	1,280.3	1,293.8	1,321.2	1,316.6	1,308.3	1,308.3	1,308.1	1,318.2	1,319.2	1,319.8	1,320.2	1,321.7	1,314.6	1,334.9
Organic soils managed for peat extraction	kha	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
Flooded land	kha	1,280.3	1,293.8	1,321.2	1,316.6	1,308.3	1,308.3	1,308.1	1,318.2	1,319.2	1,319.8	1,320.2	1,321.7	1,314.6	1,334.9
other wetlands	kha	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

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 CO₂ emissions, we use the value, about “150ha” for peat extraction area that from private company of peat extraction. And we also use the default values of EF, 0.2tC/ha (Boreal and Temperate, Nutrient- Poor on Table 7.4, Chp.7, Vol.4, 2006GLs), and the result of this calculation is approximately 0.1kt-CO₂. To calculate off-site CO₂ emissions, we use the value from National production data, which is available since 2003, ranged from 17 to 34kt in air-dry weight basis. And we also use the default value of carbon fractions, 0.45tC/t(dry) (Boreal and Temperate, Nutrient-Poor on Table 7.5, Chp.7, Vol.4, 2006GLs). So the result of this calculation is ranged from 30 to 50 kt-CO₂. Furthermore, N₂O emissions from peat extraction are not included in these calculations, 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 suggested by paragraph 37b) of Annex 1 in Decision 24/CP19 and country specific standard of 90 kt-CO₂ (this value is 0.1 % of the removals from LULUCF section in 2005). Please refer to annex 5 of NIR, for more information about our criteria for “NE”.

c) Category-specific Recalculations

- **Correction in accordance with revision of D area**

Areas of deforestation (D area) is used for determining each land use area converted from forest land. Since the method of estimating D area from the satellite image interpretation results were revised, areas of wetlands remaining wetlands were recalculated for all years.
See Chapter 10 for impact on trend.

6.8.2. 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 FY2017 were 47 kt-CO₂ emissions, this represents a decrease of 48.2% below the FY1990 value and a decrease of 2.6% below the FY2016 value.

With respect to living biomass, its carbon stock change as a result of land-use conversion from other land use to wetlands is estimated. This process includes both temporary loss of living biomass in the land before and subsequent gain after conversion.

With respect to dead organic matter, Japan used the CENTURY-jfos model to estimate carbon stocks in dead organic matter in forest land, 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 CO₂ 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 the carbon pool were reported as “NE”.

b) Methodological Issues

1) Carbon stock change in Living biomass in “Land converted to Wetlands”

● *Estimation Method*

The Tier 2 method was applied for the land converted to wetlands (flooded land). The equations are given in section 6.6.2.b)1).

● *Parameters*

➤ *Biomass stock in each Land-Use Category*

The values shown in Table 6-8a and Table 6-8b 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) 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 6.6.2.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.

It should be noted that the area presented in the CRF “Table 4.D Sectoral background data for land use, land-use change and forestry – Wetlands” is not the annually converted area in FY2017 but the sum of annually converted areas during the past 20 years.

Table 6-36 Area of land annually converted to wetlands (single year)

Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Land converted to Wetlands	kha	0.43	1.72	2.04	0.19	0.36	0.56	0.56	0.27	0.27	0.13	0.13	0.25	0.25	0.25
Forest land converted to Wetlands	kha	0.31	1.24	1.48	0.14	0.26	0.41	0.41	0.20	0.20	0.09	0.09	0.18	0.18	0.18
Cropland converted to Wetlands	kha	0.02	0.10	0.13	0.01	0.02	0.04	0.04	0.02	0.02	0.01	0.01	0.02	0.02	0.02
Rice field	kha	0.01	0.02	0.09	0.01	0.01	0.02	0.02	0.01	0.01	0.003	0.01	0.01	0.01	0.01
Upland field	kha	0.01	0.05	0.03	0.001	0.01	0.01	0.01	0.01	0.01	0.003	0.002	0.005	0.004	0.005
Orchard	kha	0.005	0.02	0.01	0.0004	0.002	0.003	0.003	0.002	0.002	0.001	0.001	0.001	0.001	0.001
Wetlands converted to Wetlands	kha	0.007	0.029	0.019	0.001	0.004	0.006	0.006	0.003	0.004	0.002	0.001	0.003	0.002	0.003
Settlements converted to Wetlands	kha	0.002	0.006	0.007	0.001	0.001	0.002	0.002	0.001	0.001	0.0004	0.0004	0.001	0.001	0.001
Other land converted to Wetlands	kha	0.09	0.34	0.41	0.04	0.07	0.11	0.11	0.05	0.05	0.03	0.03	0.05	0.05	0.05

2) Carbon Stock Change in Dead Organic Matter in “Land converted to Wetlands”

● Estimation Method

➤ Carbon stock changes in Dead Organic Matter

Carbon stock changes in dead organic matter in forest land converted to wetlands were estimated by applying the Tier 2 estimation method as described in section 6.6.2.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 Tables 6-9 and 6-10. It is assumed that they become zero immediately after conversion, and are not accumulated after conversion.

● Activity Data (Area)

The area of land that was converted to wetlands during the past 20 years is determined by subtracting the estimated area that was not converted during the past 20 years from the total area of wetlands in those years. The areas are shown in Table 6-37 below.

Table 6-37 Area of land converted to wetlands within the past 20 years

Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Land converted to Wetlands	kha	28.5	24.7	27.0	21.5	19.6	19.7	19.8	19.7	18.8	18.2	17.8	16.3	13.5	13.2
Forest land converted to Wetlands	kha	20.6	17.9	19.6	15.5	14.2	14.3	14.4	14.3	13.6	13.2	12.9	11.8	9.8	9.6
Cropland converted to Wetlands	kha	1.8	1.5	1.6	1.3	1.2	1.2	1.2	1.2	1.1	1.1	1.1	1.0	0.8	0.8
Rice field	kha	0.7	0.5	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.5	0.5
Upland field	kha	0.8	0.7	0.7	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.3	0.3	0.3
Orchard	kha	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
Grassland converted to Wetlands	kha	0.3	0.3	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	0.1
Settlements converted to Wetlands	kha	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.05	0.05
Other land converted to Wetlands	kha	5.7	4.9	5.4	4.3	3.9	3.9	4.0	3.9	3.8	3.6	3.6	3.3	2.7	2.6

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 21% 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 6.6.2.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 Chapter 1.

e) Category-specific Recalculations

● **Correction in accordance with revision of D area**

Since the method of estimating D area, which is used for estimating the areas of wetlands converted from forest land were revised, carbon stock changes in living biomass and dead organic matter in this category were recalculated 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.

● **Method of Obtaining Data of the Area of Storage Reservoirs**

Storage reservoirs (excluding dams) can be considered as artificial flooded land, but the area they cover are not included in the area of flooded land. Therefore, a method used to obtain data on the area covered by the reservoirs needs to be considered.

● **Estimation Method of Soil Carbon Stock Change upon “Land-Use Conversion from Other Land to Wetlands”**

The estimation method will be considered when new data and information are obtained.

6.9. Settlements (4.E)

Settlements are all developed land, including transportation infrastructure and human habitats, and preclude lands that have been placed in other land-use categories. In settlements, trees existing in urban green areas such as urban parks and special greenery conservation zones absorb carbon.

In FY2017, Japan’s settlement area was about 3.86 million ha, equivalent to about 10.2% of the national land. The carbon stock changes in this category was 2,645 kt-CO₂ emissions in FY1990, 14 kt-CO₂ emissions in FY2016, and 111 kt-CO₂ removals in FY2017.

In this section, settlements are divided into two subcategories, “Settlements remaining Settlements (4.E.1.)” and “Land converted to Settlements (4.E.2.)”, and described separately in the following subsections.

Carbon pools estimated in settlements are living biomass, dead organic matter and soils. Dead organic matters for several subcategories are included in living biomass stock changes.

Urban green areas included in the activity data are divided into two categories; urban green facilities

established as urban parks and others, and special greenery conservation zones for which conservation measures are taken and permanent protection is ensured.

➤ Urban green areas

- Urban Green Facilities (urban parks, green areas on roads, green areas at ports, green areas around sewage treatment facilities, green areas by greenery promoting system for private green space, green areas along rivers and erosion control sites, green areas around government buildings and green areas around public rental housing, which are within 30 years after establishment).
- Special Greenery Conservation Zones, which are within 30 years after designation.

Table 6-38 Emissions and removals in settlements resulting from carbon stock changes

Gas	Category	Carbon pool	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
CO ₂	4.E. Settlements	Total	kt-CO ₂	2,645	1,093	-595	-1,034	408	-211	-300	-901	-661	-498	-344	-76	14	-111
		Living Biomass	kt-CO ₂	1,720	591	-635	-966	160	-395	-488	-891	-655	-595	-446	-220	-136	-200
		Dead Wood	kt-CO ₂	816	568	288	233	442	396	396	256	255	319	318	344	343	297
		Litter	kt-CO ₂	379	257	120	93	194	173	174	107	107	138	139	153	153	131
		Mineral soil	kt-CO ₂	-270	-323	-368	-394	-389	-386	-381	-372	-368	-361	-355	-352	-346	-339
		Organic soil	kt-CO ₂	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
	4.E.1. Settlements remaining Settlements	Total	kt-CO ₂	-1,381	-1,660	-1,874	-2,036	-2,035	-2,047	-2,035	-1,989	-1,955	-1,906	-1,780	-1,661	-1,582	-1,504
		Living Biomass	kt-CO ₂	-1,148	-1,371	-1,538	-1,668	-1,667	-1,680	-1,670	-1,631	-1,599	-1,555	-1,433	-1,316	-1,243	-1,170
		Dead Wood	kt-CO ₂	IE,NE	IE,NE	IE,NE	IE,NE	IE,NE	IE,NE	IE,NE	IE,NE	IE,NE	IE,NE	IE,NE	IE,NE	IE,NE	IE,NE
		Litter	kt-CO ₂	-11	-13	-15	-17	-17	-17	-17	-16	-16	-16	-16	-16	-15	-15
		Mineral soil	kt-CO ₂	-222	-276	-321	-351	-351	-350	-348	-342	-341	-335	-331	-329	-324	-318
		Organic soil	kt-CO ₂	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	4,026	2,753	1,279	1,002	2,443	1,835	1,735	1,088	1,294	1,407	1,436	1,585	1,596	1,393
		Living Biomass	kt-CO ₂	2,868	1,962	903	702	1,827	1,284	1,182	740	943	960	988	1,096	1,106	970
		Dead Wood	kt-CO ₂	816	568	288	233	442	396	396	256	255	319	318	344	343	297
		Litter	kt-CO ₂	390	270	136	110	211	190	190	123	123	154	155	168	168	146
		Mineral soil	kt-CO ₂	-48	-47	-47	-43	-38	-35	-33	-30	-28	-26	-24	-23	-22	-20
		Organic soil	kt-CO ₂	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

6.9.1. Settlements remaining Settlements (4.E.1)

a) Category Description

This subcategory deals with carbon stock changes in living biomass, litter of dead organic matter and soils in urban green areas in settlements remaining settlements, which have remained settlements without conversion during the past 20 years. This subcategory is divided into three subparts: “Special Greenery Conservation Zones”, “Urban Green Facilities” and “Other”. In these subparts, carbon stock changes in the “Special Greenery Conservation Zones” and “Urban Green Facilities” are estimated. In addition, carbon stock changes reported in “Revegetation (RV)” activities under Article 3, paragraph 4, of the Kyoto Protocol correspond to those in the “Urban Green Facilities” constructed in and after 1990⁸. However, “Special Greenery Conservation Zones” are not included in the areas of the Revegetation activities. In the CRF tables, “Special Greenery Conservation Zones” are described as “Urban Green Areas not subject to RV”, “Urban Green Facilities” as “Urban Green Areas subject to RV”, and “Other” as “Other than Urban Green Areas”, respectively. Carbon stock changes that are possibly included in the subpart “Other”, such as trees in gardens in personal residences, are reported as “NE” because their activity data are not available. Moreover, with respect to litter and soils, carbon stock changes in urban parks and green areas at ports are reported due to limited availability of parameters. The net removal by this subcategory in FY2017 was 1,504 kt-CO₂; this represents an increase of 8.9% over the FY1990

⁸ The “Special Greenery Conservation Zones” are not included in Revegetation because they do not meet its definition.

value and a decrease of 4.9% below the FY2016 value.

b) Methodological Issues

1) Carbon Stock Changes in Living Biomass in “Settlements remaining Settlements”

● Estimation Method

Due to the differences of characteristics of urban green areas, the Tier 2a method is used for special greenery conservation zones that are communal green areas, and Tier 2b is used for urban green facilities.

The results of field survey on green area in settlements in Japan revealed that the trees have been growing for more than default growth period of 20 years, which are set in the Tier 2a and Tier 2b of the 2006 IPCC Guidelines. It was concluded that, for up to 30 year tree, estimating gain of carbon stocks using the same factor as the 0~20 year trees absorption would be possible. Therefore, carbon stock changes in urban green areas younger than 30 years after establishment are estimated in the same way as 0~20 year urban green area.

➤ Tier 2a: Special Greenery Conservation Zones

$$\Delta C_{SSaLB} = \Delta C_{LBaG} - \Delta C_{LBaL}$$

$$\Delta C_{LBaG} = A \times PW \times BI$$

ΔC_{SSaLB} : Changes in carbon stocks in living biomass in special greenery conservation zones [t-C/yr]

ΔC_{LBaG} : Gains in carbon stocks due to growth in living biomass in special greenery conservation zones [t-C/yr]

ΔC_{LBaL} : Losses in carbon stocks due to losses in living biomass in special greenery conservation zones [t-C/yr].

Note: assumed as “0” (zero) in accordance with the 2006 IPCC Guidelines

A : Area of special greenery conservation zones younger than or equal to 30 years since designation [ha]

PW : Rate of forested area (rate of forested area per park area). Note: assumed as 100%

BI : Growth per crown cover area [t-C/ha crown cover/yr]

➤ Tier 2b: Urban Green Facilities

$$\Delta C_{SSbLB} = \sum_i (\Delta C_{LBbGi} - \Delta C_{LBbLi})$$

$$\Delta C_{LBbGi} = \Delta B_{LBbGi}$$

$$\Delta B_{LBbGi} = \sum_j NT_{i,j} \times C_{Rate\ i,j}$$

ΔC_{SSbLB} : Changes in carbon stocks in living biomass in urban green facilities [t-C/yr]

ΔC_{LBbGi} : Gains in carbon stocks due to growth in living biomass in urban green facility i [t-C/yr]

ΔC_{LBbLi} : Losses in carbon stocks due to losses in living biomass in urban green facility i [t-C/yr]. Note: assumed as “0” (zero) in accordance with the 2006 IPCC Guidelines

ΔB_{LBbGi} : Annual biomass growth in urban green facility i [t-C/yr]

$C_{Rate\ i,j}$: Annual living biomass growth in urban green facility i in climate type j per tree [t-C/tree/yr]
See table 6-39

$NT_{i,j}$: Number of trees 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 by greenery promoting systems for private green space, 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: Annual rate of living biomass growth per crown cover area (special greenery conservation areas)

The default value, 2.9 t-C/ha crown cover/yr, indicated in the 2006 IPCC Guidelines (p. 8.9) is taken for the annual rate of living biomass growth of trees per crown cover area in special greenery conservation zones.

➤ Tier 2b: Annual rate of living biomass growth per tree (urban green facilities)

The following parameters are taken as the annual living biomass growth rates per tree in urban green facilities.

Table 6-39 Annual biomass growth rate per tree in urban green facilities

Climate category		Annual living biomass growth per tree [t-C/tree/yr]	Remarks
Urban green facilities	Hokkaido	(Other than green areas on roads) 0.0098 (Green areas on roads) 0.0103	Default values 0.0033-0.0142 [t-C/tree/y] provided in the 2006 IPCC Guidelines (p. 8.10, Table 8.2) and the annual growth rates of living biomass for the trees in Japan (0.0204 for Japanese zelkova, 0.0103 for ginkgo, 0.0095, for bamboo-leaf oak and 0.0122 t-C/tree/yr for camphor tree) are combined with the distribution ratio of tree types in sampled urban parks ⁹ . For green areas on roads, the distribution ratio of tree species indicated by the surveys in green areas on roads ¹⁰ is taken into account.
	Areas other than Hokkaido	(Other than green areas on roads) 0.0105 (Green areas on roads) 0.0108	

● Activity Data

The areas of settlements remaining settlements in a certain year reported in the CRF tables are estimated by subtracting the cumulative total area of land converted to settlements during the past 20 years in a year subject to estimation from the total area of settlements in the year subject to estimation. Moreover, in the CRF tables, the areas of settlements remaining settlements are reported in three subparts: “Special Greenery Conservation Zones”, “Urban Green Facilities” and “Other”. Within these subparts, carbon stock changes in trees less than or equal to 30-year growth in “Special Greenery Conservation Zones” and “Urban Green Facilities” are estimated.

Japan assumes trees less than or equal to 30-year growth as those growing in urban green areas less than or equal to 30 years since establishment or designation. With respect to Tier 2a, tree crown areas in the “Special Greenery Conservation Zones” are applied as activity data. Tier 2b applies the number of tall trees planted in the “Urban Green Facilities” as activity data.

⁹ The annual growth rates of living biomass for these trees are calculated by using the growth curve for each tree species, which were developed based on the results of surveys conducted by the National Institute for Land and Infrastructure Management (NILIM) of the MLIT (Matsue et al., 2009) 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.

¹⁰ The distribution ratio of tree types is taken from the Road Tree Planting Status Survey (The Street tree of Japan VI), which covered green areas on roads throughout Japan.

Table 6-40 Areas of settlements remaining settlements within the past 20 years

Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Settlements remaining Settlements	kha	2,345.1	2,682.2	2,901.9	3,092.1	3,207.7	3,243.3	3,285.9	3,316.3	3,369.6	3,401.5	3,438.3	3,462.2	3,484.9	3,517.5
Urban green facilities	kha	89.1	106.5	120.6	130.8	130.6	131.1	130.2	127.1	125.0	121.8	114.4	107.3	102.5	97.7
Special greenery conservation zones	kha	1.9	3.7	3.8	4.1	4.1	4.2	4.2	4.4	4.4	4.5	4.5	4.6	4.7	4.7
Other	kha	2,254.1	2,572.1	2,777.6	2,957.1	3,073.0	3,108.0	3,151.5	3,184.8	3,240.2	3,275.2	3,319.3	3,350.2	3,377.8	3,415.2

➤ **Tier 2a: Tree crown areas (“Special Greenery Conservation Zones”)**

The tree crown areas of the special greenery conservation zones are calculated by multiplying the area of special greenery conservation zones determined by the Ministry of Land, Infrastructure, Transport and Tourism by the rate of tree crown area, which is assumed to be 100%.

Table 6-41 Areas of special greenery conservation zones younger than or equal to 30 years since notification

Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total	kha	1.9	3.7	3.8	4.1	4.1	4.2	4.2	4.4	4.4	4.5	4.5	4.6	4.7	4.7
Green space conservation zones	kha	0.6	0.9	1.4	1.9	1.8	2.0	1.9	1.9	2.0	2.0	2.0	2.1	2.2	2.2
Suburban green space conservation zones	kha	1.2	2.7	2.4	2.2	2.2	2.3	2.3	2.5	2.5	2.5	2.5	2.5	2.5	2.5

➤ **Tier 2b: Number of tall trees (“Urban Green Facilities”)**

The number of tall trees in urban green facilities is calculated according to the same methods that are used for revegetation activities under Article 3, paragraph 4, of the Kyoto Protocol. Brief descriptions of the calculation methods for each urban green facility are stated below. In addition, for a detailed description of these calculation methods see section 11.4.2.7.a. in Chapter 11 in this NIR.

- **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 number of tall trees is calculated by (1) calculating the areas falling under this category by multiplying each area by the area ratio of land conversion area for the whole country, and then (2) calculating the number of tall trees in the calculated areas by multiplying each of the areas by the number of tall trees per area. The number of tall trees per area for each urban green facility is shown in the table below.

Table 6-42 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	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

- **Green areas on roads**

Activity data (the number of tall trees) in these facilities are calculated by the following procedures.

1. The number of tall trees planted during 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 each corresponding fiscal year during the

commitment period,

2. The number of tall trees calculated in Step 1 is multiplied by the ratio of the number of tall trees planted on the roads whose planted area is more than 500 m²,
3. The number of tall trees calculated in Step 2 is multiplied by the area ratio of settlements remaining settlements.

The values of Step 3 become the number of tall trees constituting the activity data on green areas on roads.

- ***Green areas by greenery promoting systems for private green space***

Activity data (the number of tall trees) are available for each facility. Therefore, the total number of tall trees is used as activity data.

2) Carbon Stock Changes in litter in “Settlements remaining Settlements”

In this category carbon stock changes in litter in urban parks and green areas at ports are estimated. Carbon stock changes in dead wood result in “IE” because they are included in carbon stock changes in living biomass. Carbon stock changes in litter in the subcategories other than urban parks and green areas at ports are not estimated due to the difficulties of obtaining such activity data.

● ***Estimation Method***

In accordance with the decision tree provided in the *2006 IPCC Guidelines*, a country-specific method is applied for this estimation. The estimation method is described below.

$$\Delta C_{SSLit} = \sum_i (A_i \times Lit_i)$$

ΔC_{SSLit} : Carbon stock changes in litter in settlements remaining settlements [t-C/yr]

A : Area of urban parks and green areas at ports in settlements remaining settlements [ha]

Lit_i : Carbon stock change in litter per area in urban parks or green areas at ports [t-C/ha/yr]

i : Type of Urban Green Facilities (urban parks or green areas at ports)

● ***Parameters***

For litter, Japan estimates carbon stock changes only in branches and leaves dropped naturally from tall trees. Carbon stock changes in litter per urban park area is calculated by using annual accumulation of litter per tree (Hokkaido and other prefectures: 0.0006 t-C/tree/yr) based on the results of field surveys in urban parks, and the number of tall trees per area and the ratio of litter moved to off-site due to management including cleaning (54.4%). As a result, carbon stock changes in litter per urban park area have been calculated to 0.0882 t-C/ha/yr for Hokkaido and 0.0594 t-C/ha/yr for other prefectures. In addition, 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* (p. 8.21).

● ***Activity Data***

Activity data on this category are the same as those on living biomass in urban parks and green areas at ports, as described in activity data of “Remaining land: Above-ground biomass, Below-ground biomass” (section 11.5.1.1.f. a) of Chapter 11.

3) Carbon Stock Changes in Soils in “Settlements remaining Settlements”

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 of estimation. In general, soils in RV land are not organic soils (peat soils and muck soils). Therefore, organic soils are reported as “NO”, and only mineral soils are estimated.

● Estimation Method

Carbon stock changes in soils on settlements is estimated based on Tier 2 (Country specific data are used) estimation method.

$$\Delta C_{SSSoils} = \sum_i (\Delta C_{Mineral_i} - L_{Organic_i})$$

$$\Delta C_{Mineral_i} = A_i \times \Delta C_{Soil_i}$$

$\Delta C_{SSSoils}$: Annual carbon stock changes in soils in settlements remaining settlements [t-C/yr]

$\Delta C_{Mineral}$: Annual carbon stock changes in mineral soils in settlements remaining settlements [t-C/yr]

$L_{Organic}$: Annual carbon stock changes in organic soils in settlements remaining settlements (=0) [t-C/yr]

A : Area of settlements remaining settlements [ha]

C_{Soil} : Annual carbon stock changes in soils per area of settlements remaining settlements [t-C/ha/yr]

i : Type of Urban Green Facilities (Urban parks and Green areas at ports)

● Parameters

As described in section 11.5.1.1.f. d), carbon stock changes in soils per area of Urban parks and Green areas at port (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 based on the results of surveys conducted in urban parks which have been established within 30 years (Tonosaki et al., 2013, Parks, Green Spaces and Landscape Division, Ministry of Land, Infrastructure, Transport and Tourism, 2015). Thus, this value is applicable to Urban parks and Green areas at port which were established within 30 years.

● Activity Data

Activity data on this category are the same as the area of urban parks and green areas at ports, as described in activity data of “Remaining land: Above-ground biomass, Below-ground biomass” (section 11.5.1.1.f. a) of Chapter 11).

c) Uncertainties and Time-series Consistency

● Uncertainty Assessment

The default values shown on page 8.10 in the 2006 IPCC Guidelines were applied to the annual carbon stock changes for trees in special greenery conservation zones. Following the decision tree, the uncertainty was determined $\pm 50\%$ through application of the standard value shown in the 2006 IPCC Guidelines (page 8.12).

Moreover, the uncertainty estimates for living biomass in special greenery conservation zones apply expert judgment 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 by greenery promoting systems for private green space, 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 6.6.2.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 Chapter 1.

e) Category-specific Recalculations

- ***Correction in accordance with revision of D area***

Areas of deforestation (D area) is used for determining each land use area converted from forest land. Since the method of estimating D area from the satellite image interpretation results were revised, areas of Settlements remaining Settlements and 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 “Special Greenery Conservation Zones”***

The default values in the *2006 IPCC Guidelines* were applied to the living biomass growth rate per unit of greening area in special greenery conservation zones. 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 validity of the assumption is under re-examination.

6.9.2. 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. With respect to dead organic matter, Japan used the CENTURY-jfos model to estimate carbon stocks in dead organic matter in forest land, and then estimated carbon stock changes in forest land converted to settlements. However,

the area of wetlands converted to settlements and other land converted to settlements cannot be obtained by the current method. Thus, carbon stock changes in these carbon pools were reported as “NO”.

The net emissions by this subcategory in FY2017 were 1,393 kt-CO₂; this represents a decrease of 65.4% below the FY1990 value and a decrease of 12.7% below the FY2016 value. Emissions from land converted to settlements increased from FY1990 to FY1993. After 1993, the emissions have been on a decreasing trend by 2003, and have been fluctuated since 2003 up to now. These trends resulted from 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 living biomass in land converted to settlements are estimated by calculating the carbon stock changes before and after conversion and adding annual carbon stock changes in “Land converted to urban green facilities”. The carbon stock changes in living biomass before and after conversion are estimated by applying the equation in section 2.3.1.2 in Volume 4 of the 2006 IPCC Guidelines (multiplying the land area converted from each land use to settlements by the difference between the values of living biomass stock before and after conversion, and by the carbon fraction). Biomass stocks in land converted to urban green areas are increased due to the growth of trees planted after conversion. Hence, carbon stock changes in living biomass in land converted to urban green facilities are estimated by calculating carbon stock changes before and after conversion and adding annual carbon stock changes after conversion that are estimated by applying the Tier 2b method in section 8.2.1.1 in Volume 4 of in the 2006 IPCC Guidelines.

$$\Delta C_{LSLB} = \sum_I \left\{ A_I \times (CR_a - CR_{b,I}) \times CF \right\} + \sum_i (\Delta C_{LS(UG)G_i} - \Delta C_{LS(UG)L_i})$$

$$\Delta C_{LS(UG)G_i} = \Delta B_{LS(UG)G_i}$$

$$\Delta B_{LS(UG)G_i} = \sum_j NT_{i,j} \times C_{Rate_{i,j}}$$

ΔC_{LSLB} : Carbon stock changes in living biomass in land converted to settlements [t-C/yr]

A_I : Area of land converted annually to settlements from land-use type I [ha/yr]

CR_a : Carbon reserves immediately following conversion to settlements [t-d.m./ha], default=0

$CR_{b,I}$: Biomass dry matter in land-use type I immediately before conversion to settlements [t-d.m./ha]

CF : Carbon fraction of dry matter [t-C/t-d.m.]

I : Type of land before conversion

$\Delta C_{LS(UG)G_i}$: Annual carbon stock gain in living biomass in land converted to urban green facility i due to growth in living biomass [t-C/yr]

$\Delta C_{LS(UG)L_i}$: Annual carbon stock loss in living biomass due to loss of living biomass [t-C/yr]

Note: the averaged ages of estimated trees are less than or equal to 30 years old; therefore, the loss is assumed as “0” (zero) based on the domestic survey and in accordance with the 2006 IPCC Guidelines

$\Delta B_{LS(UG)G_i}$: Annual living biomass growth in land converted to urban green facility i [t-C/yr]

$C_{Rate_{i,j}}$: Annual living biomass growth in urban green facility i in climate type j per tree [t-C/tree/yr]

See table 6-39

$NT_{i,j}$: Number of trees in urban green facility i in climate type j

i : Type of urban green area after conversion (urban parks, green areas on roads, green areas at ports, green areas around sewage treatment facilities, green areas by greenery promoting systems for private

green space, green areas along rivers and erosion control sites, green areas around government buildings, or green areas around public rental housing)

j : Climate type (Hokkaido, areas other than Hokkaido)

● **Parameters**

➤ **Living biomass stocks for each land-use category**

Tables 6-8a and 6-8b show the living biomass stocks before and after conversion. Carbon stock losses due to loss of living biomass are assumed as “0” (zero) based on the domestic survey (*Parks, Green Spaces and Landscape Division, Ministry of Land, Infrastructure, Transport and Tourism (MLIT)*, 2015) and in accordance with the *2006 IPCC Guidelines*, because trees subject to estimation are all younger than or equal to 30 years old. Table 6-39 shows the annual living biomass growth of trees in land converted to urban green areas.

➤ **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**

With respect to the area of land converted to settlements, only the areas converted to settlements from forest land, cropland and grassland are determined. 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”.

It should be noted that the area presented in the CRF “Table 4.E Sectoral background data for land use, land-use change and forestry—Settlements” is not the annually converted area in FY2017 but the sum of annually converted areas during the past 20 years.

- **Conversion from Forest land**

Areas of forest land converted to settlements were estimated as described in section 6.6.2.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 6-43 Area of land converted to settlements (single year)

Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Land converted to Settlements	kha	39.3	32.9	21.8	14.7	20.5	16.7	15.7	12.1	12.1	14.7	16.3	17.0	16.8	15.8
Forest land converted to Settlements	kha	14.8	10.3	5.2	4.2	8.0	7.2	7.2	4.7	4.7	5.8	5.8	6.3	6.3	5.5
Cropland converted to Settlements	kha	21.4	19.5	14.5	9.2	10.9	8.2	7.2	6.3	6.4	7.5	8.8	9.0	8.9	8.5
Rice field converted to Settlements	kha	13.0	12.1	9.5	6.0	7.1	5.0	4.1	3.5	3.9	4.3	5.0	5.1	5.3	4.2
Upland field converted to Settlements	kha	0.5	0.3	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0
Orchard converted to Settlements	kha	12.5	11.8	9.2	5.8	7.0	4.8	4.0	3.4	3.8	4.2	5.0	5.1	5.2	4.2
Grassland converted to Settlements	kha	3.2	3.1	2.1	1.3	1.6	1.3	1.3	1.2	1.1	1.4	1.6	1.6	1.5	1.8
Wetlands converted to Settlements	kha	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Other land converted to settlements	kha	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE

➤ Area and number of trees in “Land converted to urban green areas”

The areas of land converted to urban green areas are calculated by multiplying the whole area of each urban green area by the area ratio of land conversion area for settlements. The number of trees is calculated by multiplying each urban green area converted from other land-use categories by the number of trees per area. For detailed information regarding these activity data see section 11.4.2.7.a.in Chapter 11 in this NIR.

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 land converted to urban parks and green areas at ports are estimated.

With respect to dead wood, only the carbon stock change in forest land converted to settlements was estimated. The Tier 2 method was applied to the estimation in accordance with the method for conversion from other land use to cropland in the *2006 IPCC Guidelines*. Carbon stock changes in dead wood in land converted to urban green facilities are reported as “IE” because they are included in living biomass.

In regard to litter, the carbon stock changes in settlements converted from forest land and land converted to urban parks and green areas at ports are estimated. The Tier 2 method is applied to the estimation of the carbon stock changes in settlements converted from forest land in accordance with the method for conversion from other land use to cropland in the *2006 IPCC Guidelines*. Carbon stock changes in litter in land converted to urban parks and green areas at ports are estimated by applying Japan’s country-specific estimation method due to the lack of an estimation method in the *2006 IPCC Guidelines*. Carbon stock changes in litter in land converted to urban green areas other than urban parks and green areas at ports are not estimated due to the difficulties of obtaining their activity data.

The area of wetlands converted to settlements and other land converted to settlements cannot be obtained by the current method. Thus, carbon stock changes in these carbon pools were reported as “NO”.

● Estimation Method

$$\Delta C_{LS} = \Delta C_{FS} + \Delta C_{LSLit}$$

ΔC_{FS} : Carbon stock changes in dead organic matter in settlements converted from forest land [t-C/yr]

ΔC_{LSLit} : Carbon stock changes in litter in urban parks and green areas at ports converted from land use categories [t-C/yr]

➤ Carbon stock changes in dead organic matter in “Settlements converted from Forest land”

Carbon stock changes in dead organic matter in forest land converted to settlements are estimated by

using the CENTURY-jfos model. In addition, all carbon stocks in dead organic matter in the subcategory are assumed oxidized and emitted as CO₂ within the year of conversion.

$$\Delta C_{FS} = \sum_i \{ (C_{after_i} - C_{before_i}) \times A \}$$

ΔC_{FS} : Carbon stock changes in dead organic matter in forest land converted to settlements [t-C/yr]

C_{after_i} : Carbon stock in dead wood or litter after conversion [t-C/ha] Note: carbon stocks after conversion are assumed as “0” (zero).

C_{before_i} : Carbon stock in dead wood or litter before conversion [t-C/ha]

A : Area of forest land converted to settlements in a year subject to estimation [ha]

i : Type of dead organic matter (dead wood or litter)

➤ **Carbon stock changes in litter in “Urban parks and green areas at ports converted from land-use categories other than Forest land”**

$$\Delta C_{LSLit} = \sum_{I,i} \{ A_i \times (C_{AfterLit_i} - C_{BeforeLit_i}) + A_i \times Lit_i \}$$

ΔC_{LSLit} : Carbon stock changes in litter in urban parks and green areas at ports converted from land-use categories [t-C/yr]

A : Area of urban parks or green areas at ports converted from land-use categories for the past year [ha]

$C_{AfterLit}$: Carbon stock in litter after conversion [t-C/ha]

$C_{BeforeLit}$: Carbon stock in litter before conversion [t-C/ha]

Lit : Annual carbon stock changes per area in litter in urban parks or green areas at ports converted from land-use categories [t-C/ha/yr]

I : Land-use type before conversion

i : Type of urban green facilities after conversion (urban parks or green areas at ports)

● **Parameters**

➤ **Carbon stocks in dead organic matter in “Forest land converted to Settlements”**

Average carbon stocks in dead wood and litter in forest land before conversion are shown in Tables 6-9 and 6-10. The average carbon stocks in these categories from FY1990 to FY2004 are not estimated; therefore the carbon stocks in FY2005 are substituted for them. In addition, it is assumed that they become zero immediately after conversion, and are not accumulated after conversion.

➤ **Carbon stocks in litter in “Urban parks and green areas at ports converted from land-use categories other than Forest land”**

When urban parks and green areas at ports are converted from land-use categories other than forest land, litter stocked before conversion does not moved to off-site because the soil ground before conversion, including litter, stays after conversion, or is covered with additional soils by soil dressing. Hence, litter stocked before conversion does not decrease after conversion. In addition, litter stocks scarcely increase immediately after conversion because newly planted trees do not immediately produce litter. Due to these facts, carbon stock changes before and after conversion are regarded as “0” (zero). Litter stocks accumulated in a year after conversion are calculated by the same method with urban parks and green areas at ports in settlements remaining settlements. This is based on the research finding that litter stocks are accumulated in the same way with settlements remaining settlements, namely accumulated by natural drop of fallen leaves and branches from trees in land converted to urban parks and green areas.

- **Activity Data**

- **Carbon stocks in dead organic matter in “Forest land converted to Settlements”**

The cumulative value of the area of land that was converted from forest land to settlements within the past 20 years was used. For the areas, see Table 6-43.

Table 6-44 Area of land converted to settlements within the past 20 years

Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Land converted to Settlements	kha	863.9	746.8	692.1	605.9	545.3	516.7	493.1	462.7	429.4	406.5	388.7	372.8	359.1	345.5
Forest land converted to Settlements	kha	284.0	280.5	260.0	216.9	179.1	163.0	155.4	143.0	128.9	121.1	116.2	112.3	110.5	108.6
Cropland converted to Settlements	kha	520.6	409.1	376.8	338.8	318.8	307.8	293.7	278.0	261.3	247.9	236.5	226.0	215.3	204.6
Rice field converted to Settlements	kha	320.9	252.1	236.6	215.2	204.6	197.6	188.7	178.9	168.3	159.3	151.8	144.8	137.2	128.7
Upland field converted to Settlements	kha	7.2	6.1	6.1	5.7	5.3	5.1	4.7	4.4	4.0	3.7	3.2	2.9	2.6	2.3
Orchard converted to Settlements	kha	313.6	246.0	230.5	209.5	199.3	192.6	183.9	174.5	164.3	155.6	148.6	142.0	134.6	126.4
Grassland converted to Settlements	kha	59.3	57.2	55.3	50.3	47.4	45.9	44.0	41.7	39.2	37.5	36.0	34.5	33.2	32.3
Wetlands converted to Settlements	kha	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
Other land converted to settlements	kha	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE

- **Carbon stock changes in litter in “Land converted to urban parks and green areas at ports”**

Areas of land converted to urban green areas are calculated in the same manner as the carbon stock changes in living biomass in land converted to urban green areas. They are calculated by multiplying the areas of urban parks and green areas at ports by the area ratio of land conversion area to the settlements, respectively. For detailed information regarding these areas see section 11.5.1.1.f) in Chapter 11 in this NIR.

3) Carbon Stock Change in Soils in “Land converted to Settlements”

In this category, forest land converted to settlements, urban parks and green areas at ports, the management practices of which were similar with those in urban parks, were subject to estimation.

- **Estimation Method**

Carbon stock changes in soils in land converted to settlements are estimated based on Tier 2 (Country specific methodology and data are used) estimation method.

$$\Delta C_{LSSoils_all} = \Delta C_{FSSoils} + \Delta C_{LSSoils}$$

$\Delta C_{LSSoils_all}$: Carbon stock changes in soils in land converted to settlements [t-C/yr]

$\Delta C_{FSSoils}$: Carbon stock changes in soils in forest land converted to settlements [t-C/yr]

$\Delta C_{LSSoils}$: Carbon stock changes in urban parks and green areas at ports in settlements converted from other land use [t-C/yr]

$$\Delta C_{LSSoils} = \sum_i (\Delta C_{LSMineral_i} - L_{LSOrganic_i})$$

$$\Delta C_{LSMineral_i} = \Delta A_i \times (C_{AfterSoil} - C_{BeforeSoil}) + A_i \times \Delta C_{Soil_i}$$

$\Delta C_{LSMineral}$: Annual carbon stock changes in mineral soils in urban parks and green areas at port following land-use conversion [t-C/yr]

$L_{LSOrganic}$: Annual carbon stock changes in organic soils in urban parks and green areas at port in settlements converted from land use other than from forest land (=0) [t-C/yr]

ΔA : Area of urban parks and green areas at port converted from other land use within a year [ha/yr]

$C_{AfterSoil}$: Soil carbon stocks immediately after land-use conversion [t-C/ha]

$C_{BeforeSoil}$: Soil carbon stocks before land-use conversion [t-C/ha]

- A : Area of urban parks and green areas at port converted from other land use [ha]
 ΔC_{Soil} : Annual carbon stock changes in soils per land area of urban parks and green areas at port following land-use conversion [t-C/ha/yr]
 i : Type of urban green facilities (urban parks or green areas at ports)

● **Parameters**

Parameters described in Table 6-11 were applied to estimation of carbon stock changes in soils in forest land converted to settlements. In addition, when urban parks were constructed, soils in the areas before conversion were almost never moved to off-site. In general, these soils stay in the same places after conversion or covered by additional soils. Therefore, carbon stock changes in soils resulting from land conversion did not occur.

The parameters same as for urban parks and green areas at port in settlements remaining settlements were used for estimation of carbon stock changes in soils in urban green facilities converted from other land use.

● **Activity Data**

➤ **Forest land converted to settlements**

The values shown in Table 6-44 were applied to forest land converted to settlements.

➤ **Settlements converted from land use other than forest land**

The activity data of settlements converted from other land use were the same as urban parks and green areas at port described in section 11.5.1.1.f. f) in Chapter 11.

c) **Uncertainties and Time-series Consistency**

● **Uncertainty Assessment**

The uncertainties of the parameters and 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 estimate was 21% 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 6.6.2.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 Chapter 1.

e) **Category-specific Recalculations**

● **Correction in accordance with revision of D area**

Since the method of estimating D area, which is used for estimating the areas of Settlements converted from forest land were revised, carbon stock changes in living biomass and dead organic matter in this

category were recalculated 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 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.

6.10. 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 FY2017, Japan’s other land area was about 2.49 million ha, which is equivalent to about 6.6% of the national land. The classification of other land is shown in Table 6-45 below¹¹.

Table 6-45 Land included in the other land category

Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Other land	kha	2,204	2,267	2,223	2,206	2,255	2,276	2,275	2,310	2,304	2,300	2,295	2,302	2,313	2,334
Defense Facility Site	kha	139	140	140	140	140	140	140	140	140	140	139	139	135	135
Coast	kha	46	46	46	46	46	46	46	46	46	46	46	46	46	46
Northern Territories	kha	504	504	504	504	504	504	504	504	504	504	504	504	504	504
Wasteland	kha	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other	kha	1,516	1,577	1,534	1,517	1,565	1,586	1,585	1,620	1,615	1,610	1,607	1,613	1,628	1,649

The emissions from this category in FY2017 were 188 kt-CO₂; this represents a decrease of 83.7% below the FY1990 value and an increase of 4.0% over the FY2016 value.

In this section, other land is divided into two subcategories, “Other land remaining Other land (4.F.1.)” and “Land converted to Other land (4.F.2.)”, and describes them separately in the following subsections.

¹¹ These land areas are based on the following statistics: “*Defense of Japan*” by the Ministry of Defense for “Defense Facility Site”, “*Digital national land information*” by MLIT for “Coast” and “*Land Survey of Prefectures, Shi, Ku, Machi and Mura*” by the Geographical Survey Institute for “Northern Territories”.

Table 6-46 Emissions and removals resulting from carbon stock changes in other land

Gas	Category	Carbon pool	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
CO ₂	4.F. Other land	Total	kt-CO ₂	1,155	950	684	156	314	227	212	175	177	160	159	182	181	188	
		Living Biomass	kt-CO ₂	761	619	434	70	199	131	119	101	106	89	91	109	109	115	
		Dead Wood	kt-CO ₂	202	163	115	17	44	35	35	24	24	26	26	31	31	33	
		Litter	kt-CO ₂	97	78	55	8	21	17	17	12	12	13	13	15	15	16	
		Mineral soil	kt-CO ₂	95	90	80	60	49	44	41	38	35	32	29	27	25	24	
		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	1,155	950	684	156	314	227	212	175	177	160	159	182	181	188	
		Living Biomass	kt-CO ₂	761	619	434	70	199	131	119	101	106	89	91	109	109	115	
		Dead Wood	kt-CO ₂	202	163	115	17	44	35	35	24	24	26	26	31	31	33	
		Litter	kt-CO ₂	97	78	55	8	21	17	17	12	12	13	13	15	15	16	
		Mineral soil	kt-CO ₂	95	90	80	60	49	44	41	38	35	32	29	27	25	24	
		Organic soil	kt-CO ₂	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO

6.10.1. Other land remaining Other land (4.F.1)

a) Category Description

This subcategory deals with carbon stock changes in other land remaining other land during the past 20 years. The land area of this subcategory is determined by subtracting the summed areas of the other five land-use categories from the total national land area shown in the *Statistical Reports on the Land Area by Prefectures and Municipalities in Japan* compiled by the Geospatial Information Authority of Japan. In concrete terms, the land area of this category includes defense facility sites, coasts, and northern territories. However, carbon stock changes in this subcategory are not considered in accordance with the 2006 IPCC Guidelines.

Table 6-47 Areas of other land remaining other land within the past 20 years

Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Other land remaining Other land	kha	2,287.8	2,345.0	2,299.4	2,198.7	2,252.7	2,290.7	2,272.5	2,311.3	2,308.3	2,099.4	2,147.6	2,368.3	2,502.4	2,415.6

b) Category-specific Recalculations

There have been no source-specific recalculations

c) Category-specific Planned Improvements

None.

6.10.2. 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 FY2017 were 188 kt-CO₂. This represents a decrease of 83.7% below the FY1990 value and an increase of 4.0% over the FY2016 value.

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, Japan used the CENTURY-jfos model to estimate carbon stocks in dead organic matter in forest land, and then estimated carbon stock changes in forest land converted to other land. 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 6.6.2.b)2) and 6.7.2.b)2).

With respect to carbon stock changes in soils, carbon stock changes in soils in forest land converted to other land are estimated. Carbon stock changes in soils in cropland and grassland converted to other land are reported as NA because it is assumed that the pools of soils before and after conversion are the same.

In addition, the area of wetlands converted to other land and settlements converted to other land cannot be obtained by the current method. 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 as described in section 6.6.2.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 Tables 6-8a and 6-8b 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)

Only the areas converted from forest land and cropland to other land are determined. Since no data were available on the area converted from wetlands and settlements to other land, estimations for those land-use categories could not be made. Instead, they are reported as “IE” since they are included in “Other land remaining Other land”.

It should be noted that the area presented in the CRF “Table 4.F Sectoral background data for land use, land-use change and forestry—Other land” is not the annually converted area in FY2017 but the sum of annually converted areas during the past 20 years.

➤ **Conversion from Forest Land**

See section 6.6.2.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 6-48 Area of land converted to other land (single year)

Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Land converted to Other land	kha	6.2	6.1	4.3	5.0	1.8	2.1	1.7	18.1	3.0	1.5	2.7	2.0	3.5	3.1
Forest land converted to Other land	kha	3.7	2.9	2.1	0.3	0.8	0.6	0.6	0.4	0.4	0.5	0.5	0.6	0.6	0.6
Cropland converted to Other land	kha	2.2	2.6	2.0	4.5	0.9	1.2	0.9	16.8	2.3	0.8	2.0	1.2	2.7	2.3
Rice field	kha	1.2	1.5	1.6	4.2	0.5	0.8	0.6	14.9	1.7	0.3	1.3	0.8	2.3	1.8
Upland field	kha	0.7	0.9	0.3	0.2	0.3	0.4	0.2	1.6	0.5	0.4	0.5	0.4	0.4	0.4
Orchard	kha	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.4	0.1	0.1	0.1	0.1	0.1	0.1
Grassland converted to Other land	kha	0.4	0.5	0.2	0.2	0.2	0.2	0.1	0.8	0.3	0.2	0.3	0.2	0.2	0.2
Wetlands converted to Other land	kha	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

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 6.6.2.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 Tables 6-9 and 6-10. It is assumed that carbon stocks become zero immediately after conversion, and are not accumulated after conversion.

● **Activity Data (Area)**

The values of annually converted area from each land-use category to other land during the past 20 years are summed up to obtain the total area that is converted to other land during the same time period.

Table 6-49 Area of land converted to other land within the past 20 years

Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Land converted to Other land	kha	173.4	150.0	129.9	110.4	95.3	89.2	84.7	96.9	95.0	89.0	84.7	80.6	79.4	77.4
Forest land converted to Other land	kha	102.4	96.9	85.7	64.8	51.5	46.3	43.3	39.6	36.8	33.3	30.2	27.8	25.7	22.6
Cropland converted to Other land	kha	55.8	41.1	36.9	38.3	36.9	36.3	35.1	50.5	51.5	49.7	48.8	47.4	48.6	49.7
Rice field	kha	32.4	20.9	20.3	22.8	22.8	23.2	22.6	36.9	38.1	37.1	36.8	36.1	37.9	38.9
Upland field	kha	16.1	14.2	12.0	11.5	10.6	10.0	9.5	10.4	10.3	9.7	9.4	8.8	8.4	8.5
Orchard	kha	7.3	5.9	4.5	4.0	3.5	3.2	3.0	3.2	3.1	2.9	2.7	2.5	2.3	2.3
Grassland converted to Other land	kha	15.1	12.0	7.3	7.3	6.9	6.6	6.3	6.8	6.7	6.1	5.6	5.3	5.1	5.1
Wetlands converted to Other land	kha	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

3) Carbon Stock Changes in Soils in “Land converted to Other land”

In this category, carbon stock changes in mineral soils in forest land converted to other land were estimated.

- **Estimation Method**

Carbon stock changes in mineral soils in this category were estimated as same as section 6.6.2.b)3.

- **Parameters**

The parameters described in Table 6-11 were applied to estimating the carbon stock changes in mineral soils in forest land converted to other land.

- **Activity Data (Area)**

The areas of forest land converted to other land within 20 years were calculated by summing the annually converted areas during the past 20 years. The areas were shown in Table 6-49.

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 18% 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 6.6.2.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 Chapter 1.

e) Category-specific Recalculations

- **Correction in accordance with revision of D area**

Since the method of estimating D area, which is used for estimating the areas of Other land converted from forest were revised, carbon stock changes in living biomass and dead organic matter 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.

● **Estimation Method of Soil Carbon Stock Changes in “Forest land, Cropland and Grassland converted to Other Land”**

The estimation method will be considered when new data and information are obtained.

6.11. Harvested Wood Products (4.G)

Harvested Wood Products (HWP) that have been removed from forest through harvest, store these carbon substances while HWP has been used, such as housing materials and furniture. Eventually, CO₂ are emitted when it is discarded due to incineration or decayed.

This category deals with annual carbon stock changes in the HWP pool. The HWP (such as sawn-wood, wooden board, plywood and, paper and paperboard) that are produced from “ikusei-rin forest” which forest management practices are implemented in forest land, is subject to estimation. The changes in carbon stock associated with use or disposal are estimated. The net removal (carbon stock changes) from this subcategory in FY2017 were 1,370 kt-CO₂; this represents an increase of 274.9% over the FY1990 value and an increase of 18.2% over the FY2016 value.

The main reasons for the removal fluctuation since FY1990 in the category were due to economic situation and effects of disaster.

In this section, the HWP is divided into three subcategories: “buildings”, “wood used for other than buildings” and “paper and paperboard”, these subcategories are described separately in the following subsections.

Table 6-50 CO₂ emissions and removals associated with carbon stock change in HWP pool

Gas	Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
CO ₂	Total	kt-CO ₂	-365	1,481	1,830	618	-444	644	64	2,521	60	321	-874	-1,163	-1,159	-1,370	
	Buildings	Total	kt-CO ₂	-474	-857	-3	-850	-1,762	-1,590	-1,559	938	-1,507	-799	-1,436	-1,713	-1,590	-1,607
		Sawnwood	kt-CO ₂	-259	-551	416	-368	-924	-930	-844	1,599	-761	34	-625	-821	-640	-721
		Wooden board	kt-CO ₂	-203	-313	-435	-373	-453	-316	-311	-320	-314	-311	-361	-357	-395	-410
		Plywood	kt-CO ₂	-11	7	17	-109	-384	-344	-405	-341	-432	-521	-450	-535	-556	-476
	Wood used for other than building	Total	kt-CO ₂	641	1,163	1,395	1,259	1,040	1,172	989	941	897	746	520	370	136	19
		Sawnwood	kt-CO ₂	954	1,295	1,478	1,485	1,352	1,481	1,421	1,227	1,313	1,235	1,171	1,095	1,089	1,068
		Wooden board	kt-CO ₂	-325	-211	-198	-130	-21	40	24	3	-99	-112	-95	-88	-116	-130
		Plywood	kt-CO ₂	11	80	115	-96	-291	-348	-457	-289	-317	-377	-556	-637	-837	-919
	Paper and paperboard	kt-CO ₂	-533	1,175	438	209	277	1,062	635	642	670	374	43	179	295	218	

6.11.1. Buildings

a) Category Description

This category deals with annual change in carbon stock in sawnwood, wooden board, and plywood used in buildings. The net removal (carbon stock changes) from this subcategory in FY 2017 were 1,607 kt-CO₂; this represents an increase of 239.3% over the FY1990 value and an increase of 1.1% over the FY2016 value.

b) Methodological Issues

● Estimation Method

Since sawn-wood, wooden board, and plywood are mainly used for buildings and their statistics related to the buildings have been compiled with a certain accuracy in Japan, the carbon stock changes in these pools are estimated by using country-specific stock inventory method (Tier 3).

Carbon stock changes in sawn-wood, wooden board, and plywood that are used when buildings are constructed are recorded as inflow and released carbon when the buildings are destroyed are recorded as outflow. It means that the all carbon used in the buildings are immediately oxidized when the buildings are destroyed. The estimation equation is as follows:

Sawn-wood, wooden board and plywood used in the buildings are reported in “Sawnwood”, “Wood panels”, and “Other solid wood products” under “Solid wood” in the CRF tables, respectively.

$$\Delta C_{j,i} = Inflow_{j,i} - Outflow_{j,i}$$

i : Year

j : Subcategory (sawnwood, wooden board, plywood)

$Inflow_{j,i}$: Inflow to the HWP pools of subcategory j during year i [t-C/year]

$Outflow_{j,i}$: Outflow from the HWP pools of subcategory j during year i [C/year]

$\Delta C_{j,i}$: Carbon stock change in HWP products of subcategory j during year i [t-C/year]

Regarding the carbon stock (inflow) in sawnwood, wooden board, and plywood that are used when buildings are constructed, and released carbon (outflow) when the buildings are destroyed, were calculated by the following equations.

$$Inflow_{j,i} = \{ S_{P_{st,i}} \times v_{j,st} \times f_{DP_{j,i}} - V_{IM_i} \} \times D_j \times CF_j$$

$$Outflow_{j,i} = \{ SW_{st,i} \times v_{DW_{j,st}} \times f_{DW_{j,i}} - V_{IM_i} \} \times D_j \times CF_j$$

$$S_{W_{st,i+1}} = S_{S_{st,i}} - S_{S_{st,i+1}} + S_{P_{st,i+1}}$$

i : Year

j : Subcategory (sawnwood, wooden board, plywood)

st : Use (residential or nonresidential)

$Inflow_{j,i}$: Annual carbon inflow to the HWP pools of subcategory j during year i [t-C/year]

$Outflow_{j,i}$: Outflow from the HWP pools of subcategory j during year i [t-C/year]

$SP_{st,i}$: Constructed floor area by use (residential or nonresidential) and by structure during year i [m²/year]

$v_{j,st}$: Wood input per unit floor area of subcategory j [m³/m²]

$SW_{st,i}$: Floor area of destroyed by use (residential or nonresidential) and by structure [m²/year]

$VDW_{j,st}$: Wood input per unit floor area in the year in which the destroyed buildings were constructed [m³/m²]

$f_{DP_{j,i}}$: Rate of domestic logs to total logs used for construction of subcategory j in each year [%]

$f_{DW_{j,i}}$: Rate of domestic logs for destroyed building of subcategory j in each year [%]

V_{IM_i} : Amount of wood used for imported houses in each year [m³]

- D_j : Density of subcategory j [t-d.m./m³]
 CF_j : Carbon fraction of subcategory j [t-C/t-d.m.]
 $Ss_{st,i}$: Floor area stock by use (residential or nonresidential building) and by structure in each year [m²/year]

● **Parameters**

➤ **Wood input per unit area (m³/m²)**

- **Sawnwood**

As for wooden residential building, amount of wood per unit area from FY1991 to FY2011 were identified by exiting statistics (*Survey on Actual Demand of Construction Labor and Materials* by the MLIT). As for non-wood residential building, the values of FY2013 are obtained from the survey which was implemented newly because only data until FY1991 in the *Survey on Actual Demand of Construction Labor and Materials* by the MLIT above was available. The same values of FY 2013 were applied from FY2014 onwards. The values of FY1992 to FY2012 were calculated by linear interpolation.

- **Wooden board**

The amount of wooden board by types and uses was calculated by multiplying the ratio of the amount of shipped wooden board by uses to total shipment, by the types in *Yearbook of Current Production Statistics, Paper, Ceramics and building materials Statistics* by METI. The wood input per unit area were estimated by dividing the amount of wood calculated above, by the floor areas of constructed buildings.

- **Plywood**

The values obtained from the *Survey on Actual Demand of Construction Labor and Materials* by the MLIT were applied. As for the years that data are missing, the values were calculated by linear interpolation.

➤ **Rate of domestic logs**

- **Sawnwood**

The rate of domestic logs for sawnwood by conifer and non-conifer was calculated by dividing shipment quantity of domestic sawnwood for buildings, by the total amount of shipment quantity of sawnwood for buildings and imported sawnwood.

- **Wooden board**

Amount of shipped wooden board (domestic logs) for buildings by raw material were calculated by multiplying proportion of raw materials in particle board and fiberboard, and the ratio of domestic logs for each raw material (logs, wood residue in mills and forestry practices and scrap wood). The ratio of domestic logs for each raw material were estimated from production of domestic wood chips, imported wood chips, and quantity of arrival logs for wood chips (domestic logs and imported logs). The ratio of domestic logs for each wooden board type were estimated by dividing the amount of shipped wooden board (domestic logs) above, by the sum of the amount of shipped wooden board for buildings and amount of imported wooden board for buildings.

- **Plywood**

The ratio of domestic logs for plywood constructed buildings was calculated by multiplying ratio of production of plywood to the sum of plywood production and imports, by the ratio of domestic logs for plywood.

➤ **Density and Carbon fraction**

The default values (Table 2.8.1) described in the *2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol* were applied.

Table 6-51 Default values of density and carbon fraction for the HWP categories

HWP categories		Density [Mg/m ³]	Carbon fraction [Mg-C/Mg-d. m.]
Sawnwood	Coniferous sawnwood	0.45	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

(the *2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol*: Table 2.8.1)

Table 6-52 Data used for parameters (Buildings)

	Variable	Source	Note
1	Shipment quantity of sawlogs (for building) (domestic logs)	<i>Report on Supply and Demand of Lumber</i> by MAFF	
2	Shipment quantity of sawlogs (for building) (imported logs)	<i>Report on Supply and Demand of Lumber</i> by MAFF	
3	Received quantity of logs for sawlogs	<i>Report on Supply and Demand of Lumber (the Survey on Lumber)</i> by MAFF	
4	Imports of lumber (coniferous tree)	<i>Trade Statistics of Japan</i> by MOF	Softwood (coniferous tree) is assumed as building materials because imports for building structures cannot be obtained in the statistics.
5	Shipment quantity of wooden board	<i>Yearbook of Current Production Statistics, Paper, Ceramics and building materials Statistics</i> by METI	Including own-use
6	Imports of wooden board	<i>Trade Statistics of Japan</i> by MOF	
7	Imported wood chips	<i>Trade Statistics of Japan</i> by MOF	
8	Production of domestic wood chips	<i>Report on Supply and Demand of Lumber</i> by MAFF	
9	Quantity of arrival logs for wood chips (domestic logs)	<i>Report on Supply and Demand of Lumber</i> by MAFF	
10	Quantity of arrival of logs for wood chips (imported logs)	<i>Report on Supply and Demand of Lumber</i> by MAFF	
11	Shipment quantity of wooden board by use	<i>Shipments of wood-based board production</i> by Japan Fiberboard and Particleboard Manufacturers Association	
12	Production of plywood	<i>Report on Supply and Demand of Lumber</i> by MAFF	
13	Imports of veneer for plywood	<i>Trade Statistics of Japan</i> by MOF	Calculated by multiplying rate of veneer for plywood to imports of veneer, by imports of veneer obtained from FAOSTAT
14	Imports of plywood	<i>FAOSTAT</i> by FAO <i>Trade Statistics of Japan</i> by MOF	Calculated by subtracting bonded wood and bamboo of plywood by <i>Trade Statistics of Japan</i> from bonded wood by <i>FAOSTAT</i>
15	Received quantity of logs for plywood (domestic logs)	<i>Report on Supply and Demand of Lumber</i> by MAFF	
16	Received quantity of logs for plywood (imported logs)	<i>Report on Supply and Demand of Lumber</i> by MAFF	

MIC: Ministry of Internal Affairs and Communications; METI: Ministry of Economy, Trade and Industry; MOF: Ministry of Finance

● Activity Data

Activity data were floor area of construction (inflow) and demolition (outflow). Floor area of construction by uses (residential or nonresidential) and by structures in *Construction Statistics for Housing* and *Construction Statistics for Building* by MLIT was applied, and floor area stock in *Fixed Property Tax Division, Local Tax Bureau (Houses)* by MIC was applied. Floor area of demolition was calculated by these differences. These values were based on statistics, and this method considered economic recessions and natural disasters.

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 *2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol* 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 were obtained from the *Survey on Actual Demand of Construction Labor and Materials* by the MLIT which is implemented every three years, the data for missing years were calculated by interpolation by means of linear expression. 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 the checking of the parameters for activity data and emission factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

e) Category-specific Recalculations

Until the previous report, amount of wood used per unit floor area since FY2012 were the same value as in FY2011. In this submission, interpolated values for FY2011 and FY2015 were used from FY2012 onwards (values of FY2016 and FY2017 are set as the same value of FY2015). Following this correction, the inflow of buildings after FY2012 were recalculated. In addition, with the adjustment of the area of destroyed building in the existing statistics, the discarded carbon (outflow) of the buildings after FY2011 were recalculated.

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

Due to increasing use of wood for building material caused by the revision of Building Code Act and spread of Cross Laminated Timber (CLT), there is a possibility that the wood input per unit area will be changed in the future.

6.11.2. Wood used for other than buildings

a) Category Description

This category deals with carbon stock changes in sawnwood, wooden board, and plywood used in other than buildings. The net emissions (carbon stock changes) from this subcategory in FY2017 were 19 kt-CO₂; this represents a decrease of 97.0% below the FY1990 value and a decrease of 85.8% below the FY2016 value.

b) Methodological Issues

- **Estimation Method**

The carbon stock change in the HWP pool of this category were estimated from the difference between the HWP pool in reference year and prior year by using the Tier 2 method by the first-order decay (FOD) function described in the *2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol*. Inflow to the HWP pool during one year were estimated by multiplying amount of wood used in other than buildings, rate of domestic logs of each subcategory (sawnwood, wooden board and plywood), by carbon conversion factor. The estimation equations are as follows.

In the CRF tables, “Sawnwood” are reported as “Sawnwood for non-buildings”, “Wooden board” as “Wooden board for non-buildings”, and “Plywood” as “Plywood for non-buildings” under “Other

(please specify)”, respectively.

$$C_{j,i+1} = e^{-k_j} \times C_{j,i} + \left[\frac{(1 - e^{-k_j})}{k_j} \right] \times Inflow_{j,i}$$

$$\Delta C_{j,i} = C_{j,i+1} - C_{j,i}$$

i : Year

j : Subcategories (sawnwood, wooden board and plywood)

$C_{j,i}$: Carbon stock of the HWP pool in the beginning of year i [t-C]

$Inflow_{j,i}$: Inflow to the HWP pool during year i [t-C/year]

k_j : Decay constant of FOD for each HWP category, $k_j = \ln(2)/HL_j$

HL_j : half-life of the HWP pool in years

$\Delta C_{j,i}$: Carbon stock change in the HWP category during year i [t-C/year]

$C_{j,(1900)}$: Carbon stock in 1900 was assumed to be zero

$$Inflow_{j,i} = V_{P,j,i} \times f_{DP,j,i} \times D_j \times CF_j$$

i : Year

j : Subcategories (sawnwood, wooden board and plywood)

$V_{P,j,i}$: Amount of wood used in other than buildings [m³/year]

$f_{DP,j,i}$: Rate of domestic logs used in other than buildings during year i [%]

D_j : Density [t-d.m./m³]

CF_j : Carbon fraction [t-C/t-d.m.]

● Parameters

➤ Rate of domestic logs

- Sawnwood

The ratio of domestic logs for sawnwood used for other than buildings were calculated by dividing the amount of shipped sawnwood from domestic logs by tree species, by the amount of shipment.

- Wooden board

The ratio of domestic logs for wooden board production were estimated by multiplying proportion of raw materials used for practical board and fiber board, by the ratio of domestic logs for each raw material (logs, wood residue in mills and forestry practices, and scrap wood). The rate of domestic logs for each raw material were estimated from production of domestic wood chips, imported wood chips, and quantity of arrival logs for wood chips (domestic logs and imported logs).

- Plywood

The ratio of domestic logs in plywood used for other than buildings, were calculated by dividing the amount of received materials from domestic logs for plywood for other than buildings by sum of the amount of received materials for plywood and imported veneers for plywood (converted to roundwood).

➤ Default Half-lives

The default half-lives (sawnwood: 35 year, wood panels: 25 year) described in *the 2013 Revised*

Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol were applied (Table 2.8.2). The default half-lives of wood panels are used for wooden board and plywood.

➤ **Density and Carbon fraction**

The default values used are the same as section 6.11.1 “Building” (See Table 6-51 for the details).

Table 6-53 Data used for parameters (wood used for other than buildings)

	Variable	Source	Note
1	Shipment quantity of lumber (for other than domestic logs and building lumber)	<i>Report on Supply and Demand of Lumber</i> by MAFF	
2	Shipment quantity of wooden board	<i>Yearbook of Current Production Statistics, Paper, Ceramics and building materials Statistics</i> by METI	Including own-use
3	Imported wood chips	<i>Trade Statistics of Japan</i> by MOF	
4	Production of domestic wood chips	<i>Report on Supply and Demand of Lumber</i> by MAFF	
5	Domestic wood chips (for pulp)	<i>Trends in Pulp Collection</i> by Japan Paper Association	
6	Received quantity of logs for wood chips (domestic logs)	<i>Report on Supply and Demand of Lumber</i> by MAFF	
7	Received quantity of logs for wood chips (imported logs)	<i>Report on Supply and Demand of Lumber</i> by MAFF	
8	Imports of plywood (veneer)	<i>Trade Statistics of Japan</i> by MOF	Calculated by multiplying rate of veneer for plywood to imports of veneer, by imports of veneer obtained from FAOSTAT
9	Received quantity of logs for plywood (domestic logs)	<i>Report on Supply and Demand of Lumber</i> by MAFF	
10	Received quantity of logs for plywood (imported logs)	<i>Report on Supply and Demand of Lumber</i> by MAFF	

METI: Ministry of Economy, Trade and Industry; MOF: Ministry of Finance

● **Activity Data**

Activity data were input of lumber, volume of wooden board, and production of plywood. Input of lumber were estimated by subtracting lumber for building material from sold shipment quantity of lumber in *Report on Supply and Demand of Lumber* by MAFF. The amount of wooden board were estimated by (1) calculating the volume from sale area of each PB, HB, MDF, and LDF in *Yearbook of Current Production Statistics Mineral Resources and Petroleum Products, Ceramics and Building Materials Statistics* by METI; (2) subtracting the volume of sold wooden board for buildings from volumes calculated at (1). Production of plywood were used in *Report on Supply and Demand of Lumber (the Survey on Lumber)* by MAFF.

➤ **Method of tracing back up to 1900**

As for wood used for other than buildings, they were extrapolated backward to 1990 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), 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
 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

c) *Uncertainties and Time-series Consistency*

● *Uncertainty Assessment*

The uncertainties of carbon stock changes of wood use other than buildings were assessed based on the uncertainties of the default factors in provided in the *2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol* and the uncertainties of statistical data. The uncertainty was estimated as 30% for the carbon stock changes in wood used for other than buildings.

● *Time-series Consistency*

The data before 1961 were extrapolated backward to 1990 using the equation 12.6 described in section 12.2.3 in the *2006 IPCC Guidelines*, the time-series consistency for this subcategory is ensured. The activity data and any parameter after 1962 were used consistent 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 Chapter 1.

e) *Category-specific Recalculations*

Since amount of wood used per unit floor and total floor area scrapped were revised, the emissions/removals were recalculated from FY2011-FY2016.

See Chapter 10 for impact on trend.

f) *Category-specific Planned Improvements*

Wood which is used mainly in roundwood form in civil engineering and construction field, are not estimated at present.

6.11.3. Paper and paperboard

a) *Category Description*

This category deals with carbon stock changes in paper and paperboard (including waste paper). The net removal (carbon stock changes) from this subcategory in FY1990 were 533 kt-CO₂, the net emissions in FY2016 were 295 kt-CO₂, in FY2017 were 218 kt-CO₂.

b) *Methodological Issues*

● *Estimation Method*

The carbon stocks change in the HWP pool in paper and paperboard were estimated from the difference between the HWP pool in reference year and prior year in the same way as wood for other use by using the Tier 2 method by the first order decay (FOD) function described in the *2013 Revised Supplementary*

Methods and Good Practice Guidance Arising from the Kyoto Protocol. Inflow to the HWP pool during one year were estimated by multiplying amount of production of paper and paperboard, rate of domestic logs for paper and paperboard, by carbon conversion factor. The estimation equations are as follows.

$$C_{j,i+1} = e^{-k_j} \times C_{j,i} + \left[\frac{(1 - e^{-k_j})}{k_j} \right] \times Inflow_{j,i}$$

$$\Delta C_{j,i} = C_{j,i+1} - C_{j,i}$$

i : year

j : Subcategories (paper and paperboard)

$C_{j,i}$: Carbon stock in HWP pool in the beginning of year i [t-C]

$Inflow_{j,i}$: Inflow to the HWP pool during year i [t-C/year]

k_j : Decay constant of FOD for paper products, $k_j = \ln(2)/HL_j$

HL_j : half-life of the HWP pool: two years

$\Delta C_{j,i}$: Carbon stock change of the HWP category during year i [t-C/year]

$C_{j,(1900)}$: Carbon stock in 1900 was assumed to be zero

$$Inflow_{j,i} = PP_{j,i} \times f_{DP_{j,i}} \times D_j \times CF_j$$

i : year

j : Subcategories (paper and paperboard)

$PP_{j,i}$: Production of paper and paperboard during year i [t]

$f_{DP_{j,i}}$: Rate of domestic logs for paper and paperboard during year i [%]

D_j : Density (oven dry mass over air dry mass)

CF_j : Carbon fraction [t-C/t-d.m.]

● Parameters

➤ Ratio of domestic logs

Ratio of domestic logs of paper and paperboard was estimated by dividing consumption of domestic production of paper and paperboard, by total amount of domestic production of paper and paper pulp, waste paper and waste paper pulp that were produced from domestic logs. Domestic production of paper pulp, waste paper and waste paper pulp that were made from domestic logs were estimated, respectively.

Ratio of domestic logs of paper pulp were estimated by dividing domestic and imported consumption by made from raw woods and chips, by total consumption of raw materials in *Yearbook of current production statistics Paper, printing, plastic products and rubber products* by METI. But, domestic chips included chips which were made from imported logs in domestic industries, the ratio of domestic logs in paper pulp were estimated by subtracting chips which were made from imported logs, using input of domestic and imported raw materials for chips, and the ratio of domestic logs in buildings.

Ratio of domestic logs of waste paper and waste paper pulp were estimated domestic amount of supply from production of waste paper in *Yearbook of current production statistics Paper, printing, plastic products and rubber products* by METI and import and export amount of waste paper in *Trade Statistics of Japan* by MOF.

Table 6-54 Data used for parameters (Paper and paperboard)

	Variable	Source	Note
1	Consumption of raw materials for pulp products	<i>Yearbook of Current Production Statistics, Paper, Printing, Plastic Products and Rubber Products Statistics Current Survey of Production</i> by METI	Used for calculating rate of domestic logs
	Made from domestic logs		
	Raw woods		
	Chips		
	Chips made from imported logs		
2	Production of waste paper	<i>Yearbook of Current Production Statistics, Paper, Printing, Plastic Products and Rubber Products Statistics Current Survey of Production</i> by METI	FAOSTAT (Recovered paper)
3	Imports and Exports of waste paper	<i>Trade Statistics of Japan</i> by MOF	FAOSTAT (Recovered paper)
4	Imports and Exports of paper and paperboard	<i>Trade Statistics of Japan</i> by MOF	FAOSTAT (Recovered paper)
5	Rate of production of wood chips	<i>Report on Supply and Demand of Lumber</i> by MAFF	Used for estimating the ratio of domestic logs for pulp production chips
6	Received quantity of logs for wood chips (domestic logs)	<i>Report on Supply and Demand of Lumber</i> by MAFF	
7	Received quantity of logs for wood chips (imported logs)	<i>Report on Supply and Demand of Lumber</i> by MAFF	

METI: Ministry of Economy, Trade and Industry; MOF: Ministry of Finance

➤ *Half-life*

Default half-life of paper and paperboard (2 year) described in the *2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol* (Tables 2.8.2) was used.

➤ *Default conversion factors for Paper and paperboard*

Default parameters (oven dry mass over air dry mass: 0.9 t-d.m./t, carbon fraction: 0.386 t-C/t-d.m.) for paper and paperboard described in the *2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol* (Tables 2.8.2) were used.

● *Activity Data*

➤ *Method since 1961*

Amount of production of paper, paperboard and domestic logs (Pulpwood and Chips) were used in *Yearbook of Current Production Statistics, Paper, Printing, Plastic Products and Rubber Products Statistics Current Survey of Production* by METI. These are same with production amount of Paper and Paperboard in FAOSTAT.

➤ *Method of tracing back up to 1900*

For paper and paperboard, the estimation method is the same as wood used for other than buildings. For detailed information on the equation and the parameters, see section 6.11.2.

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 *2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol* 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 data before 1961 were extrapolated backward to 1990 using the equation 12.6 described in section 12.2.3 in the 2006 IPCC Guidelines, the time-series consistency for this subcategory is ensured. The activity data and any parameter after 1962 were used consistent 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 Chapter 1.

e) Category-specific Recalculations

In accordance with the revision of statistics such as wood chips production, the emissions were recalculated from FY2014 to FY2016.

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

None.

6.12. Direct N₂O emissions from N inputs to managed soils (4. (I))

a) Category Description

This category deals with direct N₂O emissions from N fertilization in land other than cropland and grassland. The direct N₂O emissions from N fertilization in forest land were estimated but in wetlands and settlements were reported as “IE” because those are included in the Agriculture sector. The emissions by this subcategory in FY2017 were 0.54 kt-CO₂ eq. This represents a decrease of 35.5% below the FY1990 value.

Table 6-55 Direct N₂O emissions from N fertilization

Gas	Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
N ₂ O	Total	kt-N ₂ O	0.003	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	
		kt-CO ₂ eq.	0.84	0.72	0.67	0.64	0.46	0.48	0.56	0.53	0.54	0.56	0.54	0.54	0.54	0.54	
	Forest land	Inorganic N fertilizers	kt-N ₂ O	0.003	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
	Forest land remaining Forest land	Inorganic N fertilizers	kt-N ₂ O	0.003	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
	Land converted to Forest land	Inorganic N fertilizers	kt-N ₂ O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	
	Wetlands	Inorganic N fertilizers	kt-N ₂ O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	
	Wetlands remaining Wetlands	Inorganic N fertilizers	kt-N ₂ O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	
	Land converted to Wetlands	Inorganic N fertilizers	kt-N ₂ O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	
	Settlements	Inorganic N fertilizers	kt-N ₂ O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	
	Settlements land remaining Settlements	Inorganic N fertilizers	kt-N ₂ O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	
	Land converted to Settlements	Inorganic N fertilizers	kt-N ₂ O	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	
	Other	Inorganic N fertilizers	kt-N ₂ O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	

b) Methodological Issues

- **Estimation Method**

The direct N₂O emissions from 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**

- **Emission factor**

The emission factor (0.62% [kg-N₂O-N/kg-N¹²]), which was applied to the estimation of N₂O emissions resulting from application of synthetic fertilizer to agricultural soils, was also applied to the estimation of N₂O emissions from N fertilization to soils in forest land. For detailed information on the emission factor, see section 5.5.1.1.b) in chapter 5 in this NIR.

- **Activity Data**

Results of surveys from 2006 to 2008 on fertilizer application to soils in forest land by the Forestry Agency of Japan are applied to activity data. The amount of synthetic 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 fertilizer application in *Yearbook of Fertilizer Statistics (Pocket Edition)* by the average percentage of synthetic 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 fertilizer application. With respect to kinds of fertilizer applied to soils in forest land, most of them are synthetic fertilizer according to the surveys by the Forestry Agency of Japan. Hence, the fertilizer applied to soils in forest land is regarded as synthetic fertilizer.

Since the application of crop residues to forest land and the grazing in the forest land have not been carried out, the amount of crop residues applied to soils in forest land and, grazing land, and paddock were zero.

- c) **Uncertainties and Time-series Consistency**

- **Uncertainty Assessment**

The uncertainty estimates of N₂O emissions from N fertilization were 31% by applying the same value as the estimation of the N₂O emissions from N fertilization in the Agriculture sector.

- **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 Chapter 1.

- e) **Category-specific Recalculations**

There have been no source-specific recalculations.

- f) **Category-specific Planned Improvements**

None.

¹² Akiyama et al., Direct N₂O emissions and estimate of N₂O emission factors from Japanese agricultural soils. (2006)

6.13. Emissions and Removals from Drainage and Rewetting and Other Management of Organic and Mineral soils (4.(II))

a) Category Description

Regarding the non-CO₂ emissions from drainage and rewetting and other management of organic and mineral soils, the emissions from drainage of organic soils were estimated in Japan. CH₄ emission from drainage of organic soils in upland fields and pasture land were estimated in this subcategory (CH₄ emissions from drainage of organic soils in rice fields were reported in the Agriculture sector). Regarding the rewetted organic soils and coastal wetlands that methodology is described in the *Wetlands guidelines*, the estimation method has not been applied. Hence, the emissions were reported as “NA”.

Regarding the emissions from soil drainage activities in forest land, the non-CO₂ emissions did not occur, because soil drainage activities are not carried out in general in Japan. CH₄ and N₂O emissions from drainage of organic soils in forest land are reported as “NO”. As explained in section 4.D.1, peatland classified as wetlands was reported as “NE” because it can be considered insignificant in terms of overall level and trend in national emissions. Flooded land and other wetlands were reported as “NA” because the estimation method was not applied.

The emissions by this subcategory in FY2017 were 37.1 kt-CO₂ eq. This represents a decrease of 2.8% below the FY1990 value, and an increase of 0.3 % over the FY2016 value.

Table 6-56 CH₄ emission from drainage of organic soils

Gas	Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017		
CH ₄	Total	kt-CO ₂ eq.	38.2	37.8	37.5	37.3	37.2	37.7	37.1	37.5	37.6	37.3	37.7	37.9	37.0	37.1		
	Total	kt-CH ₄	1.53	1.51	1.50	1.49	1.49	1.51	1.48	1.50	1.50	1.49	1.51	1.51	1.48	1.49		
		kt-CO ₂ eq.	38.2	37.8	37.5	37.3	37.2	37.7	37.1	37.5	37.6	37.3	37.7	37.9	37.0	37.1		
		Forest land	kt-CH ₄	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	
		Cropland	kt-CH ₄	1.44	1.42	1.41	1.40	1.40	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.39	1.40	
		Grassland	kt-CH ₄	0.09	0.09	0.09	0.09	0.09	0.11	0.09	0.11	0.11	0.10	0.12	0.12	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	
		Peat land	kt-CH ₄	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	
		Other wetlands	kt-CH ₄	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
		Other	kt-CH ₄	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
	N ₂ O	Total	kt-N ₂ O															
		Total	kt-CO ₂ eq.															
			Forest land	kt-N ₂ O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
			Wetlands	kt-N ₂ O	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 ₂ O	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	
			Flooded land	kt-N ₂ O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
Other wetlands			kt-N ₂ O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		
Other			kt-N ₂ O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA		

b) Methodological Issues

● Estimation Method

CH₄ emissions from drained inland organic soils were estimated by using Tier 1 method described in section 2.2.2.1 in the *Wetlands guidelines*. The estimation equation is as follows:

$$CH_{4-organic} = \sum \{ A \times [(1 - Frac_{ditch}) \times EF_{CH_4_land} + Frac_{ditch} \times EF_{CH_4_ditch}] \}$$

$CH_{4-organic}$: Annual CH₄ loss from drained organic soils [kg-CH₄]

A : Land area of drained organic soils [ha]

$EF_{CH_4_land}$: Emission factors for direct CH₄ from drained organic soil [kg-CH₄/ha]

$EF_{CH_4,ditch}$: Emission factors for CH₄ emissions from drainage ditches [kg-CH₄/ha]

$Frac_{ditch}$: Fraction of the total area of drained organic soil which is occupied by ditches

● **Parameters**

The following emission factors for CH₄ from drained organic soil, emission factors for CH₄ from drainage ditches, and the proportion of ditches to the total area of drained organic soil which were provided by the *Wetlands guidelines* Table 2.3 and Table 2.4, were applied to the estimation.

Table 6-57 CH₄ emission factors for drained organic soils (land surface)

Land-use category	Emission factor	Unit	Climate/ vegetation zones
Cropland, drained	0	kgCH ₄ /ha/yr	Cropland, temperate
Grassland, deep-drained, nutrient-rich	16	kgCH ₄ /ha/yr	Grassland, deep-drained, nutrient rich, temperate

Wetlands guidelines: Table 2.3

Table 6-58 Default CH₄ emission factors for drained organic ditches

Land-use category	Emission factor	Unit	Frac _{ditch} (indicative values)	Climate/ vegetation zones
Deep-drained Grassland, Cropland	1165	kgCH ₄ /ha/yr	0.05	Boreal/ Temperate

Wetlands guidelines: Table 2.4

● **Activity Data**

For detailed information on the methods of determining the areas of organic soils in upland fields and grassland, see section 6.6.1 and section 6.7.1.

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 CH₄ emissions from drained inland organic soils were 115%.

● **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 Chapter 1.

e) **Category-specific Recalculations**

● **Correction in accordance with revision of D area**

Since area of deforestation (D area) were revised, the emissions from FY2008 to FY2016 were recalculated.

● **Correction in accordance with revision of estimation method of organic soil area in cropland and grassland**

Following the revision of estimation method of organic soil area, CH₄ emission from drainage of organic soils in cropland and in grassland were recalculated for all years.

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

None.

6.14. Direct N₂O emissions from N mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils (4.(III))

a) Category Description

This category deals with direct N₂O emissions from N mineralization resulting from change of land use or management of mineral soils. Therefore, according to the *2006 IPCC Guidelines*, N immobilization associated with gain of soil carbon on mineral soils is not considered, only N₂O emissions from mineralization associated with loss of soil organic matter were estimated.

The direct N₂O emissions in forest land remaining forest land and land converted to other land were estimated by using Tier 1 method according to N mineralization associated with loss of soil organic matter. The N₂O emissions in land converted to cropland and grassland were estimated with the same country specific emission factors as for the Agriculture sector. Carbon stock change in soil organic matter only for pasture land among 3 sub-categories of grassland were estimated. Thus, the estimation in this category was implemented only for pasture land subcategory as well. For land-use categories other than those categories described above, N₂O emissions were reported as “NA” because the loss of soil carbon does not occur (Only for wetlands converted from land was reported as “NE” because the methodology is not provided in the *2006 IPCC Guidelines*). The emissions from this subcategory in FY2017 were 135.1 kt-CO₂ eq. This represents a decrease of 12.0 % below the FY1990 value, and an increase of 1.1 % over the FY2016 value.

Table 6-59 N₂O emissions from N mineralization resulting from change of land use or management of mineral soils

Gas	Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
N ₂ O	Total	kt-N ₂ O	0.52	0.50	0.48	0.45	0.44	0.44	0.44	0.44	0.44	0.44	0.44	0.45	0.45	0.45	
		kt-CO ₂ eq.	153.5	148.0	142.1	135.4	132.2	131.2	130.0	129.9	131.0	131.2	131.9	132.7	133.7	135.1	
	Forest land	kt-N ₂ O	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.41	0.41	0.42	0.42	0.43
		Forest land remaining Forest land	kt-N ₂ O	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.41	0.41	0.42	0.42	0.43
		Land converted to Forest land	kt-N ₂ O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Cropland	kt-N ₂ O	0.08	0.06	0.04	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
		Land converted to Cropland	kt-N ₂ O	0.08	0.06	0.04	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
	Grassland	kt-N ₂ O	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
		Grassland remaining Grassland	kt-N ₂ O	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
		Land converted to Grassland	kt-N ₂ O	IE		IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE	IE
	Wetlands	kt-N ₂ O	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 ₂ O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Land converted to Wetlands	kt-N ₂ O	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE
	Settlements	kt-N ₂ O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Settlements remaining Settlements	kt-N ₂ O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
		Land converted to Settlements	kt-N ₂ O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	Other land	kt-N ₂ O	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	

b) Methodological Issues

● Estimation Method

The Tier 1 method described in the 2006 IPCC Guidelines is used for forest land remaining forest land and other land. The estimation equation is as follows. Equation 2.25 described Session 2.3.3.1 in the 2006 IPCC Guidelines is used for loss of soil organic matter.

$$N_2O_{direct-N_{Mineral}} = F_{SOM} \times EF_1$$

$$F_{SOM} = \sum_{LU} \left[\left(\Delta C_{Mineral,LU} \times \frac{1}{R} \right) \times 1000 \right]$$

$N_2O_{direct-N_{Mineral}}$: Annual direct N₂O-N emissions produced from N mineralization [kg-N₂O-N]

F_{SOM} : Net amount of N mineralized in mineral soil [kg-N]

EF_1 : Emission factor [kg-N₂O-N/kg-N input]

$\Delta C_{Mineral,LU}$: Average annual loss of soil carbon for each land-use type [t-C]

R : C:N ratio for the soil organic matter

For land converted to cropland and grassland, annual amount of loss of soil carbon due to N mineralization in mineral soils cannot be obtained, when using the estimation method described in the 2006 IPCC Guidelines. Therefore, N₂O emissions from land converted to cropland and grassland were estimated by using country specific method, by multiplying the area of mineral soils in cropland converted from other land use and in grassland, by the N₂O emission per unit area in cropland. Carbon stock change of soil organic matter only for pasture land among 3 sub-categories of grassland was estimated. Thus, the estimation in this category was implemented only for pasture land subcategory as well and the estimations from grazed meadow and wild land are excluded. For a detailed description of the calculation methods, see the Agriculture sector.

$$N_2O_{direct-N_{Mineral_{C,G}}} = \sum_i A_i \times EF_{1_{C,G}}$$

$N_2O_{direct-N_{Mineral_{C,G}}}$: Annual direct N₂O-N emissions produced from N mineralization [kg-N₂O-N]

A : The cumulative total mineral soil area of land converted to cropland and grassland [ha]

$EF_{1_{C,G}}$: N₂O emission from N mineralization per unit area of mineral soil [kg-N₂O-N/ha]

i : Type of land use

● Parameters

➤ CN ratio for soils

11.3 (Country specific data (Ministry of the Environment, 2006))

➤ N-N₂O emission factor for soils

For forest land and other land, default value [0.01 kg- N₂O-N/kg- N] described in the 2006 IPCC Guidelines was used. For cropland and grassland, the value used in the Agriculture sector [0.23 kg- N₂O-N/ha] was applied. (For detailed information, see section 5.5.1.5.b).

● Activity Data

For amount of N mineralized in mineral soil in forest land remaining forest land and in other land,

annual loss of soil carbon in mineral soil for estimating carbon stock changes in mineral soils was used (see Chapter 6.5.2. and Chapter 6.10.2.). The area of mineral soil in land converted to cropland, which are calculated by subtracting the area of organic soil from the total area of land converted to cropland, are used for the estimation as activity data (see Chapter 6.6.1. b) 2)).

The area of mineral soil in grassland was calculated by multiplying the area of pasture land obtained from existing statistics by the ratio of mineral soil area to the area of pasture land and renewal ratio (see section 6.7.1.) of pasture land (see Chapter 6.7.1.).

c) Uncertainties and Time-series Consistency

● **Uncertainty Assessment**

The uncertainties of emission/removal for forest land 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. For the uncertainty assessment for cropland and grassland converted from other land-use category, 31% which is the same value of the uncertainties for the emissions in the Agriculture sector was applied. As a result, the uncertainties in the N₂O emissions from N mineralization associated with loss of soil organic matter were -71%~+190%.

● **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 Chapter 1.

e) Category-specific Recalculations

Since area of afforestation and reforestation (AR area) and area of deforestation (D area) were revised, the emissions from N mineralization associated with loss of soil organic matter in forest land, cropland, grassland and other land from FY1990 to FY2016 were recalculated. Also, due to the revision of the method of estimating the area of organic soil in cropland converted from land and in grassland, the emissions were recalculated for all years.

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

None.

6.15. Indirect nitrous oxide (N₂O) emissions from managed soils (4.(IV))

a) Category Description

This category deals with indirect N₂O emissions from managed soils. The indirect N₂O emissions include, N₂O emissions from N volatilization as NH₃ and NO_x and deposition of these gases and their products NH₄⁺ and NO₃⁻ onto soils and the surface of lakes and other waters, and N₂O emissions from leaching and runoff in regions where these events occur. In Japan, the indirect N₂O emissions from N

fertilization in forest land and the indirect N₂O emissions from N mineralization associated with loss of soil organic matter were estimated.

The emissions from this category in FY2017 were 32.3 kt-CO₂ eq. This represents a decrease of 21.5% below FY1990 value, and an increase of 1.6% over FY2016 value.

Table 6-60 Indirect N₂O emissions from managed soils

Gas	Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
N ₂ O	Total	kt-N ₂ O	0.14	0.13	0.12	0.11	0.11	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11	0.11
		kt-CO ₂ eq.	41.1	37.6	34.7	32.3	31.3	31.0	30.7	30.7	31.2	31.3	31.5	31.7	31.8	32.3
	Atmospheric deposition	kt-N ₂ O	0.0005	0.0004	0.0004	0.0003	0.0002	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003	0.0003
	Nitrogen leaching and run-off	kt-N ₂ O	0.14	0.13	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.11	0.11	0.11

b) Methodological Issues

1) N₂O emission from atmospheric deposition of N volatilized

● Estimation Method

The Tier 1 method described in section 11.2.1.1 in the 2006 IPCC Guidelines is used.

$$N_2O_{(ATD)} - N = [(F_{SN} \times Frac_{GASF}) + ((F_{ON} + F_{PRP}) \times Frac_{GASM})] \times EF_4$$

$N_2O_{(ATD)}-N$: Annual amount of N₂O–N produced from atmospheric deposition of N volatilized [kg N₂O–N]

F_{SN} : Annual amount of synthetic fertilizer N applied to forest land [kg-N]

F_{ON} : Annual amount of organic N additions applied to forest land [kg-N]

F_{PRP} : Annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock [kg-N]

$Frac_{GASF}$: Fraction of synthetic fertilizer N that volatilized as NH₃ and NO_x [kg-NH₃-N + NO_x-N/kg-N applied]

$Frac_{GASM}$: Fraction of applied organic N fertilizer (F_{ON}) and of urine and dung N deposited by grazing animals (F_{PRP}) that volatilizes as NH₃ and NO_x [kg-NH₃-N + NO_x-N/kg-N]

EF_4 : Emission factor for N₂O emissions from atmospheric deposition of N on soils and water surfaces [kg-N₂O-N/kg-NH₃-N+NO_x-N]

● Parameters

➤ Fraction of synthetic fertilizer N that volatilized as NH₃ and NO_x

0.1 [kg NH₃-N +NO_x-N/kg N applied] (Table 11.3 in Vol.4 of the 2006 IPCC Guidelines)

➤ Emission factor (N volatilization and re-deposition)

0.01 [kg N₂O-N/kg NH₃-N +NO_x-N volatilized] (Table 11.3 in Vol.4 of the 2006 IPCC Guidelines)

● Activity Data

For amount of N fertilizer applied to forest land, see section 6.12 in this NIR.

2) N₂O emission from leaching/runoff

● Estimation Method

The Tier 1 method described in section 11.2.2.1 in the 2006 IPCC Guidelines is used.

$$N_2O_{(L)} - N = (F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM}) \times Frac_{LEACH-(H)} \times EF_5$$

$N_2O_{(L)}-N$: Annual amount of N₂O–N produced from leaching and runoff of N additions [kg N₂O–N]

F_{CR} : Amount of N in crop residues [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 N₂O emissions from N leaching and runoff [kg-N₂O-N]

● **Parameters**

➤ **Fraction of all N mineralized in managed soils**

0.3 [kg N/kg nitrogen of fertilizer] (Table 11.3 in Vol.4 of the 2006 IPCC Guidelines)

➤ **Emission factor (N leaching and runoff)**

0.0075 [kg N₂O-N/(kg N leaching/runoff)] (Table 11.3 in Vol.4 of the 2006 IPCC Guidelines)

● **Activity Data**

For amount of N fertilizer applied to forest land, see section 6.12 in this NIR. For amount of N mineralization associated with loss of soil organic matter, see section 6.13 in this NIR.

c) Uncertainties and Time-series Consistency

● **Uncertainty Assessment**

The uncertainty of indirect N₂O emissions from N fertilizer was assessed based on the uncertainty of the emission factor (see the 2006 IPCC Guidelines, p.11.24) and that of the amount of fertilizer. The uncertainty of indirect N₂O emissions from N mineralization associated with loss of soil organic matter was 288%, which is the same value with the uncertainty of in direct N₂O emissions from N mineralization associated with loss of soil organic matter. Consequently, the uncertainty of indirect N₂O emissions from this category was assessed as -109%~+368%.

● **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 Chapter 1.

e) Category-specific Recalculations

Following the revision of mineral soil area, the indirect N₂O emissions from managed soils were recalculated for all years (see section 6.14).

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

None.

6.16. Biomass burning (4.(V))

a) Category Description

This category deals with emissions of CH₄, CO, N₂O and NO_x from biomass burning. For the emissions of CO and NO_x, see Annex 3.

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”.

CH₄ and N₂O 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. CH₄ and N₂O emissions from wildfires in cropland are reported as “NO”. In addition, CH₄ and N₂O emissions from controlled burning in grassland are estimated. CH₄ and N₂O emissions from wildfires in grassland are reported as “NO” for the same reasons as cropland.

CH₄ and N₂O emissions from wildfires in land other than forest land, cropland and grassland are reported as “NE” because information on wildfires is not enough. CH₄ and N₂O emissions from biomass burning in Wetlands are reported as “NE” because it can be considered insignificant.

CO₂ emission is not included in this category because it was included in estimation of carbon stock changes.

The emissions by this subcategory in FY2017 were 72.6 kt-CO₂ eq. This represents an increase of 4.7% over the FY1990 value and an increase of 47.7% over the FY2016 value. 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 wild fire occurrences also effect it.

Table 6-61 Non-CO₂ emissions from biomass burning

Gas	Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
All	Total	kt-CO ₂ eq.	69.4	66.8	63.0	62.9	78.0	60.9	54.9	56.1	51.0	53.0	73.1	54.7	49.2	72.6	
CH ₄	Total	kt-CH ₄	1.9	1.8	1.7	1.7	2.3	1.6	1.4	1.5	1.3	1.3	2.1	1.4	1.2	2.1	
		kt-CO ₂ eq.	47.2	45.3	42.2	42.4	56.5	40.8	35.3	36.5	31.8	33.7	52.3	35.3	30.3	52.0	
	Forest land	kt-CH ₄	0.4	0.4	0.4	0.4	1.0	0.4	0.2	0.3	0.1	0.2	0.9	0.2	0.1	0.9	
	Cropland	kt-CH ₄	1.0	0.9	0.8	0.8	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	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	
	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	
	Settlements	kt-CH ₄	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	
	Other	kt-CH ₄	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
N ₂ O	Total	kt-N ₂ O	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.07	0.06	0.06	0.07
		kt-CO ₂ eq.	22.1	21.5	20.8	20.5	21.5	20.1	19.6	19.7	19.2	19.3	20.8	19.4	18.9	20.6	
	Forest land	kt-N ₂ O	0.003	0.003	0.003	0.003	0.007	0.003	0.001	0.002	0.001	0.001	0.006	0.002	0.0004	0.006	
	Cropland	kt-N ₂ O	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	
	Grassland	kt-N ₂ O	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 ₂ O	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 ₂ O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	
	Other land	kt-N ₂ O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	
	Other	kt-N ₂ O	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	

b) Methodological Issues**1) Non CO₂ gases from forest fires****● Estimation Method**

For CH₄, and N₂O emissions due to biomass burning from forest fires, the Tier 1 method is used in the 2006 IPCC Guidelines.

➤ Forest land**- CH₄**

$$bbGHG_f = L_{forestfires} \times ER$$

- N₂O

$$bbGHG_f = L_{forestfires} \times ER \times NC_{ratio}$$

$bbGHG_f$: GHG emissions due to forest biomass burning

$L_{forestfires}$: Carbon released due to forest fires [t-C/yr]

ER : Emission ratio (CH₄ : 0.012, N₂O : 0.007)

NC_{ratio} : Nitrogen Carbon ratio of the biomass

● Parameters**➤ Emission ratio**

The following values are applied to emission ratios for non-CO₂ gases due to biomass burning.

CH₄: 0.012, N₂O: 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 loss due to forest fire is used. Carbon 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 loss are calculated from the fire-damaged timber volume multiplied by wood density, the biomass expansion factor and the carbon fraction of dry matter.

$$L_{forestfires} = \Delta C_n + \Delta C_p$$

$L_{forestfires}$: carbon loss due to fire [t-C/yr]

ΔC_n : carbon loss due to fire in national forests [t-C/yr]

ΔC_p : carbon 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**

$$\Delta C_{fn,p} = Vf_{n,p} \times D_{n,p} \times BEF_{n,p} \times CF$$

$\Delta C_{fn,p}$: Carbon loss due to fire in national forests and private forest [t-C/yr]

$Vf_{fn,p}$: Damaged timber volume due to fire in national forests and private forest [m³/yr]

$D_{n,p}$: Wood density in national forests and private forest [t-d.m./m³]

$BEF_{n,p}$: Biomass expansion factor for national forests and private forest

CF : Carbon fraction of dry matter [t-C/t-d.m.]

The values for wood density and biomass expansion factors for national and private forest land are determined as weighted averages using the ratios of intensively managed forests and semi-natural forests.

Table 6-62 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

Source: Based on Forestry Agency data

Table 6-63 Damaged timber volume due to wild fire

Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
Damaged timber volume due to disturbance in national forest	m ³	3,688	1,014	1,599	359	1,901	976	16,091	934	360	279	5,326	2,472	916	75	
Damaged timber volume due to disturbance in private forest	m ³	63,602	68,361	60,228	72,575	170,730	67,417	15,810	41,537	12,269	26,620	147,989	38,571	8,151	157,051	
Ⅳ-5	Actual damaged area	kha	0.29	0.94	0.48	0.35	0.57	0.37	0.07	0.59	0.10	0.18	0.53	0.22	0.04	0.35
	Damaged timber volume	m ³	47,390	58,129	54,487	59,235	119,900	55,628	12,780	40,477	11,566	25,204	137,078	36,693	7,370	153,412
Ⅳ-4	Actual damaged area	kha	0.27	0.51	0.16	0.27	0.85	0.28	0.06	0.07	0.03	0.04	0.18	0.05	0.02	0.04
	Damaged timber volume	m ³	16,212	10,232	5,741	13,340	50,830	11,789	3,030	1,060	703	1,416	10,911	1,878	781	3,639

Source: 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) **Non CO₂ from burning of pruned branches from orchard trees**

● **Estimation Method**

For CH₄ and N₂O 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 6-64 Emission factors [t/kt-d.m.]

Category	CH ₄	N ₂ O
Agricultural residue	2.7	0.07

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 in 1982, and ratio of burning of pruned branches in field (25%) from the survey result in 2008.

$$W_B = \left(\sum_i A_i \times E \times 10 \right) \times R$$

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) Non CO₂ from biomass burning in Grassland

● Estimation method

For CH₄ and N₂O 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 6-65 Emission factors [t/kt-d.m.]

Category	CH ₄	N ₂ O
Savanna and grassland	2.3	0.21

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) Non CO₂ 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-CO₂ eq./ha)

From the fire and disaster statistics, 5,500-8000 wild fire occurred on non-forest, agriculture and settlement area per year which included wild fire at riverside. Under the assumption that all these wild fires occurred at riverside, if area burned per a wild fire 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 wild fire in forest land in Japan reaches some hundreds ha at the most. Over 10 ha wild fire 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 wild fire is available was about 300 t-CO₂ 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 (CH₄: 296%, N₂O: 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* (CH₄: 56%, N₂O: 63%). As a result, the uncertainty estimates for the emissions resulting from biomass burning were 146% for CH₄ and 182% for N₂O, 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 2013. 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 Chapter 1.

e) Category-specific Recalculations

Since cultivation area for orchard trees were revised, CH₄ and N₂O emissions from burning of pruned branches from orchard trees for all years were recalculated.

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

None.

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. IPCC, *2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands*, 2014.
4. Japan Meteorological Agency, *Mesh climatic data of Japan for the 1970-2000* [CD-ROM], Japan Meteorological Business Support Center, Tokyo, 2002.
5. Environmental Agency Committee for the Greenhouse Gases Emissions Estimation Methods, *Review of Greenhouse Gases Emissions Estimation Methods Part 1*, September 2000.
6. Ministry of the Environment Committee for the Greenhouse Gases Emissions Estimation Methods, *Review of Greenhouse Gases Emissions Estimation Methods Part 3*, August 2002.
7. Ministry of the Environment Committee for the Greenhouse Gases Emissions Estimation Methods, *Review of Greenhouse Gases Emissions Estimation Methods Part 5*, August 2006.
8. Ministry of Agriculture, Forestry and Fisheries, *World Census of agriculture and Forestry*, 2000.
9. Ministry of Agriculture, Forestry and Fisheries, *Statistics of Cultivated and Planted Area* (Survey of Cropland area).
10. Ministry of Agriculture, Forestry and Fisheries, *A Move and Conversion of Cropland*.
11. Forestry Agency, *Handbook of Forestry Statistics*.
12. Ministry of Land, Infrastructure, Transport and Tourism, *Land Use Status Survey*.
13. Ministry of Land, Infrastructure, Transport and Tourism, *Urban Park Status Survey*.
14. Ministry of Land, Infrastructure, Transport and Tourism, *Road Tree Planting Status Survey*.
15. Ministry of Land, Infrastructure, Transport and Tourism, *Sewage Treatment Facility Status Survey*.
16. Ministry of Land, Infrastructure, Transport and Tourism, *Urban Greening Status Survey*.
17. Ministry of Land, Infrastructure, Transport and Tourism, *Survey on Carbon Dioxide Absorption at Source in River Works*.
18. Ministry of Land, Infrastructure, Transport and Tourism, *Progress Survey on Tree Planting for Public Rental Housing*.
19. National Land Policy Research Team, National Land Agency, *Handbook for National Land Planners*, November 1996.
20. Japan Dam Foundation, *Dam Yearbook*.
21. National Astronomical Observatory, *2019 Chronological Scientific Tables* (Tokyo: Maruzen Inc., 2018).
22. Ministry of Internal Affairs and Communications, *Housing and Land Survey of Japan*.
23. UNFCCC, Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to Convention (FCCC/SBSTA/2013/10/Add.3).
24. UNFCCC, *Tables of the common reporting format for land use, land-use change and forestry* (FCCC/SBSTA/2013/L.29, FCCC/SBSTA/2013/L.29/Add.1).
25. FAO, WORLD BAMBOO RESOURCES, A thematic study prepared in the framework of the Global Forest Resources Assessment 2005, 2007.
26. FRA "COUNTRY REPORT GLOBAL FOREST RESOURCES ASSESSMENT 2010", 2010

27. Mariko Handa, Kochi Tonosaki, Kazutaka Imai, Shinichi Goto, "A study to estimate the amount of Carbon stocks of soil and litter in revegetation areas", *Urban Green Tech.* 69, 18-22, 2008.
28. Kazuhito Morisada, Kenji Ono, Hidesato Kanomata, "Organic carbon stock in forest soil in Japan", *Geoderma* 119, 21-32, 2004.
29. Makoto Nakai, "Carbon accumulation in soils due to soil management" Association for Advancement of Agricultural Science "Survey on method for quantification of amount of GHG emission cuts (2000)".
30. Sakai, H., Hashimoto, S., Ishizuka, S., Kaneko, S., Takahashi, M. Estimation of the effect of forest management on the carbon stocks in Japanese planted forests using CENTURY-jfos: a modified CENTURY model. *The International Forestry Review*, 12(5):31-32(Forests for the Future: Sustaining Society and the Environment XXIII IUFRO World Congress, Republic of Korea Abstracts), 2010
31. Masahiko Matsue, Yosuke Nagahama, Yasuo Iizuka, Miyuki Murata, Nobuo Fujiwara, "Estimation equations for the amount of CO₂ fixed by planted trees in cities in Japan", *Journal of the Japanese Society of Revegetation Technology*, 35 (2), 318-324, 2009.
32. Parks and Green Spaces Division of the Ministry of Land, Infrastructure and Transport, "FY2004 Survey on evaluation techniques for the effectiveness of greening in urban parks for preventing global warming", March, 2005.
33. National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure, Transport and Tourism, Japan, *Technical note of National Institute for Land and Infrastructure Management No.506 The Street tree of Japan VI*, 2009.
34. Tonosaki K., Murayama K., Imai K., Nagino Y., *Estimation of Soil Carbon Accumulation Rate in Urban Parks*. *Journal of the Japanese Society of Revegetation Technology*, Vol. 38 (3), 373-380, 2013
35. Geographical Survey Institute, *Degrees of Latitudes and Longitudes of Japan's Northernmost, Southernmost, Easternmost and Westernmost Points*.
36. Geographical Survey Institute, *Statistical Reports on the Land Area by Prefectures and Municipalities in Japan*.
37. Coleman, K. and D. S. Jenkinson: 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 and J. U. Smith, p. 237-246, Springer, Berlin, 1996
38. Yasuhito Shirato, Masayuki Yokozawa and Ichiro Taniyama: Modified Roth C Model for Paddy Soils and Andosols, *Research Highlights* 27,56-57, 2011
39. Yusuke Takata, Toshiaki Ohkura, Kazunori Kohyama, Hiroshi Obara and Yasuhito Shirato: Modification of Roth C Model for Andosols (Roth C-26.3_vPAC) Using Phosphate Adsorption Coefficient, *Research Highlights* 28, 18-19, 2012
40. Hiroshi Seino : An Estimation of Distribution of Meteorological Elements using GIO and AMeDAS Data, *J.Agr. Met.*,48(4), 379-383, 1993
41. Yasuhito Shirato: Validation and Modification of Soil Organic Matter Models in Arable Soils in Japan and Thailand, *Bull. Natl. Inst. Agro-Environ. Sci.*, 24, 23-94, 2006
42. Shirato, Y. and I. Taniyama (2003): Testing the suitability of the Rothamsted carbon model for long-term experiments on Japanese non-volcanic upland soils. *Soil Sci. Plant Nutr.*, 49, 921-925, 2003
43. Shirato, Y., T. Hakamata and I. Taniyama: Modified Rothamsted carbon model for Andosols and its validation: Changing humus decomposition rate constant with pyrophosphate-extractable Al. *Soil Sci.*

- Plant Nutr.*, 50, 149-158, 2004
44. Shirato.Y & Yokozawa.M: Applying the Rothamsted Carbon Model for Long-Term Experiments on Japanese Paddy Soils and Modifying It by Simple Tuning of the Decomposition Rate, *Soil Science and Plant Nutrition*, 51(3), 405-415, 2005
 45. Takata Y, Ito T, Ohkura T, Obara H, Kohyama K, Shirato Y.: Phosphate adsorption coefficient can improve the validity of Roth C model for Andosols, *Soil Sci. Plant Nutr.* 57: 421-428, 2011
 46. Shirato, Y., Yagasaki, Y. and Nishida, M.: Using different versions of the Rothamsted Carbon model to Simulate soil carbon in long-term experimental plots subjected to paddy-upland rotation in Japan, *Soil Sci. Plant Nutr.*, 57, 597-606, 2011
 47. Yagasaki, Y. and Shirato, Y.: Assessment on the rates and potentials of soil organic carbon sequestration in agricultural lands in Japan using a process-based model and spatially explicit land-use change inventories –Part 1: Historical trend and validation based on nation-wide soil monitoring, *Biogeosciences*, 11, 4429-4442, doi:10.5194/bg-11-4429-2014, 2014
 48. National Institute of Resources, Research on energy comprehensive utilization of biomass resources, 1982
 49. Survey result on measurement and control technology demonstration of greenhouse gas resulting from soils (FY2008-FY2012)
 50. Ministry of Land, Infrastructure, Transport and Tourism, *Construction Statistics, Building Starts*
 51. Ministry of Internal Affairs and Communications, *Fixed Property Tax Division, Local Tax Bureau (Houses)*
 52. Ministry of Internal Affairs and Communications, *Survey on Supply and Demand of Construction Labor*
 53. Ministry of Economy, Trade and Industry, *Yearbook of Current Production Statistics, Paper, Ceramics and building materials Statistics*
 54. Japan Fiberboard and Particleboard Manufacturers Association, *Shipment quantity of wooden board by use*
 55. Ministry of Agriculture, Forestry and Fisheries, *Report on Supply and Demand of Lumber (the Survey on Lumber)*
 56. Ministry of Finance, *Trade Statistics of Japan*
 57. Ministry of Economy, Trade and Industry, *Yearbook of Current Production Statistics, Paper, Ceramics and Building Materials Statistics*
 58. Parks, Green Spaces and Landscape Division of the Ministry of Land, Infrastructure, Transport and Tourism, *Survey on policies of sinks measures by urban planting for the next framework*, 2014.
 59. Parks, Green Spaces and Landscape Division of the Ministry of Land, Infrastructure, Transport and Tourism, *FY 2014 Survey on promotion of greenhouse gas sink measures by urban planting*, 2015.
 60. Hatano Ryusuke, “Project Title: Survey on actual situation of grassland management for feed”, Project Report of Livestock Industry Promotion by Japan Racing Association in FY2016 (2017)

Chapter 7. Waste (CRF sector 5)

7.1. Overview of Sector

7.1.1. Overview of Waste Management and Estimation Category

In the waste sector, greenhouse gas 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.

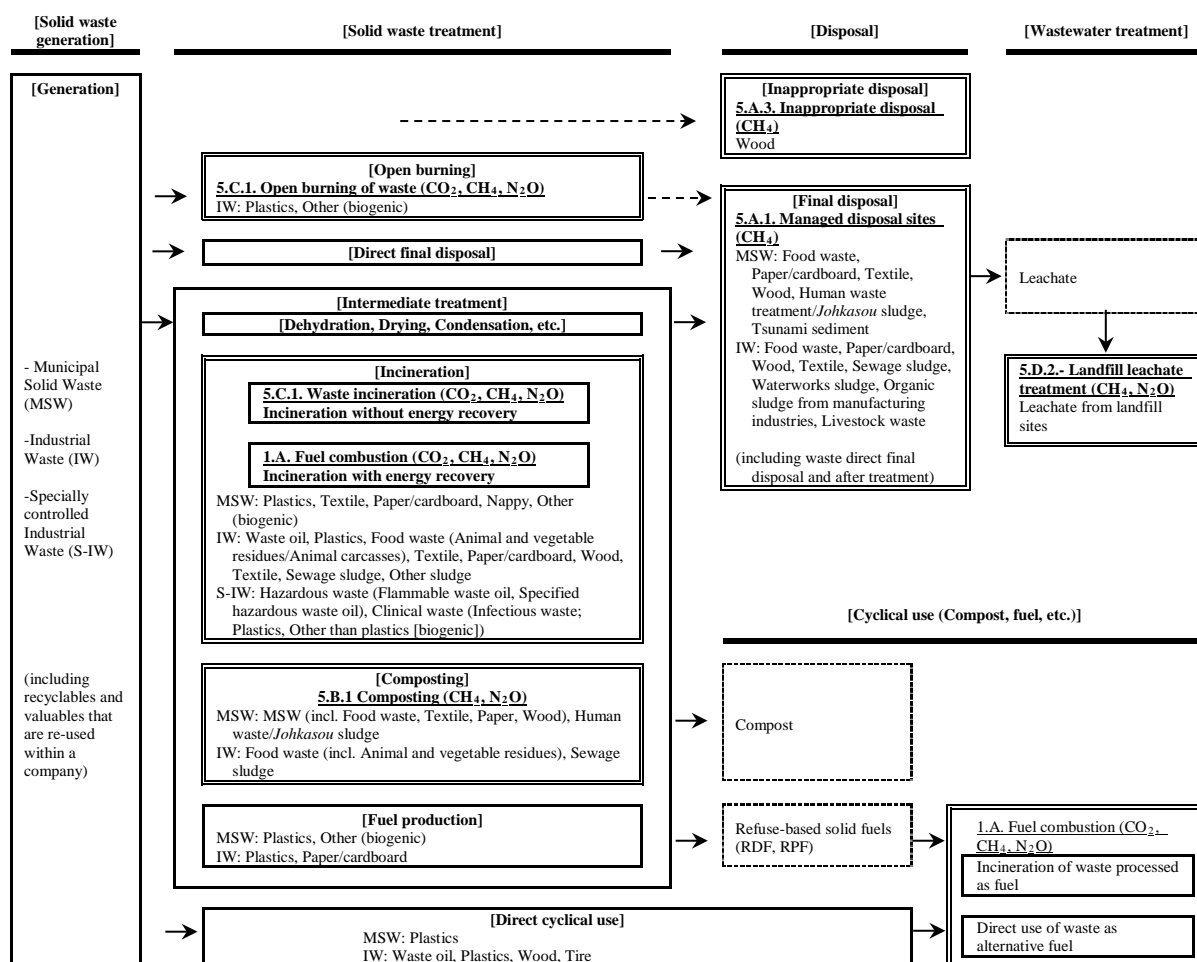


Figure 7-1 Flow chart of solid waste managements and the estimation categories

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 *Report of the Waste Panel on Greenhouse Gas Emission Estimate (2006)* (hereinafter referred to as Reference #7) and the website of the Ministry of the Environment, *Review of Greenhouse Gases Emissions Estimation Methods* (<http://www.env.go.jp/earth/ondanka/santeiho/kento/index.html>).

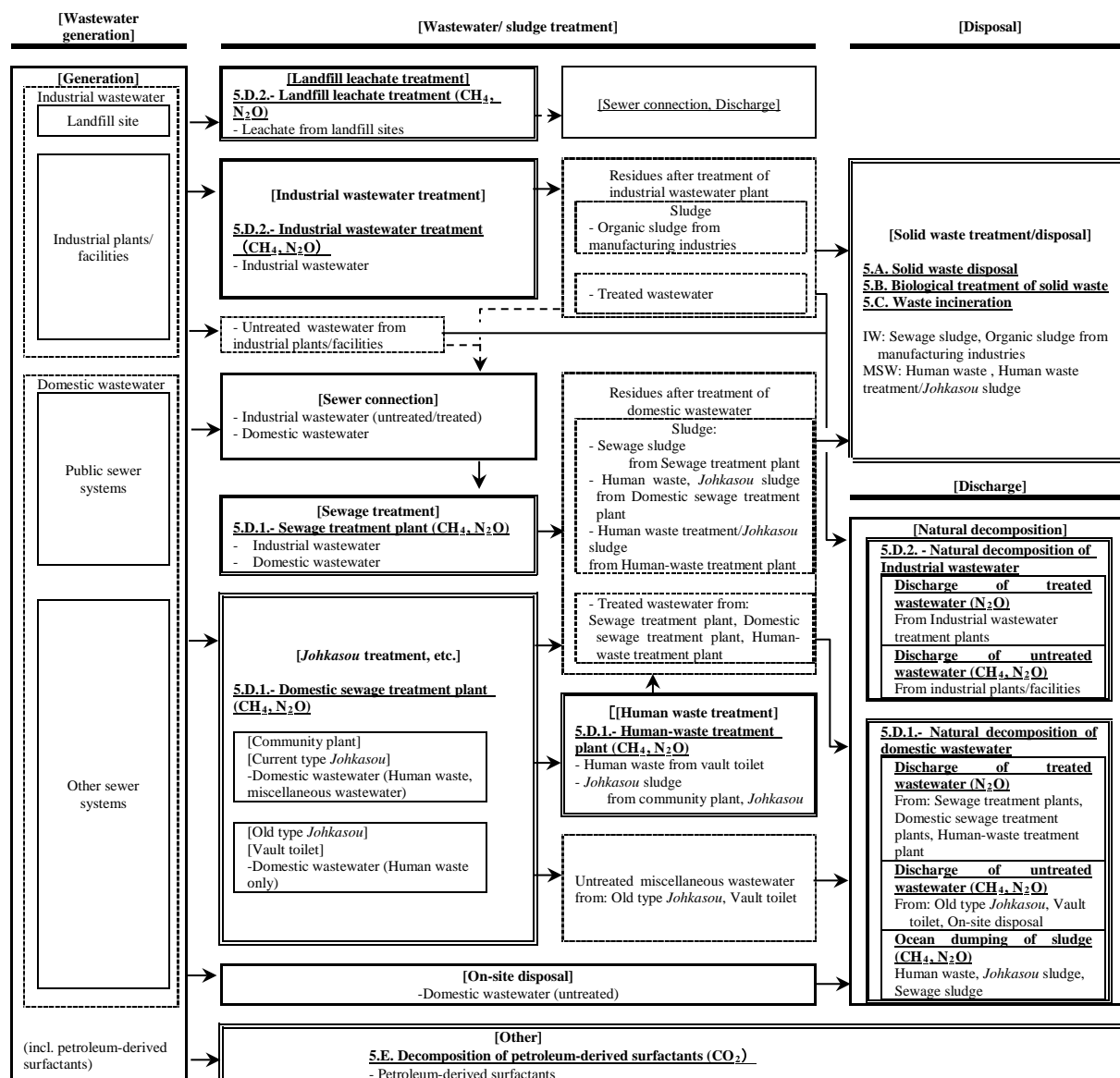


Figure 7-2 Flow chart of wastewater/sludge treatments and the estimation categories

“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 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 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 FY2017, emissions from the Waste sector resulted in 20,110 kt-CO₂ eq. and accounted for 1.6% of Japan’s total greenhouse gas emissions (excluding LULUCF). Total emissions had decreased by 32.4%

compared to those of FY1990 and decreased by 0.9% compared to those of FY2016. Breakdown of FY2017 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 60.9% (a decrease by 11.9% from FY1990) followed by the Wastewater Treatment and Discharge (5.D.) accounting for 18.4% (a decrease by 30.4% compared to FY1990), Solid Waste Disposal (5.A.) accounting for 15.3% (a decrease by 67.8% from FY1990), Other (5.E.) accounting for 3.2% (a decrease by 9.4% from FY1990), and Biological Treatment of Solid Waste (5.B.) accounting for 2.2% (an increase by 90.5% from FY1990). Breakdown of the emissions of the Waste sector by gas shows that the largest contributor to the emissions is CO₂ emissions associated with the incineration/open burning of petroleum-derived waste such as waste plastic and waste oil accounting for 54%, followed by CH₄ emissions from solid waste disposal on land accounting for 15%, N₂O emissions from wastewater treatment and discharge accounting for 10%.

The changes in greenhouse gas emissions from the Waste sector since FY1990 show a trend in a decrease in CH₄ 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 FY2015 (16%) in comparison with FY1990 (7.4%), the total disposal amount has reduced in FY2015 (14 Mt/year) in comparison with FY1990 (109 Mt/year) (the *Annual Report on the Environment in Japan*, Ministry of the Environment). On the other hand, emissions from the incineration of petroleum-derived waste with energy recovery, emissions from the direct use of petroleum-derived waste as alternative fuel, and emissions from the incineration of petroleum-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 58.0% 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 ₂ O	
	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

D: IPCC default, T1: IPCC Tier1, T2: IPCC Tier2, T3: IPCC Tier3, 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 the Ministry of the Environment (hereinafter referred to

as the *Cyclical Use of Waste Report*), the *Waste Treatment in Japan*, the same agency (hereinafter referred to as the *Waste Treatment in Japan*), and the *annual editions of Sewage Statistics (Admin. Ed.)*, Japan Sewage Works Association (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, Ministry of the Environment, 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 the *guideline of uncertainty assessment for National GHG inventories*, Ministry of the Environment (Reference #29). 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 using parameters, the uncertainty is assessed by combining the uncertainties of these parameters.

- ***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 <i>2006 IPCC Guidelines</i> , the value ($\pm 10\%$) 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 <i>2006 IPCC Guidelines</i> , the value ($\pm 30\%$) "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 <i>2006 IPCC Guidelines</i> , the value ($\pm 30\%$) "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, an additional 5% to the upper limit of uncertainty is added 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.

7.1.5. General Recalculations for Emissions from Waste Sector

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 statistical compilation 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 main categories. To obtain such better activity data related to solid waste to be quoted from the *Cyclical Use of Waste Report* as main statistics, "the Committee for improvement of the research on cyclical use of waste" organized by Environmental Regeneration and Material Cycles Bureau, Ministry of the Environment, 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. Thus, GHG emissions for 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.

7.2. Solid Waste Disposal (5.A.)

This category covers CH₄ 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.

Table 7-3 Categories whose emissions are estimated for solid waste disposal (5.A.)

Category	Waste type		Disposal type	CO ₂	CH ₄			
5.A.1. (7.2.1)	Municipal solid waste	Food waste	Managed disposal sites	Anaerobic/ Semi-aerobic landfill	NO	○		
		Paper/cardboard				○		
		Wood				○		
		Textiles				Natural fiber ¹⁾	○	
		Sludge				Human waste treatment/ <i>Johkasou</i> sludge	○	
						Tsunami sediment ²⁾	○	
	Industrial waste	Food waste ³⁾	Animal and vegetable residues, Animal carcasses	Managed disposal sites	Anaerobic/ Semi-aerobic landfill	NO	○	
		Paper/cardboard					○	
		Wood					○	
		Textiles	Natural fiber ¹⁾				○	
		Sludge	Sewage sludge				Digested sewage sludge ⁴⁾	○
							Other sewage sludge	○
			Waterworks sludge					○
			Organic sludge from manufacturing industries					○
Livestock waste ⁵⁾			○					
5.A.2. (7.2.2)	-		Unmanaged disposal sites	NO	NO			
5.A.3. (7.2.3)	Industrial waste	Wood	Inappropriate disposal ⁶⁾ (Anaerobic landfill)	NE	○			

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, CH₄ emissions from this source are estimated using the emission factor for wood by expert judgment.
- 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, CH₄ 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.
- 7) Since the disposal type for tsunami sediment have not been identified, it is conservatively assumed as anaerobic landfill (MCF=1.0) which derives larger emissions.

Table 7-4 GHG emissions from solid waste disposal (5.A.)

Gas	Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017		
CO ₂	5.A.1. Managed waste disposal sites	a. Anaerobic landfill	kt-CO ₂	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO		
		b. Semiaerobic landfill	kt-CO ₂	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	
	5.A.2. Unmanaged waste disposal sites	kt-CO ₂	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO		
	5.A.3. Uncategorized waste disposal sites	Inappropriate disposal	kt-CO ₂	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE		
	Total	kt-CO ₂	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		
CH ₄	5.A.1. Managed waste disposal sites	a. Anaerobic landfill	MSW	kt-CH ₄	218.0	187.2	145.3	110.2	91.2	85.6	79.8	74.8	70.2	65.8	62.1	58.1	54.3	51.3
		ISW	kt-CH ₄	141.5	135.7	111.9	83.1	67.5	63.1	58.9	55.7	52.8	49.9	47.1	44.7	42.7	41.0	
	b. Semiaerobic landfill	MSW	kt-CH ₄	18.7	28.0	31.8	34.6	32.3	30.6	28.8	27.4	26.3	25.6	24.0	23.2	21.4	20.2	
		ISW	kt-CH ₄	4.2	7.7	11.3	13.2	12.3	11.8	11.0	10.8	10.8	10.8	10.3	10.0	9.5	9.2	
	5.A.2. Unmanaged waste disposal sites	kt-CH ₄	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	0.3	0.8	2.5	2.4	2.3	2.2	2.2	2.2	2.2	2.1	1.9	1.7	1.7	1.6	
		Total	kt-CH ₄	382.8	359.4	302.8	243.6	205.6	193.4	180.8	170.9	162.3	154.2	145.4	137.6	129.7	123.2	
		kt-CO ₂ eq.	9,570	8,985	7,570	6,090	5,141	4,835	4,521	4,272	4,058	3,855	3,635	3,440	3,242	3,081		
	Total	kt-CO ₂ eq.	9,570	8,985	7,570	6,090	5,141	4,835	4,521	4,272	4,058	3,855	3,635	3,440	3,242	3,081		

Estimated greenhouse gas emissions from solid waste disposal on land are shown in Table 7-4. In FY2017, greenhouse gas emissions from this source category are 3,081 kt-CO₂ eq. and accounted for 0.2% of the national total emissions (excluding LULUCF). Emissions from this category decreased by 67.8% compared to the emissions in FY1990. This CH₄ 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 CH₄ 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 CH₄ 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, CH₄ 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 CH₄ emitted from there is reported under this category “Managed Disposal Sites (5.A.1.)”. Emissions of CO₂ from waste incineration at the managed disposal sites are reported as NO, because waste incineration is not implemented at that site in Japan.

b) Methodological Issues

● Estimation Method

The revised first order decay (FOD) method given in the 2006 IPCC Guidelines is applied for its emission estimates since this method assumes the delay time from the deposition of waste to the generation of CH₄. According to the decision tree indicated in the said guidelines, the revised FOD method with country-specific parameters (Tier 3) is used to estimate emissions from this source.

In Japan, emission factor is defined as “CH₄ emissions from biodegradable waste”, and activity data are defined as “the amount of waste biodegraded within the reporting fiscal year”.

$$E = \left\{ \sum_{i,j} (EF_{i,j} \times A_{i,j}) - R \right\} \times (1 - OX)$$

Where :

- E : CH₄ emissions from landfill sites [kg-CH₄]
- $EF_{i,j}$: Emission factor for a biodegradable waste i (dry basis) that is damped into a landfill site j without incineration [kg-CH₄/t]
- $A_{i,j}$: Amount of a biodegradable waste i (dry basis) that is damped into a landfill site j without incineration and is biodegraded within an inventory year) [t]
- R : Recovered CH₄ in an inventory year [kg-CH₄]
- OX : Oxidation factor of CH₄ related to soil cover

● Emission Factors

Emission factors are defined as the amount of CH₄ [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.

$$EF = DOC_i \times DOCF \times MCF_j \times F \times 1000 \times \frac{16}{12}$$

DOC_i : Fraction of carbon content in a biodegradable waste i

$DOCF$: Fraction of degradable organic carbon dissimilated

MCF_j : Methane correction factor in a landfill site j

F : Percentages of CH₄ 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 the “*Ministry of the Environment, Survey Study on Improving the Accuracy of Emission Factors for Greenhouse Gas Emissions from the Waste Sector, 2010*” (hereinafter referred to as Reference #24) and Reference #7 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 [%]	Data source
Food waste	43.4	MSW: Calculated by taking the averages of carbon contents of MSW provided by Tokyo, Yokohama, Kawasaki, Kobe, and Fukuoka (FY1990-2004) IW: Substituted the carbon content of MSW for IW because its properties are similar to those of MSW (Reference #7)
Paper/cardboard	40.9	
Wood	45.2	
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) (Reference #7)
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
Digested sewage sludge	30.0	Expert judgment based on Fujimoto (2000), Fujishima, et al. (2004), Oshima, et al. (1986) and Tanaka, et al. (1980) (Reference #67, 69, 77, 82)
Other sewage sludge	40.0	Expert judgment based on domestic researches (Reference #7)
Waterworks sludge	6.0	Average values of survey results conducted at 23 water purification plants (Reference #24)
Organic sludge from manufacturing	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 (Reference #7)
Livestock waste	40.0	Substituted the value for “Other sewage sludge”

➤ **Fraction of degradable organic carbon dissimilated (DOCF)**

Fraction of degradable organic carbon dissimilated for the biodegradable waste is set at 50% based on Ito (1992) (Reference #71).

➤ **Methane Correction Factor (MCF)**

- **Anaerobic landfill sites**

For Methane Correction Factor of anaerobic landfill sites (MCF_{an}), default values of 1.0 given in the 2006 IPCC Guidelines is used.

- **Semi-aerobic landfill sites**

For Methane Correction Factor of semi-aerobic landfill sites in ideal condition (MCF_{semi}) default values of 0.5 given in the 2006 IPCC Guidelines is used. However, semi-aerobic landfill site in Japan is in an anaerobic condition when 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 extend. 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; the methane correction factor of semi-aerobic landfill site in actual condition ($MCF_{semi,act}$) is estimated for municipal solid waste disposal sites and industrial waste disposal sites, respectively, as follows:

$$MCF_{semi,act} = \{ P \times MCF_{semi} + (1 - P) \times MCF_{an} \}$$

$MCF_{semi,act}$: Methane correction factor of semi-aerobic landfill sites in actual condition

MCF_{semi} : Methane correction factor of semi-aerobic landfill sites in ideal condition (0.5)

MCF_{an} : Methane correction factor of anaerobic landfill sites (1.0)

P : Percentage of open outflow port of leachate collection system

Where,

$$P = W' / W$$

W' : Disposal amount in a reporting year at semi-aerobic landfill sites in ideal condition, where open outflow port of leachate collection system [for municipal solid waste: t, for industrial waste: m³]

W : Disposal amount in a reporting year at whole semi-aerobic landfill sites [for municipal solid waste: t, for industrial waste: m³]

To evaluate W' and W for municipal solid waste, 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 Ministry of the Environment, are used.

Table 7-6 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	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Municipal solid waste	%	64.7	64.7	64.7	64.7	64.7	66.7	69.1	71.2	71.2	69.7	71.9	70.3	73.2	73.2
Industrial solid waste	%	57.9	57.9	57.9	57.9	57.3	57.9	55.9	57.2	57.2	57.2	57.2	57.2	57.2	57.2

➤ **Proportions of CH₄ 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 7-7.

Table 7-7 Emission factors by type of biodegradable waste and by treatment

Item	Anaerobic landfill [kg-CH ₄ /t]	Semi-aerobic landfill ¹⁾ [kg-CH ₄ /t]
Food waste	145	72
Paper/cardboard	136	68
Textiles (natural fiber)	150	75
Wood	151	75
Human waste treatment/ <i>Johkasou</i> sludge	133	67
Tsunami sediment	15	NA
Digested sewage sludge	100	50
Other sewage sludge	133	67
Waterworks sludge	20	10
Organic sludge from manufacturing	150	75
Livestock waste	133	67

- 1) Each emission factor indicated in the table are the values in the ideal condition of semi-aerobic landfill. (MCF=0.5).

● 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 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. Activity data are estimated going back as far as FY1954, when the Public Cleansing Law (now the Waste Management and Public Cleansing Act) was enforced.

$$A_{i,j}(T) = W_{i,j}(T - 1) \times (1 - e^{-k_i})$$

$$W_{i,j}(T) = W_{i,j}(T - 1) \times e^{-k_i} + w_{i,j}(T)$$

$A_{i,j}(T)$: Amount of waste i degraded in site j 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 [1/year]

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 [%]

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]

➤ Amount of Biodegradable Waste Disposed of in Landfills

Table 7-8 shows the annual amount of biodegradable waste landfilled (dry basis) in Japan.

Table 7-8 Annual amount of biodegradable waste disposed of in landfills
(Total amount of anaerobic and semi-aerobic landfilling)

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
MSW															
Food waste	kt / year (dry)	424	272	196	78	38	30	30	27	22	21	18	16	13	13
Paper/ cardboard	kt / year (dry)	1,140	859	698	492	376	300	311	294	260	226	182	142	125	115
Textiles (natural fiber)	kt / year (dry)	59	46	34	67	10	4	3	5	4	3	3	3	2	2
Wood	kt / year (dry)	363	200	155	81	53	42	40	36	31	65	27	22	21	20
Human waste treatment/ Jokasou sludge	kt / year (dry)	78	51	46	47	19	17	20	14	15	10	8	7	8	9
Tsunami sediment ¹⁾	kt / year (dry)	NO	NO	NO	NO	NO	NO	NO	9	10	29	NO	NO	NO	NO
ISW															
Food waste	kt / year (dry)	65	177	109	45	24	22	22	23	30	11	15	12	13	13
Paper/ cardboard	kt / year (dry)	102	125	137	89	63	44	31	37	32	16	17	12	15	15
Textiles (natural fiber)	kt / year (dry)	4	16	15	17	9	6	7	10	7	6	10	11	11	10
Wood	kt / year (dry)	465	490	235	230	151	125	145	149	106	111	116	124	110	113
Digested sewage sludge	kt / year (dry)	59	50	31	11	4	3	3	5	5	4	5	3	3	3
Other sewage sludge	kt / year (dry)	219	185	114	42	17	17	17	34	22	11	12	12	12	12
Waterworks sludge	kt / year (dry)	199	166	146	66	67	67	67	67	67	67	67	67	67	67
Organic sludge from manufacturing industry	kt / year (dry)	345	157	69	48	23	22	31	39	27	17	14	13	11	12
Livestock waste	kt / year (dry)	12	12	11	11	11	14	11	11	9	12	13	13	13	12

- 1) Disposal amount of tsunami sediment has increased in FY2013 compared to FY2012, 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.

As indicated in Table 7-9, for the data sources for the amount of biodegradable waste landfilled by waste type, the *Cyclical Use of Waste Report*, and the *Sewage Statistics* are used.

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 most current year available (primarily the data of FY1980) are applied. For the years where the data are unavailable even after FY1980, interpolated values are applied. For details, see Table 7-9.

Table 7-9 Overview of data for the amount of biodegradable waste disposed of in landfill

Waste type		Data source	Detail	Historical data	
Municipal solid waste	Food waste	<i>Cyclical Use of Waste Report (MoEJ)</i>	- Amount directly landfilled	- Estimated by interpolation for some fiscal years, - Substituted FY1980 value for the years prior to FY1980	
	Paper/cardboard		- Amount landfilled after intermediate treatment.		
	Wood				
	Textiles (natural fiber) *		* The ratios of natural fiber textiles in textile products for each year are estimated by using data from the <i>Yearbook of Textile and Consumer Goods Statistics (METI)</i> and <i>Textile Handbook (Japan Chemical Fibers Association)</i> .		
	Human waste treatment/ <i>Johkasou</i> sludge	(Direct final disposal)	<i>Waste Management in Japan (MoEJ)</i>	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)	<i>Cyclical Use of Waste Report (MoEJ)</i>	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		<i>Waste Treatment in Japan (MoEJ)</i>	Direct final disposal of "Tsunami sediment"	Disposed from FY2011	
Industrial waste	Food waste (Animal and vegetable residues, Animal carcasses)	<i>Cyclical Use of Waste Report (MoEJ)</i>	- Amount directly landfilled	- Estimated by interpolation for some fiscal years, - Substituted FY1980 value for the years prior to FY1980	
	Paper/cardboard		- Amount landfilled after intermediate treatment, excluding ash after incineration by using reference data		
	Wood				
	Textiles (natural fiber) *		* All textiles in industrial waste are considered to consist of natural fiber due to the Waste Management and Public Cleansing Act		
	Digested sewage sludge		<i>Data provided by MLIT</i>	Compiled and provided by MLIT	- For some fiscal years, estimated by interpolation - Substituted FY1985 value for the years prior to FY1985
	Other sewage sludge		<i>Annual editions of Sewage Statistics (Admin. Ed.)</i>	Total amount of sewage sludge excluding the amount of digested sewage sludge	
	Waterworks sludge		<i>Waterworks Statistics (Japan Water Works Association)</i>	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	Paper industry	Data provided by Japan Paper Association, Japan Technical Association of the Pulp and Paper Industry	Total amount of organic sludge landfilled for papermaking industry	Substituted FY1989 value for the years prior to FY1989
		Chemical industry	<i>Survey of generation status of industry - specific by-products (industrial waste and recyclable waste) (METI), etc.</i>	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 <i>Follow-up Action Result of the Voluntary Action Plan on the Environment (Japan Business Federation)</i> and the <i>Report on the State of Industrial Waste Generation and Treatment Survey (MoEJ)</i> - For the years prior to FY1998, estimated with the data from <i>Follow-up Action Result of the Voluntary Action Plan on the Environment (Japan Business Federation)</i> - Substituted FY1990 value for the years prior to FY1990
		Food manufacturing industry			
Livestock waste		Survey conducted by MoEJ		Substituted FY1980 value for the years prior to FY1980	

➤ 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 7-10. In order to estimate the CO₂ emissions for the category “7.4. Incineration and Open Burning of Waste (5.C.)” as well as this source category, dry basis activity are used for the same reason.

Table 7-10 Percentage of water content in waste disposed of in managed landfill sites

Items		Intermediate treatment	Water content [%]	Source	
Municipal solid waste	Food waste	Untreated	75	Water percentage of food waste in <i>Cyclical Use of Waste Report</i>	
		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/ <i>Johkasou</i> 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 <i>Cyclical Use of Waste Report</i>	
		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 <i>Sewage Statistics (Admin. Ed.)</i>
		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
	Food manufacturing		(Unseparated)	77	Reference of Clean Japan Center Survey
Livestock waste	Untreated	83.1	Percentage of water content in <i>Controlling the Generation of Greenhouse Gases in the Livestock Industry</i> , Japan Livestock Technology Association		
	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 *Annual editions of Results of Study on Municipal Solid Waste Disposal*, Environmental Regeneration and Material Cycles Bureau, Ministry of the Environment (hereinafter referred to as *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 [m³] 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 FY1977.
- 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 IW landfill site survey results conducted by the Ministry of the Environment.
- 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 FY1977.
- 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 7-11 Percentages of landfill sites by site structure

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Municipal solid waste															
Anaerobic landfill	%	74.2	64.2	54.4	43.5	41.5	36.5	36.1	38.7	33.1	39.9	28.4	29.0	29.6	29.6
Semi-aerobic landfill	%	25.8	35.8	45.6	56.5	58.5	63.5	63.9	61.3	66.9	60.1	71.6	71.0	70.4	70.4
Industrial solid waste															
Anaerobic landfill	%	90.2	81.1	66.4	48.3	45.8	36.9	47.0	36.7	28.5	30.0	35.0	37.7	37.7	37.7
Semi-aerobic landfill	%	9.8	18.9	33.6	51.7	54.2	63.1	53.0	63.3	71.5	70.0	65.0	62.3	62.3	62.3

➤ 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. According to Ito (1992) (Reference #71), the half-lives for food waste, paper/cardboard, textiles (natural fiber), and wood are respectively 3, 7, 7, and 36 years. 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 7-12 Decomposition half-life for biodegradable waste

Item		Half-life [year]	Data source
Food waste ¹⁾		3	Ito (1992)
Paper/cardboard		7	
Textiles (natural fiber)		7	
Wood ²⁾		36	The half-life of wood is applied by expert judgment.
Sludge	Tsunami sediment	36	
	Human waste treatment/ <i>Johkasou</i> sludge	3.7	
	Digested sewage sludge		
	Other sewage sludge		
	Waterworks sludge		
	Organic sludge from manufacturing		
	Livestock waste		
Digested sewage sludge ³⁾	2006 IPCC Guidelines		

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 (reference #7).
- 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 (reference #7).
- 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.

➤ 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 7-13 Amount of biodegraded waste decomposed in each year (Activity data)

		Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
a. Anaerobic landfill	Municipal solid waste	Food waste	kt / year (dry)	358	278	172	99	63	53	44	37	32	27	23	19	16	14	
		Paper/cardboard	kt / year (dry)	1,042	913	724	545	451	423	393	367	343	319	297	274	252	232	
		Textiles (natural fiber)	kt / year (dry)	54	48	38	31	28	25	23	21	19	18	16	15	13	12	
		Wood	kt / year (dry)	186	186	179	167	160	157	155	152	149	147	144	142	139	137	
		Human waste treatment/ Jokasou sludge	kt / year (dry)	96	66	44	29	22	20	17	16	14	12	11	10	8	7	
		Tsunami sediment	kt / year (dry)	NO	NO	NO	NO	NO	NO	NO	NO	NO	0	0	1	1	1	1
		Food waste	kt / year (dry)	69	102	117	74	45	38	32	28	24	21	17	15	12	11	
	Industrial solid waste	Paper/cardboard	kt / year (dry)	137	138	121	99	85	80	74	68	63	58	53	49	44	41	
		Textiles (natural fiber)	kt / year (dry)	22	16	15	12	11	10	10	9	8	8	7	7	7	6	
		Wood	kt / year (dry)	224	261	258	247	238	235	232	228	225	221	218	214	211	208	
		Digested sewage sludge	kt / year (dry)	59	52	38	22	14	12	10	9	8	7	6	5	4	4	
		Other sewage sludge	kt / year (dry)	221	196	144	83	53	46	39	34	30	26	22	19	17	15	
		Waterworks sludge	kt / year (dry)	180	165	127	85	61	56	51	48	44	40	36	34	33	31	
		Organic sludge from manufacturing industry	kt / year (dry)	341	263	154	88	58	50	43	38	34	30	25	22	19	17	
b. Semiaerobic landfill	Municipal solid waste	Food waste	kt / year (dry)	70	94	90	81	59	51	45	39	35	31	27	24	21	19	
		Paper/cardboard	kt / year (dry)	119	191	232	262	257	254	248	243	237	231	222	214	203	192	
		Textiles (natural fiber)	kt / year (dry)	6	10	12	18	19	18	16	15	14	13	12	11	10	9	
		Woods	kt / year (dry)	10	16	21	25	26	26	26	26	26	26	26	26	26	26	
		Human waste treatment/ Jokasou sludge	kt / year (dry)	14	18	20	22	20	18	17	16	15	14	13	12	10	10	
	Industrial solid waste	Food waste	kt / year (dry)	4	15	36	39	29	26	23	21	19	20	17	16	14	13	
		Paper/cardboard	kt / year (dry)	6	12	21	31	35	35	35	33	32	31	29	28	26	24	
		Textiles (natural fiber)	kt / year (dry)	1	1	2	4	5	5	5	5	5	5	5	5	5	5	
		Wood	kt / year (dry)	6	15	20	27	32	33	34	35	36	37	37	38	39	39	
		Digested sewage sludge	kt / year (dry)	3	6	9	8	7	6	5	5	4	4	4	4	4	3	
		Other sewage sludge	kt / year (dry)	13	23	33	32	25	22	20	18	19	18	17	15	14	13	
		Waterworks sludge	kt / year (dry)	12	20	30	36	35	36	37	37	38	39	41	41	41	41	
		Organic sludge from manufacturing industry	kt / year (dry)	21	28	29	31	27	24	22	21	22	22	20	18	16	15	
		Livestock waste	kt / year (dry)	1	1	2	4	4	5	5	5	5	6	6	6	7	7	7

Note: The declining trend in the amount of biodegraded waste is affected by the improvement of waste reduction that causes the decrease of landfilled waste.

➤ Amount of CH₄ recovered from Landfills

In order to reduce the amount of organic matter content and CH₄ emissions at landfill sites, certain intermediate treatments and landfill methods have been conducted; CH₄ recovery from landfills is not very common practice in Japan. CH₄ 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 CH₄ recovery from landfills implemented in Japan. Because CO₂ emitted from the combustion of recovered CH₄ is of biogenic-origin, it is not included in the total emissions.

$$R = r \times f \times 16 / 22.4 / 1000$$

Where:

- R : Amount of CH₄ recovered in landfill [g]
 r : Amount of recovered landfill gas used for electric power generation [m³ N]
 f : Ratio of CH₄ 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 CH₄ to the recovered gas**

The fraction of CH₄ 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 fraction 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 7-14 Amount of CH₄ used at landfill sites in Japan

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Amount of landfill gas use	km ³ N	1,985	2,375	2,372	140	1,161	1,154	1,266	1,032	1,681	1,734	1,612	1,565	1,488	NO
CH ₄ ratio	%	53.3	42.2	40.0	48.5	37.1	40.0	43.8	51.2	49.5	44.9	41.0	39.2	40.2	NA
Amount of CH ₄ use	km ³ N	1,059	1,003	949	68	431	462	555	528	832	779	661	613	598	NO
CH ₄ unit conversion	Gg-CH ₄	0.76	0.72	0.68	0.05	0.31	0.33	0.40	0.38	0.59	0.56	0.47	0.44	0.43	NO

Note: The trend of landfill gas use significantly depends on the operation of the only power plant at the Central Breakwater Landfill Site. The operation of the power plant has stopped since the beginning of CY2017.

➤ **CH₄ 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 CH₄ 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 7-15.

Table 7-15 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 2006GL, 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	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%			
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	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 the 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 2006GLs 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 Chapter 1.

e) Category-specific Recalculations

By updating the statistical data including past landfill amounts, emissions 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*, CH₄ emissions from inappropriate disposal are reported under “Uncategorized waste disposal sites (5.A.3.)”.

Very few fires are observed in inappropriate landfill sites, and they may be emitting fossil-fuel derived CO₂. However, since actual data are not available, the emissions from the fires at inappropriate landfill sites are reported as “NE”.

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. Since the condition of CH₄ emissions from inappropriate disposal is unidentified, it is regarded as almost the same as for the anaerobic landfill.

● *Emission Factor*

Adopting 1.0 of methane correction factor for anaerobic decomposition and 45.2% of fraction of carbon content in wood, the same emission factor as shown in Table 7-7 is used for the anaerobic disposal sites for “wood emissions from managed disposal sites”.

● *Activity Data*

Activity data (dry basis) is obtained by subtracting the water content from the residual amount of inappropriately disposed wood (wet basis) and multiplied by methane generation rate constant. The amount of inappropriately disposed wood is provided by “Wood (Construction and Demolition)” in *Study on Residual Amounts of Industrial Waste from Illegal Dumping and other Sources* (Environmental Regeneration and Material Cycles Bureau, Ministry of the Environment). The percentage of water content and the methane generation rate constant used for estimating emissions from wood in managed disposal sites are also used for this source.

Table 7-16 Inappropriately disposed wood to be degraded in each estimation year (dry basis)

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Activity data	kt (dry)	2.3	5.5	16.3	16.3	15.2	14.7	14.7	14.5	14.4	13.6	12.7	11.0	11.1	10.6

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 7-17.

Table 7-17 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 Chapter 1.

e) Category-specific Recalculations

Due to the removals of inappropriate disposal, revelations of past inappropriate disposal, and etc., the amount of identified inappropriate disposal in the past has been updated annually. Due to the changes in the amount of inappropriate disposal, emissions 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, CH₄ and N₂O emissions from biological treatment of solid waste are calculated. The target categories are shown in Table 7-18.

Table 7-18 Categories whose emissions are estimated for biological treatment of solid waste (5.B.)

Category	Waste type		Category to be allocated to CRF	Treatment type	CH ₄	N ₂ O
5.B.1. (7.3.1)	Municipal solid waste	Food waste	Municipal solid waste (excl. human waste)	Composting	○	○
		Paper/cardboard				
		Textile				
		Wood (garden and park waste)				
	Human waste/Johkasou sludge	Human waste				
	Industrial waste	Food waste (animal and vegetable residues, other food waste)	Food waste (industrial waste)			
Sewage sludge		Sewage sludge	○	○		
5.B.3. (7.3.2)	-		-	Anaerobic digestion	NE	NO

Estimated greenhouse gas emissions from this category are shown in Table 7-19. In FY2017, emissions from this source category are 447 kt-CO₂ eq. and accounted for 0.03% of the national total emissions (excluding LULUCF). The emissions from this source category had increased by 90.5% 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-CH₄/t [dry] and 0.78-0.79 kg-N₂O/t [dry]).

Table 7-19 GHG emissions from biological treatment of solid waste (5.B.)

Gas	Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
CH ₄	5.B.1. Composting	Municipal solid waste (excl. human waste)	kt-CH ₄	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.1	0.1	0.2	0.2	
		Human waste	kt-CH ₄	NO	NO	NO	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
		Food waste (industrial waste)	kt-CH ₄	2.0	2.0	2.0	3.6	4.0	3.9	3.4	3.8	3.8	3.7	3.7	3.8	3.8	3.8
		Sewage sludge	kt-CH ₄	0.1	0.1	0.1	0.1	0.2	0.2	0.1	0.2	0.1	0.1	0.1	0.1	0.1	0.1
	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	
Total	kt-CH ₄	2.2	2.1	2.2	3.8	4.3	4.2	3.7	4.1	4.1	4.0	4.0	4.1	4.1	4.1		
	kt-CO ₂ eq.	54	53	54	95	107	106	93	102	101	100	100	102	103	103		
N ₂ O	5.B.1. Composting	Municipal solid waste (excl. human waste)	kt-N ₂ O	0.02	0.01	0.01	0.02	0.03	0.03	0.03	0.04	0.03	0.03	0.03	0.04	0.04	
		Human waste	kt-N ₂ O	NO	NO	NO	0.00	0.01	0.02	0.00	0.00	0.01	0.01	0.01	0.01	0.01	
		Food waste (industrial waste)	kt-N ₂ O	0.56	0.56	0.56	1.01	1.12	1.09	0.96	1.06	1.06	1.05	1.04	1.06	1.07	1.07
		Sewage sludge	kt-N ₂ O	0.03	0.03	0.04	0.04	0.05	0.05	0.04	0.05	0.04	0.04	0.04	0.04	0.03	0.03
	5.B.2. Anaerobic digestion at biogas facilities	kt-N ₂ O	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	
Total	kt-N ₂ O	0.61	0.60	0.61	1.07	1.20	1.19	1.04	1.15	1.14	1.12	1.12	1.14	1.15	1.15		
	kt-CO ₂ eq.	181	179	181	319	357	354	309	342	338	335	333	340	343	344		
Total	kt-CO ₂ eq.	235	233	235	414	464	460	402	444	440	435	433	441	446	447		

7.3.1. Composting (5.B.1)

a) Category Description

Part of the MSW and industrial waste generated in Japan is composted, and CH₄ and N₂O 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 CH₄ and N₂O emissions.

$$E = \sum_i EF_i \times A_i$$

E : Amount of CH₄ or N₂O emissions generated by composting organic waste [kg-CH₄], [kg-N₂O]

EF_i : Emission factor for organic waste i (wet basis) [kg-CH₄/t], [kg-N₂O/t]

A_i : Amount of composted organic waste i (wet basis) [t]

● Emission Factor

Country-specific emission factors obtained from actual measurements of the *Survey for the Development of Emission Factor to Estimate Effect of the Mitigation Measures for GHG Emissions from the Waste Sector*, Ministry of the Environment (Reference #30) are adopted (Reference #26).

Table 7-20 GHG emission factors for composting (5.B.1) (wet basis)

Waste type		CH ₄ emission factor [kg-CH ₄ /t]	N ₂ O emission factor [kg-N ₂ O/t]	Note
MSW	Wood (garden and park waste)	0.35	0.0015	Low compostable
	Food waste	0.96	0.27	High compostable
	Paper/cardboard			
	Textile			
	Human waste/ <i>Johkasou</i> sludge			
ISW	Food waste (animal and vegetable residues, other food waste)			
	Sewage sludge			

● Activity Data

Activity data for the category composting (5.B.1) are obtained from the data sources shown on the Table 7-21.

Table 7-21 Sources of activity data for composting (5.B.1)

Waste type		Data source	Note
MSW	Food waste	- the <i>Waste Treatment in Japan</i> - the <i>Cyclical Use of Waste Report</i>	Amount of MSW treated at waste composting facilities indicated in the <i>Waste Treatment in Japan</i> , is disaggregated by using MSW composition treated at high-rate composting facilities provided in the <i>Cyclical Use of Waste Report</i> .
	Paper/cardboard		
	Textile		
	Wood (garden and park waste)		
	Human waste/ <i>Johkasou</i> sludge	the <i>Waste Treatment in Japan</i>	
ISW	Food waste (animal and vegetable residues, other food waste)	the <i>Review Report on Improvement of Accuracy and Faster Compilation of Waste Statistics</i> , MoEJ	This category includes; - Animal and vegetable residues generated by food and beverage manufacturing. - Food waste including valuables other than the above: although under the Waste Management and Public Cleansing Act, they fall under the category of industrial waste, 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 <i>Cyclical Use of Waste Report</i> .
	Sewage sludge	the <i>Sewage Statistics</i>	
	Additives (e.g. wood, etc.)	Data provided by MLIT	

Activity data (wet basis) obtained is shown on the Table 7-22. As for the activity data (dry basis) reported on the CRF tables is calculated by using percentages of water content shown on the Table 7-10; in case the ratio is separated, percentages for untreated waste are applied.

Table 7-22 Amounts of composted waste (wet basis)

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Municipal solid waste															
Food waste	kt (wet)	35	20	29	66	99	108	117	143	120	121	115	122	134	134
Paper/cardboard	kt (wet)	28	16	23	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Textile	kt (wet)	3	2	2	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Wood (garden and park waste)	kt (wet)	8	5	4	33	37	44	48	41	40	45	60	60	85	85
Human waste/ <i>Johkasou</i> sludge	kt (wet)	NO	NO	NO	4	28	58	17	15	21	19	25	35	30	30
Industrial solid waste															
Food waste (incl. additive)	kt (wet)	2,063	2,063	2,063	3,747	4,146	4,051	3,564	3,923	3,920	3,883	3,861	3,923	3,973	3,981
Sewage sludge (incl. additive)	kt (wet)	118	126	135	147	170	186	144	168	145	136	139	140	129	129

c) Uncertainties and Time-series Consistency

● Uncertainties

The uncertainty in emission factors are evaluated according to the survey for EFs (Reference #30). As for the uncertainty in activity data, since valuables account for much of activity data in biological treatment, the uncertainty for valuables indicated in Table 7-2 is adopted for activity data based on expert judgment. Details of the uncertainty assessment on this category are indicated in the Table 7-23.

Table 7-23 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 EFs (Reference #30)	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 ₂ O	-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 Chapter 1.

- e) **Category-specific Recalculations**

By updating the statistical data, emissions were recalculated. For detail, see the section “7.1.5. General Recalculations for Emissions from Waste Sector”. 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**

“*Guidelines and Explanation of Sewerage Facility Design, Japan Sewage Works Association, 2009*” states that, digestion tanks for sludge at sewage treatment plants should be kept air tight to prohibit explosions and odors caused by biogas leakage. It also states that unutilized digestion gas from these equipment should be combusted in views of safety and climate change mitigation. In addition, Japan estimates CH₄ and N₂O emissions from sludge thickening tank and dehydration room by using emission factors considering whole treatment system including these processes; CH₄ and N₂O emissions from this source stated in the *2006 IPCC Guidelines* are included in “5.D.1. domestic wastewater”.

- **Biogas facilities for municipal waste**

“*Manual on biogas facilities maintenance, Ministry of Environment, 2008*” states that fermentation equipment at biogas facilities for municipal waste should be kept air tight. It also states that biogas from these 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 air tight 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 CH₄. By assuming 2% of the leakage fraction of biogas produced in a facility (a consideration of actual situation of the CH₄ emission) and 60% of the CH₄ concentration in biogas (*the JARUS Reference System for Information of Biomass Recycling Technology*, The Japan Association of Rural Resource Recycling Solutions), the CH₄ emissions from this source category were tentatively estimated as 1.4 [kt-CO₂ 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 A5-2 of Annex 5.

Assumed to be negligible in accordance with the *2006 IPCC Guidelines*, N₂O 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 as shown in Table 7-24. CO₂, CH₄, N₂O 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 7-24 Categories whose emissions are estimated for waste incineration and open burning (5.C.)

Category	Waste type		Category to be allocated to CRF	Treatment type	CO ₂	CH ₄	N ₂ O	
5.C.1 (7.4.1)	Municipal solid waste (7.4.1.1)	Plastics	Fossil-fuel derived plastics	Non-biogenic/MSW	Incinerator -continuous -semi-continuous -batch type	○	○ ²⁾	○ ²⁾
			Biomass-based plastics	Biogenic/MSW		NA ¹⁾		
		Paper/ cardboard	Fossil-fuel derived fraction	Non-biogenic/MSW		○		
			Biogenic fraction	Biogenic/MSW		NA ¹⁾		
		Nappy (Fossil-fuel derived fraction)		Non-biogenic/MSW		○		
				Biogenic/MSW		○		
		Textiles	Synthetic textile	Non-biogenic/MSW		○		
	Natural fiber		Biogenic/MSW	NA ¹⁾				
	Other (Biogenic)		Biogenic/MSW	NA ¹⁾				
	Industrial waste (7.4.1.2)	Waste oil	Fossil-fuel derived oil	Non-biogenic/ Fossil liquid waste	Incinerator	○	○	○
			Animal and vegetable oil	Biogenic/ Non- fossil liquid waste		NA ¹⁾	○	○
		Plastics	Fossil-fuel derived plastics	Non-biogenic/ISW		○	○	○
			Biomass-based plastics	Biogenic/ISW		NA ¹⁾	IE ³⁾	IE ³⁾
		Food waste [Animal and vegetable residues/animal carcasses]		Biogenic/ISW		NA ¹⁾	○	○
		Paper/ cardboard	Fossil-fuel derived fraction	Non-biogenic/ISW		○	IE ⁴⁾	IE ⁴⁾
			Biogenic fraction	Biogenic/ISW		NA ¹⁾	○	○
		Wood		Biogenic/ISW		NA ¹⁾	○	○
		Textile	Synthetic textile	-		IE ³⁾	IE ³⁾	IE ³⁾
			Natural fiber	Biogenic/ISW		NA ¹⁾	○	○
		Sludge	Sewage sludge	Biogenic/Sludge		Various types of incinerations ⁵⁾	NA ¹⁾	○
	Other than sewage sludge		Biogenic/Sludge	NA ¹⁾	○		○	
	Specially controlled industrial waste (7.4.1.3)	Waste oil	Flammable waste oil	Non-biogenic/ Hazardous waste	Incinerator	○	○	○
			Specified hazardous waste oil	Non-biogenic/ Hazardous waste		○	○	○
Infectious waste		Plastics (Fossil-fuel derived)	Non-biogenic/ Clinical waste	○		○	○	
		Other (except plastics)	Biogenic/ 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)	Non-biogenic/ISW		○	○	○	
		Other (Biogenic)	Biogenic/ISW		NA ¹⁾	IE ⁶⁾	IE ⁶⁾	

Note:

- 1) CO₂ 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” in Table 5.C of the CRF.
- 2) CH₄ and N₂O emissions from incineration of municipal solid waste in bulk are estimated by each incineration type and reported under “Non-biogenic/MSW” in Table 5.C of the CRF.
- 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) CH₄ and N₂O emissions from open burning of industrial solid waste in bulk are reported under “Non-biogenic/ISW”.

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.)
- 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 7-26.

In order to avoid double-counting or any other confusion, emissions from the categories indicated in Table 7-24, Table 7-25 and Table 7-26 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 7-25 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 to be allocated to CRF	Treatment type	CO ₂	CH ₄	N ₂ O
1.A.1. (7.4.3.1) ⁷⁾	Municipal solid waste	Plastics	Fossil-fuel derived plastics	Other fossil fuels	○		
			Biomass-based plastics	Biomass ⁸⁾	NA ¹⁾		
		Paper/ cardboard	Fossil-fuel derived fraction	Other fossil fuels ⁹⁾	○	○ ²⁾	○ ²⁾
			Biogenic fraction	Biomass	NA ¹⁾		
		Nappy (Fossil-fuel derived fraction)		Other fossil fuels	○		
		Textiles	Synthetic textile	Other fossil fuels	○		
	Natural fiber		Biomass	NA ¹⁾			
	Other (biogenic)		Biomass	NA ¹⁾			
	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⁾
		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.1/2 (7.4.3.2) ⁷⁾		Municipal solid waste	Plastics	Fossil-fuel derived plastics	Other fossil fuels	○	○
	Biomass-based plastics			Biomass ⁸⁾	NA ¹⁾	IE ³⁾	IE ³⁾
	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.1/2 (7.4.3.3) ⁷⁾	Refuse Derived Fuel (RDF)	Fossil-fuel derived fraction	Other fossil fuels	○	○	○
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) CO₂ 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 CRF tables.
- 2) CH₄ and N₂O emissions from incineration of municipal solid waste in bulk are estimated by each incineration type and reported as “Other fossil fuels” in the CRF 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 CRF, see Table 7-26.
- 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 7-26 Reporting categories on 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 ₂ O	
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 & 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
		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	(Unclassified)	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 & steel	○	NO ³⁾	NO ³⁾
	Gasification			Fuel in iron manufacturing	1.A.2.a. Iron & 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) CO₂ 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 CRF tables. For detail, see Table 7-25.
- 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) N₂O 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 greenhouse gas emissions from waste incineration (category 5.C.) are shown in Table 7-27. In FY2017, emissions from waste incineration are 12,238 kt-CO₂ eq. and accounted for 0.9% of the national total emissions (excluding LULUCF). The emissions from this source category decreased by 11.9% compared to those in FY1990. For the period FY1990-FY1997, CO₂ 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 CO₂ emissions which used to be allocated to the waste sector is now allocated to the Energy sector, CO₂ emission estimates from

the waste sector decreased. The trend in the IEFs of CO₂ for this category is basically stable and range from 2.48 to 2.60 [t-CO₂/t-waste (wet)]. On the other hand, N₂O emissions increased compared to FY1990 level due to the increase in sewage sludge incineration practice for the period FY1990 - FY1997. From FY2005 onward, N₂O emissions from this source decreased because the practice of high temperature incineration of sewage sludge increased.

Table 7-27 GHG emissions from waste incineration (5.C.)

Gas	Category		Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
CO ₂	5.C.1. Waste incineration	Municipal solid waste	Plastics ¹⁾	kt-CO ₂	5,092	5,082	5,275	3,081	2,565	2,395	2,107	2,426	2,598	2,719	2,295	2,510	1,664	1,630
			Paper/cardboard ¹⁾	kt-CO ₂	71	74	71	60	53	52	53	58	55	56	52	54	36	36
		Industrial waste	Nappy ¹⁾	kt-CO ₂	32	38	34	39	43	46	49	52	52	58	59	73	48	48
			Synthetic textiles ¹⁾	kt-CO ₂	508	545	425	433	554	665	593	547	446	449	411	508	318	314
	Specially-controlled industrial waste	Waste oil ²⁾	kt-CO ₂	3,670	4,366	4,799	4,270	3,690	3,172	4,128	3,966	4,430	3,652	3,990	3,324	3,856	3,803	
		Plastics ¹⁾	kt-CO ₂	2,131	4,539	4,380	4,332	4,691	3,475	3,785	3,183	3,446	3,941	3,391	3,769	3,708	3,695	
		Paper/cardboard ¹⁾	kt-CO ₂	3	7	7	3	4	3	3	2	3	1	1	1	1	1	
	5.C.2. Open burning (Industrial waste plastics) ¹⁾	Waste oil (flammable) ¹⁾	kt-CO ₂	698	1,036	1,526	1,402	2,547	1,845	1,143	815	784	796	782	692	744	712	
		Waste oil (specific hazardous) ¹⁾	kt-CO ₂	19	28	41	38	36	39	42	44	25	55	124	149	156	156	
		Infectious waste (plastics) ¹⁾	kt-CO ₂	199	328	428	435	336	366	395	452	336	341	452	426	411	413	
	5.C.2. Open burning (Industrial waste plastics) ¹⁾		kt-CO ₂	5	5	1	0.3	0.3	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.03	0.03	0.03
	Total		kt-CO ₂	12,429	16,046	16,988	14,093	14,518	12,058	12,298	11,545	12,176	12,068	11,558	11,506	10,941	10,808	
	CH ₄	5.C.1. Waste incineration	Municipal solid waste ²⁾	Waste oil ²⁾	kt-CH ₄	0.5	0.4	0.4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	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
Industrial waste			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
			Paper/cardboard ²⁾	kt-CH ₄	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.0	0.1	0.0	0.0	0.0	0.0	0.0
			Wood ³⁾	kt-CH ₄	0.1	0.1	0.1	0.4	0.3	0.3	0.2	0.2	0.2	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
Specially-controlled industrial waste			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
			Waste oil (flammable) 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
			Waste oil (specific hazardous) 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
			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
5.C.2. Open burning (Industrial waste) ²⁾		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	
		Total	kt-CH ₄	1.1	1.2	0.8	0.7	0.6	0.5	0.5	0.4	0.5	0.5	0.5	0.4	0.4	0.4	
Total		kt-CO ₂ eq.	28	29	21	18	14	13	12	11	11	12	10	10	9	10		
N ₂ O		5.C.1. Waste incineration	Municipal solid waste ²⁾	Waste oil ²⁾	kt-N ₂ O	1.03	1.05	0.98	0.52	0.47	0.48	0.46	0.49	0.46	0.47	0.43	0.47	0.30
	Plastics ²⁾			kt-N ₂ O	0.02	0.02	0.02	0.10	0.09	0.07	0.09	0.09	0.10	0.08	0.09	0.08	0.09	0.09
	Industrial waste		Food waste ³⁾	kt-N ₂ O	0.15	0.32	0.31	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
			Paper/cardboard ²⁾	kt-N ₂ O	0.00	0.00	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
			Wood ³⁾	kt-N ₂ O	0.01	0.01	0.01	0.02	0.04	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.01	0.01
			Natural fiber ³⁾	kt-N ₂ O	0.06	0.10	0.06	0.14	0.10	0.09	0.08	0.07	0.08	0.10	0.08	0.08	0.07	0.08
	Specially-controlled industrial waste		Sewage sludge ³⁾	kt-N ₂ O	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
			Other sludge ³⁾	kt-N ₂ O	2.65	3.94	4.86	5.48	4.46	4.30	4.16	4.17	4.22	4.25	3.92	4.16	3.69	4.07
			Waste oil (flammable) ¹⁾	kt-N ₂ O	0.89	0.92	0.94	0.22	0.20	0.20	0.19	0.19	0.16	0.18	0.17	0.16	0.16	0.15
			Waste oil (specific hazardous) ¹⁾	kt-N ₂ O	0.00	0.00	0.01	0.03	0.05	0.04	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.02
	5.C.2. Open burning (Industrial waste) ²⁾	Infectious waste (plastics) ¹⁾	kt-N ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	
		Infectious waste (except plastics) ³⁾	kt-N ₂ O	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	
	Total		kt-N ₂ O	4.83	6.40	7.23	6.59	5.46	5.27	5.08	5.09	5.11	5.15	4.77	5.03	4.40	4.77	
	Total		kt-CO ₂ eq.	1,438	1,908	2,156	1,963	1,628	1,570	1,515	1,518	1,523	1,535	1,423	1,498	1,312	1,421	
Total		kt-CO ₂ eq.	13,876	17,963	19,157	16,073	16,159	13,640	13,824	13,074	13,710	13,615	12,990	13,014	12,262	12,238		

1) Include fossil-fuel derived component only

2) Include both fossil-fuel derived component and biogenic

3) Include biogenic component only

Note: CO₂ 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” in Table 5.C of the CRF.

For reference, the greenhouse gas emissions from waste incineration for energy purpose and with energy recovery are shown in Table 7-28. In FY2017, the emissions from waste incineration including these sources are 30,124 kt-CO₂, and it accounts for 2.3% of Japan’s total greenhouse gas emissions (excluding LULUCF). The emissions from this sources category had increased by 19.5% compared to those in FY1990.

Table 7-28 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	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017			
CO ₂	5.C. Waste Incineration and open burning (without energy recovery) ¹⁾	kt-CO ₂	12,429	16,046	16,988	14,093	14,518	12,058	12,298	11,545	12,176	12,068	11,558	11,506	10,941	10,808			
	I.A. Fuel combustion	Waste Incineration with Energy Recovery	MSW	Plastics ¹⁾	kt-CO ₂	5,916	6,373	8,270	6,657	5,549	4,680	4,262	4,541	5,452	5,383	4,831	4,656	5,446	5,334
				Paper/cardboard ¹⁾	kt-CO ₂	83	93	112	129	114	102	107	108	116	111	110	101	117	117
				Nappy ¹⁾	kt-CO ₂	38	48	53	83	92	90	99	98	109	114	125	135	156	156
			Synthetic textiles ¹⁾	kt-CO ₂	591	683	667	935	1,198	1,299	1,200	1,025	935	889	865	942	1,040	1,028	
			IW	Waste oil ¹⁾	kt-CO ₂	21	30	28	109	73	67	176	170	105	152	175	169	176	174
				Plastics ¹⁾	kt-CO ₂	31	66	188	307	746	351	581	687	731	607	677	898	836	834
		Paper/cardboard ¹⁾		kt-CO ₂	0.0	0.1	0.1	0.0	0.2	0.1	0.2	0.3	0.4	0.1	0.1	0.1	0.1	0.1	
		Direct Use of Waste as Alternative Fuel	MSW	Plastics ¹⁾	kt-CO ₂	NO	NO	92	510	370	413	454	434	465	233	227	264	253	266
				IW	Waste oil ¹⁾	kt-CO ₂	3,592	4,193	4,150	5,215	4,805	4,559	4,778	4,733	4,952	4,796	4,592	5,015	4,678
			Plastics ¹⁾	kt-CO ₂	55	59	450	1,238	1,459	1,707	1,835	1,740	1,818	1,890	2,180	2,093	2,239	2,134	
	Incineration of Waste Processed as Fuel	RDF ¹⁾	kt-CO ₂	26	30	114	319	296	289	292	298	294	296	297	276	274	274		
		RPF ¹⁾	kt-CO ₂	NO	11	46	684	1,074	1,114	1,093	1,147	1,195	1,263	1,234	1,260	1,354	1,376		
	Total	kt-CO ₂	23,307	28,477	32,202	31,147	31,323	27,680	28,183	27,502	29,299	28,761	27,885	28,350	28,510	28,193			
	CH ₄	5.C. Waste Incineration and open burning (without energy recovery) ²⁾	kt-CH ₄	1.1	1.2	0.8	0.7	0.6	0.5	0.5	0.4	0.5	0.5	0.4	0.4	0.4	0.4		
		I.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	
					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
IW				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	
				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	
				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	
				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	
				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	
				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	
Direct Use of Waste as Alternative Fuel			MSW	Plastics ²⁾	kt-CH ₄	NO	NO	0.0	0.0	0.0	0.0	NO	NO	NO	NO	NO	NO	NO	
				IW	Waste oil ²⁾	kt-CH ₄	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
		Plastics ²⁾	kt-CH ₄	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2			
Incineration of Waste Processed as Fuel		Waste Tire ²⁾	kt-CH ₄	1.8	1.8	2.2	2.9	4.0	4.2	4.2	4.4	4.5	4.8	5.2	5.0	4.9	5.1		
			kt-CH ₄	0.0	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
		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			
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				
Total		kt-CH ₄	3.5	3.6	3.8	4.0	5.0	5.1	5.0	5.2	5.3	5.6	6.1	5.8	5.7	5.9			
Total		kt-CO ₂ eq.	86	89	95	99	125	128	126	130	133	141	152	145	143	149			
N ₂ O		5.C. Waste Incineration and open burning (without energy recovery) ²⁾	kt-N ₂ O	4.83	6.40	7.23	6.59	5.46	5.27	5.08	5.09	5.11	5.15	4.77	5.03	4.40	4.77		
		I.A. Fuel combustion	Waste Incineration with Energy Recovery	MSW ²⁾	kt-N ₂ O	1.19	1.32	1.53	1.13	1.02	0.95	0.93	0.91	0.97	0.93	0.91	0.86	0.99	
	Waste oil ²⁾				kt-N ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
	IW			Plastics ²⁾	kt-N ₂ O	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	
				Food waste ³⁾	kt-N ₂ O	0.00	0.00	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	
				Paper/cardboard ²⁾	kt-N ₂ O	0.01	0.01	0.01	0.02	0.04	0.02	0.02	0.01	0.02	0.01	0.01	0.01	0.01	
				Wood ³⁾	kt-N ₂ O	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	
				Natural Fiber ³⁾	kt-N ₂ O	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 ₂ O	0.01	0.01	0.01	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.03	0.02	0.02	
	Direct Use of Waste as Alternative Fuel		MSW	Plastics ²⁾	kt-N ₂ O	NO	NO	0.00	0.00	0.00	0.00	NO	NO	NO	NO	NO	NO		
				IW	Waste oil ²⁾	kt-N ₂ O	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01		
		Plastics ²⁾	kt-N ₂ O	0.03	0.02	0.03	0.02	0.04	0.05	0.05	0.04	0.04	0.04	0.05	0.05				
	Incineration of Waste Processed as Fuel	Waste Tire ²⁾	kt-N ₂ O	0.02	0.02	0.03	0.03	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06				
			kt-N ₂ O	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02				
		RDF ²⁾	kt-N ₂ O	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01				
	RPF ²⁾	kt-N ₂ O	NO	0.00	0.00	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02					
	Total	kt-N ₂ O	6.11	7.81	8.89	7.87	6.70	6.41	6.21	6.20	6.28	6.28	5.91	6.11	5.61				
	Total	kt-CO ₂ eq.	1,819	2,328	2,650	2,346	1,995	1,910	1,851	1,849	1,872	1,873	1,760	1,820	1,672				
	Total	kt-CO ₂ eq.	25,213	30,894	34,947	33,592	33,443	29,718	30,160	29,481	31,304	30,774	29,798	30,316	30,325				

1) Include fossil-fuel derived component only

2) Include both fossil-fuel derived component and biogenic

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 CO₂ are reported under either “Biogenic, Municipal solid waste (MSW)” or “Non-biogenic, Municipal solid waste” in accordance with the waste type as indicated in the Table 7-24. Emissions of CH₄ and N₂O are estimated for each type of furnace. The data used for MSW incineration

cannot distinguish wastes that are either biogenic-origin or non-biogenic origin. Therefore, total emissions including biogenic-origin ones are reported altogether under “Non-biogenic, Municipal solid waste”.

b) Methodological Issues

1) CO₂

● Estimation Method

Emissions of CO₂ from this emission source is calculated based on Japan’s country-specific emission factors, the volume of waste incinerated (dry basis) and the percentage of municipal waste incinerated at the municipal incineration facilities that is 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 CO₂ emissions from the incineration of fossil-fuel derived waste², emissions from fossil-fuel derived plastics, synthetic textile and fossil-fuel derived fraction in paper/cardboard and nappy in municipal solid waste are estimated.

$$E = \sum_i EF_i \times A_i \times (1 - R)$$

E : CO₂ Emissions from the incineration of municipal solid waste type i [kg-CO₂]

EF_i : Emission factor for the incineration of waste type i (dry basis) [kg-CO₂/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.

- Fossil-fuel derived plastics, synthetic textile

$$EF_i = CF_i \times OF \times 44/12$$

EF_i : Emission factor for the incineration of waste type i (dry basis) [kg-CO₂/t]

CF_i : Carbon content in waste type i (dry basis) [%]

OF : Oxidation factor [%]

- Paper/cardboard and nappy

$$EF_i = CF_i \times FCF_i \times OF \times 44/12$$

EF_i : Emission factor for the incineration of waste type i (dry basis) [kg-CO₂/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 [%]

➤ Carbon Content

The carbon content of plastics (fossil-fuel derived and biomass-derived waste) in MSW is estimated based on the averaged value of actual measured data for the period FY1990 - FY2008 provided by four

² CO₂ 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 biogenic municipal waste. Estimation methods for their emissions are the same as those for emissions from the incineration of fossil-fuel derived waste.

municipalities (Akita city, Kawasaki city, Kobe city and Osaka pref.) and applying it for the entire time-series (Reference #24).

For the carbon content of synthetic textile in MSW, the carbon content of the synthetic fibers in the textile products is used. It is set by taking a weighted average of carbon contents determined by the molecular formula of polymer for each type of synthetic textile based on the volume of synthetic textile consumption.

For the carbon content of paper/cardboard in MSW, the carbon content of default value in the 2006 IPCC Guidelines, which is larger than country specific measured data (see Table 7-5) is conservatively applied.

For the carbon content of nappy in MSW, the carbon content of default value in the 2006 IPCC Guidelines is used due to lack of domestic research in Japan.

Table 7-29 Carbon content of plastics and synthetic textile in MSW (dry basis)

Item	Carbon content	Source
Plastics	75.1 %	Averaged value of the data provided by four municipalities
Plastic bottles	62.5%	(Reference value) Estimated from the molecular formula of polyethylene terephthalate * Not adopted to estimate CO ₂ emissions
Synthetic textile	63.0 %	Weighted average of carbon content by each type of synthetic textile
Paper/cardboard	46.0 %	2006 IPCC Guidelines
Nappy	70.0 %	2006 IPCC Guidelines

➤ Fossil-fuel derived fraction in carbon in waste

For the fossil-fuel derived fraction in carbon in paper/cardboard and nappy in MSW, the default values in the 2006 IPCC Guidelines are applied as indicated in the Table 7-30 due to lack of domestic research in Japan.

Table 7-30 Fossil-fuel derived fraction in carbon in paper/cardboard and nappy in MSW

Item	Fossil-fuel derived fraction in carbon [%]	Source
Paper/cardboard	1	2006 IPCC Guidelines
Nappy	10	2006 IPCC Guidelines

➤ 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 7-31.

Table 7-31 Emission factors for plastics and synthetic textile in MSW (dry basis)

Item	Unit	Emission factor
Plastics	kg-CO ₂ /t	2,754
Synthetic textile	kg-CO ₂ /t	2,310
Paper/cardboard (Fossil-fuel derived)	kg-CO ₂ /t	17
Nappy (Fossil-fuel derived)	kg-CO ₂ /t	257

Table 7-32(Reference value) Emission factor for plastic bottles (dry basis)

Item	Unit	Emission factor	Remarks
Plastic bottles	kg-CO ₂ /t	2,292	Not adopted to estimate CO ₂ emissions

● Activity Data

As basic information to estimate activity data, the amount of plastic, plastic 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 plastic bottles potentially include biomass-based plastics. The details of activity data estimations are shown as follows.

➤ Fossil-fuel derived plastics

The activity data for CO₂ emissions from the incineration of fossil-fuel derived plastics in MSW on a dry basis are calculated by subtracting water content from the amount of plastic incinerated (wet basis) and multiplying the fossil-fuel derived fraction of plastic incinerated in MSW.

Activity data for fossil-fuel derived plastics (MSW) incinerated (dry basis)

= Volume of plastics incinerated (wet basis) × (1 - Percentage of water content in plastics)
 × Fossil-fuel derived fraction of plastics

In this method for MSW plastics, activity data is estimated separately as plastic bottles and the rest of plastics.

Activity data for fossil-fuel derived plastics (MSW) incinerated

= Activity data for fossil-fuel derived plastic bottles (MSW) incinerated
 + Activity data for fossil-fuel derived plastics (MSW) other than plastic bottles incinerated

- Percentage of water content in plastics

The percentage of water content in plastic bottles/ plastics other than plastic bottles in MSW is defined as 20% provided by *Cyclical Use of Wastes Report*.

- Fossil-fuel derived fraction in plastic bottles/ plastics other than plastic bottles

Fossil-fuel derived fraction in plastics is estimated as follows. For MSW, the parameters in this method are distinguished for plastic bottles and plastics other than plastic bottles, separately.

$$FPF(T) = 1 - \frac{BPW(T)}{PW(T)}$$

$FPF(T)$: Fossil-fuel derived fraction in MSW plastic in FY T [%]

$BPW(T)$: Amount of biogenic fraction in MSW plastic in FY T [t]

$PW(T)$: Amount of MSW plastic generation in FY T [t]

MSW plastics (plastic bottles / plastics other than plastic bottles) generation in FY T ($BPA(T)$) are obtained from the *Cyclical Use of Wastes Report*. Amount of biogenic fraction in MSW plastics (plastic bottles / plastics other than plastic bottles) in FY T ($BPW(T)$) are calculated by following equation.

$$BPW(T) = \sum_t^T \sum_i (BP_{i,t} \times DP_{i,t} \times B_i \times W_{i,t}(T) \times DW(T))$$

$BP_{i,t}$: Amount of biomass-based plastic product i production in FY t [t]

$DP_{i,t}$: Share of domestic shipments of biomass-based plastic product i in FY t [%]

B_i : Biogenic fraction of biomass-based plastic product i [%]

$W_{i,t}(T)$: Probability that biomass-based plastic product i , which was produced in $FY t$, is disposed of as MSW in $FY T$ after use [%]

$DW(T)$: Fraction of MSW plastic treated domestically in $FY T$ [%]

For the amount of biomass-based plastic products production ($BP_{i,t}$), the share of domestic shipments ($DP_{i,t}$), 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.).

Table 7-33 Total amount of biomass-based plastic final products (dry basis) (Reference)

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total amount of biomass-based plastics production	kt / year (dry)	NO	NO	NO	71	74	76	83	76	78	92	88	94	99	101

The survey also provides the supplied amount of bio-based resin as intermediate products of bio-PE, bio-PET, PLA, etc. 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 plastic 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 plastic ($BPW(T)$) 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 “Annual Report on PET Bottle Recycling, The Council for PET Bottle Recycling”.

The probability that is disposed of as MSW ($W_{i,t}(T)$) is estimated by the expert judgement.

Fractions of MSW plastics other than plastic bottles treated domestically in FYT ($DW(T)$) are assumed as 100% for plastics other than plastic bottles since the export status are not clear. The parameters for plastic bottles are obtained from *Annual report on PET bottle recycling*, the council for PET bottle recycling (Table 7-34).

Table 7-34 Fraction of waste plastic treated domestically

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Plastics in MSW (excl. plastic bottle)	%	100	100	100	100	100	100	100	100	100	100	100	100	100	100
Plastic bottle in MSW	%	48.6	48.6	48.6	48.6	48.6	47.4	47.5	50.5	50.9	51.6	57.1	52.0	54.3	59.5
Plastics in IW	%	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Fossil-fuel derived fraction in plastic calculated by methodologies above are shown in Table 7-35.

Table 7-35 Fossil-fuel derived fraction in waste plastics (FPF)

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Plastics in MSW (excl. plastic bottle)	%	100.0	100.0	100.0	99.7	99.6	99.5	99.4	99.4	99.4	99.2	99.2	99.1	98.9	98.7
Plastic bottle in MSW	%	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	99.7	99.5	99.5	99.5	99.4
Plastics in IW	%	100.0	100.0	100.0	100.0	100.0	100.0	99.9	99.8	99.7	99.7	99.6	99.6	99.6	99.8

➤ **Synthetic textile**

The activity data of synthetic textile in MSW is estimated by multiplying the amount of textiles in MSW incinerated (wet basis) by the fraction of waste synthetic textile content in waste textile, and subtracting the water content in textiles (percentage of water content: 20%; see also Table 7-10).

Activity data for incineration of synthetic textile (MSW) (dry basis)

= Volume of textile incinerated (wet basis)
 × (1 - Percentage of water content in textiles)
 × Percentage of synthetic fiber content in textiles

- **Percentage of Synthetic Textile in Textiles**

Percentage of synthetic textile content in textiles contained in the MSW is calculated using the percentage of synthetic textile products in textile products, which is determined by taking the ratio of the annual domestic demand for synthetic textile to the one for all textiles indicated in the Textile Handbook and the Yearbook of Textiles and Consumer Goods Statistics.

Table 7-36 Percentage of synthetic textile in textiles

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Fraction of synthetic textile	%	49.1	50.7	53.5	52.8	55.9	56.6	59.6	63.2	64.1	61.9	63.1	63.6	63.6	63.6

➤ **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 7-10) in paper/cardboard from the amount of paper/cardboard in MSW incinerated (wet basis).

Activity data for incineration of paper/cardboard (MSW) (dry basis)

= Volume of paper/cardboard incinerated (wet basis)
 × (1 - Percentage of water content in paper/cardboard)

➤ **Nappy**

Although nappy in Japan's municipal waste is generally classified into paper or textile, the incinerated amount is not clearly distinguished from these categories. Therefore, conservatively considering as the independent activity from paper/cardboard and textile incinerated, the amount of domestic production of nappies is applied as the activity data for nappy incinerated.

Activity data for incineration of nappy (MSW) (dry basis)

= Amount of domestic production of nappies (dry basis)

- **Amount of domestic production of nappies**

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.

➤ **Activity data**

Activity data calculated by methodologies above is shown in Table 7-37.

Table 7-37 Activity data to estimate CO₂ emissions from MSW incinerated (dry basis)

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Fossil-fuel derived plastics	kt / year (dry)	3,998	4,160	4,919	3,536	2,947	2,569	2,313	2,530	2,923	2,942	2,588	2,602	2,582	2,529
Synthetic textile	kt / year (dry)	476	531	473	592	759	850	776	681	598	579	552	628	588	581
Paper/cardboard	kt / year (dry)	9,157	9,916	10,863	11,193	9,907	9,150	9,447	9,796	10,187	9,881	9,617	9,186	9,078	9,057
Nappy	kt / year (dry)	272	333	340	475	526	531	576	584	627	670	716	811	795	795

● **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* (Ministry of the Environment).

Table 7-38 Percentage of municipal solid waste incinerated at incineration facilities with energy recovery

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
With off-field power generation or heat utilization	%	53.7	55.6	61.1	68.4	68.4	66.1	66.9	65.2	67.7	66.4	67.8	65.0	76.6	76.6
Without off-field power generation or heat utilization	%	46.3	44.4	38.9	31.6	31.6	33.9	33.1	34.8	32.3	33.6	32.2	35.0	23.4	23.4

2) **CH₄**

● **Estimation Method**

CH₄ emissions from incinerator are estimated by multiplying the amount of MSW (wet basis) by incinerator method by each emission factor. CH₄ 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 : CH₄ emission from the incineration of MSW [kg-CH₄]

EF_i : Emission factor for incineration method i (or furnace type i) (wet basis) [kg-CH₄/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 CH₄ emission factors from the facilities renovated or rebuilt in FY2000 and later, compared to the values obtained before then (Reference #24). Therefore, based on the survey (Reference #24) and expert judgment, for the CH₄ 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 (Reference #7), and from FY2002 onward (Reference #24), 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 CH₄ 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) (Reference #24). 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 7-39 CH₄ emission factors by type of incineration method (MSW)

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Continuous incinerator	g-CH ₄ /t	8.2	8.2	8.3	2.6	2.6	2.6	2.7	2.7	2.7	2.7	2.7	2.7	2.7	2.7
Semi-continuous incinerator	g-CH ₄ /t	69.6	69.6	75.1	19.9	21.0	20.6	20.9	20.8	21.1	20.9	21.1	20.7	20.4	20.4
Batch type incinerator	g-CH ₄ /t	80.5	80.5	84.1	13.2	13.2	13.4	11.6	11.6	11.6	11.7	11.7	11.8	11.8	11.8
Gasification melting furnace	g-CH ₄ /t	NA	NA	5.6	6.9	7.1	7.0	7.0	7.0	6.9	6.9	6.9	6.9	6.9	6.9

Source: Reference #6, 9, 24, 40, 66, 72

● Activity Data

The activity data for CH₄ 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* (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 melting furnace provided by the *Waste Treatment in Japan*.

Table 7-40 Amount of incineration of MSW by incineration method

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Continuous incinerator	kt /year (wet)	26,215	29,716	32,749	32,246	29,426	28,444	27,603	27,892	28,702	28,246	27,360	27,364	26,961	26,863
Semi-continuous incinerator	kt /year (wet)	4,810	5,455	5,882	4,047	3,339	3,155	2,968	2,932	2,849	2,827	2,524	2,349	2,164	2,157
Batch type incinerator	kt /year (wet)	5,643	4,328	3,131	1,562	1,346	1,144	1,078	1,057	1,061	970	867	842	744	742
Gasification melting furnace	kt /year (wet)	NO	NO	370	2,397	3,122	3,245	3,605	3,857	4,122	4,098	4,161	4,328	4,423	4,407

3) N₂O

● Estimation Method

N₂O emissions from incinerator are estimated by multiplying the amount of MSW (wet basis) by incinerator method by each emission factor. N₂O 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 : N₂O emission from the incineration of MSW [kg-N₂O]

EF_i : Emission factor for incineration method i (or furnace type i) (wet basis) [kg-N₂O /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 CH₄ emissions estimation, for the N₂O emission factors for incinerator by type and by incineration method, different values are used for the period FY2001 and before (Reference #7), and from FY2002 onward (Reference #24), 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*.

➤ *Gasification Melting Furnace*

Different emission factor is used for each furnace type (shaft furnace, fluidized bed, and rotary kiln) (Reference #24). 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*.

Table 7-41 N₂O emission factors by incineration types (MSW)

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Continuous incinerator	g-N ₂ O/t	58.8	58.8	59.1	37.9	37.9	37.9	38.0	38.0	38.0	38.0	38.1	38.1	38.1	38.1
Semi-continuous incinerator	g-N ₂ O/t	56.8	56.8	57.3	71.5	73.3	72.7	73.2	73.1	73.4	73.1	73.5	72.8	72.3	72.3
Batch type incinerator	g-N ₂ O/t	71.4	71.4	74.8	76.0	76.0	76.0	76.2	76.2	76.2	76.2	76.2	76.2	76.2	76.2
Gasification melting furnace	g-N ₂ O/t	NA	NA	16.9	12.0	11.1	11.2	11.5	11.9	11.7	11.7	12.0	12.2	12.5	12.5

Source: Reference #7, 9, 24, 40, 66, 72

● *Activity Data*

The activity data for CH₄ emissions from incinerators and gasification melting furnaces are also applied for the activity data for N₂O emission from them.

c) *Uncertainties and Time-series Consistency*

● *Uncertainties*

The uncertainties in CO₂ emission factors are evaluated by using the 95% confidence interval of carbon content data in plastics. The uncertainties in CH₄ and N₂O 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 7-42 and Table 7-43.

Table 7-42 Uncertainty assessment for municipal solid waste on the category “waste incineration (5.C.1.-)” (CO₂)

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%	-10%	+10%	-10%	+10%	Quoted from “Report on Survey Study on Improving the Accuracy of Emission Factors for Greenhouse Gas Emissions from the Waste Sector, in FY2009”, a source of emission factors.	The uncertainty in municipal waste statistics based on expert judgment is applied.	Combined by using the formula for propagation of errors
Synthetic textile	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 textile.		
Paper/cardboard	CO ₂	-100%	+400%	-10%	+10%	-101%	+400%	It is evaluated by combining the 95% confidence interval in actual measurement data of carbon content with the uncertainty of fossil-derived carbon ratio in 2006GLs as default value.		
Nappy	CO ₂	-23%	+29%	-10%	+10%	-25%	+30%	The uncertainty is evaluated according to the default uncertainty assessment in 2006GLs because the emission factor for this item is the default value in 2006GLs.		

Table 7-43 Uncertainty assessment for municipal solid waste on the category “waste incineration (5.C.1.-)” (CH₄ and N₂O)

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	
		(-)	(+)	(-)	(+)	(-)	(+)				
No corresponding category (CH ₄)	Continuous incineration/Stoker furnace	CH ₄	-39%	+39%	-10%	+10%	-40%	+40%	The uncertainty is quoted from “Report on Survey Study on Improving the Accuracy of Emission Factors for Greenhouse Gas Emissions from the Waste Sector, in FY2009”, a source of emission factors.	The uncertainty based on expert judgment in municipal waste statistics is applied.	Combined by using the formula for propagation of errors
	Continuous incineration/Fluidized bed furnace	CH ₄	-100%	+719%	-10%	+10%	-100%	+719%			
	Semi-continuous incineration/Stoker furnace	CH ₄	-82%	+82%	-10%	+10%	-83%	+83%			
	Semi-continuous incineration / Fluidized bed furnace	CH ₄	-100%	+162%	-10%	+10%	-100%	+162%			
	Batch-type incineration/Stoker furnace	CH ₄	-75%	+75%	-10%	+10%	-76%	+76%			
	Batch-type incineration/Fluidized bed furnace	CH ₄	-100%	+394%	-10%	+10%	-100%	+394%			
	Gasification melting furnace/ Shaft furnace	CH ₄	-100%	+203%	-10%	+10%	-100%	+203%			
	Gasification melting furnace/ Fluidized bed furnace	CH ₄	-100%	+133%	-10%	+10%	-100%	+134%			
	Gasification melting furnace/ Rotary kiln	CH ₄	-54%	+54%	-10%	+10%	-55%	+55%			
No corresponding category (N ₂ O)	Continuous incineration/Stoker furnace	N ₂ O	-34%	+34%	-10%	+10%	-35%	+35%	The uncertainty is quoted from “Report on Survey Study on Improving the Accuracy of Emission Factors for Greenhouse Gas Emissions from the Waste Sector, in FY2009”, a source of emission factors.	The uncertainty based on expert judgment in municipal waste statistics is applied.	Combined by using the formula for propagation of errors
	Continuous incineration/Fluidized bed furnace	N ₂ O	-98%	+98%	-10%	+10%	-99%	+99%			
	Semi-continuous incineration/Stoker furnace	N ₂ O	-82%	+82%	-10%	+10%	-82%	+82%			
	Semi-continuous incineration / Fluidized bed furnace	N ₂ O	-64%	+64%	-10%	+10%	-64%	+64%			
	Batch-type incineration/Stoker furnace	N ₂ O	-100%	+111%	-10%	+10%	-100%	+111%			
	Batch-type incineration/Fluidized bed furnace	N ₂ O	-100%	+133%	-10%	+10%	-100%	+134%			
	Gasification melting furnace/ Shaft furnace	N ₂ O	-45%	+45%	-10%	+10%	-46%	+46%			
	Gasification melting furnace/ Fluidized bed furnace	N ₂ O	-100%	+252%	-10%	+10%	-100%	+252%			
	Gasification melting furnace/ Rotary kiln	N ₂ O	-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 Chapter 1.

e) Category-specific Recalculations

By identifying the additional uses of biomass-based plastic products, CO₂ emissions were recalculated.

By estimating additional biogenic fraction in plastics based on production data of bio-based resin which includes those in recycled plastics, CO₂ emissions were recalculated.

By updating the statistical data, emissions were recalculated. For detail, see the section “7.1.5. General Recalculations for Emissions from Waste Sector”.

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 CO₂, CH₄ and N₂O emissions from incineration of industrial waste without energy recovery by each waste type and the emissions are reported in the corresponding category either “biogenic, industrial solid waste (ISW)”, “biogenic, non-fossil liquid waste”, “biogenic, sludge” “non-biogenic, industrial solid waste” or “non-biogenic, fossil liquid waste” (see Table 7-24).

b) Methodological Issues**1) CO₂****● Estimation Method**

Emissions of fossil-fuel derived CO₂ from this source are calculated by using the volume of waste oil, plastic, 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 textile under the regulation of the Waste Management and Public Cleansing Act, the industrial textiles is regarded as waste natural fiber: thus the CO₂ 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 : CO₂ Emissions from incineration of waste type i [kg-CO₂]

EF_i : Emission factor for incineration of waste type i [kg-CO₂/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 by multiplying the carbon content of each type of waste by the oxidation factor for incineration facilities.

- **Fossil-fuel derived waste oil, plastic**

$$EF_i = CF_i \times OF \times 44/12$$

EF_i : Emission factor for the incineration of waste type i (wet basis) [kg-CO₂/t]

CF_i : Carbon content in waste type i (wet basis) [%]

OF : Oxidation factor [%]

- **Paper/cardboard**

$$EF_i = CF_i \times FCF_i \times OF \times 44/12$$

EF_i : Emission factor for the incineration of fossil-fuel derived components in paper/cardboard (dry basis) [kg-CO₂/t]

CF_i : Carbon content in paper/cardboard (dry basis) [%]

FCF_i : Fossil-fuel derived fraction in carbon in paper/cardboard [%]

OF : Oxidation factor [%]

➤ **Carbon Content**

Carbon content in waste oil is deemed to be 80% based on the factor of 0.8 [t-C/t] given in *the Report on Estimation of CO₂ Emissions in Japan* (Environmental Agency, 1992) (Reference #5). Carbon content in plastic is deemed to be 70% based on the factor of 0.7 [t-C/t] given in the said report.

For the carbon content of paper/cardboard, the carbon content of default value in the *2006 IPCC Guidelines*, as same as the value in municipal solid waste.

Table 7-44 Carbon contents of waste oil, plastic and Paper/cardboard in industrial waste

Item	Carbon contents	Remarks	References
Waste oil	80%	wet basis	Reference #5
Plastics	70%	wet basis	Reference #5
Paper/ cardboard	46 %	dry basis	<i>2006 IPCC Guidelines</i>

➤ **Fossil-fuel derived fraction in carbon in paper/cardboard in industrial waste**

For the fossil-fuel derived fraction in carbon in paper/cardboard in industrial waste, the default value of 1% in the *2006 IPCC Guidelines* are applied as same as for paper/cardboard in municipal solid waste.

➤ **Oxidation factor**

The default value of 100% given in the *2006 IPCC Guidelines* is used.

➤ **Emission factor**

Emission factors calculated by methodologies above are shown in Table 7-45.

Table 7-45 Emission factors for fossil-fuel derived fraction of waste oil, plastics and paper/cardboard in industrial waste

Item	Unit	Emission factor
Waste oil	kg-CO ₂ /t (wet)	2,933
Plastics	kg-CO ₂ /t (wet)	2,567
Paper/cardboard	kg-CO ₂ /t (dry)	17

● Activity Data

For the activity data for CO₂ 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* is used. However, the amount of incineration provided in this report includes the amount of incineration of specially controlled industrial waste which is separately reported under “Incineration of Specially Controlled Industrial Waste” (see the next section), thus it is subtracted from the activity data from this source. Details of methodologies to estimate activity data are shown below.

Activity data for the incineration of waste fossil-fuel derived oil (wet basis)

$$= \text{Amount of waste oil incinerated in industrial waste} \\ \times (1 - \text{Fraction of waste oil from animal and vegetable origin}^*) \\ - \text{Amount of waste oil incinerated in specially controlled industrial waste}^{**}$$

* : From the survey conducted by the Ministry of Environment

** : All the waste oil in specially controlled industrial waste to be estimated for emissions are waste fossil-fuel derived oil.

Table 7-46 Fraction of waste oil from animal and vegetable origin

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
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

Activity data for the incineration of plastics (IW) (wet basis)

$$= (\text{Amount of plastics incinerated in industrial waste} \\ - \text{Amount of plastics incinerated in specially controlled industrial waste}) \\ \times \text{Fossil-fuel derived fraction of plastics}^* (\text{wet basis})$$

*: 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) CO₂”. See also Table 7-35. Note it is assumed that activity data for plastics (IW) incinerated does not include plastic bottles unlike MSW plastics.

Activity data for the incineration of paper/cardboard (IW) (dry basis)

$$= \{ \text{Amount of paper/cardboard incinerated in industrial waste} \\ - (\text{Amount of infectious waste incinerated in specially controlled industrial waste} \\ - \text{Amount of plastic incinerated in specially controlled industrial waste}) \} \\ \times (1 - \text{percentage of waste content in paper or cardboard in industrial waste}^*)$$

*: Percentage of water content in paper/cardboard in industrial waste is given the value 15% (see Table 7-10).

For more detail of activity data estimated, see Table 7-49.

● 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* (Ministry of the Environment).

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 7-47 Percentage of IW incinerated at incineration facilities with energy recovery

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Waste oil ¹⁾	%	0.6	0.7	0.6	2.5	2.0	2.1	4.1	4.1	2.3	4.0	4.2	4.8	4.4	4.4
Plastics	%	1.4	1.4	4.1	6.6	13.7	9.2	13.3	17.8	17.5	13.3	16.7	19.2	18.4	18.4
Wood ²⁾	%	0.2	0.8	1.1	1.5	4.6	4.8	5.9	15.7	13.1	8.5	10.5	10.2	9.7	9.7
Sludge ³⁾	%	0.9	0.8	1.0	1.1	1.5	2.1	2.2	3.0	3.4	8.3	12.5	12.2	12.0	12.0
Other ⁴⁾	%	0.2	0.8	1.1	1.5	1.2	2.5	1.5	2.2	1.8	1.9	2.6	4.2	5.0	5.0

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) CH₄

● Estimation Method

Emissions of methane 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-CH₄]

EF_j : Emission factor for waste type j (wet basis) [kg-CH₄/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

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 - FY2001 (Reference #7) and from FY2002 onward (Reference #24), respectively, different values are used. These emission factors are established based on actual measurement survey. The correction taking into account CH₄ concentrations in the atmosphere is not made to these emission factors. The emission factor for paper/cardboard or wood in the Reference #7 and Reference #24 is substituted for the emission factor for textiles (natural fiber), and animal and vegetable residues/animal carcasses.

Table 7-48 CH₄ emission factors for industrial waste by 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

Source: Reference # 6, 7, 24, 41, 66

● Activity Data

The volume of waste incinerated (wet basis) by waste type is used as the activity data for CH₄ emissions from the incineration of industrial waste.

➤ Paper, 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*. 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*, and the “Volume of Incinerated Sewage Sludge” reported in a survey by the Ministry of Lands, Infrastructure, Transport and Tourism.

➤ Waste Oil (Fossil-fuel derived/Animal and Vegetable) and Plastic

The activity data for waste oil and plastic are provided by the *Cyclical Use of Waste Report*. 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 CO₂ emissions, waste fossil-fuel derived oil and also waste animal and vegetable oil are included for the estimation of activity data from this source. Note activity data for plastic includes biomass-based plastic.

Table 7-49 Incinerated industrial waste by waste types

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Waste fossil-fuel derived oil	kt / year (wet)	1,258	1,498	1,646	1,493	1,283	1,104	1,467	1,410	1,546	1,297	1,420	1,191	1,375	1,356
Waste animal and vegetable oil	kt / year (wet)	40	69	103	115	139	113	121	110	117	103	115	100	113	111
Plastics (fossil-fuel derived)	kt / year (wet)	842	1,794	1,780	1,808	2,118	1,491	1,701	1,508	1,627	1,772	1,585	1,818	1,770	1,765
Biomass-based plastics	kt / year (wet)	NO	NO	NO	NO	NO	NO	1.9	3.0	4.5	5.9	6.0	7.8	6.6	3.5
Paper/cardboard	kt / year (wet)	335	712	718	323	494	299	292	225	349	152	130	114	109	107
Wood	kt / year (wet)	2,679	4,744	3,114	1,865	1,313	1,283	1,101	1,135	1,181	1,388	1,137	1,120	1,062	1,099
Textiles (natural fiber)	kt / year (wet)	31	49	50	43	33	26	24	26	24	35	39	27	36	38
Animal and vegetable residues/animal carcasses	kt / year (wet)	77	125	272	167	220	181	190	184	153	151	153	168	154	158
Sewage sludge	kt / year (wet)	3,060	3,827	4,300	4,988	4,792	4,731	4,694	4,734	4,817	4,934	4,753	4,550	4,452	4,684
Sludge other than sewage sludge	kt / year (wet)	1,972	2,023	2,071	2,288	2,082	2,106	2,010	2,020	1,713	1,954	2,021	1,880	1,884	1,705

3) N₂O

● Estimation Method

Emissions of N₂O 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-N₂O]

EF_j : Emission factor for waste type j (wet basis) [kg-N₂O /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 N₂O emissions from sewage sludge incineration are determined by taking a weighted average of actually measured emission factors for N₂O at each incineration facility based on the survey on the volume of sewage sludge incinerated at the facilities conducted by the Ministry of Land, Infrastructure, Transport and Tourism. 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 7-50 (Reference #7).

Table 7-50 N₂O emission factors for sewage sludge incineration (wet basis)

Type of flocculant	Type of incinerator	Combustion Temperature	Emission factor ¹⁾ [g-N ₂ O/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
Other	—	—	—
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

Source: Reference #25, 43, 44, 45, 45, 73, 74, 80, 81

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-FY2001 (Reference #7) and from FY2002 onward (Reference #24), respectively, different values are used. These emission factors are established based on actual measurement survey. The correction taking into account CH₄ 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 Reference #7 and Reference #24.

Table 7-51 N₂O Emission factors for industrial waste by type (wet basis)

Item	Unit	FY1990-2001	From FY2002 onward
Waste oil (fossil-fuel derived/animal and vegetable)	g-N ₂ O /t	12	62
Plastics	g-N ₂ O /t	180	15
Paper/cardboard	g-N ₂ O /t	21	77
Wood	g-N ₂ O /t	21	77
Textiles (natural fiber)	g-N ₂ O /t	21	77
Animal and vegetable residues/animal carcasses	g-N ₂ O /t	21	77
Sludge (excluding sewage sludge)	g-N ₂ O /t	457	99

Source: Reference #6, 24, 41, 66, 73, 78, 79, 80, 81, 86, 87

- **Activity Data**

- **Sewage Sludge**

Data in the “volume of incinerated sewage sludge, by flocculants and by incinerator types” reported in a survey by the Ministry of Lands, Infrastructure, Transport and Tourism are used as activity data (wet basis).

Table 7-52 Amount of sewage sludge incinerated

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
High-molecular-weight flocculant/fluidized bed incinerator (normal temp.)	kt / year (wet)	1,112	1,869	2,397	2,839	1,785	1,664	1,535	1,532	1,552	1,549	1,318	1,695	1,218	1,531
High-molecular-weight flocculant/fluidized bed incinerator (high temp.)	kt / year (wet)	128	219	723	1,469	2,470	2,508	2,581	2,587	2,641	2,644	2,644	2,283	2,665	2,503
High-molecular-weight flocculant/multiple hearth	kt / year (wet)	560	656	572	102	56	64	61	52	43	40	0	0	0	0
Lime sludge	kt / year (wet)	1,010	663	272	289	193	142	109	83	74	22	1	1	1	1
Other	kt / year (wet)	55	161	175	8	1	1	1	3	0.5	12	70	27	27	27
- Multiple hearth air injection/blowing incineration method fluidized bed incinerator, - Two-stage incineration method circulating fluidized bed incinerator, - Stoker furnace	kt / year (wet)	195	259	161	280	233	282	338	439	444	565	604	411	412	465
Carbonization furnace for solid fuel production	kt / year (wet)	NO	NO	NO	NO	55	71	70	39	63	103	116	133	128	156

- **Industrial Waste other than Sewage Sludge**

Activity data (wet basis) is determined in the same manner as for the CH₄ 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 CO₂ emission factors are evaluated by using the 95% confidence interval of carbon content data in fossil fuel-based waste. The uncertainties in CH₄ and N₂O 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 7-53.

Table 7-53 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, the uncertainty in municipal waste plastics is substituted based on expert judgment. The uncertainty is quoted from “Report on Survey Study on Improving the Accuracy of Emission Factors for Greenhouse Gas Emissions from the Waste Sector, in FY2009”, a source of emission factors.	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%			
	N ₂ O	-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, the uncertainty in municipal waste plastics is substituted based on expert judgment. The uncertainties are quoted from “Report on Survey Study on Improving the Accuracy of Emission Factors for Greenhouse Gas Emissions from the Waste Sector, in FY2009”, a source of emission factors.		Combined by using the formula for propagation of errors
	CH ₄	-100%	+216%	-30%	+30%	-104%	+218%			
	N ₂ O	-44%	+44%	-30%	+30%	-53%	+53%			
Paper/card board	CO ₂	-100%	+400%	-30%	+30%	-104%	+401%	It is evaluated by combining the 95% confidence interval in actual measurement data of carbon content with the uncertainty of fossil-derived carbon ratio in 2006GLs as default value.		Combined by using the formula for propagation of errors
Paper/card board or wood	CH ₄	-100%	+412%	-30%	+30%	-104%	+413%	The uncertainty is quoted from “Report on Survey Study on Improving the Accuracy of Emission Factors for Greenhouse Gas Emissions from the Waste Sector, in FY2009”, a source of emission factors.		Combined by using the formula for propagation of errors
	N ₂ O	-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 ₂ O	-84%	+84%	-30%	+30%	-89%	+89%			
Textiles	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/card board or wood is substituted based on expert judgment.		Combined by using the formula for propagation of errors
	N ₂ O	-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 ₂ O	-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 Chapter 1.

e) Category-specific Recalculations

By identifying the additional uses of biomass-based plastic products, CO₂ emissions were recalculated.

By updating the percentages of incinerated industrial waste with energy recovery, emissions to be allocated to waste sector for and after FY2007 were recalculated.

By updating the statistical data, emissions were recalculated. For detail, see the section “7.1.5. General Recalculations for Emissions from Waste Sector”.

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 7-54.

Table 7-54 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 plastic	Plastic
Infectious waste (except plastic)	Glasses, Textile, Paper

In this category, CO₂, CH₄, and N₂O emissions from incineration of specially-controlled industrial waste are estimated by each waste type and reported in the corresponding category either “Non-biogenic, Hazardous waste”, Non-biogenic, Clinical waste” or “Biogenic, Clinical waste” (see Table 7-24).

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) CO₂

● *Estimation Method*

Emissions of CO₂ 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 by multiplying the carbon content of the item by the oxidation factor for incineration facilities.

$$EF = CF \times OF \times (1 - w) \times 44/12$$

<i>EF</i>	: Emission factor for the incineration of specified hazardous industrial waste oil [kg-CO ₂ /t]
<i>CF</i>	: Carbon content in specified hazardous industrial waste oil (dry basis) [%]
<i>OF</i>	: Oxidation factor [%]
<i>w</i>	: 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 X for incinerated substances based on the “report on the survey for the estimation of GHG emissions from specially-controlled industrial waste, Ministry of the environment” (FY2009 and FY2010). 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 7-55 CO₂ Emission factors for incineration 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* 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* 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.

$$A_{\text{flammable oil}} = A_{S\text{-IW oil}} - A_{s\text{-hazardous oil}}$$

- $A_{\text{flammable oil}}$: Amount of flammable waste oil incinerated (wet basis) [t]
 $A_{S\text{-IW oil}}$: 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 waste*, Ministry of the environment and Residual fraction of incinerated waste oil from the *Cyclical Use of Waste Report*.

$$A_{s\text{-hazardous oil}} = R_{s\text{-hazardous oil}} \times (1 + r)$$

- $A_{s\text{-hazardous oil}}$: 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* and Percentage of plastic content in infectious waste from *Waste Handbook* (reference #56). All of Infectious plastics are considered to be fossil-fuel derived.

$$A_{\text{infectious plastics}} = A_{\text{infectious total}} \times C_{\text{infectious plastic s}}$$

- $A_{\text{infectious plastics}}$: Amount of Infectious plastics incinerated (wet basis) [t]
 $A_{\text{infectious total}}$: Total amount of infectious waste incinerated (wet basis) [t]
 $C_{\text{infectious plastics}}$: Percentage of plastic content in infectious waste [%]

2) CH₄

● Estimation Method

Emissions of CH₄ 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 CO₂ emission.

- Specified hazardous industrial waste oil

Activity data is the same as those used for CO₂ emission.

- **Infectious plastics**

Activity data is the same as those used for CO₂ emission.

- **Infectious waste except plastics**

The activity data is obtained from similar equation to Infectious plastics, as follows.

$$A_{\text{infectious exc. plastics}} = A_{\text{infectious total}} \times (1 - C_{\text{infectious plastics}})$$

$A_{\text{infectious exc. plastics}}$: Amount of Infectious waste except plastics incinerated (wet basis) [t]

$A_{\text{infectious total}}$: Total amount of infectious waste incinerated (wet basis) [t]

$C_{\text{infectious plastics}}$: Percentage of plastic content in infectious waste [%]

3) N₂O

● **Estimation Method**

Emissions of N₂O 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 N₂O 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 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 CH₄ emissions is used.

Table 7-56 Amount of incineration of specially controlled industrial waste

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Flammable waste oil	kt (wet)	238	353	520	478	868	629	390	278	267	271	266	236	254	243
Specified hazardous industrial waste oil	kt (wet)	18	27	40	37	35	38	41	43	25	54	122	145	152	152
Infectious waste (plastic)	kt (wet)	78	128	167	169	131	143	154	176	131	133	176	166	160	161
Infectious waste (except plastics)	kt (wet)	105	172	225	228	91	99	106	121	90	92	121	114	110	111

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 7-57.

Table 7-57 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 ₂ O	-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 Chapter 1.

e) Category-specific Recalculations

By updating the statistical data on the amount of specially-controlled waste, emissions were recalculated. For detail, see the section “7.1.5. General Recalculations for Emissions from Waste Sector”.

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 CO₂, CH₄ and N₂O 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) CO₂

● Estimation Method

CO₂ 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 by multiplying the carbon content of industrial waste plastics by the oxidation factor for open burning.

$$EF = CF \times OF \times 44/12$$

EF : Emission factor for the open burning of industrial waste plastics (wet basis) [kg-CO₂/t]
CF : Carbon content in industrial waste plastics (wet basis) [%]
OF : Oxidation factor [%]

Table 7-58 CO₂ emission factors and relevant parameters of open burning of industrial waste plastics

Item	Value	Reference	Note
<i>EF</i>	1,489 [kg-CO ₂ /t (wet)]	-	Country-specific
<i>CF</i>	70 %	Reference #5	See also "7.4.1.2. Industrial Waste (5.C.1.-)".
<i>OF</i>	58 %	<i>2006 IPCC Guidelines</i>	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, Ministry of the Environment" 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 7-59 The amount of fossil-fuel derived industrial waste burned in the open air (wet basis)

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Plastics	kt/year (wet)	3.4	3.4	0.9	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.02	0.02	0.02

2) CH₄, N₂O

● Estimation Method

Emissions of CH₄ and N₂O 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 7-60 CH₄ and N₂O emission factors for open burning of industrial waste

Gas	EFs	Unit	Reference
CH ₄	6.5	kg-CH ₄ /t (wet)	2006 IPCC Guidelines
N ₂ O	0.15	kg-N ₂ O/t (dry)	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, Ministry of the Environment” is used as the activity data for CH₄ emission estimates. As for the activity data for N₂O 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 7-61 The amount of industrial waste burned in the open air

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Total wet weight amount	kt /year (wet)	72.2	72.2	28.9	3.5	1.7	1.7	1.3	1.1	0.9	1.3	0.6	1.0	1.0	1.0
Total dry weight amount	kt /year (dry)	62.4	62.4	25.5	3.1	1.6	1.5	1.1	1.0	0.8	1.2	0.5	0.8	0.8	0.8

c) Uncertainties and Time-series Consistency

● Uncertainties

Details of the uncertainty assessment on this category are indicated in Table 7-62.

Table 7-62 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 IPCC default emission factors.		
	N ₂ O	-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 Chapter 1.

e) Category-specific Recalculations

CO₂, CH₄ and N₂O emissions from open burning of waste were newly estimated. 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, CO₂, CH₄, and N₂O 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” and/or “Biomass” as shown on the Table 7-25.

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) CO₂**● Estimation Method****➤ Municipal Solid Waste**

$$E = EF \times A \times R$$

E : Emission of CO₂ from waste incineration [kg-CO₂]

EF : Emission factor for incineration (dry basis) [kg-CO₂/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 CO₂ from waste incineration [kg-CO₂]

EF : Emission factor for waste incineration (wet basis) [kg-CO₂/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) CH₄, N₂O**● Estimation Method****➤ Municipal Solid Waste**

$$E = \sum_i (EF_i \times A_i) \times R$$

- E : Emissions of CH₄ or N₂O from incineration of municipal solid waste [kg-CH₄], [kg-N₂O]
 EF_i : Emission factor for municipal solid waste incinerator type i (wet basis) [kg-CH₄/t] [kg-N₂O/t]
 A_i : 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**

$$E = \sum_j (EF_j \times A_j \times R_j)$$

- E : Emissions of CH₄ or N₂O from incineration of industrial waste [kg-CH₄] [kg-N₂O]
 EF_j : Emission factor for industrial waste type j (wet basis) [kg-CH₄/t], [kg-N₂O/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 CRF 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]
 A_j : Amount of industrial waste type j incinerated [kg (wet basis)]
 GCV_j : 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 7-67 (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 Chapter 1.

e) Category-specific Recalculations

Same recalculations as the category waste incineration (without energy recovery) were conducted. For detail, 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, CO₂, CH₄, and N₂O emissions from waste directly used as alternative fuel are estimated and reported. The reporting category for the emissions for each type of waste is, 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.)”. The fuel types are classified as “Other fossil fuels” and/or “Biomass” as indicated in Table 7-25.

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 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/Fuel Use” in this section.

b) Methodological Issues**1) CO₂**● **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. The remaining emission sources used the emission factors for “7.4.1. Waste Incineration (without Energy Recovery) (5.C.1.)”.

Table 7-63 CO₂ Emission factors specially defined for this category

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
MSW-coke oven	kg-CO ₂ /t(dry)	1,434	1,434	1,434	1,434	1,434	1,434	1,434	1,434	1,434	1,434	1,434	1,434	1,434	1,434
Waste tire	kg-CO ₂ /t(dry)	1,867	1,794	1,799	1,746	1,734	1,738	1,759	1,744	1,743	1,744	1,736	1,698	1,677	1,673

● **Activity Data**

For details of the amount of waste used as raw materials or fuels, see the 7.4.3.2.a - 7.4.3.2.c.

Table 7-64 Amount of direct use of waste as alternative fuel (wet basis)

Waste type	Application breakdown	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
MSW	Plastics	Liquefaction	kt (wet)	NO	NO	3	7	3	7	1	NO	NO	NO	NO	NO	NO	
		Blast furnace reducing agent	kt (wet)	NO	NO	25	37	17	28	27	26	26	30	27	31	29	28
		Coke oven chemical feedstock	kt (wet)	NO	NO	11	175	142	150	177	169	171	NO	17	29	25	32
		Gasification	kt (wet)	NO	NO	1	59	47	45	53	51	62	58	51	55	55	57
Industrial waste	Waste oil	(Unclassified)	kt (wet)	1,243	1,461	1,452	1,848	1,709	1,620	1,701	1,686	1,764	1,707	1,633	1,786	1,664	1,656
	Plastics	Blast furnace reducing agent	kt (wet)	NO	NO	57	160	74	97	134	114	134	107	149	144	156	168
		Chemical industry	kt (wet)	5	4	5	2	2	1	1	1	1	1	0.4	0.4	0.2	3.0
		Paper industry	kt (wet)	NO	NO	3	3	16	17	18	16	15	14	18	16	17	18
		Cement burning	kt (wet)	NO	9	102	302	435	457	445	469	479	518	595	576	623	643
		Automobile manufacture	kt (wet)	16	10	8	4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
		Liquefaction	kt (wet)	NO	NO	1	1	3	1	1	1	1	1	1	1	1	0
	Gasification	kt (wet)	NO	NO	NO	11	39	92	117	78	79	97	90	81	79	0	
	Wood	(Unclassified)	kt (wet)	1,635	1,635	2,061	2,683	3,724	3,918	3,900	4,065	4,151	4,425	4,878	4,628	4,555	4,737
	Waste tire	Cement burning	kt (wet)	111	275	361	181	141	112	95	77	66	62	53	59	63	70
Boiler		kt (wet)	119	126	75	12	12	9	8	6	6	6	2	2	5	3	
Iron manufacture		kt (wet)	NO	NO	57	51	39	28	30	31	30	27	27	20	19	17	
Gasification		kt (wet)	NO	NO	NO	27	48	48	49	45	45	44	50	49	51	58	
Metal refining		kt (wet)	67	37	30	10	2	1	1	1	NO	NO	NO	NO	NO	NO	
Tire manufacture		kt (wet)	NO	32	39	24	19	18	23	20	27	27	22	23	23	21	
Paper manufacture		kt (wet)	NO	26	42	210	339	349	388	377	363	372	415	439	407	436	
Power generation		kt (wet)	NO	NO	7	9	24	11	9	32	37	40	46	51	58	47	
Refuse-derived fuel (RDF)	(Unclassified)	kt (wet)	34	39	148	415	386	376	380	389	384	386	388	361	360	360	
Refuse paper and plastic fuel (RPF)	Petroleum product manufacturer	kt (wet)	NO	NO	0.4	5	3	3	4	3	4	3	4	4	3	4	
	Chemical industry	kt (wet)	NO	NO	7	15	22	25	22	26	27	26	20	22	19	18	
	Paper industry	kt (wet)	NO	8	25	465	733	753	747	783	820	869	852	872	948	960	
	Cement manufacturer	kt (wet)	NO	NO	0.2	8	16	21	15	16	14	16	17	14	11	13	

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 CO₂ emissions.
- For the activity data to estimate CO₂ 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) CH₄, N₂O

● Estimation Method

Emissions are estimated by multiplying the amount of each type of waste used as raw material or fuel by the country-specific emission factor.

● Emission Factor

Emission factors for waste used as raw material and 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 7-65 shows the data used in the estimation.

Calculation of emission factor (wet basis)

$$= (\text{Emission factor for each type of furnace [kg-CH}_4\text{/TJ], [kg-N}_2\text{O/TJ]}) \\ \times (\text{Calorific value of each waste type [MJ/kg]} / 1000)$$

Table 7-65 Data used for the calculation of CH₄ and N₂O 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 ₂ O	
MSW	Plastics	Liquefaction	Boilers (Heavy fuel oil A, gas oil, kerosene, naphtha, other liquid fuels)		Calorific value of plastic
		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, gas 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 plastic
		Paper industry			
		Automobile manufacturer	Other industrial furnaces (solid fuel)		
		Cement burning	Boilers (Heavy fuel oil A, gas oil, kerosene, naphtha, other liquid fuels)		
		Liquefaction	NA		NA
	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	Other industrial furnaces (solid fuel)				
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 ⁴⁾	
	Chemical industry				
	Paper industry	Other industrial furnaces (solid fuel)			
	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 the Waste Handbook (1997).
- 2) Source: 1997 General Survey of Emissions of Air Pollutants
- 3) The percentage of substances recovered during the gasification of waste tires. A weighted average is calculated using the proportions of gas and oil (22% and 43%) reported in the Hyogo Eco-town documents.
- 4) Weighted average of calorific values calculated based on the manufacturing ratio of Coal substitution RPF and Coke substitution RPF given by the Japan RPF Industry Association

Table 7-66 CH₄ and N₂O 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 ₂ O Emission factor [kg-N ₂ O/TJ]
Boilers (Heavy fuel oil A, gas 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 (gas fuel)	2.3	1.2

Note: Emission factors are from Chapter 3, Energy.

Table 7-67 Calorific Value of waste incinerated and used as raw material or fuel

Item	Unit	GCV	Source of calorific value	
Waste oil (including reclaimed oil)	TJ/l	40.2	Reference #37; estimated with 0.9[kg/L] from Reference #65	
Plastics	MJ/kg	29.3	Reference #37	
Paper/cardboard	MJ/kg	15.1	Reference #65 (dry basis); value is obtained by subtracting water content	
Wood	MJ/kg	14.4	Reference #37	
Textiles	MJ/kg	17.9	Reference #65 (dry basis) ; value is obtained by subtracting water content	
Food waste (Animal and vegetable residues/animal carcasses)	MJ/kg	4.4	Reference #65 (dry basis) ; value is obtained by subtracting water content	
Sludge (including sewage sludge)	MJ/kg	4.7	Reference #37 (dry basis) ; value is obtained by subtracting water content	
Waste tire	2004 and before	MJ/kg	20.9	Reference #37
	2005 and later	MJ/kg	33.2	Reference #37
RDF	MJ/kg	18.0	Reference #37	
RPF	MJ/kg	29.3	Reference #37	

● Activity Data

➤ Amount of Waste Used as Raw Material or Fuel

Activity data are determined for each category using the wet-basis values (Table 7-64). For more details, see each section.

➤ Activity Data Converted into Energy Units (Reference Value)

Activity data converted into energy units to be reported in CRF are calculated as indicated below.

Activity data converted into energy units

$$= (\text{Amount of waste used as raw material or fuel [kg (wet basis)]}) \\ \times (\text{Corresponding calorific value of waste [MJ/kg]} / 10^6)$$

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.

b) Methodological Issues

1) CO₂

● 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 CO₂ 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).

Calculation of the emission factor for plastics used as raw material in coke ovens (dry basis)

= (Emission factor for the incineration of plastics in municipal solid waste)
 × [1 – (Fraction of carbon in plastics used as chemical raw material for coke ovens that migrates to hydrocarbon)]

● 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) CO₂". Note that only fossil-fuel derived fraction of "plastics other than plastic bottles in MSW" are applied for this category since this category does not include emissions from plastic bottles incineration.

Amount of fossil-fuel derived plastics used as raw material or fuel by usage (dry basis)

= Amount of plastics used as raw material or fuel by usage (wet basis)
 × (1 – Water content in plastics)
 × Fossil-fuel derived fraction of plastics other than plastic bottles in MSW

➤ 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)* compiled by the Japan Containers and Packaging Recycling Association. Usage in products that do not emit CO₂ 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.

Amount of plastics in MSW collected by municipalities and processed into raw material or fuel
= (Amount of all plastics that are commercially recycled under the Plastic Containers and Packaging Recycling Law (wet basis)¹

— Amount of plastics (wet basis) that is commercially recycled through designated legal bodies)²

×Percentage of commercially recycled plastics by recycling method³

×Percentage of commercially recycled plastic products by recycling method⁴ (The percentage for designated legal bodies is substituted for the value for municipalities.)

¹: Amount of plastics commercially recycled under the Plastic Containers and Packaging Recycling Law (wet basis)

The results of the selective collections by municipalities and commercial recycling under the Plastic Containers and Packaging Recycling Law are determined from Annual Recycling Statistics by the Environmental Regeneration and Material Cycles Bureau of the Ministry of the Environment.

²: Amount of plastics commercially recycled through designated legal body channels (wet basis)

The amount is determined from the “Actual Collection of Plastic Containers and Packages” section of the Statistics of Commercial Recycling of Plastics (Recycling).

³: Percentage of commercially recycled plastics by recycling method

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: Percentage of commercially recycled plastic products by recycling method

The values for the commercial recycling of the plastics collected through the municipal channels are substituted for the percentage of commercially recycled plastic products collected through designated legal body channels. The percentages are calculated by dividing the amounts of commercially recycled plastic products by various recycling methods, which are established in the activity data for recycling through designated legal body channels, by the amount of commercially recycled plastics. The amount of commercially recycled plastics by each of the recycling methods is calculated by multiplying the amount of plastics commercially recycled through designated legal body channels, by the percentage of commercially recycled plastics by recycling method obtained from the Assessment and Deliberation of the Plastic Containers and Packaging Recycling Law, the Japan Containers and Packaging Recycling Association.

➤ ***Water Content Ratio***

Water content ratio of 4% is determined based on the data provided by the *Japan Containers and Packaging Recycling Association*.

➤ **Fossil-fuel Derived Fraction of Plastics other than plastic bottles in MSW**

See Table 7-35 in the section “7.4.1.1. Municipal Solid Waste (5.C.1.-).”

2) CH₄, N₂O

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 7-68.

Table 7-68 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	-2%	+2%	-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 ₂ O	-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 Chapter 1.

e) Category-specific Recalculations

By identifying the additional uses of biomass-based plastic products, CO₂ emissions 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 greenhouse gas emissions from industrial waste (plastics, waste oil, and wood) used as raw material or fuels.

b) Methodological Issues

1) CO₂

● *Estimation Method and Emission Factor*

Emissions are estimated by multiplying the amount of fossil-fuel derived plastics incinerated used as raw material or fuel and waste fossil-fuel derived oil used as raw material or fuels by emission factor used for incineration of industrial waste.

● *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 the Ministry of the environment, distinguished between plastics liquefaction and gasification. The fossil-fuel derived fraction in industrial waste plastics is estimated in the same way as indicated in “7.4.1.2. Industrial Waste (5.C.1.-) 7.4.1.2. b)1) CO₂”.

➤ *Waste Oil (Fossil-fuel derived)*

The activity data for waste oil is mainly obtained from the *Cyclical Use of Waste Report*. The valuables, which are not included in the *Cyclical Use of Waste Report*, 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 CO₂ 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) CO₂”. 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) CH₄, N₂O● **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 CO₂ emission estimates from this source is also used for CH₄ and N₂O emission estimates. Note plastics as blast furnace reducing agent and plastics gasified are not included in the activity data (see also Table 7-26).

➤ **Waste Oil (Fossil-fuel derived / Animal and Vegetable)**

The activity data used for CO₂ emission estimates from this source is also used for CH₄ and N₂O emission estimates. Unlike the activity data for CO₂ 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*. 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 7-69.

Table 7-69 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 ₂ O	-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 ₂ O	-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 ₂ O	-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 Chapter 1.

e) Category-specific Recalculations

By identifying the additional uses of biomass-based plastic products, CO₂ emissions were recalculated.

By updating the statistical data, emissions were recalculated. For detail, see the section “7.1.5. General Recalculations for Emissions from Waste Sector”

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) CO₂**● **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*.

Calculation of emission factor for the incineration of waste tires (dry basis)

$$= (\text{Fossil fuel-derived carbon content in waste tires}) \\ \times (\text{Oxidation factor of waste tires}) \times 1000 \times 44 / 12$$

● **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 reported in *the Basic Waste Data Fact Book (2000)* published by Japan Environmental Sanitation Center from the amount of waste tires used as raw material or fuel (wet basis) in the *Tire Industry of Japan*, published by the Japan Automobile Tire Manufacturers Association, Inc.

2) CH₄, N₂O

● *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 CO₂ emissions from this source is used. For the activity data, the volume of waste tires recorded in the following categories are used: “Cement kilns” for use in cement kilns; “Medium to small boilers”, “Use by tire factories”, “Use by paper manufacturers”, 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 7-70.

Table 7-70 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 ₂ O	-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 Chapter 1.

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, CO₂, CH₄, and N₂O 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 7-26. The fuel types are classified as “Other fossil fuels” and/or “Biomass” as indicated in Table 7-25.

b) Methodological Issues

1) CO₂

● 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} : CO₂ Emissions from RDF use [kg-CO₂]

EF_{RDF} : Emission factor for RDF use (dry basis) [kg-CO₂/t]

AD_{RDF} : Activity data for RDF use (dry basis) [t]

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

E_{RPF} : CO₂ Emissions from RPF use [kg-CO₂]

EF_{RPF} : Emission factor for RPF use (dry basis) [kg-CO₂/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

Emission factor for RDF use is estimated by multiplying the fraction of plastic-derived content contained in RDF (dry basis) by the fraction of carbon content contained in plastic by, the combustion rate of RDF at RDF combustion facilities by fossil-fuel derived fraction of plastic in RDF.

$$EF_{RDF} = 1000 \times P_{RDF} \times C \times OF_{RDF} \times 44/12 \times FPF_{RDF}$$

$$= 1000 \times 0.296 \times 0.751 \times 1.0 \times 44/12 \times FPF_{RDF}$$

$$= 816 \text{ [kg-CO}_2\text{/t]} \times FPF_{RDF}$$

P_{RDF} : Fraction of plastic-derived content contained in RDF (dry basis)

C : Fraction of carbon content contained in plastic (dry basis)

OF_{RDF} : Oxidation factor of RDF at RDF combustion facilities

FPF_{RDF} : Fossil-fuel derived fraction of plastic in RDF

- **Fraction of Plastic-derived Content Contained in RDF (Dry basis)(P_{RDF})**
 Fraction of plastic-derived content contained in RDF in dry basis is converted from that in wet basis. Fraction of plastic-derived content contained in RDF in wet basis (24.7%) is estimated based on the *Proper Management of Refuse-derived Fuels compiled by the Study Group for Proper Management of RDF*. It is converted into the value in dry basis with the fraction of water content of MSW (20%) applied in “7.2.1. Managed Disposal Sites (5.A.1.)” as well as “7.4.1.2. Industrial Waste (5.C.1.-), CO₂”.
- **Fraction of Carbon Content Contained in Plastic (Dry basis)(C)**
 Due to the fact that most of plastic contained in RDF is considered to be municipal solid waste-derived, the average fraction of carbon content used in “7.4.1.1. Municipal Solid Waste (5.C.1.-)” as shown in Table 7-29 is applied for the fraction of carbon content contained in plastic (dry basis).
- **Oxidation factor for RDF at RDF Combustion Facilities (OF_{RDF})**
 As applied in “7.4.1.1. Municipal Solid Waste (5.C.1.-), CO₂”, the default value provided in the 2006 IPCC Guidelines (100%) is also applied for the oxidation factor for RDF at RDF combustion facilities.
- **Fossil-fuel derived fraction of plastic in RDF (FPF_{RDF})**
 Due to the fact that most of plastic contained in RDF is considered to be municipal solid waste-derived, the same values in “7.4.1.1. Municipal Solid Waste (5.C.1.-)” are applied. Note it is assumed that plastic in RDF consist of similar composition (plastic bottles/plastics other than plastic bottles) in municipal solid waste plastics incinerated.

➤ **RPF**

Because the quality of RPF is categorized into “coal-equivalent product” and “coke-equivalent product”(see Reference #64), 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

$$\begin{aligned} EF_{RPF,coal} &= 1000 \times P_{RPF,coal} \times C \times OF_{RPF} \times 44/12 \times FPF_{RPF} \\ &= 1000 \times 0.528 \times 0.737 \times 1.0 \times 44/12 \times FPF_{RPF} \\ &= 1426 \text{ [kg-CO}_2\text{/t]} \times FPF_{RPF} \end{aligned}$$

Coke-equivalent product

$$\begin{aligned} EF_{RPF,coke} &= 1000 \times P_{RPF,coke} \times C \times OF_{RPF} \times 44 /12 \times FPF_{RPF} \\ &= 1000 \times 0.910 \times 0.737 \times 1.0 \times 44/12 \times FPF_{RPF} \\ &= 2457 \text{ [kg-CO}_2\text{/t]} \times FPF_{RPF} \end{aligned}$$

$EF_{RPF,coal}$: Emission factor for the use of coal-equivalent product RPF (dry basis) [kg-CO₂/t]

$EF_{RPF,coke}$: Emission factor for the use of coke-equivalent product RPF (dry basis) [kg-CO₂/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

FPF_{RPF} : Fossil-fuel derived fraction of plastic in RPF

- **Fraction of Waste Plastic-derived Content Contained in RPF (Dry basis) ($P_{RPF,coal/coke}$)**

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.

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 (see Reference #78), 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.-), CO₂” (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**

The same values for industrial waste plastic 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.

$$\begin{aligned} EF_{RPF,av} &= EF_{RPF,coal} \times P_{coal} + EF_{RPF,coke} \times P_{coke} \\ &= (1426 \times FPF_{RPF}) \times 0.797 + (2445 \times FPF_{RPF}) \times 0.203 \\ &= 1636 \text{ [kg-CO}_2\text{/t]} \times FPF_{RPF} \end{aligned}$$

$EF_{RPF,av}$: Emission factor for RPF use (Weighted Average) (dry basis) [kg-CO₂/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)

Table 7-71 CO₂ emission factors for the emissions from the use of refused-derived fuel (RDF) or refuse paper & plastic fuel (RPF)

Item	Emission Factor [kg-CO ₂ /t (dry)]
RDF	816
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 (*FPF*).

- **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.

$$A_{RDF} = a_{RDF} \times SC_{RDF}$$

A_{RDF} : Activity data for RDF use (dry basis)

a_{RDF} : Amount for RDF production at RDF production facilities (wet basis) [t]

SC_{RDF} : Fraction of dry matter content of RDF (estimated by (1 – fraction of water content of RDF))

- **RPF**

The amounts of RPF used in chemical industry, paper industry, cement manufacturer, and petroleum product manufacturer are estimated (See also Table 7-64). 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) CH₄, N₂O

- **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 (I.A.)”.

- **Activity Data**

- **RDF**

The entire amount of RDF production (wet basis) used for CO₂ emission estimates is also used for the amount of use of RDF for boiler.

- **RPF**

Out of the amount of RPF used for CO₂ emission estimates, the amounts of RPF used in chemical industry, paper industry, and petroleum products manufacturer are applied to the amount of RPF used for boiler (wet basis). The amount of RPF used in cement industry is applied to the amount of RPF 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 CRF is calculated as indicated below.

Activity data converted into energy units

$$= (\text{Amount of RDF \& RPF consumed [kg (wet)]}) \\ \times (\text{calorific value of corresponding fuel [MJ/kg]}) / 10^6$$

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 7-72.

Table 7-72 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	-2%	+2%	-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 ₂ O	-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 ₂ O	-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 Chapter 1.

e) Category-specific Recalculations

By updating the statistical data including emissions were recalculated.

By identifying the additional uses of biomass-based plastic products, CO₂ emissions 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 CH₄ and N₂O emissions from wastewater handling are reported under the category “Wastewater Treatment and Discharge (5.D.)”. The target categories are shown in Table 7-73. 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 7-73 Categories overview for wastewater treatment and discharge (5.D.)

Category	Wastewater type			Treatment type		CH ₄	N ₂ O			
5.D.1. (7.5.1)	Domestic wastewater	In treatment systems	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 <i>Johkasou</i>) (7.5.1.2)	Community plant		○	○	
						<i>Johkasou</i>	Current type	Advanced type	○	○
							Old type	Standard type	○	○
				Vault toilet		○	○			
				Collected human waste	Human waste and <i>Johkasou</i> sludge (from domestic sewage treatment plants) (7.5.1.3)	Human-waste treatment plants (7.5.1.3)	High-load denitrification treatment		○	○
							Membrane separation		○	○
		Anaerobic treatment					○	○		
		Aerobic treatment		○	○					
		Standard denitrification treatment		○	○					
		Other		○	○					
		Into public waters	Wastewater	Untreated wastewater	Natural decomposition of domestic wastewater (7.5.1.4)	Discharge of untreated wastewater	From old type <i>Johkasou</i>	○	○	
Treated wastewater	From vault toilet			○			○			
	From on-site treatment			○			○			
Sludge	Human waste and <i>Johkasou</i> sludge Sewage sludge		Ocean dumping of sludge ¹⁾	(From domestic sewage treatment plants)		○	○			
				(From sewage treatment plants)		○	○			
5.D.2. (7.5.2)	Industrial wastewater	In treatment systems	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			○	○			
		Into public waters	Wastewater	Untreated wastewater	Natural decomposition of Industrial wastewater (7.5.2.2)	Discharge of untreated wastewater	(from industrial plants/facilities)	○	○	
Treated wastewater	Discharge of treated wastewater			(from industrial wastewater treatment plants)			NA	○		
				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.

Estimated greenhouse gas emissions from wastewater handling are shown in Table 7-74. In FY2017, emissions from this source category are 3,708 kt-CO₂ eq. and accounted for 0.3% of the national total emissions (excluding LULUCF). The emissions from this source category decreased by 30.4%

compared to those in FY1990. This emission decrease is the result of decrease in the amount of CH₄ 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 N₂O emissions from the subcategory of “Sewage Treatment Plants (5.D.1.-)” for FY1995 through FY1998 increased.

Table 7-74 GHG emissions from wastewater treatment and discharge (5.D.)

Gas	Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017		
CH ₄	5.D.1. Domestic wastewater	Sewage treatment plant	kt-CH ₄	8.6	9.9	11.1	12.1	12.4	12.7	12.7	12.1	12.5	12.6	12.4	12.6	12.6		
		Domestic sewage treatment plant	kt-CH ₄	30.4	35.0	38.8	36.4	35.6	34.8	34.6	34.3	34.0	33.6	33.2	32.9	32.6	32.6	
		Human-waste treatment plant	kt-CH ₄	5.2	3.2	1.8	1.0	0.7	0.7	0.6	0.5	0.5	0.5	0.5	0.4	0.4	0.4	
		Natural decomposition of domestic wastewater	kt-CH ₄	61.7	50.8	39.5	28.7	23.9	22.4	21.1	20.0	19.3	18.1	17.2	16.4	15.8	15.7	
	5.D.2. Industrial wastewater	Industrial wastewater treatment	kt-CH ₄	2.2	2.2	2.1	1.9	1.9	1.9	1.8	1.7	1.7	1.6	1.7	1.7	1.7	1.7	
		Natural decomposition of industrial wastewater	kt-CH ₄	8.2	7.8	7.9	8.3	6.4	4.9	4.9	4.8	4.5	4.1	4.3	4.6	4.1	3.7	
		Landfill leachate treatment	kt-CH ₄	1.2	1.2	1.1	0.8	0.6	0.4	0.4	0.3	0.4	0.3	0.3	0.2	0.2	0.2	
	Total		kt-CH ₄	117.7	110.0	102.2	89.2	81.5	77.6	76.0	74.4	72.4	70.8	69.7	68.6	67.4	66.9	
			kt-CO ₂ eq.	2,942	2,750	2,556	2,230	2,038	1,940	1,899	1,859	1,811	1,771	1,743	1,714	1,685	1,673	
	N ₂ O	5.D.1. Domestic wastewater	Sewage treatment plant	kt-N ₂ O	1.39	1.55	1.58	1.67	1.69	1.70	1.67	1.67	1.55	1.59	1.59	1.55	1.55	1.55
Domestic sewage treatment plant			kt-N ₂ O	1.52	1.65	1.70	1.72	1.72	1.69	1.69	1.69	1.69	1.68	1.66	1.66	1.65	1.65	
Human-waste treatment plant			kt-N ₂ O	0.22	0.26	0.12	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01
Natural decomposition of domestic wastewater			kt-N ₂ O	2.79	2.72	2.49	2.24	2.09	2.02	2.04	2.06	1.97	2.01	1.94	1.95	1.93	1.93	
5.D.2. Industrial wastewater		Industrial wastewater treatment	kt-N ₂ O	1.00	0.96	0.81	1.10	1.19	1.02	1.09	1.12	1.16	1.15	1.13	1.13	1.13	1.13	
		Natural decomposition of industrial wastewater	kt-N ₂ O	1.06	1.02	1.02	0.97	0.79	0.67	0.66	0.65	0.62	0.59	0.56	0.54	0.55	0.55	
		Landfill leachate treatment	kt-N ₂ O	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	0.00	0.01
Total		kt-N ₂ O	8.01	8.18	7.72	7.74	7.50	7.13	7.19	7.22	7.00	7.03	6.90	6.84	6.82	6.83		
		kt-CO ₂ eq.	2,387	2,439	2,301	2,308	2,236	2,123	2,142	2,150	2,087	2,096	2,056	2,037	2,033	2,034		
Total		kt-CO ₂ eq.	5,329	5,189	4,857	4,538	4,274	4,063	4,041	4,010	3,898	3,867	3,799	3,751	3,717	3,708		

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 greenhouse gas emissions from these sources are reported under “Domestic and Commercial Wastewater (5.D.1.)”. Because the CH₄ and N₂O 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. As indicated in “Waste Treatment in Japan” (the Ministry of the Environment) public sewerage system is spreading from large cities to smaller municipalities and used by 74.3% of the population at the end of FY2016.

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 FY2016, *Johkasou* is used by 20.0% of the population, with the remainder being treated after collection or on-site.

“NA” is reported on the CRF table for activity data instead of reporting the amount of organic carbon based on BOD values because the activity data for this source are estimated using a country-specific method by each gas and each wastewater treatment facility.

7.5.1.1. Sewage Treatment Plant (5.D.1.-)

a) Category Description

This category covers CH₄ and N₂O emissions from treatment of wastewater at sewage treatment plants.

b) Methodological Issues

● Estimation Method

Emissions of CH₄ and N₂O 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 CH₄ or N₂O emitted from sewage treatment plants in conjunction with domestic/commercial wastewater treatment [kg-CH₄], [kg-N₂O]

EF : Emission factor [kg-CH₄/m³], [kg-N₂O/m³]

A : Yearly amount of sewage treated at a sewage treatment plant [m³]

● Emission Factors

1) CH₄

Emission factors are established by adding the simple averages for each treatment process, having taken the actual volume of CH₄ released from sludge treatment and water treatment processes measured at sewage treatment plants from research studies conducted in Japan (Refer to Reference #7).

$$\begin{aligned} EF_{CH_4} &= EF_{WWTT} + EF_{SSTT} \\ &= 8.8 \times 10^{-4} \text{ [kg-CH}_4\text{/m}^3\text{]} \end{aligned}$$

EF_{CH_4} : CH₄ Emission factor

EF_{WWTT} : Average of emission factor for wastewater treatment processes (528.7 [mg-CH₄/m³])

EF_{SSTT} : Average of emission factor for sludge treatment processes (348.0 [mg-CH₄/m³])

2) N₂O

Emission factors are established on the basis of measured values of N₂O volume emitted from wastewater and sludge treatment processes at sewage treatment plants which is obtained from research studies conducted in the country. Since the research studies revealed that the amount of N₂O emission varies according to the type of wastewater treatment process at sewage treatment plants, the N₂O emission factor for each wastewater treatment type is developed based on the latest findings in the country (Reference #25).

$$EF_{N_2O} = EF_{WWTTi} + EF_{SSTT}$$

EF_{N_2O} : N₂O Emission factor

EF_{WWTTi} : Emission factor for wastewater treatment process i (Table 7-75)

EF_{SSTT} : Average of emission factor for sludge treatment process (0.6 [mg-N₂O/m³])

Table 7-75 N₂O Emission factor by wastewater treatment process at sewage treatment plant

Wastewater treatment process	N ₂ O EF for wastewater treatment process [mg-N ₂ O/m ³]	N ₂ O EF for sludge treatment process [mg-N ₂ O/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.

● Activity Data

Activity data for N₂O emissions by wastewater treatment process at sewage treatment plants are provided by the Ministry of Land, Infrastructure, Transport and Tourism. Total amount of wastewater treated used for N₂O emission estimates are also used for the activity data for CH₄ emission estimates.

Table 7-76 Activity data for wastewater treated at sewage treatment plant

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Standard activated sludge process	10 ⁶ m ³	9,761	10,780	10,686	11,405	11,508	11,552	11,358	11,288	10,485	10,736	10,699	10,401	10,394	10,394
Anaerobic-aerobic activated sludge process	10 ⁶ m ³	73	446	1,523	1,039	809	868	909	909	953	931	938	933	962	962
Anaerobic-anoxic-oxic process and recycled nitrification; denitrification process	10 ⁶ m ³	23	89	487	1,374	1,858	2,049	2,181	2,308	2,355	2,629	2,684	2,819	3,033	3,033
Recycled nitrification-denitrification membrane bioreactor	10 ⁶ m ³	NO	NO	NO	0.1	1	1	2	20	20	15	0.1	0.2	5	5
Total	10 ⁶ m ³	38,920	29,409	20,358	13,920	11,301	10,671	9,984	9,348	8,849	8,242	7,727	7,197	6,871	6,871

c) Uncertainties and Time-series Consistency

● Uncertainties

The uncertainties in emission factors for CH₄ and N₂O 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 7-77.

Table 7-77 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 “FY2006, Review of Greenhouse Gases Emissions Estimation Methods, Vol. 4 waste sector”.	The uncertainty in sewage statistics based on expert judgment is used.	Combined by using the formula for propagation of errors
	N ₂ O	-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 Chapter 1.

e) Category-specific Recalculations

By updating the statistical data including emissions for FY2016 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

7.5.1.2. Domestic Sewage Treatment 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 7-78 Type of sewage and sewage treatment

Plant type		Description		Sewage type	
Community plants		Small-scale wastewater treatment facility regionally established		Human waste and miscellaneous wastewater	
<i>Johkasou</i>	Current type	Advanced type	Wastewater treatment unit installed at an individual household	Advanced type introduced under the amended Building Standards Act in effect FY2001	Human waste and miscellaneous wastewater
		Standard type			
	Old type	Wastewater treatment unit installed at an individual household		Human waste	
Vaults toilet		Installed at an individual household		Human waste	

This category covers CH₄ and N₂O 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 CH₄ and N₂O 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-CH₄], [kg-N₂O]

EF_i : Emission factor for domestic sewage treatment plant i [kg-CH₄/person], [kg-N₂O/person]

A_i : Population (persons) requiring waste processing at domestic sewage treatment plant i per year

● Emission Factors

CH₄ and N₂O emission factors for this source are determined as shown on the Table 7-79:

Table 7-79 Emission factors for CH₄ and N₂O from domestic wastewater treatment systems

CH ₄ emission factors (Unit: kg-CH ₄ /person-year)						
Plant type		FY1990 ~1995	FY1996 ~2001	FY2002~ 2004	FY2005 ~	Source
Community plant ¹⁾		0.195	Interpolation		0.062	1990-1995: Tanaka (1998) (Reference #85) 2005-: Ike and Soda (2010) (Reference #70)
Current type <i>Johkasou</i>	Advanced type ²⁾	NA		1.514		MoE (2012) (Reference #27), and MoE (2013) (Reference #28)
	Standard type ³⁾	2.477				
Old type <i>Johkasou</i> ³⁾		0.46				
Vault toilet ³⁾		0.062				
N ₂ O emission factors (Unit: kg-N ₂ O/person-year)						
Plant type		FY1990 ~1995	FY1996 ~2001	FY2002~ 2004	FY2005 ~	Source
Community plant ¹⁾		0.0394	Interpolation		0.0048	1990-1995: Tanaka et al. (1995) ⁴⁾ (Reference #83) 2005-: Ike and Soda (2010) (Reference #70)
Current type <i>Johkasou</i>	Advanced type ²⁾	NA		0.0889		MoE (2012) (Reference #27), and MoE (2013) (Reference #28)
	Standard type ³⁾	0.0717				
Old type <i>Johkasou</i> 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 in FY2002, the next year of when the technical guidelines for *Johkasou* of the Building Standards Act were 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* is used as the activity data for CH₄ and N₂O emitted in association with domestic sewage treatment plants. Activity data for current type *Johkasou* are classified as advanced type and standard type by using installation share derived from installation number of each type, which can be assumed as a share of annual treatment population, shown in the *Survey of guidance promotion of Johkasou* (Ministry of the environment).

Table 7-80 Annual treatment population by type of domestic sewage treatment plant (1,000 persons)

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Community plant	1000 person	493	398	414	552	416	297	293	286	289	304	302	294	286	286
Current advanced type <i>Johkasou</i>	1000 person	NO	NO	NO	4,801	6,799	7,110	7,611	8,092	8,406	8,795	9,105	9,316	9,527	9,527
Current standard type <i>Johkasou</i>	1000 person	6,274	8,515	10,806	7,991	7,055	6,682	6,471	6,184	5,935	5,697	5,459	5,284	5,103	5,103
Old type <i>Johkasou</i>	1000 person	26,828	26,105	23,289	18,303	15,413	14,712	13,948	13,316	13,052	12,383	11,822	11,415	11,018	11,018
Vault toilet	1000 person	38,920	29,409	20,358	13,920	11,301	10,671	9,984	9,348	8,849	8,242	7,727	7,197	6,871	6,871
Total	1000 person	72,515	64,427	54,867	45,567	40,984	39,472	38,307	37,226	36,531	35,421	34,415	33,506	32,805	32,805

c) Uncertainties and Time-series Consistency

● Uncertainties

The uncertainties in emission factors for CH₄ and N₂O 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 CH₄ and N₂O 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 7-81.

Table 7-81 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 <i>Johkasou</i> is substituted). Quoted from “Report in FY2012, Survey and Studies for the Development of Emission Factor for the Decentralized Commercial Wastewater Treatment for the National Greenhouse Gas Inventory”	The uncertainty in municipal waste statistics based on expert judgment is used.	Combined by using the formula for propagation of errors
	N ₂ O	-45%	+45%	-10%	+10%	-46%	+46%			
Current type <i>Johkasou</i>	CH ₄	-32%	+32%	-10%	+10%	-33%	+33%			Combined by using the formula for propagation of errors
	N ₂ O	-45%	+45%	-10%	+10%	-46%	+46%			
Old type <i>Johkasou</i>	CH ₄	-84%	+84%	-10%	+10%	-84%	+84%			Combined by using the formula for propagation of errors
	N ₂ O	-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 ₂ O	-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 Chapter 1.

e) Category-specific Recalculations

By classifying emission factors for current type *Johkasou* as advanced type and standard type, CH₄ and N₂O emission from this source from FY2002 onward were recalculated.

By correcting annual treatment population of current and old type *Johkasou*, CH₄ and N₂O emission from this source for FY1990 were recalculated.

By updating the statistical data including emissions for FY2016 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 CH₄ and N₂O emissions from treatment of vault toilet human waste and *Johkasou* sludge collected at human waste treatment plants.

b) Methodological Issues

1) CH₄

● Estimation Method

Emissions of CH₄ 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-CH₄]

EF_i : Emission factor for human waste treatment plants (for treatment process i) [kg-CH₄/m³]

A_i : Input volume of human waste and *Johkasou* sludge at human waste treatment plants (for treatment process i) [m³]

● Emission Factors

Emission factors for CH₄ 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 (Refer to Reference #7).

Table 7-82 CH₄ emission factors by each treatment process

Treatment method	CH ₄ Emission factor [kg-CH ₄ /m ³]	Data source
Anaerobic treatment	0.543	Estimated by multiplying the actual methane emissions given in Reference #49 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	Reference #83
High load de-nitrification treatment	0.005	Reference #83
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 CH₄ 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 7-85), 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* (Table 7-83) by the capacity of each treatment process (Table 7-84).

Activity data for human waste treatment method i

= (Total amount of human waste and *Johkasou* sludge by treatment method i)

× (Capacity of waste treatment method i) / (Total capacity of all waste treatment methods)

Table 7-83 Volume of human waste and *Johkasou* sludge treated at their treatment plants

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Human waste from vault toilet	1000 kl/year	20,406	18,049	14,673	10,400	8,894	8,353	7,917	7,365	7,018	6,771	6,375	6,153	5,890	5,890
<i>Johkasou</i> sludge	1000 kl/year	9,224	11,545	13,234	13,790	14,064	13,989	13,760	13,547	13,519	13,726	13,562	13,537	13,648	13,648
Total	1000 kl/year	29,630	29,594	27,907	24,190	22,958	22,342	21,677	20,912	20,537	20,497	19,937	19,690	19,538	19,538

Table 7-84 Trends in treatment capacity by treatment process

Unit	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Anaerobic treatment	kl/day	34,580	19,869	10,996	6,476	4,444	4,144	3,891	3,265	3,159	3,059	2,779	2,245	2,155	2,155
Aerobic treatment	kl/day	26,654	19,716	12,166	8,465	7,535	6,961	6,753	6,200	6,469	6,001	5,899	5,979	5,600	5,600
Standard denitrification	kl/day	25,196	30,157	31,908	29,655	27,737	27,748	26,173	25,694	25,608	25,153	24,663	24,023	22,812	22,812
High-intensity denitrification	kl/day	8,158	13,817	16,498	17,493	14,938	16,285	16,104	15,778	15,030	14,529	14,336	13,831	13,651	13,651
Membrane separation	kl/day	NO	1,616	2,375	3,055	3,650	3,573	3,684	3,684	4,062	4,074	2,204	3,373	3,184	3,184
Other	kl/day	13,777	20,028	25,917	30,277	35,441	34,654	34,577	34,622	33,556	33,975	34,983	33,940	36,074	36,074

Table 7-85 Activity Data for human waste by treatment types

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Anaerobic treatment	1000 kl/year	9,455	5,589	3,073	1,642	1,088	992	925	765	738	722	653	530	504	504
Aerobic treatment	1000 kl/year	7,288	5,546	3,400	2,146	1,845	1,666	1,605	1,453	1,512	1,417	1,386	1,412	1,311	1,311
Standard denitrification	1000 kl/year	6,889	8,483	8,917	7,518	6,793	6,640	6,222	6,021	5,984	5,940	5,794	5,672	5,339	5,339
High-intensity denitrification	1000 kl/year	2,231	3,887	4,611	4,435	3,658	3,897	3,828	3,697	3,512	3,431	3,368	3,266	3,195	3,195
Membrane separation	1000 kl/year	NO	455	664	774	894	855	876	863	949	962	518	796	745	745
Other	1000 kl/year	3,767	5,634	7,243	7,676	8,679	8,293	8,220	8,113	7,841	8,024	8,219	8,014	8,443	8,443
Total	1000 kl/year	29,630	29,594	27,907	24,190	22,958	22,342	21,677	20,912	20,537	20,497	19,937	19,690	19,538	19,538

2) N₂O

● Estimation Method

Emissions of N₂O 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-N₂O]

EF_i : Emission factor for human waste treatment plants (by treatment process i) [kg-N₂O/kg-N]

A_i : Amount of nitrous oxide in human waste and *Johkasou* sludge input at human waste treatment plants (treatment process i) [kg-N]

● Emission Factors

The emission factors for N₂O are determined for each treatment process including high-load denitrification treatment and membrane separation systems using the results of actual case studies in Japan (Refer to Reference #7).

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 7-86 Nitrous oxide emission factors by each treatment process

Treatment method	N ₂ O emission factors [kg-N ₂ O-N/kg-N]		
	FY1990-1994	FY1995-2002	From FY2003
High load de-nitrification treatment	0.033 ¹⁾	Calculated by interpolation using the values of FY1994 and FY2003	0.0029 ²⁾
Membrane separation	0.033 ¹⁾	Calculated by interpolation using the values of FY1994 and FY2003	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 Reference #84
- 2) Use median value of actual measurements at 13 plants given in Reference #76
- 3) Referred to Reference #83 (Calculated by dividing upper limit value for standard de-nitrification treatment (1.0×10^{-5} kg-N₂O/m³) 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*. 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.

Activity data

$$= [(\text{Input volume of human waste at human waste treatment plants}) \times (\text{Nitrogen concentration in human waste}) + (\text{Input volume of Johkasou sludge at human waste treatment plants}) \times (\text{Nitrogen concentration in Johkasou sludge})] \times (\text{percentage throughput of treatment process } i)$$

➤ **Input Volume of Human Waste and Johkasou sludge at Human Waste Treatment Plants:**

See the data used for the calculation of CH₄ emissions from human waste treatment plants (Table 7-83).

➤ **Percentage Throughput of the Human Waste Treatment Processes:**

See the data used for the calculation of CH₄ emission from human waste treatment plants (Table 7-84).

➤ **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 - FY1991, FY1992 - FY1994, FY1995 - FY1997, and FY1998 - FY2000, 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 7-87).

Table 7-87 Concentration of nitrogen contained in collected human waste and *Johkasou* sludge

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
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
<i>Johkasou</i> sludge	mg-N/l	1,060	300	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	1,401	1,373	1,354	1,327	1,304	1,280	1,258	1,242	1,219	1,219

Table 7-88 Activity data: Amount of nitrogen in human waste and *Johkasou* sludge processed at human waste treatment plants

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Anaerobic treatment	kt-N	28.8	11.2	5.2	2.4	1.5	1.4	1.3	1.0	1.0	0.9	0.8	0.7	0.6	0.6
Aerobic treatment	kt-N	22.2	11.1	5.8	3.2	2.6	2.3	2.2	1.9	2.0	1.8	1.7	1.8	1.6	1.6
Standard denitrification	kt-N	21.0	17.0	15.1	11.2	9.5	9.1	8.4	8.0	7.8	7.6	7.3	7.0	6.5	6.5
High-intensity denitrification	kt-N	6.8	7.8	7.8	6.6	5.1	5.3	5.2	4.9	4.6	4.4	4.2	4.1	3.9	3.9
Membrane separation	kt-N	NO	0.9	1.1	1.2	1.3	1.2	1.2	1.1	1.2	1.2	0.7	1.0	0.9	0.9
Other	kt-N	11.5	11.3	12.3	11.4	12.2	11.4	11.1	10.8	10.2	10.3	10.3	10.0	10.3	10.3
Total	kt-N	90.2	59.4	47.3	36.1	32.2	30.7	29.4	27.7	26.8	26.2	25.1	24.5	23.8	23.8

c) Uncertainties and Time-series Consistency

● Uncertainties

As for the uncertainties in emission factors for CH₄ and N₂O 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 7-89.

Table 7-89 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 <i>Johkasou</i> is substituted).	The uncertainty in municipal waste statistics based on expert judgment is used.	Combined by using the formula for propagation of errors
	N ₂ O	-87%	+87%	-10%	+10%	-88%	+88%			

● Time-series Consistency

For N₂O emission factor, consistent data over the time series are constructed based on the actual measurement data by using the methods described in Table 7-86. 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 Chapter 1.

e) Category-specific Recalculations

By updating the statistical data including emissions for FY2016 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

7.5.1.4. Natural Decomposition of Domestic Wastewater (5.D.1.-)

a) Category Description

Although most of the 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 CH₄ and N₂O emissions from untreated wastewater and sludge decomposing in public waters and the N₂O from treated wastewater are reported under this category.

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 CH₄ are zero. Accordingly, CH₄ 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 N₂O 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-CH₄], [kg-N₂O]

EF : Emission factor [kg-CH₄/kg-BOD], [kg-N₂O/kg-N]

A : Volume 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 CH₄ is established by multiplying the maximum CH₄ generation potential (B_0) by a CH₄ conversion factor (MCF). The maximum CH₄ generation potential is set to 0.6 kg-CH₄/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”.

$$\begin{aligned} EF_{CH_4} &= B_0 \times MCF \\ &= 0.6 \text{ [kg-CH}_4\text{/kg-BOD]} \times 0.1 \\ &= 0.06 \text{ [kg-CH}_4\text{/kg-BOD]} \end{aligned}$$

The emission factor for N₂O is calculated from the value of 0.005 kg N₂O-N/kg N after conversion of the units.

$$\begin{aligned} EF_{N_2O} &= 0.005 \text{ [kg-N}_2\text{O-N/kg-N]} \times 44/28 \\ &= 0.0079 \text{ [kg-N}_2\text{O/kg-N]} \end{aligned}$$

● Activity Data

Activity data to be calculated are the following sources:

➤ Untreated wastewater

- 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**

- Treated wastewater from sewage treatment plants
- Treated wastewater from community plants and current advanced/standard type *Johkasou*
- Treated wastewater from old type *Johkasou*, which is derived from human waste
- Treated wastewater from treatment of human waste/*Johkasou* sludge in human waste treatment plants

➤ **Sludge**

- Human waste and *Johkasou* sludge dumped into the ocean
- Sewage sludge dumped into the ocean

Definition for each activity data is provided as in Table 7-90. Estimated activity data are shown in Table 7-91.

Table 7-90 Calculation method for activity data used for the calculation of GHG emissions from the natural decomposition of domestic wastewater

Wastewater type		Methane emission activity data	Nitrous oxide emission activity data
Untreated wastewater	From old type <i>Johkasou</i>	User population ²⁾ [persons] × Unit BOD from untreated miscellaneous wastewater ⁶⁾ [g-BOD/person-day]	User population ²⁾ [persons] × Unit nitrogen from untreated miscellaneous wastewater ⁶⁾ [g-N/person-day]
	From Vault toilet		
	From On-site disposal *	Population using on-site disposal system ²⁾ [person] × Unit BOD from untreated miscellaneous wastewater ⁶⁾ [g-BOD/person-day]	Population using on-site disposal system ²⁾ [person] × Unit nitrogen from untreated miscellaneous wastewater ⁶⁾ [g-N/person-day]
Treated wastewater		-	Sum of the following items: <Sewage treatment plants (calculated for each individual plant)> Amount of treated wastewater ¹⁾ [m ³] × Nitrogen concentration in treated wastewater ¹⁾ [mg-N/l] < Community plants, <i>Johkasou</i> (current advanced/ current standard/old type) > User population ²⁾ [persons] × Unit nitrogen from domestic wastewater ³⁾ [g-N/person-day] × (1-Fraction of nitrogen removal ⁴⁾ [%]) <Human waste treatment plant> Amount of human waste and <i>Johkasou</i> sludge treated ²⁾ [m ³] × Nitrogen concentration in treated ⁵⁾ wastewater from plants [mg-N/l]
Sludge	Human waste, <i>Johkasou</i> sludge (Ocean dumping)	{ Human waste dumped in ocean ²⁾ [kl] × BOD concentration in human waste ⁷⁾ [mg-BOD/l]} + { <i>Johkasou</i> sludge dumped in ocean ²⁾ [kl] × BOD concentration in <i>Johkasou</i> sludge ⁷⁾ [mg-BOD/l]}	{ Human waste dumped in ocean ²⁾ [kl] × nitrogen concentration in <i>Johkasou</i> sludge ⁷⁾ [mg-N/l]} + { <i>Johkasou</i> sludge dumped in ocean ²⁾ [kl] × nitrogen concentration in <i>Johkasou</i> sludge ⁷⁾ [mg-N/l]}
	Sewage sludge (Ocean dumping)	Sewage sludge dumped in ocean ¹⁾ [kl] × BOD concentration in sewage sludge ⁸⁾ [mg-BOD/l]	Sewage sludge dumped in ocean ¹⁾ [kl] × nitrogen concentration in sewage sludge ⁸⁾ [mg-N/l]

Source:

- 1) Reference #58
- 2) Reference #9

- 3) Reference #18
- 4) Reference #50 and expert judgement
- 5) Estimated based on Reference #75 and Reference #9
- 6) Reference #60
- 7) Reference #75
- 8) Expert judgement based on Reference #75

Note:

* A portion of the human waste in on-site disposal systems is utilized as fertilizer on farmlands in Japan. The nitrous oxide emission from this portion of human waste is already included in the “Direct soil emission (3.D.1.)” category in the Agriculture section, and therefore, not included in the calculation for this source.

Table 7-91 Activity data: Amount of organic material and nitrogen in untreated domestic wastewater and discharged into public water zone

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Organic mater in:															
Untreated wastewater (from old type <i>Johkasou</i>)	kt-BOD	1,006	832	648	474	399	373	351	333	322	302	287	273	263	262
Untreated wastewater (from Vault toilet)	kt-BOD	392	381	341	267	226	215	204	194	191	181	173	167	161	161
Untreated wastewater (from On-site disposal)	kt-BOD	568	429	298	203	165	156	146	136	130	120	113	105	101	100
Human waste, <i>Johkasou</i> sludge (Ocean dumping)	kt-BOD	22	14	9	4	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
Total	kt-BOD	1,989	1,656	1,297	948	790	743	701	663	643	604	572	544	525	523
Nitrogen in:															
Untreated wastewater (from old type <i>Johkasou</i>)	kt-N	1.4	1.1	0.7	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3
Untreated wastewater (from Vault toilet)	kt-N	50	42	32	24	20	19	18	17	16	15	14	14	13	13
Untreated wastewater (from on-site disposal)	kt-N	355	346	316	285	266	257	260	263	250	256	247	248	246	246
Treated wastewater	kt-N	20	19	17	13	11	11	10	10	10	9	9	8	8	8
Human waste, <i>Johkasou</i> sludge (Ocean dumping)	kt-N	7.2	3.2	2.2	0.8	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
Total	kt-N	433.3	411.0	368.8	323.2	297.6	286.7	288.3	289.3	276.4	280.6	270.0	270.0	267.7	267.5

c) Uncertainties and Time-series Consistency

● Uncertainties

As for the uncertainties in emission factors for CH₄ and N₂O 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 7-92.

Table 7-92 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 2006 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 ₂ O	-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 Chapter 1.

e) Category-specific Recalculations

By classifying the fraction of nitrogen removal of current type *Johkasou* as advanced type and standard type, N₂O emission from treated wastewater from FY2002 onward were recalculated.

By correcting annual treatment population of current and old type *Johkasou*, N₂O emission from treated wastewater for FY1990 were recalculated.

By updating the statistical data including emissions for FY2016 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.)

CH₄ and N₂O 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.-)”, CH₄ and N₂O 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 CH₄ and N₂O 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

CH₄ and N₂O 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), CH₄ and N₂O 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, CH₄ 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 CH₄ emission factor per unit BOD that is based on Japan’s country-specific wastewater handling. Because CH₄ 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, CH₄ emissions are calculated using BOD in Japan. With regard to N₂O emissions, no estimation methodologies are given in the *2006 IPCC Guidelines*. Therefore, in the same manner for estimating CH₄ emissions, N₂O emissions are estimated by multiplying the amount of nitrogen in industrial wastewater by Japan's country-specific N₂O emission factor.

$$E = EF \times A$$

Where:

- E* : Amount of CH₄ or N₂O emissions generated when treating industrial wastewater [kg-CH₄], [kg-N₂O]
EF : Emission factor [kg-CH₄/kg-BOD], [kg-N₂O/kg-N]
A : Amount of BOD or nitrogen in industrial wastewater [kg-BOD], [kg-N]

● Emission Factor

Country-specific emission factors obtained from an actual measurement of the *Survey for the Development of Emission Factor to Estimate Effect of the Mitigation Measures for GHG Emissions from the Waste Sector*, Ministry of the Environment (Reference #30) are adopted (Reference #26).

Table 7-93 Emission Factors for industrial wastewater treatment facilities

Category of Manufacturing	CH ₄ Emission factor [g-CH ₄ /kg-BOD]	N ₂ O Emission factor [g-N ₂ O/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, CH₄ emissions generated by anaerobic wastewater treatment are entirely recovered. For a small amount of CH₄ 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 CH₄ emission differs from that for the use of default value for the CH₄ emissions generated from anaerobic treatment defined in the *2006 IPCC Guidelines*.

● Activity Data

The activity data for CH₄ 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 7-94). The amount of organic matter is obtained by sorting and aggregating by industry type according to the middle industrial classification provided by the Guidelines and Explanation of Sewage Facility Design (Japan Sewage Works Association, 2001).

The use of COD concentrations is required to report activity data on CRF; however, activity data are reported as "NE" because country-specific methodology is used for this source.

CH₄ Activity data

$$= \sum [(Amount\ of\ industrial\ wastewater\ flowing\ into\ wastewater\ treatment\ facilities) \\ \times (Percentage\ of\ industrial\ wastewater\ treated\ at\ treatment\ facilities\ emitting\ CH_4) \\ \times (Percentage\ of\ industrial\ wastewater\ treated\ on-site) \\ \times (BOD\ concentration\ of\ runoff\ water)]$$

The activity data for N₂O 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 CH₄ emissions.

N₂O Activity data

$$= \Sigma [(Amount\ of\ industrial\ wastewater\ flowing\ into\ wastewater\ treatment\ facilities) \\ \times (Percentage\ of\ industrial\ wastewater\ treated\ at\ treatment\ facilities\ emitting\ N_2O) \\ \times (Percentage\ of\ industrial\ wastewater\ treated\ on-site) \\ \times (Nitrogen\ concentration\ of\ runoff\ water)]$$

➤ **Amount of Industrial Wastewater Inflow 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* (Ministry of Economy, Trade and Industry) are used for the amount of industrial wastewater treated at wastewater treatment facilities.

➤ **Percentage of Industrial Wastewater Treated at Facilities Generating CH₄**

Emissions of CH₄ 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, Ministry of the Environment).

➤ **Percentage of Industrial Wastewater Treated at Facilities Generating N₂O**

Emissions of N₂O 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 CH₄ is also used for N₂O 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 the *Guidelines and Analysis of Comprehensive Planning Surveys for the Provision of Water Mains, by Catchment Area 1999 Edition* (Japan Sewage Works Association) 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 7-94 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 7-95 BOD load [kt-BOD] and TN load [kt-N] of industrial wastewater

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
BOD load															
Manufacture of food	kt-BOD	297.8	326.2	306.8	289.4	313.0	305.7	311.7	299.8	288.0	307.2	348.4	348.4	348.4	348.4
Manufacture of beverages, tobacco and feed	kt-BOD	88.7	100.5	92.0	71.5	63.2	62.6	58.0	56.9	55.7	52.8	62.0	62.0	62.0	62.0
Manufacture of textile products	kt-BOD	98.1	94.2	65.5	47.7	45.1	40.2	40.1	42.8	45.4	38.2	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	415.5	401.0	365.4	353.1	340.9	321.4	324.0	324.0	324.0	324.0
Manufacture of chemical and allied product	kt-BOD	110.2	95.3	103.0	160.1	160.1	151.8	162.9	157.1	151.3	154.2	146.1	146.1	146.1	146.1
Manufacture of petroleum and coal products	kt-BOD	0.3	0.3	0.3	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3
Manufacture of plastic products	kt-BOD	6.2	5.9	6.2	6.9	6.8	7.8	6.9	7.1	7.4	7.1	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
Manufacture of leather tanning, leather products and fur skins	kt-BOD	1.3	1.1	0.8	0.5	0.3	0.3	0.4	0.4	0.3	0.3	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	1.8	1.8	1.7	1.7	1.6	1.4	1.4	1.4	1.4
TN load															
Manufacture of food	kt-N	15.5	16.9	16.3	15.0	15.5	15.1	16.0	15.3	14.6	15.8	17.4	17.4	17.4	17.4
Manufacture of beverages, tobacco and feed	kt-N	3.8	4.2	4.3	3.9	2.9	2.7	2.6	2.5	2.4	2.8	3.3	3.3	3.3	3.3
Manufacture of textile products	kt-N	10.8	10.5	7.4	5.2	5.0	4.5	4.4	4.8	5.3	4.3	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	16.3	20.2	14.4	13.8	13.2	11.8	12.0	12.0	12.0	12.0
Manufacture of chemical and allied product	kt-N	40.0	38.8	30.1	48.5	53.9	47.3	50.8	50.7	50.6	50.8	49.8	49.8	49.8	49.8
Manufacture of petroleum and coal products	kt-N	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Manufacture of plastic products	kt-N	0.2	0.2	0.3	0.4	0.3	0.4	0.4	0.4	0.5	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	0.03	0.03	0.03	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Manufacture of iron and steel	kt-N	57.7	53.9	55.5	54.7	56.4	42.3	45.6	53.4	61.2	58.9	57.5	57.5	57.5	57.5

c) Uncertainties and Time-series Consistency

● Uncertainties

The uncertainty in emission factors are evaluated according to the survey for EFs (Reference #30). 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 7-96.

Table 7-96 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 (Reference #30.)	The uncertainty in industrial waste statistics based on expert judgment is used.	Combined by using the formula for propagation of errors
	N ₂ O	-95%	+95%	-30%	+30%	-100%	+100%			

● **Time-series Consistency**

Data on the percentage of industrial wastewater treated at CH₄- and N₂O-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 Chapter 1.

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 CH₄ and N₂O emissions from untreated wastewater decomposing in public waters and the N₂O from treated wastewater are reported under this category.

b) Methodological Issues

● **Estimation Method**

CH₄ and N₂O 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-CH₄], [kg-N₂O]
EF : Emission factor [kg-CH₄/kg-BOD], [kg-N₂O/kg-N]
A : Volume of organic matter [kg-BOD] or nitrogen [kg-N] in industrial wastewater

● **Emission Factor**

As for CH₄ and N₂O 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 7-97 CH₄ and N₂O 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 ₂ O	kg-N ₂ O/ kg-N	0.0079	2006 IPCC Guidelines

● **Activity Data**

Activity data for this category cover 10 middle industrial classification shown on the Table 7-94 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 “Comprehensive Survey on Water Pollutant Discharge, Ministry of the Environment”.

$$A = \sum (V_i \times Q_i)$$

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* [m³]

Q_i : BOD or TN concentration of untreated industrial wastewater discharged from industrial plant/facility *i* [g-BOD/L], [g-N/L]

Table 7-98 BOD and TN loadings in untreated wastewater discharged into public waters (Activity data)

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
BOD load															
Manufacture of food	kt-BOD	8.0	8.5	9.0	16.3	7.3	6.0	6.2	6.3	5.3	4.3	4.6	5.0	5.3	5.5
Manufacture of beverages, tobacco and feed	kt-BOD	0.6	0.6	0.6	0.6	0.5	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.3	0.4
Manufacture of textile products	kt-BOD	3.4	2.9	2.2	2.2	6.0	4.4	4.4	4.5	4.8	5.1	3.8	2.5	2.9	3.3
Manufacture of pulp, paper and paper products	kt-BOD	9.4	8.9	8.9	8.4	8.8	3.7	3.6	3.6	5.3	6.9	5.2	3.4	3.7	4.1
Manufacture of chemical and allied product	kt-BOD	49.5	50.6	44.9	46.7	41.6	28.2	28.3	28.4	25.9	23.4	25.3	27.2	24.0	20.8
Manufacture of petroleum and coal products	kt-BOD	25.4	20.8	24.6	26.9	13.3	12.3	11.3	10.2	9.3	8.5	9.8	11.2	10.2	9.1
Manufacture of plastic products	kt-BOD	0.6	0.6	0.6	0.8	0.8	0.7	0.7	0.7	0.6	0.5	0.6	0.6	0.4	0.1
Manufacture of rubber products	kt-BOD	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.04	0.1	0.1	0.1	0.04
Manufacture of leather tanning, leather products and fur skins	kt-BOD	0.3	0.3	0.2	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Manufacture of iron and steel	kt-BOD	39.7	37.3	40.3	36.5	27.5	25.7	26.1	26.4	22.8	19.1	22.5	26.0	22.2	18.5
TN load															
Manufacture of food	kt-N	5.8	6.2	6.5	7.0	7.2	3.9	4.0	4.2	6.0	7.9	6.6	5.3	5.3	5.4
Manufacture of beverages, tobacco and feed	kt-N	1.1	1.1	1.1	0.7	1.1	0.6	0.6	0.6	0.5	0.5	0.4	0.4	0.7	1.1
Manufacture of textile products	kt-N	2.5	2.1	1.6	2.1	2.0	1.7	1.7	1.7	1.6	1.5	1.3	1.1	1.2	1.4
Manufacture of pulp, paper and paper products	kt-N	8.4	8.0	8.0	8.0	7.0	5.4	5.4	5.4	4.6	3.8	4.1	4.4	5.6	6.8
Manufacture of chemical and allied product	kt-N	17.0	17.4	15.5	14.2	16.0	16.5	15.9	15.4	14.6	13.7	13.2	12.7	11.2	9.7
Manufacture of petroleum and coal products	kt-N	2.2	1.8	2.1	1.1	0.7	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
Manufacture of rubber products	kt-N	0.2	0.2	0.1	0.1	0.0	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	0.3	0.2	0.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Manufacture of iron and steel	kt-N	5.3	5.0	5.4	4.1	3.6	3.1	3.1	3.1	2.6	2.1	2.4	2.7	2.8	2.9

➤ 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 “Comprehensive Survey on Water Pollutant Discharge, Ministry of the Environment”.

$$A = \sum (V_i \times TN_i)$$

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 [m³]

Q_i : TN concentration in treated industrial wastewater discharged from industrial plant/facility i [g-BOD/L], [g-N/L]

Table 7-99 TN loadings in treated industrial wastewater discharged into public waters (Activity data)

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Manufacture of food	kt-N	5.0	5.3	5.6	5.3	4.5	3.1	3.2	3.3	3.3	3.3	2.9	2.6	2.5	2.4
Manufacture of beverages, tobacco and feed	kt-N	0.6	0.6	0.6	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.3
Manufacture of textile products	kt-N	0.8	0.7	0.5	0.4	2.6	1.7	1.7	1.7	1.8	1.8	1.7	1.6	1.6	1.6
Manufacture of pulp, paper and paper products	kt-N	0.7	0.7	0.7	0.5	0.8	0.6	0.6	0.6	0.5	0.4	0.5	0.5	0.5	0.5
Manufacture of chemical and allied product	kt-N	31.4	32.2	28.5	28.2	25.8	22.1	21.3	20.6	18.3	16.1	15.8	15.5	15.9	16.2
Manufacture of petroleum and coal products	kt-N	19.6	16.0	18.9	8.8	8.7	7.6	7.6	7.6	7.4	7.2	7.0	6.7	6.5	6.3
Manufacture of plastic products	kt-N	0.3	0.3	0.3	0.4	0.7	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.2	0.1
Manufacture of rubber products	kt-N	0.3	0.3	0.2	0.3	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0
Manufacture of leather tanning, leather products and fur skins	kt-N	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Manufacture of iron and steel	kt-N	33.3	31.2	33.7	41.8	18.6	17.6	17.6	17.6	16.3	14.9	14.6	14.2	14.7	15.2

c) Uncertainties and Time-series Consistency

● Uncertainties

As for the uncertainties in emission factors for CH₄ and N₂O 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 7-100.

Table 7-100 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 2006 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 ₂ O	-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 Chapter 1.

e) Category-specific Recalculations

CH₄ and N₂O emissions derived from BOD and nitrogen in untreated industrial wastewater were newly estimated.

N₂O emissions derived from nitrogen in treated industrial wastewater were newly estimated.

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

7.5.2.3. Landfill Leachate Treatment (5.D.2.-)**a) Category Description**

CH₄ and N₂O 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/year] and TN load [kg-N/year] 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 CH₄ and N₂O emissions from this source as described below:

$$E = EF \times L_i$$

E : CH₄ and N₂O emissions

EF : CH₄ and N₂O emission factor

L_i : Potential BOD load [kg-BOD/year] and TN load [kg-N/year] to be remained in leachate percolated thorough organic waste disposed of in MSW and IW landfill sites

● **Emission Factors**

Emission factors for CH₄ and N₂O are determined in accordance with the methodology for the natural decomposition of domestic wastewater given in the *2006 IPCC Guidelines* as described below.

CH₄ Emission factor

According to *the 2006 IPCC Guidelines*, the emission factor for CH₄ is established by multiplying the maximum CH₄ generation potential (B_0) by a CH₄ conversion factor (MCF). The maximum CH₄ generation potential (B_0) is determined to be 0.6 kg-CH₄/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*.

$$\begin{aligned} EF_{CH_4} &= B_0 \times MCF \\ &= 0.6 \text{ [kg-CH}_4\text{/kg-BOD]} \times 0.8 \\ &= 0.48 \text{ [kg-CH}_4\text{/kg-BOD]} \end{aligned}$$

B_0 : Maximum CH₄ generation potential [kg-CH₄/kg-BOD], (IPCC default value:0.6)

MCF : CH₄ conversion factor (IPCC default value: 0.8)

N₂O Emission Factor

The emission factor for N₂O is determined from a default value of 0.005 (kg N₂O-N/kg N) given in the *2006 IPCC Guidelines* after unit conversion.

$$\begin{aligned} EF_{N_2O} &= 0.005 \text{ [kg-N}_2\text{O-N/kg N]} \times 44/28 \\ &= 0.0079 \text{ [kg-N}_2\text{O/kg N]} \end{aligned}$$

● Activity Data

Based on the *Survey Study on Improving the Accuracy of Emission Factors for Greenhouse Gas Emissions from the Waste Sector*, 2010, the Ministry of the Environment (Reference #24), the activity data for CH₄ and N₂O 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 [kg-BOD/year] and TN load [kg-N/year].

CH₄ activity data

$$L_{BODi} = F_{BOD} \times W \times T_i$$

L_{BODi} : Potential BOD load to be remained in leachate percolated thorough organic waste disposed of in MSW and IW landfill sites [kg-BOD/year]

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 Reference #24

W : Amount of organic waste landfilled with or without intermediate treatments including incineration ash [t/year] obtained by the *Cyclical Use of Waste Report*

T_i : Ratio of leachate to be biologically treated in landfill site [%] determined to be 87.6% based on Reference #24

N₂O activity data

$$L_{TNi} = F_{TN} \times W \times T_i$$

L_{TNi} : Potential TN load to be remained in leachate percolated thorough organic waste disposed of in MSW and IW landfill sites [kg-N/year]

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 Reference #24

W : Amount of organic waste landfilled with or without intermediate treatments including incineration ash [t/year] obtained by the *Cyclical Use of Waste Report*

T_i : Ratio of leachate to be biologically treated in landfill site [%] determined to be 87.6% based on Reference #24

Table 7-101 BOD load [kt-BOD] and TN load [kt-N] of landfill leachate

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
BOD load	kt-BOD	2.6	2.5	2.2	1.6	1.3	0.8	0.8	0.7	0.8	0.6	0.5	0.5	0.5	0.5
TN load	kt-N	3.5	3.3	3.0	2.2	1.7	1.1	1.1	0.9	1.0	0.8	0.7	0.7	0.6	0.7

c) Uncertainties and Time-series Consistency

● Uncertainties

As for the uncertainties in emission factors for CH₄ and N₂O in landfill leachate treatment, 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 7-102.

Table 7-102 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 “Report on Survey Study on Improving the Accuracy of Emission Factors for Greenhouse Gas Emissions from the Waste Sector, in FY2009”, a source 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 ₂ O	-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 CH ₄ 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 Chapter 1.

e) *Category-specific Recalculations*

By reviewing the statistical data, emissions from FY1999 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, CO₂ emissions as a result of the decomposition of petroleum-derived surfactants are calculated. Estimated greenhouse gas emissions from category ‘Other’ are shown in Table 7-103.

Table 7-103 Categories whose emissions are estimated for Other (5.E.)

Category	Waste type	Treatment type	CO ₂	CH ₄	N ₂ O
5.E.1. (7.6.1)	Petroleum-Derived Surfactants	Decomposition at wastewater treatment facilities and/or the environment	○	NA	NA

In FY2017, emissions from this source category are 636 kt-CO₂ eq. and accounted for 0.05% of the national total emissions (excluding LULUCF). The emissions from this source category had decreased by 9.4% compared to those in FY1990. This emission decrease is primarily due to the decrease in CO₂ emissions from the use of alkylbenzenes by introduction of the Pollutant Release and Transfer Register (PRTR).

Table 7-104 GHG emissions from category 'Other' (5.E.)

Category	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
5.E. Other (Decomposition of petroleum-derived surfactants)	kt-CO ₂	703	668	656	507	530	514	527	524	528	605	617	625	619	636

7.6.1. Decomposition of Petroleum-Derived Surfactants (5.E.-)

a) Category Description

Surfactants are used for various cleaning activities at home and factories in Japan. Petroleum-derived surfactants discharged into wastewater treatment facilities and into the environment, and emit CO₂. 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 "CH₄ and N₂O emissions from wastewater treatment" and "CO₂ emissions from the decomposition of petroleum-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 CO₂ 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 CO₂ and emitted into the atmosphere as a result of surfactants decomposition, CO₂ 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 CO₂ emissions are calculated by multiplying the volume of the petroleum-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 CO₂ through incineration and landfilling of sludge. Therefore, the emission is included in CO₂ emission estimates.

● Emission Factor

Emission factor is determined for each type of material by calculating the amount of CO₂, expressed in kg that is emitted from the decomposition of 1 t of a surfactant using the average carbon content in the molecules.

$$EF_i = C_i \times 1,000 \times 44/12$$

EF_i : Emission factor for petroleum-derived raw material i used in a surfactant

C_i : Average carbon content of petroleum-derived raw material i used in a surfactant

Table 7-105 Average carbon content of surfactants, by petroleum-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	250	86.4%	C12-alkylbenzene as the main constituent.
Alkylphenol	15	210	85.7%	C9-alkylphenol as the main constituent.
Ethylene oxide	2	44	54.5%	Based on ethylene oxide molecules (C ₂ H ₄ O)

● Activity Data

Activity data is the amount of raw materials consumed for petroleum-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 Customs Bureau of the Ministry of Finance 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.

Export/Import correction factor

= (surfactant production + surfactants imported – surfactants exported) / surfactant production

Table 7-106 Activity data associated with decomposition of petroleum-based surfactants

Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Synthetic alcohol	t	29,239	16,253	28,285	31,609	32,988	32,872	33,750	34,870	36,193	43,324	42,947	44,299	45,551	45,587
Alkyl benzene	t	105,432	102,794	80,832	47,349	55,442	50,206	50,519	46,369	44,502	44,980	47,494	44,044	39,485	42,772
Alkyl phenol	t	10,141	8,798	7,454	3,448	2,338	2,044	2,054	2,263	2,910	4,318	4,885	4,873	4,638	5,660
Ethylene oxide	t	124,984	132,175	146,509	127,150	125,628	126,301	131,148	134,532	136,679	161,969	163,777	171,380	174,243	176,191

c) Uncertainties and Time-series Consistency

● Uncertainty

The uncertainty in emission factor for CO₂ 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 7-107 Uncertainty assessment for decomposition of petroleum-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 petroleum-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 Chapter 1.

e) Category-specific Recalculations

By updating the statistical data, emissions for FY2016 were recalculated. See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

References

1. IPCC, *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, 1997.
2. IPCC, *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, 2000.
3. IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2006.
4. Environmental Agency, *General Survey of Emissions of Air Pollutants*, 1995.
5. Environmental Agency, *The Report on Estimation of CO₂ Emissions in Japan*, 1992.
6. Environmental Agency Committee for the Greenhouse Gases Emissions Estimation Methods, *Review of Greenhouse Gases Emissions Estimation Methods Part 2*, September, 2000.
7. Ministry of the Environment, Committee for the Greenhouse Gases Emissions Estimation Methods, *Review of Greenhouse Gases Emissions Estimation Methods*, February 2006.
8. Ministry of the Environment, *the Annual Report on the Environment in Japan*.
9. Ministry of the Environment, Environmental Regeneration and Material Cycles Bureau, *Waste Treatment in Japan*.
10. Ministry of the Environment, Environmental Regeneration and Material Cycles Bureau, *The state of municipal waste treatment survey*.
11. Ministry of the Environment, Environmental Regeneration and Material Cycles Bureau, *Report of the research on the state of wide-range movement and cyclical use of wastes (the volume on cyclical use)*.
12. Ministry of the Environment, Environmental Regeneration and Material Cycles Bureau, *Review Report on Improvement of Accuracy and Faster Compilation of Waste Statistics*.
13. Ministry of the Environment, Environmental Regeneration and Material Cycles Bureau, *Study on Residual Amounts of Industrial Waste from Illegal Dumping and other Sources*, 2005.
14. Ministry of the Environment, Environmental Regeneration and Material Cycles Bureau, *Annual Recycling Statistics under the Plastic Containers and Packaging Recycling Law*.
15. Ministry of the Environment, Environmental Regeneration and Material Cycles Bureau, *Survey of guidance promotion of Johkasou*.
16. Ministry of the Environment, Waste Management and Recycling Department, *FY2009 and FY2010, report on the survey for the estimation of GHG emissions from specially-controlled industrial waste*, 2010, 2011.
17. Ministry of the Environment, Waste Management and Recycling Department, *Manual on biogas facilities maintenance*, 2008.
18. Ministry of the Environment, Waste Management and Recycling Department, *Self-management manual for Johkasou to promote aquatic conservation*, 2009
19. Ministry of the Environment, Environmental Regeneration and Material Cycles Bureau, *the Survey of Industrial Waste Treatment Facilities*.
20. Ministry of the Environment, Environmental Regeneration and Material Cycles Bureau, *Report on the state of Industrial Waste generation and Treatment survey*.
21. Ministry of the Environment, Environmental Regeneration and Material Cycles Bureau, *Report on Survey of Organizations in Industrial Waste Administration*.
22. Ministry of the Environment, Water and Air Environment Bureau, *Study on the Control of Wastewater Loading*.
23. Ministry of the Environment, Water and Air Environment Bureau, *Comprehensive Survey on Water Pollutant Discharge*.
24. Ministry of the Environment, *Survey Study on Improving the Accuracy of Emission Factors for Greenhouse Gas Emissions from the Waste Sector*, 2010.
25. Ministry of the Environment, *Committee for the Greenhouse Gases Emissions Estimation Methods, Review of Greenhouse Gases Emissions Estimation Methods, Waste Sector, Part 2*, 2013.
26. Ministry of the Environment, *Committee for the Greenhouse Gases Emissions Estimation Methods, Review of Greenhouse Gases Emissions Estimation Methods, Waste Sector, Part 2*, 2018.

27. Ministry of the Environment, *FY2011, Survey and Studies for the Development of Emission Factor for the preparation for the National Greenhouse Gas Inventory*, 2012.
28. Ministry of the Environment, *FY2012, Survey and Studies for the Development of Emission Factor for the Decentralized Commercial Wastewater Treatment for the National Greenhouse Gas Inventory*, 2013.
29. Ministry of the Environment, *The guideline of uncertainty assessment for National GHG inventories 2014*.
30. Ministry of the Environment, *Survey for the Development of Emission Factor to Estimate Effect of the Mitigation Measures for GHG Emissions from the Waste Sector*, 2018
31. Ministry of Health, Labour and Welfare, Water Supply Division, Health Service Bureau, *Report on Survey of Organizations in Industrial Waste Administration*, 1995 – 1999.
32. Ministry of Land, Infrastructure, Transport and Tourism, *Manual for Developing Plans for Biosolids Utilization (Draft)*.
33. Ministry of Economy, Trade and Industry, *Table of Industrial Statistics - Land and Water*.
34. Ministry of Economy, Trade and Industry, *Current Production Statistics*.
35. Ministry of Economy, Trade and Industry, *Yearbook of Textile and Consumer Goods Statistics*.
36. Ministry of Economy, Trade and Industry, *Survey of generation status of industry -specific by-products (industrial waste and recyclable waste)*.
37. Agency for Natural Resources and Energy, *General Energy Statistics*.
38. Ministry of Finance, *Trade statistics of Japan*.
39. Study Group for Proper Management of RDF, *Proper Management of Refuse-derived Fuels*, 2003.
40. Ishikawa Prefecture, City of Osaka, Kanagawa Prefecture, City of Kyoto, City of Kobe, Niigata Prefecture, Hiroshima Prefecture, Hyogo Prefecture, Fukuoka Prefecture, Hokkaido, *Survey of Compilation of Emission Units of Greenhouse Gas from Stationary Sources*, 1991-1997.
41. Ishikawa Prefecture, City of Osaka, Kanagawa Prefecture, City of Kyoto, Hiroshima Prefecture, Hyogo Prefecture, *Survey of Compilation of Emission Units of Greenhouse Gas from Stationary Sources*, 1991-1999.
42. Hyogo Prefecture, *Report of GHG Emission Factors from Stationary Combustion*, 1994.
43. Kanagawa Prefecture, *Report of GHG Emission Factors from Stationary Combustion*, 1994.
44. Ministry of Land, Infrastructure, Transport and Tourism, National Institute for Land and Infrastructure Management, *2000 Annual Report of Investigation and Research for Sewer*, NILIM Report 10: pp93-96, 2001.
45. Ministry of Land, Infrastructure, Transport and Tourism, National Institute for Land and Infrastructure Management, *2001 Annual Report of Investigation and Research for Sewer*, NILIM Report 64: pp119-122, 2002.
46. Japan Containers and Packaging Recycling Association, *Statistics of Commercial Recycling of Plastic (Recycling)*.
47. Japan Containers and Packaging Recycling Association, *Assessment and deliberation of the Plastic Containers and Packaging Recycling Law*.
48. Japan Environmental Sanitation Center, *Basic Waste Data (Fact Book 2000)*.
49. Japan Environmental Sanitation Center, *Report of Analytical Survey of Methane Emissions*, FY1989 Commissioned by the Environmental Agency.
50. Tokyo Environmental Public Service Corporation, *Nitrogen in effluent in waterside environment; development of small scale Gappei-shori johkasou with denitrification process*, Tokyo Metropolitan Research Institute for Environmental Protection News, No. 7, 1996
51. Japan Business Federation, *Follow-up Action Result of the Voluntary Action Plan on the Environment*.
52. Japan Iron and Steel Federation, *Current State of Plastic Waste Recycling and Future Tasks*.
53. Japan Cement Association, *Cement Handbook*.
54. Japan Automobile Tire Manufacturers Association, *Tire Industry of Japan*.
55. Japan Hygiene Products Industry Association, *JHPIA news*.

56. Japan Livestock Technology Association, *Controlling the Generation of Greenhouse Gases in the Livestock Industry*, 2002.
57. Japan Lubricating Oil Society, *Lubricant Recycle Handbook*.
58. Japan Sewage Works Association, *Waterworks Annual editions of Sewage Statistics (Admin. Ed.)*.
59. Japan Water Works Association, *Guidelines and Explanation of Sewerage Facility Design, Japan Sewage Works Association*, 2009.
60. Japan Sewage Works Association, *Guidelines and Analysis of Comprehensive Planning Surveys for the Provision of Water Mains, Catchment Area 1999 Edition*.
61. Japan Water Works Association, *Waterworks Statistics*.
62. The Japan Association of Rural Resource Recycling Solutions, *JARUS Reference System for Information of Biomass Recycling Technology*.
63. Japan Chemical Fibers Association, *Textile Handbook*.
64. Japan RPF Association, Inc., *RPF Quality Standards*, enacted in March of 2004.
65. Japan Society of Waste Management Experts, *Waste Handbook*, 1997.
66. Japan Society of Atmospheric Environment, *Report on Emission Factor Results for Combustion Facilities*, 1997
67. The Council for PET Bottle Recycling, *Annual Report on PET Bottle Recycling*.
68. Fujimoto, "Survey study on recycle by mud of sewage", Snow Management & Construction Technology Research Center of Fukui Pref.- Annual Report, 2002.
69. Fujishima *et al.*, "Establishment of Zero-emission Processing Technology for Organic Sludge by Multistage Distillation-Chemical Analysis of Sewage Sludge", Industrial Research Institute of Ishikawa Research Report, FY2004.
70. Ike, Soda, "B-071, Estimation on Carbon and Nitrogen Flows and CH₄ and N₂O Reduction of Wastewater Stream in Japan, FY2010 Global Environment Research Fund".
71. Ito, "A Study on Estimating Amounts of Landfill Gas", Metropolitan Tokyo Sanitation Engineering Journal No. 18, 1992.
72. Iwasaki, Tatsuichi, Ueno, "Review of Causes of Emissions of Nitrous Oxide and Methane from Waste Incinerators", Annual Report of the Tokyo Metropolitan Research Institute for Environmental Protection, 1992.
73. Nakamura *et al.*, "Emission of Nitrous Oxide from Incineration of Sewage Sludge", Proceedings of the 20th Japan Urban Cleaning Research Conference, pp391-393, 1998.
74. Matsubara and Mizuochi, "Survey of Emissions of Nitrous Oxide from Sewage Treatment Plants", Environmental and Sanitary Engineering Research, 8(3), 1994.
75. Okazaki, Shimizu, and Morita, "Study of Operation Records Based on Precision Function Inspection of Human Waste Management Plant", Japan Environmental Sanitation Center Report 28, 2001.
76. Omura, Kawakubo, and Yamada, "Study of Emission Factors for N₂O from High-load Human Waste Management", Journal of Waste Management 57, 260, 2004.
77. Oshima, Kawai, "Technical Note of PWRI Number 2509, Survey Study on Sewage Sludge Fuel Conversion, Annual Report of Sewage Works Research 1986", Public Works Research Institute (PRWI), 1986.
78. Seki, *Current Condition of New Solid Fuel and New Technology C-RPF*, Environment Management, 40(8), 2004.
79. Suzuki, Ochi, Miyata, "Continuous Measurement of Nitrous Oxide Emissions from Sewage Sludge Flux Furnaces", Proceedings of the 11th Environmental Engineering Symposium 2001, pp387-390, 2001.
80. Takeishi, Watanabe, Matsubara, Sato, Maebashi, Tanaka, Miwa, Wakasugi and Yamashita, *Report on Joint Research into the Behavior and Reduction of Waste Gas Components in Flux Furnaces*, Public Works Research Institute, Ministry of Construction and Nagoya City Water Authority, 1994.
81. Takeishi, Watanabe, Matsubara, Hirayama, Maebashi, Koma, Wakasugi and Yoshikawa, "Report on Joint Research into the Behavior and Reduction of Waste Gas Components in Flux Furnaces", Public Works Research Institute, Ministry of Construction and Nagoya City Water Authority, 1996.

82. Tanaka, Adachi, Seno, Yoshida, “*Components of Sewage Sludge, Tohoku Agriculture Research*”, National Agricultural Research Center for Tohoku Region Research Report, 27, 1980.
83. Tanaka, Inoue, Matsuzawa, Osako, and Watanabe, “*B-2(1) Research into Volumes Released from Waste Treatment Plants*”, 1994 Global Environment Research Fund Outcome Report, 1995.
84. Tanaka, Inoue, Osako, Yamada, and Watanabe, “*B-16(7) Research into Limiting Generation of Methane and Nitrous Oxide from the Waste Sector*”, FY1997 Global Environment Research Fund Outcome Report, 1998.
85. Tanaka, *Outline of waste management*, Maruzen, 1998
86. Ueno, Tatsuichi, and Ooiwakawa, “*Review of Measures to Reduce Nitrous Oxide in Sewage Treatment Plants*”, Tokyo Metropolitan Research Institute for Environmental Protection, 1995.
87. Yasuda, Takahashi, Yajima, and Kaneko, “*Behavior of Nitrous Oxide Emissions Associated With Incineration of Sewage Sludge*”, Journal of Japan Society of Waste Management Experts Vol. 5, No. 4, 1994.

Chapter 8. Other

8.1. Overview of Sector

UNFCCC Reporting Guidelines (Decision 24/CP.19) paragraph 29 indicates that Annex I Parties should report and explicitly describe the details of emissions from each country-specific source of gases which are not part of the *IPCC Guidelines*. According to this requirement, emissions from the Other sector (CRF sector 6) are indicated below.

8.2. CO₂, CH₄, N₂O, HFCs, PFCs, SF₆, and NF₃

Among CO₂, CH₄, N₂O, HFCs, PFCs, SF₆ and NF₃, 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 emissions from smoking are reported in the Other sector (see Annex 3).

Chapter 9. Indirect CO₂ and Nitrous Oxide Emissions

9.1. Overview of Sector

a) Category Description

Since Parties may now choose to report indirect CO₂, in accordance with paragraph 29 of the UNFCCC Inventory Reporting Guidelines, and since the estimation method reflecting Japanese actual status has been established, Japan elects to report indirect CO₂ emissions from the atmospheric oxidation of CH₄, CO, and NMVOCs, and not to report indirect N₂O emissions arising from sources other than those in the agriculture and LULUCF sectors.

Indirect CO₂ emissions originating from the use and/or evaporation of NMVOCs and CH₄ from the sub-categories indicated in Table 9-1 are estimated. Other than evaporation of CH₄ and NMVOCs, CH₄, CO, and NMVOCs originating from fuel combustion, evaporative fuel emissions from vehicles¹, and CH₄, CO, and NMVOCs from the incineration of fossil-fuel derived waste are oxidized to CO₂ in the atmosphere; these indirect CO₂ emissions are not reported, because these emissions are included in CO₂ emissions from fuel combustion (1.A), and CO₂ emissions from incineration and open burning of Waste (5.C)², respectively. According to the 2006 IPCC Guidelines, indirect CO₂ emissions originating from biogenic CH₄, CO, and NMVOC emissions from the agriculture sector, LULUCF sector, waste sector, and the Other sector were not reported from the viewpoint of carbon-neutrality.

Table 9-1 Source sub-categories of indirect CO₂

Sub-category	Originated from CH ₄	Originated from CO	Originated from NMVOCs
1.B Fugitive emissions from Fuels	○	NE, NO	○
2. Industrial process and product use	○	NE	○

b) Methodological Issues

● Estimation Method

CO₂ emissions occurring from the oxidation of evaporative NMVOCs and CH₄ in the atmosphere are estimated with the following conversion formulae which are mentioned in the 2006 IPCC Guidelines;

$$E_{CO_2} = E_{CH_4} \times \frac{44}{16}$$

$$E_{CO_2} = E_{NMVOC} \times C \times \frac{44}{12}$$

E_{CO_2} : Indirect CO₂ emissions [kt]

E_{CH_4} : CH₄ emissions [kt]

E_{NMVOC} : NMVOC emissions [kt]

C : Average carbon content of NMVOCs

¹ Emissions are reported in 3. Transport in 1.A. Fuel Combustion

² Japan assumes 100% oxidation during the combustion of fuel in 1.A Fuel Combustion and in 5 Waste

- **Parameters**

The average carbon content is calculated by weighting it by the composition rate 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 rate of NMVOCs were estimated based on the national emission inventory for volatile organic compounds (VOC) by the Ministry of Environment and other information. The average carbon content is calculated for each emission source until FY2014. The average carbon content across all emission sources in FY2014 of 0.73 is applied from FY2015 onward for all emission sources, because the yearly fluctuation of the carbon content is small. But for emission sources such as removers, that started to be reported from the 2018 submission, 0.73 is applied for years FY1990 and onward.

- **Activity Data**

Refer to Chapter 3 for information on CH₄ emissions from fugitive emissions from fuels (1.B.). Refer to Chapter 4 for information on CH₄ emissions from the chemical industry (2.B) and metal industry (2.C). Refer to Annex 3 for information on carbon monoxide (CO) and non-methane volatile organic compounds (NMVOCs).

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 Chapter 1.

e) Category-specific Recalculations

See Chapter 10 for impact on trend.

f) Category-specific Planned Improvements

No improvements are planned.

References

1. IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2006
2. UNFCCC “*UNFCCC Reporting Guidelines on Annual Inventories*”. (Decision 24/CP.19 Annex I)
3. Ministry of the Environment, *The national emission inventory for volatile organic compounds (VOCs)*

Chapter 10. Recalculation and Improvements

10.1. Explanations and Justifications for Recalculations

This section explains improvements on estimation of emissions and removals in the inventory submitted in 2019.

In accordance with the UNFCCC Reporting Guidelines and the *2006 IPCC Guidelines*, Annex I Parties should recalculate their inventories for the base year and all subsequent years of the times series in the cases of 1) application of new estimation methods, 2) addition of new categories for emissions and removals, and 3) data refinement. Major changes from the previous inventory are indicated below.

10.1.1. General Issues

As Japan's own specific circumstance, it can generally be said that activity data for the latest year available at the time when the inventory is compiled are often revised in the year following the submission year because of such as the publication of data in the fiscal year basis. In the national inventory submitted this year, activity data in many sources for FY2016 have been changed and as a result, the emissions from those sources for the inventory year have been recalculated.

10.1.2. Recalculations in Each Sector

The information of recalculation for sectors (energy; industrial processes and product use; agriculture; land use, land-use change and forestry; and waste), occurring due to Japan's own specific circumstance and needs, is described separately under sections named as "Category-specific Recalculations" in Chapters 3 to 7.

10.2. Implications for Emission Levels

The following shows the changes made to the overall emission estimates due to the recalculations indicated in "Section 10.1. Explanation and Justification for Recalculations".

10.2.1. GHG Inventory

Compared to the values reported in the previous year's inventory, total emissions (excluding the LULUCF sector, and including indirect CO₂) in the base year (FY 1990) under the UNFCCC increased by 0.27%, and the total emissions in year FY 2016 increased by 0.09% (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. See each category for details on the reasons of recalculations.

Table 10-1 Comparison of emissions and removals in the inventories submitted in 2018 and 2019

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
CO ₂	1,092.5	1,096.3	1,031.1	1,093.3	1,148.6	1,160.3	1,167.7	1,158.8	1,117.8	1,153.6	1,174.6	1,159.4	1,187.1	1,185.1	1,183.3	1,195.3	1,176.5	1,217.3	1,159.3	1,091.9	1,141.5	1,190.9	1,229.0	1,246.9	1,198.9	1,163.1	1,147.3
with LULUCF	1,095.7	1,099.2	1,055.9	1,095.8	1,150.1	1,169.4	1,169.9	1,160.7	1,119.6	1,155.9	1,176.8	1,161.6	1,189.4	1,187.4	1,186.2	1,198.7	1,181.0	1,221.7	1,161.2	1,095.7	1,143.6	1,194.4	1,232.8	1,248.7	1,200.1	1,164.7	1,151.4
diff. excl. Indirect CO ₂	0.30%	0.27%	-0.25%	0.23%	0.21%	0.18%	0.19%	0.17%	0.16%	0.20%	0.18%	0.19%	0.20%	0.20%	0.22%	0.29%	0.39%	0.35%	0.17%	0.19%	0.23%	0.31%	0.31%	0.14%	0.10%	0.14%	0.36%
CO ₂ (excl. Indirect CO ₂)	1,155.3	1,167.0	1,176.9	1,170.2	1,225.2	1,237.9	1,249.9	1,243.4	1,203.7	1,239.8	1,262.7	1,248.1	1,277.2	1,285.4	1,280.0	1,286.9	1,262.6	1,300.1	1,239.2	1,160.2	1,211.6	1,301.2	1,331.4	1,314.1	1,264.2	1,223.7	1,204.3
without LULUCF	1,158.5	1,170.0	1,179.8	1,172.7	1,227.6	1,240.0	1,252.1	1,245.3	1,205.6	1,242.2	1,265.0	1,250.3	1,279.6	1,287.8	1,283.0	1,290.3	1,267.2	1,302.9	1,232.2	1,165.0	1,214.4	1,284.5	1,305.9	1,315.1	1,264.9	1,224.5	1,206.2
diff. excl. Indirect CO ₂	0.28%	0.26%	0.24%	0.22%	0.20%	0.17%	0.18%	0.16%	0.16%	0.19%	0.18%	0.18%	0.18%	0.19%	0.23%	0.27%	0.26%	0.22%	0.24%	0.24%	0.24%	0.25%	0.29%	0.08%	0.06%	0.07%	0.15%
CH ₄	44.4	43.2	44.0	40.1	43.3	41.8	40.7	39.9	38.0	37.9	37.9	37.9	36.8	36.2	34.8	35.6	35.1	35.4	35.1	34.2	34.8	33.8	32.9	32.6	32.0	31.2	30.9
with LULUCF	44.4	43.3	44.1	40.1	43.4	41.9	40.8	40.0	38.2	38.0	38.0	37.2	36.4	34.9	35.7	35.1	35.3	35.0	34.1	34.6	34.6	33.6	32.7	32.4	31.7	30.9	30.6
diff. excl. Indirect CO ₂	0.02%	0.16%	0.20%	0.23%	0.22%	0.25%	0.30%	0.30%	0.11%	0.42%	0.46%	0.89%	0.58%	0.55%	0.34%	0.32%	-0.05%	-0.24%	-0.25%	-0.42%	-0.68%	-0.55%	-0.63%	-0.69%	-0.70%	-0.99%	-0.93%
CH ₄ (excl. Indirect CO ₂)	44.3	43.1	44.0	39.9	43.3	41.8	40.5	39.8	37.9	37.8	37.8	36.7	36.1	34.7	35.7	35.6	35.1	35.4	35.0	34.1	34.7	33.7	32.8	32.5	31.9	31.1	30.8
without LULUCF	44.3	43.2	44.0	40.0	43.3	41.9	40.7	39.9	38.1	38.0	38.0	37.1	36.3	34.9	35.9	35.7	35.0	35.3	34.9	34.0	34.5	33.5	32.6	32.3	31.7	30.8	30.5
diff. excl. Indirect CO ₂	0.02%	0.16%	0.20%	0.23%	0.22%	0.25%	0.30%	0.30%	0.11%	0.42%	0.46%	0.89%	0.58%	0.55%	0.34%	0.32%	-0.05%	-0.24%	-0.25%	-0.42%	-0.68%	-0.55%	-0.63%	-0.70%	-0.70%	-1.00%	-0.94%
N ₂ O	32.0	31.7	31.8	31.7	33.0	33.3	34.4	35.2	33.6	32.4	29.9	26.3	25.8	25.7	25.3	25.2	24.6	23.7	23.2	22.7	22.2	21.8	21.9	21.5	21.5	21.2	20.9
with LULUCF	32.0	31.7	31.9	31.8	33.0	33.4	34.5	35.3	33.5	32.6	30.1	26.5	26.0	25.8	25.2	25.1	24.5	23.7	23.1	22.5	22.0	21.7	21.8	21.4	21.0	20.4	
diff. excl. Indirect CO ₂	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%	0.02%	0.02%	0.04%	0.05%	-0.01%	0.05%	0.05%	0.03%	0.05%	0.05%	0.05%	0.13%	
N ₂ O (excl. Indirect CO ₂)	31.7	31.4	31.6	31.5	32.7	33.0	34.2	34.9	33.4	32.2	28.7	26.1	25.6	25.5	25.5	25.1	25.0	24.4	23.6	23.0	22.5	22.0	21.7	21.7	21.3	21.0	20.7
without LULUCF	31.8	31.5	31.7	31.6	32.8	33.2	34.3	35.1	33.5	32.4	29.9	26.3	25.8	25.6	25.5	25.0	24.9	24.3	23.5	22.9	22.3	21.9	21.5	21.6	21.2	20.8	20.3
diff. excl. Indirect CO ₂	0.15%	0.28%	0.30%	0.33%	0.30%	0.36%	0.40%	0.40%	0.17%	0.67%	0.65%	0.58%	0.58%	0.59%	-0.12%	-0.06%	-0.29%	-0.45%	-0.13%	-0.57%	-0.86%	-0.64%	-0.55%	-0.60%	-0.47%	-0.83%	-2.01%
HFCs	15.9	17.3	17.8	18.1	21.1	25.2	24.6	24.4	23.7	24.4	22.9	19.5	16.2	16.2	12.4	12.8	14.6	16.7	19.3	20.9	23.3	26.1	29.3	32.1	35.8	39.2	42.5
with LULUCF	15.9	17.3	17.8	18.1	21.1	25.2	24.6	24.4	23.7	24.4	22.9	19.5	16.2	16.2	12.4	12.8	14.6	16.7	19.3	20.9	23.3	26.1	29.4	32.1	35.8	39.3	42.6
diff. excl. Indirect CO ₂	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%	0.01%	0.02%	0.04%	0.05%	-0.01%	0.05%	0.13%	0.04%	0.03%	0.05%	0.05%	0.13%	
PFCs	6.5	7.5	7.6	10.9	13.4	17.6	18.3	20.0	16.6	13.1	11.9	9.9	9.2	8.9	9.2	8.6	9.0	7.9	5.7	4.0	4.2	3.8	3.4	3.3	3.4	3.3	3.4
with LULUCF	6.5	7.5	7.6	10.9	13.4	17.6	18.3	20.0	16.6	13.1	11.9	9.9	9.2	8.9	9.2	8.6	9.0	7.9	5.7	4.0	4.2	3.8	3.4	3.3	3.4	3.3	3.4
diff. excl. Indirect CO ₂	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%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
SF ₆	12.9	14.2	15.6	15.7	15.0	16.4	17.0	14.5	13.2	9.2	7.0	6.1	5.7	5.4	5.3	5.1	5.2	4.7	4.2	2.4	2.4	2.2	2.2	2.1	2.1	2.2	2.3
with LULUCF	12.9	14.2	15.6	15.7	15.0	16.4	17.0	14.5	13.2	9.2	7.0	6.1	5.7	5.4	5.3	5.1	5.2	4.7	4.2	2.4	2.4	2.2	2.2	2.1	2.1	2.2	2.2
diff. excl. Indirect CO ₂	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%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
NF ₃	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5	1.5	1.4	1.6	1.5	1.4	1.5	1.8	1.5	1.6	1.1	0.6	0.6
with LULUCF	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.5	1.5	1.4	1.6	1.5	1.4	1.5	1.8	1.5	1.6	1.1	0.6	0.6
diff. excl. Indirect CO ₂	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%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	
Indirect CO ₂	5.4	5.2	4.9	4.7	4.7	4.6	4.6	4.4	4.1	4.1	4.1	3.7	3.4	3.3	3.2	3.1	3.0	2.9	2.6	2.4	2.4	2.3	2.2	2.2	2.1	2.1	
with LULUCF	5.5	5.3	5.0	4.8	4.8	4.7	4.7	4.5	4.2	4.1	4.2	3.8	3.5	3.4	3.3	3.2	3.1	3.0	2.7	2.5	2.4	2.3	2.2	2.2	2.2	2.2	
diff. excl. Indirect CO ₂	1.93%	1.98%	2.01%	2.09%	2.16%	2.19%	2.17%	2.19%	2.23%	2.30%	2.34%	2.31%	2.34%	2.36%	2.66%	2.73%	2.84%	2.76%	2.47%	2.15%	2.12%	1.97%	2.10%	2.11%	2.03%	2.30%	
Total	1,260.7	1,280.7	1,295.6	1,286.3	1,350.8	1,372.1	1,384.7	1,377.2	1,338.7	1,351.8	1,372.2	1,346.7	1,370.5	1,376.4	1,368.7	1,375.4	1,353.0	1,390.8	1,318.5	1,246.1	1,300.3	1,351.0	1,393.1	1,407.4	1,359.1	1,321.1	1,304.6
without LULUCF	1,267.0	1,283.8	1,296.5	1,289.1	1,353.4	1,374.5	1,387.1	1,379.4	1,330.9	1,354.5	1,374.8	1,349.4	1,373.2	1,379.2	1,371.8	1,379.0	1,357.4	1,393.4	1,321.4	1,248.6	1,302.7	1,353.8	1,396.6	1,408.1	1,360.1	1,321.5	1,305.8
diff. excl. Indirect CO ₂	0.26%	0.25%	0.23%	0.21%	0.17%	0.18%	0.16%	0.16%	0.20%	0.20%	0.19%	0.20%	0.20%	0.20%	0.26%	0.33%	0.19%	0.22%	0.20%	0.19%	0.20%	0.21%	0.25%	0.05%	0.03%	0.09%	
Total (excl. Indirect CO ₂)	1,204.2	1,210.2	1,220.0	1,209.8	1,274.5	1,294.9	1,302.8	1,293.0	1,243.1	1,265.8	1,284.4	1,258.3	1,280.7	1,276.4	1,272.2	1,284.1	1,267.0	1,308.3	1,248.8	1,178.1	1,230.5	1,280.8	1,320.3	1,340.5	1,294.7	1,260.7	1,247.8
with LULUCF	1,207.5	1,213.3	1,222.9	1,212.4	1,277.1	1,297.2	1,305.2	1,295.1	1,245.2	1,268.4	1,286.9	1,261.0	1,283.3	1,279.1	1,275.2	1,287.6	1,271.5	1,312.5	1,250.7	1,181.6	1,232.2	1,283.9	1,323.7	1,341.9	1,295.5	1,261.9	1,251.2
diff. excl. Indirect CO ₂	0.27%	0.26%	0.24%	0.22%	0.21%	0.18%	0.19%	0.17%	0.17%	0.21%	0.20%	0.21%	0.21%	0.24%	0.28%	0.35%	0.32%	0.15%	0.30%	0.14%	0.25%	0.26%	0.11%	0.07%	0.09%	0.28%	
Total (incl. Indirect CO ₂)	1,272.1	1,289.1	1,298.5	1,291.1	1,355.4	1,376.7	1,389.3	1,381.7	1,332.8	1,355.8	1,376.4	1,350.4	1,374.														

Table 10-3 Comparison of emissions and removals in the inventories submitted in 2018 and 2019 (Industrial processes and product use sector) (1/2)

Energy Use	Gase	[Mt-CO ₂ eq.]																										
		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
A. Mineral Products	CO ₂	49.2	50.5	51.0	50.2	51.3	51.1	51.5	48.8	43.8	45.6	43.9	43.0	40.5	40.1	39.8	41.2	41.2	40.2	37.4	32.8	32.7	33.1	33.7	35.1	34.8	33.7	33.6
	difference	0.02%	0.02%	0.02%	0.02%	0.03%	0.03%	0.03%	0.04%	0.04%	0.04%	0.04%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.01%	0.01%	0.01%	0.01%	0.02%	0.01%	0.01%	0.01%	0.01%	-0.01%
B. Chemical Industry	CO ₂	7.0	7.0	6.8	6.4	6.8	7.0	7.1	7.1	6.4	6.9	6.8	6.3	6.2	6.0	6.1	5.8	5.9	6.0	5.1	4.9	5.4	5.1	4.6	4.8	4.7	4.6	4.3
	difference	0.03%	0.03%	0.03%	0.02%	0.02%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.04%	0.06%	0.08%	0.08%	0.07%	0.08%	0.08%	0.08%	0.08%	0.10%	0.13%	0.00%	0.00%	0.00%	-0.11%
CH ₄	JNGI 2018	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	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%	0.00%
N ₂ O	JNGI 2018	9.6	9.1	9.0	8.7	9.8	9.7	10.7	11.3	10.0	3.8	6.3	3.0	2.8	2.9	3.2	2.7	2.9	2.2	2.4	2.5	2.0	1.7	1.4	1.4	1.1	0.9	0.9
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	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%	0.00%
HFCs	JNGI 2018	15.9	17.3	17.6	17.1	18.9	22.0	20.3	19.0	17.7	18.0	16.0	12.2	8.1	6.9	1.9	1.0	1.2	0.6	0.9	0.3	0.2	0.2	0.1	0.1	0.1	0.1	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%	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%
PFCs	JNGI 2018	0.3	0.4	0.4	0.6	0.7	0.9	1.2	1.7	1.6	1.6	1.7	1.3	1.3	1.2	1.1	1.0	1.1	1.0	0.6	0.5	0.2	0.2	0.1	0.1	0.1	0.1	0.1
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	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%	0.00%
SF ₆	JNGI 2018	3.5	3.9	4.3	4.3	4.1	4.5	4.0	2.5	2.0	1.5	0.8	0.8	0.8	0.8	0.7	0.9	1.3	1.1	1.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	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%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
NF ₃	JNGI 2018	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.2	0.1	0.1	0.1	1.2	1.1	1.2	1.2	1.1	1.3	1.6	1.3	1.5	1.0	0.4
	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%	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%
C. Metal Production	CO ₂	7.2	7.1	6.8	6.7	6.8	6.9	6.8	6.5	6.5	6.5	6.7	6.8	6.6	6.4	6.5	6.5	6.6	6.7	6.2	5.5	6.1	6.0	6.1	6.2	6.1	5.9	5.8
	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%	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%
CH ₄	JNGI 2018	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	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%	0.00%
HFCs	JNGI 2018	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	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%	0.00%
PFCs	JNGI 2018	0.2	0.2	0.1	0.1	0.1	0.1	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	0.0	0.0	0.0	0.0	0.0	0.0
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	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%	0.00%
SF ₆	JNGI 2018	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.4	0.6	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.0	0.6	0.2	0.3	0.2	0.2	0.2	0.2	0.2	0.3
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	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%	0.00%
D. Non-energy Products from Fuels and Solvent Use	CO ₂	1.5	1.5	1.5	1.5	1.7	1.7	1.8	1.9	1.7	1.8	1.8	1.9	2.0	1.9	2.0	2.0	2.2	2.1	1.9	2.1	2.0	2.0	1.8	1.9	1.8	1.9	2.9
	difference	41.30%	39.43%	40.32%	42.14%	44.18%	43.15%	51.50%	50.24%	53.97%	51.74%	53.25%	50.75%	51.10%	51.59%	49.75%	53.93%	57.81%	60.00%	59.99%	55.58%	58.09%	54.30%	63.44%	60.70%	64.56%	52.50%	52.82%

*Excluding indirect CO₂

Table 10-3 Comparison of emissions and removals in the inventories submitted in 2018 and 2019 (Industrial processes and product use sector) (2/2)

2. Industrial Processes and Product Use		[Mt-CO ₂ eq]																											
(2/2)		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	
E. Electronic Industry	HFCs	0.0	NO	0.0	0.1	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
	JNGI 2018	0.0	NO	0.0	0.1	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	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%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
PFCs	JNGI 2018	1.5	1.7	1.7	2.5	3.1	4.0	4.7	6.0	6.1	6.5	7.0	5.3	5.4	5.3	5.6	4.7	5.1	4.5	3.4	2.1	2.3	1.9	1.7	1.6	1.7	1.7	1.8	
	JNGI 2019	1.5	1.7	1.7	2.5	3.1	4.0	4.7	6.0	6.1	6.5	7.0	5.3	5.4	5.3	5.6	4.7	5.1	4.5	3.4	2.1	2.3	1.9	1.7	1.6	1.7	1.7	1.8	
	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%	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%	
SF ₆	JNGI 2018	0.4	0.5	0.5	0.5	0.5	0.5	0.8	1.1	1.2	1.4	1.5	1.3	1.4	1.4	1.4	1.3	1.0	0.8	0.6	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.3	
	JNGI 2019	0.4	0.5	0.5	0.5	0.5	0.5	0.8	1.1	1.2	1.4	1.5	1.3	1.4	1.4	1.4	1.3	1.0	0.8	0.6	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.3	
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	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%	0.00%	
NF ₃	JNGI 2018	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.3	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.2
	JNGI 2019	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.2	0.3	0.4	0.3	0.2	0.2	0.2	0.2	0.2	0.1	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%	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%
F. Product Uses as ODS Substitutes	HFCs	0.0	NO	0.1	0.9	1.9	2.9	4.1	5.1	5.7	6.1	6.6	7.0	7.9	9.1	10.3	11.5	13.2	15.8	18.1	20.5	23.0	25.8	29.1	31.8	35.5	39.0	42.3	
	JNGI 2018	0.0	NO	0.1	0.9	1.9	2.9	4.1	5.1	5.7	6.1	6.6	7.0	7.9	9.1	10.3	11.5	13.2	15.8	18.2	20.5	23.0	25.8	29.1	31.8	35.5	39.0	42.3	
	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%	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%
PFCs	JNGI 2018	4.5	5.3	5.4	7.8	9.6	12.6	12.2	12.3	8.8	5.0	3.2	3.2	2.6	2.3	2.5	2.8	2.8	2.4	1.6	1.4	1.7	1.6	1.6	1.5	1.5	1.5	1.5	
	JNGI 2019	4.5	5.3	5.4	7.8	9.6	12.6	12.2	12.3	8.8	5.0	3.2	3.2	2.6	2.3	2.5	2.8	2.8	2.4	1.6	1.4	1.7	1.6	1.6	1.5	1.5	1.5	1.5	
	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%	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%	
G. Other Product Manufacture and Use	N ₂ O	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	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.6	0.4	0.4
	JNGI 2018	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	0.4	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.6	0.4	0.4
	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%	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%
PFCs	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO
	JNGI 2018	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO
	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%	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%
SF ₆	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO
	JNGI 2018	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO	NANO
	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%	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. Other	CO ₂	8.8	9.7	10.7	10.8	10.3	11.3	12.1	10.8	9.6	5.7	3.7	2.9	2.4	2.2	2.0	1.8	1.8	1.8	1.7	1.6	1.4	1.4	1.5	1.6	1.5	1.5	1.5	
	JNGI 2018	8.8	9.7	10.7	10.8	10.3	11.3	12.1	10.8	9.6	5.7	3.7	2.9	2.4	2.2	2.0	1.8	1.8	1.8	1.7	1.6	1.4	1.4	1.5	1.6	1.5	1.5	1.5	
	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%	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%
2. Total	GHG	110.4	114.8	116.7	118.9	126.3	136.4	135.6	122.8	110.1	108.2	97.2	90.2	88.8	85.6	86.7	89.5	88.7	84.2	76.8	80.2	76.8	80.2	82.1	84.6	88.9	91.5	92.8	95.9
	JNGI 2018	110.4	114.8	116.7	118.9	126.3	136.4	135.6	122.8	110.1	108.2	97.2	90.2	88.8	85.6	86.7	89.5	88.7	84.2	76.8	80.2	76.8	80.2	82.1	84.6	88.9	91.5	92.8	95.9
	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%	0.00%	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%
*Excluding Indirect CO ₂	CO ₂	0.59%	0.53%	0.53%	0.55%	0.59%	0.55%	0.68%	0.71%	0.76%	0.88%	0.92%	1.01%	1.13%	1.14%	1.00%	1.10%	1.20%	1.22%	1.28%	1.25%	1.22%	1.19%	1.25%	1.20%	1.17%	1.20%	1.17%	1.17%
	JNGI 2018	0.59%	0.53%	0.53%	0.55%	0.59%	0.55%	0.68%	0.71%	0.76%	0.88%	0.92%	1.01%	1.13%	1.14%	1.00%	1.10%	1.20%	1.22%	1.28%	1.25%	1.22%	1.19%	1.25%	1.20%	1.17%	1.20%	1.17%	1.17%
	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%	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%

*Excluding Indirect CO₂

Table 10-4 Comparison of emissions and removals in the inventories submitted in 2018 and 2019 (Agriculture sector)

3. Agriculture		[Mt-CO ₂ eq.]																												
Category	Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016		
A. Enteric	CH ₄	9.2	9.4	9.5	9.4	9.2	9.2	9.1	9.0	9.0	8.9	8.8	8.9	8.8	8.7	8.5	8.4	8.5	8.5	8.4	8.2	8.0	7.9	7.7	7.7	7.5	7.3	7.3	7.3	
	difference	1.33%	1.37%	1.26%	1.13%	1.08%	0.96%	0.87%	0.91%	1.17%	1.09%	1.08%	1.04%	1.04%	0.98%	0.98%	0.98%	0.98%	-0.03%	-0.01%	0.02%	0.03%	0.00%	-0.02%	-0.04%	-0.04%	-0.05%	-0.07%	-0.08%	
B. Manure Management	CH ₄	3.4	3.4	3.3	3.3	3.2	3.1	3.1	3.1	3.0	2.9	2.9	2.9	2.8	2.8	2.8	2.7	2.7	2.7	2.6	2.6	2.6	2.5	2.5	2.5	2.4	2.3	2.3	2.3	
	difference	-6.93%	-6.57%	-5.74%	-5.54%	-5.40%	-5.02%	-4.32%	-4.09%	-3.95%	-2.97%	-2.60%	-2.39%	-2.02%	-1.80%	-1.10%	-0.59%	-0.36%	-0.18%	0.09%	0.34%	0.08%	-0.15%	0.15%	0.28%	0.67%	1.13%	1.28%		
C. Rice Cultivation	N ₂ O	4.2	4.3	4.3	4.2	4.1	4.0	4.0	4.0	3.9	3.8	3.8	3.9	3.9	4.0	4.0	4.0	4.1	4.2	4.2	4.3	4.3	4.2	4.2	4.1	4.0	4.0	3.9	3.9	
	difference	-2.81%	-2.66%	-2.84%	-2.21%	-2.03%	-1.76%	-1.64%	-1.54%	-1.19%	-1.18%	-1.21%	-1.24%	-1.17%	-1.07%	-1.07%	-1.07%	-1.07%	-1.17%	-1.06%	-1.04%	-1.14%	-1.33%	-1.25%	-1.15%	-1.19%	-1.06%	-0.74%	-0.73%	
D. Agricultural Soils	CH ₄	12.8	12.0	13.3	10.2	14.4	13.6	13.1	13.0	11.8	12.2	12.7	12.5	12.7	12.5	12.7	11.8	13.3	13.4	13.3	13.9	14.2	13.9	15.0	14.7	14.3	14.6	14.4	13.9	13.9
	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%	0.00%	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%	
E. Agricultural Soils	N ₂ O	7.3	7.1	7.0	7.1	7.0	6.7	6.6	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.0	5.9	6.3	5.5	5.3	5.2	5.6	5.5	5.5	5.5	5.5	5.5	5.4	5.4
	difference	-1.97%	-1.89%	-1.75%	-1.67%	-1.59%	-1.33%	-1.43%	-1.45%	-1.40%	-1.27%	-1.20%	-1.21%	-1.18%	-1.18%	-1.09%	-1.04%	-0.96%	-0.98%	-0.87%	-0.93%	-0.97%	-0.96%	-0.93%	-0.91%	-0.90%	-0.83%	-1.01%	-0.99%	
F. Field Burning of Agricultural Residues	CH ₄	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	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	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%	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%	
G. Liming	N ₂ O	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	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
	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%	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	0.6	0.5	0.5	0.5	0.3	0.3	0.3	0.3	0.3	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	0.2	0.4	0.4	0.4	0.4
	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%	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	37.6	36.9	38.1	34.8	38.4	37.1	36.3	36.0	34.6	34.8	35.3	34.8	35.1	34.0	35.1	35.2	35.0	35.1	35.2	35.5	34.8	35.8	35.2	35.2	34.7	34.7	34.2	33.6	33.5
	difference	-0.98%	-0.98%	-0.78%	-0.78%	-0.66%	-0.65%	-0.57%	-0.55%	-0.53%	-0.29%	-0.29%	-0.27%	-0.25%	-0.20%	-0.16%	-0.11%	-0.34%	-0.26%	-0.22%	-0.26%	-0.30%	-0.31%	-0.28%	-0.27%	-0.22%	-0.20%	-0.19%		

Table 10-5 Comparison of emissions and removals in the inventories submitted in 2018 and 2019 (Land use, land-use change and forestry sector)

Category	Gas	4. Land Use, Land-Use Change and Forestry [MLCO ₂ eq.]																										
		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
A. Forest Land	CO ₂	-79.1	-86.2	-86.6	-86.9	-87.3	-87.6	-91.3	-91.1	-91.0	-90.8	-90.6	-90.5	-90.3	-99.0	-98.5	-92.7	-86.8	-85.5	-80.8	-75.9	-76.4	-78.1	-77.7	-70.0	-68.8	-63.1	-60.7
	JNCGI 2018	-79.1	-86.2	-86.6	-86.9	-87.3	-87.6	-91.3	-91.1	-91.0	-90.8	-90.6	-90.5	-90.3	-99.0	-98.5	-92.7	-86.8	-85.5	-80.8	-75.9	-76.4	-78.1	-77.7	-70.0	-68.8	-63.1	-60.7
	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%	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%
CH ₄	JNCGI 2018	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	JNCGI 2019	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	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%	0.00%
N ₂ O	JNCGI 2018	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	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	JNCGI 2019	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	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	-0.39%	-0.14%	0.59%	0.88%	1.01%	1.11%	0.99%	0.85%	0.73%	0.82%	0.67%	0.57%	0.80%	0.88%	0.75%	0.47%	0.43%	0.26%	0.09%	0.15%	0.11%	0.41%	0.46%	0.44%	0.59%	0.60%	0.60%
B. Cropland	CO ₂	11.7	10.6	7.2	8.5	6.3	5.5	3.8	3.2	3.2	2.1	0.1	0.1	0.2	-0.6	2.7	2.3	4.8	10.4	7.8	5.5	5.8	4.9	3.6	4.3	4.3	4.7	
	JNCGI 2018	11.7	10.6	7.2	8.5	6.3	5.5	3.8	3.2	3.2	2.1	0.1	0.1	0.2	-0.6	2.7	2.3	4.8	10.4	7.8	5.5	5.8	4.9	3.6	4.3	4.3	4.7	
	difference	0.13%	0.18%	0.17%	0.25%	-0.05%	0.16%	-0.38%	-1.09%	-0.38%	-3.34%	-46.82%	-63.00%	-19.60%	7.72%	-0.59%	0.16%	2.32%	3.79%	0.35%	2.18%	-0.10%	2.66%	1.93%	2.27%	2.00%	1.08%	2.07%
CH ₄	JNCGI 2018	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	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
	JNCGI 2019	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	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	-0.39%	-0.14%	0.59%	0.88%	1.01%	1.11%	0.99%	0.85%	0.73%	0.82%	0.67%	0.57%	0.80%	0.88%	0.75%	0.47%	0.43%	0.26%	0.09%	0.15%	0.11%	0.41%	0.46%	0.44%	0.59%	0.60%	0.60%
N ₂ O	JNCGI 2018	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	JNCGI 2019	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	difference	-8.17%	-8.50%	-8.92%	-10.78%	-11.33%	-12.70%	-14.69%	-15.48%	-15.10%	-15.50%	-11.54%	-10.35%	-9.80%	-11.01%	-14.80%	-16.94%	-15.35%	-10.44%	-17.31%	-11.89%	-11.28%	-7.31%	-2.97%	-2.85%	-2.94%	-4.41%	
C. Grassland	CO ₂	1.1	0.8	0.1	-0.2	0.1	0.7	0.3	0.1	0.0	-0.4	0.0	-0.3	-0.5	-1.2	-0.9	-1.0	-0.4	-0.9	-0.3	0.1	0.3	0.0	-0.2	0.0	-0.1	0.0	
	JNCGI 2018	1.1	0.8	0.1	-0.2	0.1	0.7	0.3	0.1	0.0	-0.4	0.0	-0.3	-0.5	-1.2	-0.9	-1.0	-0.4	-0.9	-0.3	0.1	0.3	0.0	-0.2	0.0	-0.1	0.0	
	difference	-0.22%	-0.14%	-1.07%	0.36%	-0.62%	-0.02%	-1.12%	-0.92%	-1.91%	0.12%	-0.48%	0.03%	0.06%	0.03%	0.02%	-0.22%	-0.54%	-1.01%	10.39%	-48.40%	-61.52%	-15.10%	173.46%	-40.83%	86.10%	-71.34%	208.83%
CH ₄	JNCGI 2018	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	JNCGI 2019	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	difference	0.55%	0.34%	0.00%	-0.13%	-0.17%	-0.20%	-0.18%	-0.12%	-0.08%	-0.06%	-0.04%	-0.00%	-0.04%	-0.03%	-0.01%	0.07%	0.11%	0.17%	0.21%	0.28%	0.25%	0.26%	0.30%	0.29%	0.33%	0.30%	0.24%
N ₂ O	JNCGI 2018	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	JNCGI 2019	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	difference	-0.63%	-0.02%	0.00%	0.01%	0.01%	0.01%	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%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
D. Wetlands	CO ₂	0.1	0.1	0.3	0.1	0.1	0.4	0.6	0.1	0.5	0.5	0.4	0.4	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
	JNCGI 2018	0.1	0.1	0.3	0.1	0.1	0.4	0.6	0.1	0.5	0.5	0.4	0.4	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
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.12%	-0.23%	-0.10%	-0.11%	-0.13%	0.35%	0.39%	-15.94%	68.22%	-32.01%	212.77%	51.37%	89.27%	17.75%	17.75%	17.75%	17.75%	17.75%	17.75%	17.75%	17.75%
E. Settlements	CO ₂	2.7	3.3	3.7	2.2	1.3	1.1	0.4	0.2	0.1	-0.3	-0.6	-0.8	-1.4	-1.5	-1.5	-1.0	-1.0	-1.0	1.3	-1.0	0.3	-1.1	-0.6	-1.1	-0.5	0.2	
	JNCGI 2018	2.7	3.3	3.7	2.2	1.3	1.1	0.4	0.2	0.1	-0.3	-0.6	-0.8	-1.4	-1.5	-1.5	-1.0	-1.0	-1.0	1.3	-1.0	0.3	-1.1	-0.6	-1.1	-0.5	0.2	
	difference	-1.18%	-1.10%	-1.10%	-1.35%	-1.80%	-2.11%	-4.58%	-7.97%	-22.43%	5.86%	2.25%	1.48%	0.41%	0.35%	0.35%	1.95%	1.98%	-108.70%	-69.06%	-78.40%	-188.02%	-21.37%	12.36%	355.91%	188.41%	-85.03%	-91.90%
F. Other Land	CO ₂	1.2	1.3	1.0	1.3	1.1	1.0	0.9	1.2	0.9	0.9	0.7	0.7	0.7	0.6	0.6	0.2	0.2	0.2	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	JNCGI 2018	1.2	1.3	1.0	1.3	1.1	1.0	0.9	1.2	0.9	0.9	0.7	0.7	0.7	0.6	0.6	0.2	0.2	0.2	0.4	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	difference	-0.67%	-0.68%	-0.68%	-0.69%	-0.69%	-0.72%	-0.78%	-0.70%	-0.71%	-0.73%	-0.72%	-0.75%	-0.72%	-0.70%	-0.70%	-3.58%	-3.74%	-34.34%	-16.33%	-23.01%	-21.30%	-20.86%	-10.94%	-7.53%	-22.69%	-6.71%	
N ₂ O	JNCGI 2018	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	JNCGI 2019	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	difference	-0.08%	-0.08%	-0.08%	-0.11%	-0.14%	-0.17%	-0.19%	-0.23%	-0.26%	-0.29%	-0.33%	-0.36%	-0.41%	-0.45%	-0.49%	-0.53%	-0.57%	-0.60%	-0.63%	-0.66%	-0.69%	-0.72%	-0.75%	-0.78%	-0.81%	-0.84%	-0.87%
G. Harvested Wood Products	CO ₂	-0.4	-0.6	0.5	1.2	1.7	1.5	3.0	1.8	0.4	1.7	1.8	1.7	1.2	1.4	0.9	0.6	0.4	-0.4	-0.4	0.6	0.1	2.5	0.0	0.3	-0.9	-1.4	-1.2
	JNCGI 2018	-0.4	-0.6	0.5	1.2	1.7	1.5	3.0	1.8	0.4	1.7	1.8	1.7	1.2	1.4	0.9	0.6	0.4	-0.4	-0.4	0.6	0.1	2.5	0.0	0.3	-0.9	-1.4	-1.2
	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%	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%
(IV) Indirect N ₂ O emissions from managed soils	CO 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	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
	JNCGI 2018	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	difference	0.75%	0.45%	-0.01%	-0.94%	-1.26%	-1.81%	-2.71%	-3.09%	-2.97%	-2.34%	-1.69%	-1.38%	-1.19%	-1.35%	-1.93%	-2.16%	-1.63%	-1.07%	-0.53%	-0.54%	-0.50%	-0.51%	0.36%	1.13%	1.21%	1.13%	0.85%
4. Total	GHG	-62.4	-70.5	-73.6	-76.6	-76.3	-77.2	-81.9	-84.3	-85.7	-86.0	-87.8	-88.4	-89.8	-100.0	-96.3	-91.3	-85.9	-82.5	-69.7	-68.0	-70.2	-72.8	-66.9	-65.0	-60.3	-58.8	
	JNCGI 2018	-62.4	-70.5	-73.6	-76.6	-76.3	-77.2	-81.9	-84.3	-85.7	-86.0	-87.8	-88.4	-89.8	-100.0	-96.3	-91.3	-85.9	-82.5	-69.7	-68.0	-70.2	-72.8	-66.9	-65.0	-60.3	-58.8	
	difference	0.65%	0.04%	0.05%	0.04%	0.05%	0.03%	0.02%	0.05%	0.0																		

Table 10-6 Comparison of emissions and removals in the inventories submitted in 2018 and 2019 (Waste sector)

		[Mt CO ₂ eq.]																											
Category	Gas	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	
A. Solid Waste Disposal	CH ₄	9.6	9.5	9.5	9.3	9.2	9.0	8.7	8.5	8.2	7.9	7.6	7.3	7.0	6.7	6.4	6.1	5.8	5.5	5.1	4.8	4.5	4.3	4.1	3.9	3.6	3.4	3.3	
	NGGI 2018																												
	difference	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%	-0.01%	-0.02%	0.21%	0.17%	0.14%	0.11%	0.09%	0.07%	0.05%	0.04%	-0.34%	
B. Biological Treatment of Solid Waste	CH ₄	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	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	
	NGGI 2018																												
	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%	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%	
C. Incineration and Open Burning of Waste	N ₂ O	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	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.3	0.3	0.3	0.3	0.3	0.3	
	NGGI 2018																												
	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%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.41%	
D. Waste Water Treatment and Discharge	CO ₂	12.4	12.5	13.5	13.3	15.8	16.0	16.5	17.1	17.1	16.8	17.0	15.8	15.2	15.2	14.6	14.1	13.2	13.1	14.7	12.0	12.5	11.9	12.5	12.3	11.9	12.0	12.3	
	NGGI 2018																												
	difference	0.04%	0.04%	0.04%	0.03%	0.03%	0.03%	0.01%	0.02%	0.01%	0.00%	0.01%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.51%	-1.46%	0.16%	-1.98%	-3.33%	-2.71%	-1.98%	-3.15%	-3.98%	
E. Other	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	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
	NGGI 2018																												
	difference	73.13%	75.36%	73.39%	73.89%	68.04%	66.30%	64.69%	42.53%	37.56%	41.36%	29.57%	10.83%	3.99%	4.10%	3.02%	3.32%	2.01%	3.86%	1.59%	1.43%	0.29%	-6.59%	-5.60%	-1.70%	-3.86%	-3.42%		
5. Total	N ₂ O	1.4	1.5	1.6	1.6	1.8	1.9	2.0	2.1	2.1	2.2	2.2	2.1	1.9	1.9	1.9	1.9	2.0	1.8	1.7	1.6	1.6	1.5	1.5	1.5	1.5	1.4	1.5	
	NGGI 2018																												
	difference	0.19%	0.19%	0.17%	0.17%	0.16%	0.15%	0.14%	0.09%	0.08%	0.08%	0.05%	0.02%	0.01%	0.01%	0.01%	0.01%	0.01%	0.01%	0.07%	-0.06%	-0.07%	-0.15%	-0.40%	-0.43%	-0.70%	-0.91%		
5. Total	CH ₄	2.8	2.7	2.7	2.6	2.6	2.6	2.5	2.5	2.4	2.4	2.4	2.4	2.4	2.4	2.3	2.2	2.2	2.2	2.1	2.0	1.9	1.9	1.7	1.7	1.6	1.6	1.6	
	NGGI 2018																												
	difference	5.63%	7.50%	7.46%	7.40%	7.29%	7.68%	7.72%	7.91%	8.18%	8.36%	16.51%	15.63%	15.05%	14.62%	15.41%	13.09%	13.09%	11.94%	9.75%	9.47%	9.14%	8.37%	7.50%	7.59%	7.82%	5.87%		
5. Total	CO ₂	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	1.9	1.9	1.9	1.9	1.9	1.9	
	NGGI 2018																												
	difference	14.35%	14.91%	14.70%	14.31%	13.92%	14.19%	14.10%	14.14%	14.28%	14.78%	15.21%	13.30%	14.80%	14.40%	14.42%	14.93%	13.98%	13.97%	13.97%	12.43%	11.15%	10.94%	10.81%	10.61%	10.60%	9.56%	9.34%	
5. Total	GHG	29.2	29.2	30.3	29.9	32.4	32.5	33.2	33.2	32.8	32.2	32.0	30.2	29.1	28.8	27.9	27.0	25.7	25.1	26.3	23.1	23.2	22.4	22.4	22.6	22.3	21.6	21.6	
	NGGI 2018																												
	difference	1.63%	1.84%	1.75%	1.73%	1.55%	1.59%	1.57%	1.54%	1.56%	1.58%	1.59%	2.06%	2.13%	2.08%	2.10%	2.21%	2.09%	3.38%	0.99%	1.78%	0.58%	-0.15%	-0.01%	0.30%	-0.36%	-0.87%		

10.2.2. KP-LULUCF Inventory

Compared to the values reported in the previous year's inventory, total emissions/removals arising from KP-LULUCF activities in FY2016 decreased by 0.27% (Table 10-7).

Table 10-7 Comparison of emissions and removals in the inventories submitted in 2018 and 2019 for KP-LULUCF activities

KP-LULUCF activities		[Mt-CO ₂ eq.]					
Activity	Gas		1990	2013	2014	2015	2016
Afforestation and Reforestation	CO ₂	JNGI 2018	-	-1.5	-1.5	-1.5	-1.5
		JNGI 2019	-	-1.6	-1.6	-1.6	-1.6
		<i>difference</i>	-	7.74%	7.78%	7.96%	8.47%
	CH ₄	JNGI 2018	-	0.0	0.0	0.0	0.0
		JNGI 2019	-	0.0	0.0	0.0	0.0
		<i>difference</i>	-	7.70%	7.73%	7.95%	8.61%
	N ₂ O	JNGI 2018	-	0.0	0.0	0.0	0.0
		JNGI 2019	-	0.0	0.0	0.0	0.0
		<i>difference</i>	-	7.70%	7.73%	7.95%	8.61%
Deforestation	CO ₂	JNGI 2018	-	1.4	2.3	1.7	2.4
		JNGI 2019	-	2.0	2.0	2.1	2.1
		<i>difference</i>	-	47.54%	-11.76%	24.13%	-10.33%
	N ₂ O	JNGI 2018	-	0.0	0.0	0.0	0.0
		JNGI 2019	-	0.0	0.0	0.0	0.0
		<i>difference</i>	-	-12.25%	-12.95%	-13.19%	-14.24%
Forest Management	CO ₂	JNGI 2018	-	-50.8	-52.3	-49.1	-47.0
		JNGI 2019	-	-51.2	-51.5	-49.1	-46.6
		<i>difference</i>	-	0.62%	-1.49%	-0.02%	-0.85%
	CH ₄	JNGI 2018	-	0.0	0.0	0.0	0.0
		JNGI 2019	-	0.0	0.0	0.0	0.0
		<i>difference</i>	-	-0.05%	-0.05%	-0.05%	-0.06%
	N ₂ O	JNGI 2018	-	0.1	0.1	0.1	0.1
		JNGI 2019	-	0.1	0.1	0.1	0.1
		<i>difference</i>	-	-0.41%	-0.31%	-0.31%	-0.34%
Cropland Management	CO ₂	JNGI 2018	10.2	3.5	4.2	4.1	4.6
		JNGI 2019	10.2	3.6	4.3	4.2	4.7
		<i>difference</i>	0.26%	2.38%	2.31%	2.25%	1.84%
	CH ₄	JNGI 2018	0.1	0.1	0.1	0.1	0.1
		JNGI 2019	0.1	0.1	0.1	0.1	0.1
		<i>difference</i>	-0.41%	0.46%	0.61%	0.62%	0.62%
	N ₂ O	JNGI 2018	0.0	0.0	0.0	0.0	0.0
		JNGI 2019	0.0	0.0	0.0	0.0	0.0
		<i>difference</i>	-6.52%	-14.17%	-14.07%	-14.97%	-20.58%
Grazing Land Management	CO ₂	JNGI 2018	0.8	-0.3	-0.1	-0.2	-0.2
		JNGI 2019	0.8	-0.3	-0.1	-0.2	-0.2
		<i>difference</i>	-0.09%	-0.29%	-4.35%	0.45%	-1.39%
	CH ₄	JNGI 2018	0.0	0.0	0.0	0.0	0.0
		JNGI 2019	0.0	0.0	0.0	0.0	0.0
		<i>difference</i>	3.72%	1.85%	1.84%	1.55%	1.70%
	N ₂ O	JNGI 2018	0.0	0.0	0.0	0.0	0.0
		JNGI 2019	0.0	0.0	0.0	0.0	0.0
		<i>difference</i>	-0.27%	-2.05%	-2.03%	-2.00%	-1.94%
Revegetation	CO ₂	JNGI 2018	-0.1	-1.2	-1.2	-1.3	-1.3
		JNGI 2019	-0.1	-1.2	-1.2	-1.3	-1.3
		<i>difference</i>	0.00%	-0.08%	-0.06%	-0.10%	-0.07%
Total		JNGI 2018	11.0	-48.8	-48.4	-46.0	-42.8
		JNGI 2019	11.0	-48.5	-47.9	-45.6	-42.7
		<i>difference</i>	0.21%	-0.62%	-1.02%	-0.87%	-0.27%

10.3. Implication for Emission Trends, including Time Series Consistency

Table 10-8 shows the changes made to the emission trends due to the recalculations indicated in “Section 10.1. Explanation and Justification for Recalculations”. The comparison between the 2018 submission and the 2019 submission is made through the comparison of values between FY1990 and FY2016.

10.3.1. GHG Inventory

The change between FY1990 and FY2016 total emissions (excluding the LULUCF sector, and including indirect CO₂) in the 2019 submission decreased by approximately 2.2 million tonnes (in CO₂ equivalents) and decreased by 0.2 percentage points, compared to the data reported in the previous submission.

Table 10-8 Comparison of change between 1990 and 2016 total emissions (excluding the LULUCF sector, and including indirect CO₂) between the inventories submitted in 2018 and 2019

	Emissions (2016) - Emissions (1990) [Mt-CO ₂ eq.]			Emissions (2016) / Emissions (1990) - 1 [%]		
	JNGI 2018	JNGI 2019	Difference	JNGI 2018	JNGI 2019	Difference
CO ₂	49.1	47.7	-1.4	4.2%	4.1%	-0.1%
CH ₄	-13.5	-13.8	-0.3	-30.6%	-31.2%	-0.7%
N ₂ O	-11.1	-11.5	-0.5	-34.9%	-36.3%	-1.4%
HFCs	26.6	26.6	0.1	166.9%	167.2%	0.3%
PFCs	-3.2	-3.2	0.0	-48.4%	-48.4%	0%
SF ₆	-10.6	-10.6	0.0	-82.5%	-82.6%	-0.1%
NF ₃	0.6	0.6	0.0	1845.5%	1845.5%	0%
Indirect CO ₂	-3.3	-3.4	-0.1	-60.9%	-61.6%	-1%
Total	34.6	32.4	-2.2	2.7%	2.5%	-0.2%

10.4. Recalculations and improvement plan, including response to the review process

10.4.1. Improvements after submission of the inventory

The major improvements carried out since the submission of the 2018 inventory are listed below.

10.4.1.1. Methodology for estimating emissions and removals of GHGs

Changed calculation methods are provided in Table 10-9.

10.4.1.1.a. GHG Inventory

Table 10-9 Changes in estimation methods

Sector and category		Changes in estimation methods
1.A.1.a, 1.A.4.a	Public electricity and heat production, Commercial/institutional	In the <i>General Energy Statistics</i> , fossil fuel consumption in the “Production, Transmission and Distribution of Electricity” [#255330] under the “Auto power production” was previously included in the Commercial/institutional subcategory (1.A.4.a), but it was reclassified into the Public electricity and heat production subcategory (1.A.1.a) for FY1990 through FY2015.
1.A.1.a, 1.A.4.a	Public electricity and heat production, Commercial/institutional	The emissions from the waste incineration for energy purposes and with energy recovery reported in 1.A.1.a were reclassified into 1.A.4.a for all years
1.A.3.b	CH ₄ and N ₂ O emissions from road transportation	For gasoline hybrid passenger vehicles (PV) after FY2003, light PV and gasoline PV after FY2005, new measurements of raw emission factors for the vehicles were provided by JAMA, and emission factors since FY2003 were revised.
1A1 1A2 1A4	CH ₄ and N ₂ O emissions from Energy Industries, Manufacturing Industries and Construction, Other Sectors	For combustion in the biomass boilers, CH ₄ and N ₂ O country-specific emission factors were newly adopted.
1A2 1A4	CO ₂ , CH ₄ and N ₂ O emissions from Manufacturing Industries and Construction, Other Sectors	The activity data for FY1990-2001 of non-specified biomass from combustion in the biomass boilers were revised.
2.A.3	Glass production	Emissions from barium carbonate, potassium carbonate, strontium carbonate, and lithium carbonate were newly estimated.
2.D.3.-	NM VOC Incineration	Updates were made to the methods of establishment of domestic supply of solvents.
2.D.3	Use of Use of Fishing Net Antifouling Agents, Use of Converting Solvents, Use of coating Solvents, Use of Synthetic Leather Solvents, Use of Fumigants	NM VOC emissions were newly estimated.
2.F.5	Solvents	The method for establishing the amounts of solvents used, under dry cleaning solvents, was revised.
3.A.1.	Enteric Fermentation/ Cattle	The calculation method of body weight for dairy cattle was revised for all year and the calculation method of DMI for non-lactating dairy cattle was revised for years FY2005 and before.
3.B.1. 3.D.a.2	Manure Management/ Cattle Agricultural Soils/ Direct N ₂ O Emissions/ Organic N Fertilizers	The calculation method of amount of excretion and nitrogen content in excretion for dairy cattle has been revised.
3.D.a.4 3.F	Agricultural Soils/ Direct N ₂ O Emissions/ Crop Residues Field Burning of Agricultural Residues	The data for rice straw and rice chaff plowed into soil in FY2015 and 2016 were updated.
3.D.a.5/6	Agricultural Soils/ Direct N ₂ O Emissions/ Mineralization/Immobilization Associated with Loss/Gain of Soil Organic Matter Cultivation of organic soils	The estimation method for mineral soil area associated with land use conversion in LULUCF sector was changed.
3.D.b.1 3.D.b.2	Agricultural Soils/ Indirect N ₂ O Emissions/ Atmospheric deposition, Nitrogen leaching and run-off	The calculation method of amount of excretion and nitrogen content in excretion for dairy cattle has been revised.
4.A.	Forest land remaining forestland, Land converted to forest land	Due to revision of areas of afforestation and reforestation (AR areas), areas of forest land remaining forest land and land converted to forest land, and carbon stock changes in living biomass, dead organic matter and mineral soils in these subcategories were recalculated for all years.

Sector and category		Changes in estimation methods
4.B.1	Cropland remaining cropland	Due to revision of areas of deforestation (D area), areas of cropland remaining cropland were recalculated for all years. Following the correction of organic soil area in rice fields and upland, CO ₂ emissions (on-site and off-site) from organic soils and carbon stock changes in mineral soils for all years were recalculated. Furthermore, in addition to 15 main perennial crops, planted area of minor perennial crops were included in the total orchard area. With this correction, the carbon stock changes in living biomass in cropland remaining cropland for all years were recalculated.
4.B.2 4.C.2 4.D.2 4.E.2 4.F.2.	Land converted to cropland, land converted to grassland, land converted to wetlands, land converted to settlements and land converted to other land	Due to revision of areas of deforestation (D area), areas of each land use converted from forest land, and carbon stock change in living biomass and dead organic matter were recalculated for all years.
4.C.1	Grassland remaining grassland	Due to revision of areas of deforestation (D area), areas of grassland remaining grassland were recalculated for all years. Following the revision of organic soil area in pasture land, CO ₂ emissions from organic soils (on-site and off-site) and carbon stock change in mineral soils were recalculated for all years.
4.D.1, 4.E.1	Wetlands remaining wetlands, Settlements remaining settlements	Due to revision of deforestation areas (D areas), areas of wetlands remaining wetlands, and settlements remaining settlements, and carbon stock changes in living biomass, dead organic matter and mineral soils (mineral soils is only for Settlements subcategory) in these subcategories were recalculated for all years.
4.G.	Harvested Wood Products Buildings	Due to correction of amount of wood used per unit floor area, the inflow of buildings after FY2012 were recalculated. In addition, with the adjustment of the area of destroyed building, the discarded carbon (outflow) of the buildings after FY2011 were recalculated.
4.G.	Harvested Wood Products Wood used for other than buildings	Since amount of wood used per unit floor and total floor area scraped were revised, the emissions/removals were recalculated from FY2011-FY2016.
4.G.	Harvested Wood Products Paper and paperboard	In accordance with the revision of statistics such as wood chips production, the emissions were recalculated from FY1990 to FY2016.
4(II)	Emissions and Removals from Drainage and Rewetting and Other Management of Organic and Mineral soils	Since area of deforestation (D area) were revised, CH ₄ emissions in this category from FY2008 to FY2016 were recalculated. In addition, due to the revision of organic soil area in cropland and pasture land, CH ₄ emission from drainage of organic soils in cropland and grassland were recalculated for all years.
4(III)	Direct N ₂ O emissions from N mineralization/immobilization associated with loss/gain of soil organic matter resulting from change of land use or management of mineral soils	Since area of afforestation and reforestation (AR area) and area of deforestation (D area) were revised, the emissions from Forest land, Cropland, Grassland and Other land were recalculated for all years. In addition, due to the revision of organic soil area in cropland and pasture land, the emission from mineralization associated with loss of soil organic matter in cropland and grassland were recalculated for all year.
4(IV)	Indirect nitrous oxide (N ₂ O) emissions from managed soils	Following the revision of mineral soil area, the indirect N ₂ O emissions from managed soils were recalculated for all years.
4(V)	Biomass burning	Due to revision of cultivation area for orchard trees, CH ₄ and N ₂ O emissions from burning of pruned branches from orchard trees for all years were recalculated.
5.C.1	Waste incineration	By identifying the additional uses of biomass-based plastic products, and by estimating additional biogenic fraction in plastics based on production data of bio-based resin, which includes those in recycled plastics, CO ₂ emissions were recalculated.
1.A.	Waste incineration and energy use (reported on energy sector)	By identifying the additional uses of biomass-based plastic products, and by estimating additional biogenic fraction in plastics based on production data of bio-based resin, which includes those in recycled plastics, CO ₂ emissions were recalculated.
5.C.2.	Open burning of waste	CO ₂ , CH ₄ and N ₂ O emissions from open burning of waste were newly estimated.
5.D.1.	Domestic wastewater (domestic sewage treatment plant)	By classifying emission factors for current type <i>Johkasou</i> as advanced type and standard type, CH ₄ and N ₂ O emissions were recalculated.

Sector and category		Changes in estimation methods
5.D.1.	Domestic wastewater (natural decomposition of domestic wastewater)	By classifying the fraction of nitrogen removal of current type <i>Johkasou</i> as advanced type and standard type, N ₂ O emissions from treated wastewater were recalculated.
5.D.2.	Industrial wastewater (natural decomposition of industrial wastewater)	CH ₄ and N ₂ O emissions from natural decomposition of industrial wastewater were newly estimated.

10.4.1.1.b. KP-LULUCF Inventory

Table 10-10 Changes in estimation methods

Sector and category	Changes in estimation methods
Afforestation (A), Reforestation (R), Deforestation (D)	AR areas and D areas were recalculated due to revision of ARD identification results and their way of apply for estimating the areas. As a result, carbon stock changes in all carbon pools under AR and D activities and CH ₄ and N ₂ O emissions from biomass burning under AR for FY2013 - FY 2016 were recalculated.
Forest Management (FM)	Carbon stock changes in all carbon pools under the FM activities for FY 2013 - 2016 were recalculated due to the revision of ARD areas mentioned above. According to this revision, the amount of loss of soil carbon was revised, and N ₂ O emissions from N mineralization associated with loss of soil organic matter for FY 2013 -FY 2016 were recalculated. In addition, carbon stock change in HWP for FY 2013 - FY 2016 were also recalculated due to revision of both activity data and parameters used for the estimation.
Cropland Management (CM)	Emissions from organic soils and mineral soils in CM for FY1990 and FY2013 - FY2015 were recalculated due to the revision of ARD areas mentioned above as well as the revision of the estimation method for organic soils in CM. Furthermore, the carbon stock change of living biomass in orchard and CH ₄ and N ₂ O emissions associated with the biomass burning from orchard were recalculated since the revisions of the areas of fruit trees.
Grazing Land Management (GM)	Emissions from organic soils and mineral soils in GM for FY1990 and FY2013 - FY2015 were recalculated due to the revision of ARD areas mentioned above as well as the revision of the estimation method for organic soils in GM.
Revegetation (RV)	RV areas were recalculated because D areas and correspondent Article 3.4 areas which subject to both D and RV activities were recalculated due to the revision of AR areas and D areas. As a result, carbon stock changes in all carbon pools in RV for FY 1990, FY 2013 - FY 2016 were also recalculated.

10.4.1.2. National Greenhouse Gas Inventory Report

No major changes since the previous submission.

10.4.1.3. Improvements by following UNFCCC-ERT recommendations

Actions taken in response to recommendations from UNFCCC review are summarized below. See relative sections for details.

The Committee for Greenhouse Gas Estimation Methods (see “Committee for Greenhouse Gas Estimation Methods” (Chapter 1.2.1.2.) address all the recommendations raised by ERT, and efforts have been made to tackle the issues and improve the national GHG inventory with due consideration of the priority.

Table 10-11 Summary of improvements made to the national inventory
in response to recommendations from UNFCCC review

Sector/Category	Recommendations by ERT	Actions taken	NIR/CRF
Energy/ Non-energy use of fuels	Provide greater transparency in the NIR and CRF tables (e.g. documentation boxes) and justification for the application of the “NE” notation key when fuels are used for non-energy purposes to demonstrate that there are no omissions of any potential emissions (ARR 2016 E.15)	The reporting was improved for the following fuels: other kerosene, gas/diesel oil, residual fuel oil, liquefied petroleum gases, petroleum coke, coke oven/gas coke.	CRF Table 1.A(d), NIR Chapter 3 (3.2.3)
IPPU/Direct reduced iron production (2.C.1.c)	Correct the notation key for the AD of DRI in CRF table to NO. (PMF2018).	The notation key in the CRF table is corrected.	CRF Table2(I).A-Hs2
IPPU/ Refrigeration and air conditioning (2.F.1)	Report the emissions from domestic refrigeration, stationary air conditioning and mobile air conditioning and the AD and recovery of all subcategories of category 2.F.1 for all phases of the lifetime of the equipment (ARR2016 I.19)	In addition to emissions, the CRF table is corrected for activity data and recovery.	CRF Table2(II)B-Hs2
LULUCF Cropland remaining cropland (4.B.1)	Explain in the NIR the resulting estimates from the Roth-C model and their trends (ARR 2016 L.12)	The descriptions on outputs from Roth C model and their trends were included in the NIR. However, more clear explanation in driver for the trends was under investigation.	NIR Chapter 6 (6.6.1.a))
LULUCF Grassland remaining grassland (4.C.1)	Explain in the NIR the resulting estimates from the Roth-C model and their trends (ARR 2016 L.14)	The descriptions on outputs from Roth C model and their trends were included in the NIR. However, more clear explanation in driver for the trends was under investigation.	NIR Chapter 6 (6.7.1.a))

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 NIR, and by adding necessary information to NIR.

Chapter 11. Supplementary Information on LULUCF activities under Article 3, Paragraphs 3 and 4 of the Kyoto Protocol

11.1. Summary of removal related trends, and emissions and removals from KPLULUCF activities

In accordance with the decision 2/CMP.8 in paragraph 4 adopted by the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (COP/MOP8), Japan reports afforestation/reforestation (AR), deforestation (D), forest management (FM), cropland management (CM), grazing land management (GM) and revegetation (RV) as LULUCF activities under Article 3, paragraphs 3 and 4 of the Kyoto Protocol for the second commitment period. Table 11-1 shows the activity coverage and other information relating to activities under Article 3.3, forest management under Article 3.4 and elected activities under Article 3.4. The net removals in FY2017 by those activities were 42,890 kt-CO₂ eq. (Table 11-2). Methodological tiers used are shown in Table 11-3.

Table 11-1 Activity coverage and other information relating to activities under Article 3.3 and elected activities under Article 3.4 (CRF-Table NIR 1)

Activity		Change in carbon pool reported						Greenhouse gas sources reported										
		Above-ground biomass	Below-ground biomass	Litter	Dead wood	Soil		HWP	Fertilization		Drained, rewetted and other soils		Nitrogen mineralization in mineral soils		Indirect N ₂ O emissions from managed soil		Biomass burning	
						Mineral	Organic		N ₂ O	CH ₄	N ₂ O	N ₂ O	N ₂ O	CO ₂	CH ₄	N ₂ O		
Article 3.3 activities	Afforestation and reforestation	R	R	R	R	R	NO	NO	IE	NO	NO	NA	IE	IE	R	R		
	Deforestation	R	R	R	R	R	NO	IO	IE	NO	NO	R	R	NO	NO	NO		
Article 3.4 activities	Forest management	R	R	R	R	R	NO	R	R	NO	NO	R	R	IE	R	R		
	Cropland management	R	R	NR	NR	R	R			R		R		IE	R	R		
	Grazing land management	R	R	NR	NR	R	R			R		R		NO	NO	NO		
	Revegetation	R	R	R	IE	R	NO		IE	NO	NO	NA	IE,NA	NO	NO	NO		
	Wetland drainage and rewet/ting	NA	NA	NA	NA	NA	NA		NA	NA	NA		NA	NA	NA	NA		

*R: Reported; NR: Not reported; IO: Instantaneous oxidation;
See annex 5 for the definitions of the other notation keys.

Table 11-2 Accounting summary for activities under Articles 3.3 and 3.4 of the Kyoto Protocol

Greenhouse gas source and sink activities	Net Emissions/removals [kt CO ₂ eq.]					
	1990 (Base Year)	2013	2014	2015	2016	2017
A. Article 3.3 activities						
A.1. Afforestation/reforestation		-1,607	-1,610	-1,604	-1,598	-1,569
Excluded emissions from natural disturbances		NA	NA	NA	NA	NA
Excluded subsequent removals from land subject to natural disturbances		NA	NA	NA	NA	NA
A.2. Deforestation		2,029	2,032	2,141	2,137	1,846
B. Article 3.4 activities						
B.1. Forest management						
Net emissions/removals		-51,065	-51,394	-49,002	-46,463	-46,135
Excluded emissions from natural disturbances		NA	NA	NA	NA	NA
Excluded subsequent removals from land subject to natural disturbances		NA	NA	NA	NA	NA
Any debits from newly established forest (CEF-ne)		NA	NA	NA	NA	NA
Forest management reference level (FMRL)		0	0	0	0	0
Technical corrections to FMRL		1,097	1,284	1,438	1,581	1,724
Forest management cap						
B.2. Cropland management	10,281	3,625	4,370	4,291	4,764	4,515
B.3. Grazing land management	841	-273	-95	-161	-219	-257
B.4. Revegetation	-79	-1,223	-1,241	-1,262	-1,280	-1,290
B.5. Wetland drainage and rewet/ting (not elected)	NA	NA	NA	NA	NA	NA
Total (excluding Technical corrections to FMRL)		-48,514	-47,938	-45,597	-42,659	-42,890

* The total values and results of summing up each figure are not always the same because of the difference in display digit.

Table 11-3 Methodological tiers used under Articles 3.3 and 3.4 of the Kyoto Protocol

Activity		CO ₂		CH ₄		N ₂ O	
		Method applied	Emission factor	Method applied	Emission factor	Method applied	Emission factor
Article 3.3 activities	Afforestation and reforestation	T2	CS	T1	D	T1	D
	Deforestation	T2	CS,D			T1	CS,D
Article 3.4 activities	Forest management	T2,T3	CS,D	T1	D	T1,T2	CS,D
	Cropland management	T2,T3	CS,D	T1	CS,D	T1,CS	CS,D
	Grazing land management	T2,T3	CS,D	T1	CS,D	CS	CS
	Revegetation	T2	CS,D				
	Wetland drainage and rewetting						

D: IPCC default, T1: IPCC Tier1, T2: IPCC Tier2, T3: IPCC Tier3, CS: country-specific method or emissions factor

11.2. Information relating to the decision 3/CMP.11 in paragraph 8

In reporting LULUCF activities under Article 3, paragraphs 4 of the Kyoto Protocol for the second commitment period, in order to clarify estimations and reporting method during the period, Japan describes information relating to LULUCF which has been identified in decision 3/CMP.11 in paragraph 8, as follows:

- Japan reports CM and GM as new activities under Article 3, paragraph 4, of the Kyoto Protocol, in addition to FM which became mandatory in the second commitment period, and RV which was elected in the first commitment period.
- For the FM and the RV, the methodology on land identification, which was applied to the first commitment period, is also applied to the second commitment period; lands that have been accounted for the first commitment period are also included in the second commitment period. Regarding the CM and the GM, the lands are identified based on statistics which are applied for reporting of LULUCF under the Convention. Detailed information is described in relevant sections of each activity.

11.3. General information

11.3.1. Definition of forest and any other criteria

The definitions of forest in Japan of forest are identified as the following, in accordance with decision 16/CMP.1, paragraph 20 of the annex to decision 2/CMP.7 and the requirement from *the 2013 Revised Supplementary Methods and Good Practice Guidance Arising from the Kyoto Protocol* (hereafter *KP Supplement*).

- Minimum value for forest area: 0.3 [ha]
- Minimum value for tree crown cover: 30 [%]
- Minimum value for tree height: 5 [m]
- Minimum value for forest width: 20 [m]

The minimum tree crown cover and the minimum forest width (mentioned above) are consistent with forests under the existing forest planning system in Japan. Although any minimum values for tree height is not defined under the existing system, forests with usual composition of tree species and under usual climate conditions in Japan usually reach a tree height of 5 m at maturity *in situ*. Each prefecture has surveyed and compiled information on forest resources under the forest planning system into Forest Registers, which are primarily intended to be prepared for establishing forest plans. Therefore, forests

under the forest planning system are considered as forests under the Kyoto Protocol, and Forest Registers are suitable as basic data source for reporting. This is the same concept as the one used for reporting the LULUCF forest sector under the Convention. The definitions of forest used for the second commitment period are the same as the first commitment period.

The definitions of forest mentioned above are consistent with those in the Country Report under Global Forest Resources Assessment (FRA) having been conducted every 5 years since 2005 by the Food and Agriculture Organization of the United Nation (FAO) (Table 11-4).

Table 11-4 Japan's forest categories and definition used in reporting to FAO

Category	Definition
Forest	Land on which trees and/or bamboo grow collectively, together with those trees and bamboo, or any other lands that are provided for collective growth of trees and/or bamboo covering 0.3 ha or more. Lands that are utilized mainly for agriculture, residential use or other similar purposes, and trees and bamboo on these lands, are not included.
Forest with standing trees	Forest that has a tree crown cover of 30 percent or higher (including young stands with the degree of stocking of 3 or higher).
Forest with less standing trees (Cut-over forest, lesser stocked forest)	Forest that does not fall under "forest with standing trees" or "bamboo forest".
Bamboo forest	Forest that does not fall under "forest with standing trees" and is mainly dominated by bamboo (excluding bamboo grass).

* See section 6.2. for a more detailed definition of each category

Before 1995, Japan classified forests with standing trees into two sub-categories, "intensively managed forests" and "semi-natural forests" in the Forestry Status Survey. Since 2002, Japan has introduced new sub-categories which are "ikusei-rin forest" and "tennensei-rin forest". In these new sub-categories, the degree of human-induced activities and stratification of forest have been taken into account. In ikusei-rin forests, intensively managed forests regenerated mainly by planting after felling and semi-natural forests regenerated by supplementary works such as site preparation are included. The definitions of intensively managed forest, semi-natural forest, ikusei-rin forest and tennensei-rin forest are shown below.

Table 11-5 Definitions of intensively managed forest, semi-natural forest, ikusei-rin forest and tennensei-rin forest¹

Sub-categories by regeneration method		Sub-categories by management types	
Intensively managed forest	Forest regenerated by planting and so on.	Ikusei-rin Forest	Forest where practices for establishment and maintenance of single-storied forests have been carried out after clear-cutting ("ikusei-tansou-rin"), or forest where practices for establishment and maintenance of multi-storied forests have been carried out after selective cutting ("ikusei-fukusou-rin").
Semi-natural forest	Forest which is not classified as intensively managed forest.		Tennensei-rin forest

11.3.2. Elected activities under Article 3, paragraph 4 of the Kyoto Protocol

Japan elected FM, CM, GM and RV defined by decision 2/CMP.7 in paragraph 6 and 7 of the annex, as "additional human-induced activities related to changes in GHG emissions by sources and removals by sinks in the agricultural soils and the land-use change and forestry categories" defined by Article 3,

¹ Explanations for Ikusei-rin forest and Tennensei-rin forest have been changed in accordance with the revision of the "Basic Plan for Forest and Forestry". However, the coverage of those forests remains the same.

paragraph 4 of the Kyoto Protocol.

Japan interprets the definition of elected activities as follows by recalling *the KP Supplement* which the parties shall apply in accordance with decision 6/CMP.9, paragraph 9.

11.3.2.1. Forest Management

FM is defined in paragraph 1 (f) of the annex to decision 16/CMP.1 as “a system of practices for stewardship and use of forest land aimed at fulfilling relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner”. Japan interprets the definition of FM as the following.

- Activities for FM in ikusei-rin forests are appropriate forest practices including regeneration (land preparation, soil scarification, planting, etc.), tending (weeding, pre-commercial cutting, etc.), thinning and harvesting which have been carried out since 1990.
- Activities for FM in tennensei-rin forests are practices for protection or conservation of forests including controlling logging activities and land-use change which have been carried out by law.

11.3.2.2. Cropland Management

CM is defined in paragraph 1 (g) of the annex to decision 16/CMP.1 as “a system of practices on land on which agricultural crops are grown and on land that is set aside or temporarily not being used for crop production”. Japan interprets the definition of CM as follows:

- Practices for cultivating in rice fields, upland fields and orchard²

11.3.2.3. Grazing Land Management

GM is defined in paragraph 1 (h) of the annex to decision 16/CMP.1 as “a system of practices on land used for livestock production aimed at manipulating the amount and type of vegetation and livestock produced”. Japan interprets the definition of GM as follows:

- Practices for meadow and grazing in pasture land³

11.3.2.4. Revegetation

RV is defined in paragraph 1 (e) of the annex to decision 16/CMP.1 as “a direct human-induced activity to increase carbon stocks on sites through the establishment of vegetation that covers a minimum area of 0.05 ha and does not meet the definitions of AR”. Japan interprets the definition of RV as follows:

- Practices for the creation of “parks and green space”, “public green space”, and “private green space guaranteed by administration” which have been carried out in settlements since 1990⁴. Activities which cover less than an area of 0.05 ha or meet the definitions of AR are not included.

² Abandoned cultivated land which is included in cropland for reporting of LULUCF under the Convention, is not included in the CM because appropriate managements have not been carried out there.

³ As for grazed meadow and wild land that are included in grassland for reporting of LULUCF under the Convention, they are not included in GM because management practices changes have not been occurred in grazed meadow and wild land is not for use of grazing.

⁴ In Japan, the urban green facilities subject to RV activities are: “urban parks”, “green areas on roads”, “green areas at ports”, “green areas around sewage treatment facilities”, “green areas by greenery promoting systems for private green space”, “green areas along rivers and erosion control sites”, “green areas around government buildings”, and “green areas around public rental housing”.

11.3.3. Description of how the definitions of each activity under Article 3.3 and each elected activity under Article 3.4 have been implemented and applied consistently over time

The forest definition explained in section 11.3.1 has not changed over time. The same forest definition is used for AR and D under Article 3.3 as well as FM under Article 3.4. The definitions of FM, CM, GM and RV explained in section 11.3.2 above have been implemented and applied consistently over time.

11.3.4. Description of precedence conditions and/or hierarchy among elected Article 3.4 activities, and how they have been consistently applied in determining how land was classified

Japan interprets that FM activities occur only in forest land, and CM, GM, and RV activities occur only in non-forest land (cropland, grassland and settlements). Therefore, there is no overlap between FM and non-FM activities (CM, GM, and RV).

There is a possibility that overlap may occur between CM, GM and RV when new planting is implemented in settlements converted from cropland and pasture land. In this case, the carbon stock changes are calculated in RV.

In the land conversion between CM and GM, the emissions/removals are reported under CM and GM respectively in accordance with current land use.

11.4. Land-related information

11.4.1. Spatial assessment unit used for determining the area of the units of land under Article 3.3

In accordance with the definition of forest explained in section 11.3.1, Japan determines the spatial assessment unit used for determining the area of the units of land under Article 3.3 as 0.3 ha.

11.4.2. Methodology used to develop the land transition matrix

11.4.2.1. Description of land transition matrix (CRF-NIR Table 2)

Table 11-6 shows the land transition matrix related to the activities under Articles 3.3 and 3.4 of the Kyoto Protocol. The FM area in Japan is estimated by using the narrow approach concept described in section 2.7.1 of *the KP Supplement*. Therefore, new FM areas are identified every year due to the progress of FM practices in managed forests which previously had not been categorized as FM area. These areas are classified as land transition from “other” to FM in table 11-6. Also, areas where RV practices have been newly performed become new RV areas and are classified as land transition from “other” to RV in table 11-6.

Regarding CM and GM, Japan basically estimates emissions/removals for current cropland (except for cultivation abandoned agricultural land) and current grazing land respectively; in accordance with paragraph 24 of the annex to the decision 2/CMP.7, cropland and pasture land converted to other land-use since 2013, were also included in CM and in GM with the following exceptions. The area of cropland or grassland converted to forest land is reported under “Afforestation and Reforestation”, the area of cropland or grassland converted to settlements with new planting is reported under “RV” land and newly created cropland or pasture land derived from the conversion of forests is reported under “Deforestation”. Moreover, the land conversion across CM and GM is reported as “IE”, because the changed areas between CM and GM from the previous year cannot be clearly separated from each other,

although the spatially explicit data used in the tier 3 model itself considers the above-mentioned land use changes in its calculation.

As for the values of 2017 in the land transition matrix, changes from reported figures in 2016, are reported.

Table 11-6 Land transition matrix of Kyoto Protocol activities (CRF-Table NIR 2)

TO 2017 FROM 2016		Article 3.3 activities		Article 3.4 activities					Other	Total area at the end of the previous inventory year
		Afforestation and reforestation	Deforestation	Forest management	Cropland management (if elected)	Grazing land management (if elected)	Revegetation (if elected)	Wetland drainage and rewetting (if elected)		
(kha)										
Article 3.3 activities	Afforestation and Reforestation	108.04	0.27							108.31
	Deforestation		307.68							307.68
Article 3.4 activities	Forest management		4.39	15,676.84						15,681.23
	Cropland management	0.04		NA	3,911.02	IE	NO	NA		3,911.05
	Grazing land management	0.13		NA	IE	601.37	0.43	NA		601.92
	Revegetation	NO		NA	NA	NA	86.44	NA		86.44
	Wetland drainage and rewetting (if elected)	NA		NA	NA	NA	NA	NA		NA
Other		0.02	2.23	148.95	0.09	NO	0.31	NA	16,949.12	17,100.74
Total area at the end of the current inventory year		108.22	314.58	15,825.80	3,911.11	601.37	87.18	NA	16,949.12	37,797.39

11.4.2.2. Overview of the procedures to estimate emissions and removals

This section gives an overview of the procedures to estimate emissions and removals for AR, D and FM activities in Japan. For AR and D activities, emissions and removals are estimated in AR and D areas which are detected for each prefecture based on sample survey data. For FM activity, emissions and removals are estimated by firstly subtracting emissions and removals in AR and D land from those in all managed forests for each prefecture, and then applying the FM ratio determined by the sample survey to the remaining emissions and removals.

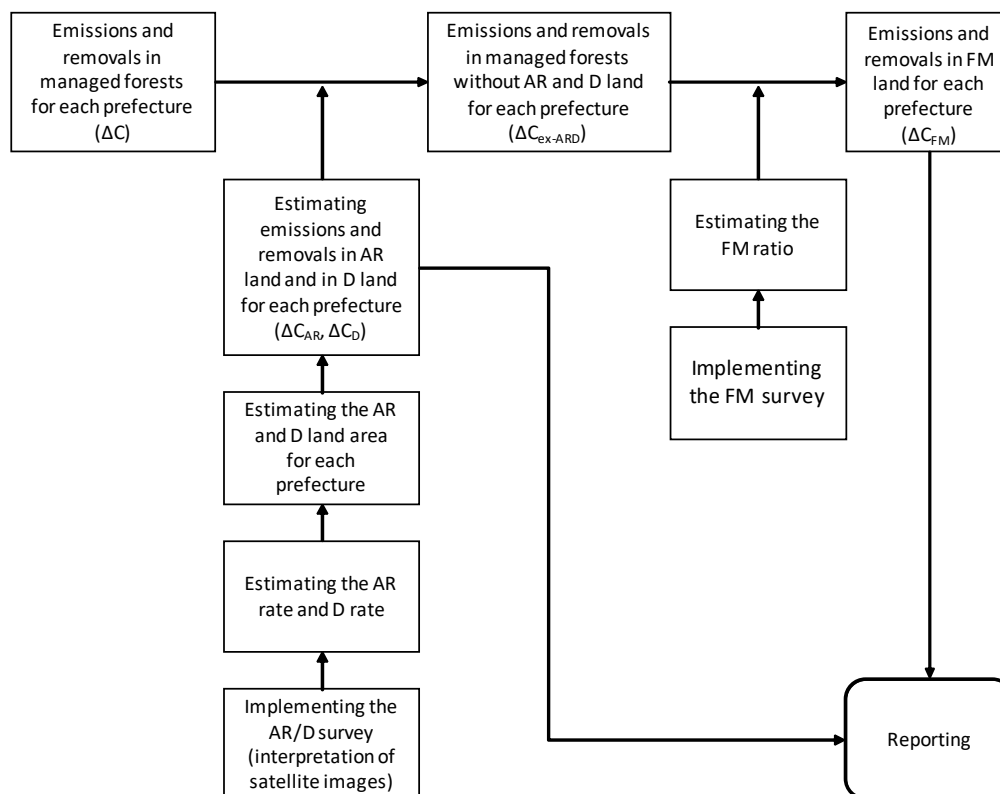


Figure 11-1 Procedures to estimate emissions and removals for AR, D and FM activities

11.4.2.3. Afforestation/Reforestation and Deforestation

11.4.2.3.a. Methodology and Procedure

a) Plot design

Japan identifies the change of forest cover in each sample plot by using orthophotos taken at the end of 1989 and recent satellite images, considering the spatial assessment unit (area 0.3 ha and width 20 m). Plots identified as non-forest land converted to forest land due to human-induced forestation practice are categorized as AR plot, and plots identified as forest land converted to non-forest land are categorized as D plot (Hayashi et al., 2008). The plots on the whole country are set in a grid with an interval of 500 m, which are approximately 1,500 thousand plots in total. Satellite images since 2005 are used for the following time series to count the number of AR and/or D plots occurring from the end of 1989 up to recent images by comparing the orthophotos in 1989. Interpretation is annually done for the half of the total number of plots and it takes two years to complete one cycle of interpretation covering whole land area. AR and D land areas are calculated based on the results of the most recent two sets of interpretation work (Ministry of Agriculture, Forestry and Fisheries, 2017 and 2018). Plots which are difficult to interpret are excluded from “available sample plots” which are used for the estimation of AR or D rates. Furthermore, the land-use status before / after conversion from / to forest land is analyzed from satellite images at each plot point and these data are used for the estimation of previous land-use in AR land and/or of new land-use status in D land.

b) Estimate land area of AR and D

Estimate AR rate for FY1990-FY2017:

Plots recognized as AR from FY1990 to FY2017 are counted from the interpretation by comparison between orthophotos taken at the end of 1989 and the latest two satellite images of SPOT/7HRV-P taken in 2016 and 2017. And after that, the year when all AR plots occurred are detected, using the orthophotos taken at the end of 1989 and the images taken every 2 years since 2005 (see table 11-7 for the data used). For the AR plots occurred between FY1990 and FY2005, the total AR rate for FY1990-2005 was derived by dividing the total number of AR occurrence by the “available sample plots” (i). For those AR plots occurred from 2005 onward, the number of AR that occurred between two images photographed in two year intervals is divided by 2 to estimate the occurrence of AR in a single year and then divided by the “available sample plots”. This becomes the AR rate for each year (ii). As one interpretation cycle is completed with 2 works, the number of occurrences is summed up for these two. As it is mentioned above, one cycle is completed in two years, if that is the year when the latter half of interpretation work is not available yet, the results of the latter half interpretation of previous cycle is used to cover the entire land area. The AR rate in 2006 is not included in the calculation above, so the amount of the total AR rate for FY 1990-2005 (i) divided into 16, counted the number of years from 1990 to 2005, is considered as the rate of 2006’s AR rate (iii). Finally, the rates from (i), (ii) and (iii) are aggregated to become the total AR rate for FY1990 to FY2017.

Estimate D rate for FY1990-FY2017:

The total D rate for FY 1990-FY2017 is estimated based on the same procedure applied for AR explained above. But, the way of allocation for the rate for 2006 is different from the one in AR rate estimation. D rate for 2006 is estimated through dividing the number of D plots during FY1990-FY2005 by land conversion rate in each fiscal year provided by statistics. The rate for 2005 is alternatively used for 2006.

Estimate land area of AR and D for FY1990-FY2017:

The AR land area for each prefecture during FY1990-FY2017 is calculated by multiplying the land area for each prefecture by the total AR rate during FY1990-FY2017, which is obtained by summing the total AR rates as mentioned above. In the same way, the D land area for each prefecture during FY1990-FY2017 is calculated by multiplying the land area for each prefecture by the D rate during FY1990-FY2017, which is obtained by summing the increase of D rate in each year during FY1990-FY2017.

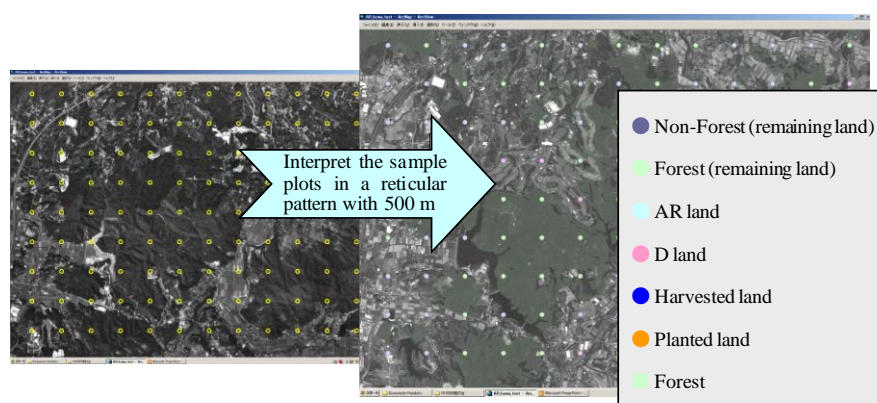


Figure 11-2 ARD land identification by interpreting remote sensing images

Although Forest Registers are used as basic data source for reporting since forests under the forest planning system are considered as forests under the Kyoto Protocol in Japan, orthophotos and satellite images are used for AR and D detection. This is because it is difficult to simulate the forest status during FY1990-FY2005 from the data in the Forest Registers, and to distinguish human-induced AR from forest expansion due to other causes.

With respect to possible over- or under-estimation of D rate based on orthophotos and satellite images, there is a possibility that the D rate may be over-estimated. The reason is that there is a possibility that plots on cut-over forests, which have lost forest cover but not classified as deforested, and those on areas of decreasing tree cover in land other than forest land may be misidentified as D plots. Hence, Japan has implemented field surveys on a part of plots identified as D plots thus far. As a result of the surveys so far, about 90% of plots identified as D plots was accurate, but about 10% was located on cut-over forests or on areas of decreasing tree cover in land other than forest land. In contrast, the result of double-checking a part of plots identified as not changed revealed that there were very few misidentifications; hence, possibility of under-estimation of D rate was extremely low. Therefore, it can be said that possibility of under-estimation of D rate is extremely low, but that the D rate may be over-estimated.

11.4.2.3.b. Data

Japan determines the ARD land area by using the following data.

Table 11-7 Data used in ARD land detection

	Resolution [m]	Data format
Ortho air-photo (at the end of 1989)	1	Raster
SPOT5/HRV-P (2005, 2007 and 2009 - 2014)	2.5	Raster
SPOT6/7/HRV-P (2015 - 2017)	1.5	Raster

11.4.2.3.c. Land-use change in deforested land

Japan determines the area of D land in accordance with the procedures mentioned in section 11.4.2.3.a. However, these procedures do not cover the continuous tracking of land-use change in D land. Therefore, the land-use change status in the D land has been assessed separately.

Japan has compiled land-use mesh data in the so called “Digital National Land Information” continuously over time. Although this mesh data cannot be used directly to monitor land-use change in the plots identified as D land because this mesh data is not absolutely consistent with the system mentioned in section 11.4.2.3.a (e.g. definition, resolution and land identification method), it can detect the overall tendency of land-use transition in the D plot. The results of the analysis of this mesh data show that D land is seldom converted to other land use again. Therefore, Japan assumes that the status of land use after D will continue to be the same and secondary land-use change will not occur.

11.4.2.4. Forest Management

11.4.2.4.a. Procedure

Japan estimates the FM land area for ikusei-rin forests and tennensei-rin forests according to the following procedures. As explained in section 11.3.2.1., forests to which activities for FM have been implemented since 1990 are subject to FM. Hence, if forests do not fulfill this condition, they are not counted as the forests subject to FM even if they are reported as managed forests under the Convention. Therefore, areas of the forests subject to FM are not equivalent to those of the managed forests under the Convention.

Areas subject to forest management are extracted from the areas of remaining managed forests which are determined after the areas of deforestation have been subtracted from the area of the total managed forests of the previous year; hence, the area subject to forest management has reflects the decrease in forest management area resulting from deforestation. This means that the areas subject to forest management are not overestimated.

a) *Ikusei-rin forests*

1. A field survey in private forests and national forests is implemented each year to identify lands which have been subject to FM activities (the number of sample plots are systematically distributed by tree species and regions; then, sample plots are selected randomly from the National Forest Resource Database (NFRDB)).

Survey items: current status of forests (tree species, stand age, number of trees, etc.), status and contents of practices since 1990, etc.

2. The ratio of these FM land areas (FM ratio) is estimated according to the survey findings.
3. After the AR land area for each prefecture is subtracted from the total forest area, the remaining forest area for each prefecture is multiplied by the FM ratio for each tree species, region and age class.

Table 11-8 FM ratio for ikusei-rin forests (private forests / national forests)

Sub-category / Tree species		Region	Private forest	National forest
Intensively managed forest	Japanese cedar	Tohoku, Kita-kanto, Hokuriku, Tosan	0.88	0.91
		Minami-kanto, Tokai	0.69	0.86
		Kinki, Chugoku, Shikoku, Kyusyu	0.77	0.91
	Hinoki cypress	Tohoku, Kanto, Chubu	0.82	0.91
		Kinki, Chugoku, Shikoku, Kyusyu	0.85	0.93
	Japanese larch	All	0.87	0.83
Other	All	0.70	0.82	
Semi-natural forest / All		All	0.42	0.66

* Data at the end of FY2017. About 22,400 sample plots are located all across the country.

* These regions generally used broad boundaries which aggregated several prefectures.

* FM ratios shown in this table are area-weighted average values of FM ratio for each age class.

* Uncertainty for FM ratios is 5% for entire Japan.

b) *Tennensei-rin forests*

For tennensei-rin forests, forest lands subject to practices for protection or conservation such as controlling logging activities and land-use change which have been carried out under law are identified by the NFRDB. Tennensei-rin forests under Article 3.4 of KP consist of Protection Forests, Special Zones and Special Protection Zones of National Parks and other protected forests/zones as shown in Table 11-9 below. The Protection Forests are designated under article 25 of the Forest Law (legislation No. 249 of 26th June 1951) for the purpose of fulfilling forest multiple functions (such as headwater conservation and disaster prevention). In the Protection Forests, implementing cutting stands, changing land characteristics and related activities without pre-permission 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

restriction of development and changing land characteristics, prohibition of hunting animals and harvesting plants, limitation of people's and vehicles' accesses, based on the Natural Parks Law (legislation No.161 of 1st June, 1957). These measures have been applied to the Tennensei-rin forests under Article 3.4 of KP continuously after FY1990.

Table 11-9 Area of protected/conserved tennensei-rin forests

[Unit: kha]

Protected / Conserved forest type	Private forest	National forest	Total
Protection Forest	2,809	4,550	7,359
Area for Conservation facility installation project	1	0	1
Protected Forest	0	606	606
Special Protected Zones in National Parks	44	113	156
Class I Special Zones in National Parks	42	164	206
Class II Special Zones in National Parks	139	201	340
Special Protected Zones in Quasi-National Parks	9	37	47
Class I Special Zones in Quasi-National Parks	30	104	135
Class II Special Zones in Quasi-National Parks	94	84	178
Special Zone in National Environment Conservation Area	0	9	9
Special Seed Forest	1	1	1
Total	3,169 (2,703)	5,870 (4,308)	9,039 (7,011)

* NFRDB (1st April 2017)

* This table includes forests with less standing trees.

* () means total land area excluding overlaps.

11.4.2.4.b. Data

a) Basic data for estimation

The basic data sources for FM estimation are Forest Registers and yield tables developed by prefectures or regional forest offices. Some of the yield tables are developed by the Forestry and Forest Products Research Institute. These Forest Registers and yield tables are also used for reporting under the Convention. Detailed information on Forest Registers and yield tables is provided in section 6.5.1.b) 1), Chapter 6 of this report.

b) Development of the National Forest Resources Database

To estimate emissions from or removals by forests, the Forestry Agency has developed the NFRDB. In the NFRDB, Forest Registers which are the basic data source for estimation and report, administrative information including forest planning maps and geographical location data such as orthophotos and satellite images like Landsat-TM and SPOT are archived.

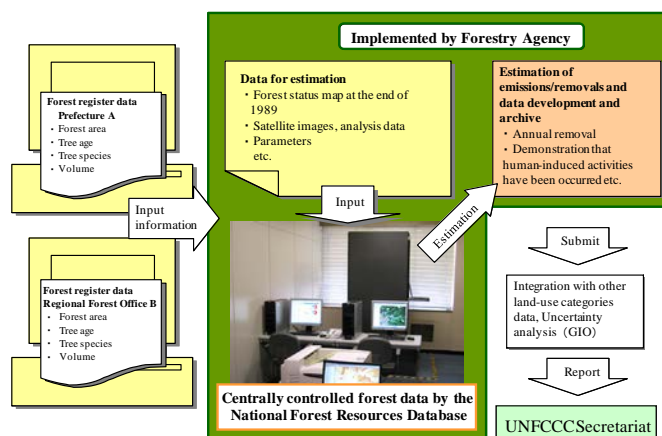


Figure 11-3 Summary of the National Forest Resources Database

11.4.2.5. Cropland Management

Basically, current cropland is subject to CM, area of CM was obtained from *Statistics of Cultivated and Planted Area* by the MAFF in each prefecture for each land-use category (rice fields, upland fields and orchards). The data source and definition of land use are the same as reporting of LULUCF under the Convention (see section 6.6 in Chapter 6 in this NIR).

Since, land which was converted from forest land to cropland is classified as D activity, area of CM were calculated by subtracting the area of cropland converted from forest land since 1990 obtained from the D survey, from the current area of rice fields, upland fields and orchards in each prefecture.

The land converted from cropland between 1991 and 2012 was not been included in the estimation because the land is not subject to CM activity in accordance with *the KP Supplement*.

In accordance with paragraph 24 of the annex to the decision 2/CMP.7, the land converted from cropland in the second commitment period since 2013 is included in area of CM activity; hence, the annual decrease area of cropland for each land-use category (rice fields, upland fields and orchard) in each prefecture obtained from *Statistics of Cultivated and Planted Area* by the MAFF, etc. was included in area as “current non-cropland subject to CM activity”. However, as planting on cropland is classified as AR activity, the decrease of cropland area is calculated by subtracting annual area of afforestation (AR) in cropland since 2013 obtained from the AR survey, from the area subject to CM activity.

11.4.2.6. Grazing Land Management

Method of determining and procedure for GM area are the same as the CM. Using the cultivation area of pasture in each prefecture obtained from *Statistics of Cultivated and Planted Area* by the MAFF as base data, GM area was calculated by identifying area of current pasture, current non-pasture converted from pasture since 2013, past-pasture area subject to D activity and subject to AR activity by using the same method as CM.

11.4.2.7. Revegetation

11.4.2.7.a. Procedure

Japan estimates the RV land area by types of urban green facilities according to the following procedures.

a) Urban parks

1. The information on the notification date and the establishment areas are sorted out as of the end of

each corresponding fiscal year during the commitment period for all urban parks which are installed in our country.

2. The urban parks which have been notified since 1 January 1990 and whose establishment area is 500 m² or more are extracted.
3. The urban parks extracted in step 2 are sorted out by geographical boundaries (prefectures) are counted.
4. The area of land which was classified as forest land on 31 December 1989 is calculated by multiplying the establishment area estimated in step 3 by the sum of the area ratios of “Land that has been converted from forest land to settlements per annum” since 1990 until each corresponding fiscal year during the commitment period. This area is excluded from the establishment areas because it is classified as D. The remaining area is considered as RV land area.
5. The areas of “Remaining land (settlements remaining settlements)” and “Land converted from other land-use categories (cropland / grassland / wetlands / other land converted to settlements)” are calculated by multiplying the land area estimated in step 4 by the area ratio of “Land converted to settlements” in the single year⁵.

b) Green areas on roads

1. The number of tall trees at the end of each corresponding fiscal year during the commitment period is calculated by geographical boundaries (prefectures) based on the results of “Road Tree Planting Status Survey”.
2. The number of tall trees on 31 March 1990 is calculated by using linear regression of two surveyed data sets (1986 and 1991) from the “Road Tree Planting Status Survey”. Next, the number of tall trees for each prefecture on 31 March 1990 is calculated by multiplying these values by the ratio of the number of tall trees for each prefecture on 31 March 2007. The ratio of the number of tall trees on 31 March 1990 is fixed to the value on 31 March 2007.
3. The number of tall trees which have been planted since 1 April 1990 is calculated by subtracting the value estimated in step 1 from the value in step 2 (RV is considered to be an activity which takes place after 1 January 1990. However, Japan considers RV as an activity after 1 April 1990 because the “Road Tree Planting Status Survey” has been implemented on a fiscal year basis).
4. The ratio of the number of tall trees planted on roads with a planted area less than 500 m² is estimated by using data from the sampling survey implemented in 2006 (general road: 1.00%, expressway: 0.00%, significance level: 95%).
5. The land area per tall tree is estimated by using modeled data from the sampling survey implemented in 2006 (general road: 0.0062 ha/tree, expressway: 0.0008 ha/tree, significance level: 95%). (These modeled data are calculated by dividing randomly sampled RV land areas by the number of tall trees planted on the land).
6. The area of land planted with tall trees, which is 500 m² or more, is calculated by multiplying the values estimated in steps 4 and 5 by the number of tall trees for each geographical boundary (prefecture) estimated in step 3.

⁵ Land-use change from the previous year to each corresponding year is applied when the area ratio of “single year” is used.

Area of land where tall trees have been planted since 1 April 1990 and whose size is 500 m² or more[ha]
 = Number of tall trees planted since 1 April 1990 [tree]
 * Ratio of the number of tall trees planted on land which is 500 m² or more [%]
 * Land area per tall tree [ha/tree]

7. The area of land which was classified as forest land on 31 December 1989 is calculated by multiplying the area estimated in step 6 by the sum of the area ratios of “Land that has been converted from Forest land to settlements per annum” since 1990 until each corresponding fiscal year during the commitment period. This area is excluded because it is classified as D area. The remaining area is considered as RV land area.
8. The areas of “Remaining land (settlements remaining settlements)” and “Land converted from other land-use categories (cropland / grassland / wetlands / other land converted to settlements)” are calculated by multiplying the land area estimated in step 7 by the area ratio of “Land converted to settlements” in the single year.

c) Green areas at ports

1. The green areas at ports which have been established since 1 January 1990 and which have a service area of 500 m² or more are extracted. Then, their areas are sorted out by geographical boundaries (All green areas at ports can be reported because they are considered not to be classified as forest land on 31 December 1989).
2. The areas of “Remaining land (settlements remaining settlements)” and “Land converted from other land-use categories (cropland / grassland / wetlands / other land converted to settlements)” are calculated by multiplying the land area estimated in step 1 by the area ratio of “Land converted to settlements” in the single year.

d) Green areas around sewage treatment facilities

1. The green areas around sewage treatment facilities which have been established since 1 January 1990 and which have a greening area of 500 m² or more are extracted. Then, their areas are sorted out by geographical boundaries.
2. The area of land which was classified as forest land on 31 December 1989 is calculated by multiplying the greening areas estimated in step 1 by the sum of the area ratios of “Land that has been converted from Forest land to settlements per annum” since 1990 until each corresponding fiscal year during the commitment period. This area is excluded because it is classified as D area. The remaining area is considered as RV land area.
3. The areas of “Remaining land (settlements remaining settlements)” and “Land converted from other land-use categories (cropland / grassland / wetlands / other land converted to settlements)” are calculated by multiplying the land area estimated in step 2 by the area ratio of “Land converted to settlements” in the single year.

e) Green areas by greenery promoting systems for private green space

1. The green areas by greenery promoting systems for private green space which have a greening area (excluding wall green areas) of 500 m² or more are extracted and their areas are sorted out by

geographical boundaries. All of them are activities which took place after 1 January 1990 because greenery promoting systems have been implemented since May 2001.

- All green areas by greenery promoting systems for private green space to be reported are “Remaining land (settlements remaining settlements)” because they were not classified as Forest land on 31 December 1989, and land-use conversion, if any in recent years, occurred only within settlements.

f) Green areas along rivers and erosion control sites

- The works of greening and erosion and sediment control including hillside works in river zones which have been established since 1 January 1990 and which have a greening area of 500 m² or more are extracted (greening works: (1) – (8), erosion and sediment control works: (9) – (11) in the following table).

Table 11-10 RV projects in green areas along rivers and erosion control sites and definition of planted land area

RV 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 river bank 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

- The planted land area in green areas along rivers and erosion control sites for each geographical boundary (prefecture) extracted in step 1 is calculated. Double-counting between RV land and D land is prevented because forested land (on 1 January 1990) is not included in step 1.
- The land areas of “Remaining land (settlements remaining settlements)” and “Land converted from other land-use categories (cropland / grassland / wetlands / other land converted to settlements)” are calculated by multiplying the land area estimated in step 2 by the area ratio of “Land converted to settlements (excluding forest land converted to settlements)” in the single year.

g) Green areas around government buildings

- The green areas around government buildings which have been established since 1 January 1990 and whose RV land area (= total land area - building area) is 500 m² or more are extracted.
- The RV land area for each geographical boundary (prefecture) extracted in step 1 is calculated.
- The area of land which was classified as Forest land on 31 December 1989 is calculated by multiplying the land area estimated in step 2 by the sum of the area ratios of “Land that has been converted from Forest land to settlements per annum” since 1990 until each corresponding fiscal year during the commitment period. This area is excluded because it is classified as D area. The

remaining area is considered as RV land area.

4. The areas of “remaining land (settlements remaining settlements)” and “land converted from other land-use categories (cropland / grassland / wetlands / other land converted to settlements)” are calculated by multiplying the land area estimated in step 3 by the area ratio of “land converted to settlements” in the single year.

h) Green areas around public rental housing

1. The green areas around public rental housing which have been established since 1 January 1990 and which have a RV land area (= total land area - building area) of 500 m² or more are extracted.
2. The RV land area for each geographical boundary (prefecture) extracted in step 1 are calculated.
3. The area of land which was classified as Forest land on 31 December 1989 is calculated by multiplying the land area estimated in step 2 by the sum of the area ratios of “Land that has been converted from Forest land to settlements per annum” since 1990 until each corresponding fiscal year during the commitment period. This area is excluded because it is classified as D area. The remaining area is considered as RV land area.
4. The areas of “Remaining land (settlements remaining settlements)” and “Land converted from other land-use categories (cropland / grassland / wetlands / other land converted to settlements)” are calculated by multiplying the land area estimated in step 3 by the area ratio of “Land converted to settlements” in the single year.

11.4.2.7.b. Data

The data applied in estimating RV land area are shown below.

Table 11-11 Data applied in estimating RV land area

Sub-division	Data type	Method for data collection
Urban parks	Area for each urban park	Urban Parks Status Survey (FY2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017)
Green area on roads	Number of tall trees	Road Tree Planting Status Survey (FY1987, 1992, 1997, 2002, 2007, 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016)
	Land area per tall tree	Basic Data Collection Survey on Tall Tree Planting on Roads (February 2007)
Green areas at ports	Service area	Complete census for FY2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017
Green areas around sewage treatment facilities	Green area	Sewage Treatment Facility Status Survey (FY2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016)
Green areas by greenery promoting systems for private green space	Greening area Wall greening area Number of tall trees	Application form for greenery promoting systems for private green space Urban Greening Status Survey (FY2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017)
Green areas along river and erosion control sites	Planted land area	Survey on carbon dioxide absorption at source in river works (FY2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016)
Green areas around government buildings	Total land area and building area	Complete census for FY2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017
Green areas around public rental housing	Total land area and building area	Progress survey on tree planting for public rental housing (FY2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016)

As for the FY2017 data, due to data acquisition problems, for the area data for “Green area on roads”, “Green areas around sewage treatment facilities”, “Green areas along river and erosion control sites” and “Green areas around public rental housing” the previous year’s values are used.

11.4.3. Maps and/or database to identify the geographical locations, and the system of identification codes for the geographical locations

Section 2.2.2 of *the KP Supplement* shows two methods for identifying and reporting the units of land subject to Article 3.3 activities and lands subject to Article 3.4 activities. Reporting Method 1 entails delineating areas that include multiple land units subject to Article 3.3 and 3.4 activities by using legal, administrative, or ecosystem boundaries. Reporting Method 2 is based on the spatially explicit and complete geographical identification of all units of land subject to Article 3.3 activities and all lands subject to Article 3.4 activities.

Japan elects Reporting Method 1 in accordance with the decision tree indicated in Figure 2.2.2 in Chapter 4 of *the KP Supplement*, which means that the entire national land is stratified by using the geographic boundary of prefectures, and the total area of each “unit of land” subject to each Article 3.3 activity and each “land” subject to each Article 3.4 activity is reported within each boundary. The identification code is determined for each prefecture as shown in the following map (see Table 11-12). Each activity under Articles 3.3 and 3.4 is detected as described in sections 11.4.2.3-11.4.2.7 and the units of land or lands subject to it are identified within prefectural boundaries in accordance with Reporting Method 1.

This geographical boundary is applied for all units of land: units of land subject to activities under Article 3.3, units of land subject to activities under 3.3 which would otherwise be included in land subject to forest management or elected activities under Article 3.4, under the provisions of paragraph 9 of the annex to the decision 2/CMP.7, and lands subject to forest management and to nay elected activities under Article 3.4.



Figure 11-4 Japan's determination of identification codes

Table 11-12 Identification codes and prefectures

ID	Prefecture	ID	Prefecture	ID	Prefecture	ID	Prefecture	ID	Prefecture
01	Hokkaido	11	Saitama	21	Gifu	31	Tottori	41	Saga
02	Aomori	12	Chiba	22	Shizuoka	32	Shimane	42	Nagasaki
03	Iwate	13	Tokyo	23	Aichi	33	Okayama	43	Kumamoto
04	Miyagi	14	Kanagawa	24	Mie	34	Hiroshima	44	Oita
05	Akita	15	Niigata	25	Shiga	35	Yamaguchi	45	Miyazaki
06	Yamagata	16	Toyama	26	Kyoto	36	Tokushima	46	Kagoshima
07	Fukushima	17	Ishikawa	27	Osaka	37	Kagawa	47	Okinawa
08	Ibaraki	18	Fukui	28	Hyogo	38	Ehime		
09	Tochigi	19	Yamanashi	29	Nara	39	Kochi		
10	Gunma	20	Nagano	30	Wakayama	40	Fukuoka		

11.5. Activity-specific information

11.5.1. Methods for carbon stock change and GHG emission and removal estimates

11.5.1.1. Description of the methodologies and the underlying assumptions used

11.5.1.1.a. Afforestation/Reforestation

a) Above-ground biomass, Below-ground biomass

● Methodology

The carbon stock change in living biomass in AR land is calculated using the Tier 2 stock difference method in accordance with the 2006 IPCC Guidelines. In this method, the carbon stock change is estimated by subtracting the carbon stock change due to land conversion from the difference between the total amount of carbon stock in biomass at two times.

$$\Delta C_{LB} = \Delta C_{SC} - \Delta C_L$$

ΔC_{LB} : Annual carbon stock change in living biomass [t-C/yr]

ΔC_{SC} : Annual carbon stock change due to biomass growth, felling, fuelwood gathering, disturbance after land conversion [t-C/yr]

ΔC_L : Annual carbon stock change due to land conversion [t-C/yr]

Carbon stock change due to biomass growth, felling, fuelwood gathering and disturbance after land conversion

$$\Delta C_{SC} = \sum_k \left\{ (C_{t_2} - C_{t_1}) / (t_2 - t_1) \right\}_k$$

ΔC_{SC} : Annual carbon stock change in living biomass [t-C/yr]

t_1, t_2 : Time point of carbon stock measurement

C_{t_1} : Total carbon stock in biomass calculated at time t_1 [t-C]

C_{t_2} : Total carbon stock in biomass calculated at time t_2 [t-C]

k : Type of forest management

The carbon stocks in living biomass are calculated from the volume for each tree species multiplied by

wood density, biomass expansion factor, root-to-shoot ratio and carbon fraction.

$$C = \sum_j \{ [V_j \times D_j \times BEF_j] \times (1 + R_j) \times CF \}$$

<i>C</i>	: Carbon stock in living biomass [t-C]
<i>V</i>	: Volume [m ³]
<i>D</i>	: Wood density [t-d.m./m ³]
<i>BEF</i>	: Biomass expansion factor [dimensionless]
<i>R</i>	: Root-to-shoot ratio [dimensionless]
<i>CF</i>	: Carbon fraction (Conifer: 0.51[t-C/t-d.m.], Broad leaf: 0.48[t-C/t-d.m.]
<i>j</i>	: Tree species

Carbon stock change due to land conversion

The carbon stock change due to land conversion is calculated as below, in accordance with the 2006 IPCC Guidelines.

$$\Delta C_L = \sum_i \{ A_i \times (B_a - B_{b,i}) \times CF \}$$

ΔC_L	: Annual biomass carbon stock change in land that has been converted from other land-use type to forest [t-C/yr]
A_i	: Annual increase of land area that has been converted from land-use type <i>i</i> to forest [ha/yr]
B_a	: Dry matter weight per unit area immediately after conversion to forest [t-d.m./ha]
$B_{b,i}$: Dry matter weight per unit area before conversion from land-use type <i>i</i> to forest [t-d.m./ha]
CF	: Carbon fraction of dry matter [t-C/t-d.m.] (0.47t-C/t-d.m. for herbaceous biomass in grassland and 0.5 t-C/t-d.m. for the others)
<i>i</i>	: Type of land use (cropland, grassland, wetlands, settlements and other land)

● **Parameters**

Data such as volume, biomass expansion factor, root-to-shoot ratio, wood density and carbon fraction are the same as those for reporting of LULUCF under the Convention. Detailed information is provided in section 6.5, Chapter 6 of this report.

The biomass stock data for each land use category to estimate carbon stock change due to land conversion are also the same as those for reporting of LULUCF under the Convention. Detailed information is provided in Table 6-8a, Chapter 6 of this report.

● **Activity data**

The activity data is AR land area which was calculated by using the procedure described in section 11.4.2.3 of this report.

b) Dead wood, Litter and Soils

● **Methodology**

The carbon stock change in dead wood and litter in AR land is calculated in accordance with the basic stock difference method provided by the 2006 IPCC Guidelines under the assumption that it takes 20 years to reach the average carbon stocks in forest land with linearly increase from carbon stock in land before conversion. The calculation is conducted by using average carbon stocks derived from the

CENTURY-jfos model, and carbon stocks in dead wood and litter before land conversion are assumed to be zero.

$$\Delta C_{DW} = \sum_i \{A_i \times (C_{DW20} - C_{DW,i}) / 20\}$$

$$\Delta C_{LT} = \sum_i \{A_i \times (C_{LT20} - C_{LT,i}) / 20\}$$

- ΔC_{DW} : Annual carbon stock change in dead wood [t-C/yr]
 ΔC_{LT} : Annual carbon stock change in litter [t-C/yr]
 A_i : Afforested or reforested land area converted from land use i [ha]
 C_{DW20} : Average carbon stocks in dead wood per unit area of 20-year-old forests [t-C/ha]
 C_{LT20} : Average carbon stocks in litter per unit area of 20-year-old forests [t-C/ha]
 $C_{DW,i}$: Average carbon stocks in dead wood per unit area of land-use i [t-C/ha] (assumed to be zero)
 $C_{LT,i}$: Average carbon stocks in litter per unit area of land-use i [t-C/ha] (assumed to be zero)
 i : Type of land-use (cropland, grassland, wetlands, settlements and other land)

The carbon stock change in soils in AR land is calculated in accordance with the basic stock change method provided by the 2006 IPCC Guidelines under the assumption that it takes 20 years to reach the average carbon stocks in forest land with linearly increase from carbon stock in land before conversion. This calculation is conducted by using average carbon stocks derived from the CENTURY-jfos model.

As mentioned in “Forest land remaining forest land” (section 6.5.1.b.2) , soil drainage activities for organic soil in forest land are not implemented in general in Japan, and it is considered as same for forests subject to AR activity. Therefore, the emissions from organic soils are reported as “NO”.

$$\Delta C_{Soil} = \sum_i \{A_i \times (C_{Soil20} - C_{Soil,i}) / 20\}$$

- ΔC_{Soil} : Annual carbon stock change in soils [t-C/yr]
 A_i : Afforested or reforested land area converted from land-use i [ha]
 C_{Soil20} : Average carbon stocks in soils per unit area of 20-year-old forests [t-C/ha]
 $C_{Soil,i}$: Average carbon stocks in soils per unit area in land-use i [t-C/ha]
 i : Type of land use (cropland, grassland, wetlands, settlements and other land)

● **Parameters**

The parameters are determined based on the CENTURY-jfos model and relevant literature.

● **Activity data**

The AR land area is calculated by using the procedure described in section 11.4.2.3 of this report.

c) **Harvested Wood Products (HWP)**

HWP from forest land subject to AR activity was reported as “NO” because wood supply for HWP from AR land do not occur in Japan.

d) **Other gases**

1) **Direct and indirect N₂O emissions from N fertilization**

The amount of nitrogen-based fertilizer applied in Forest land cannot be separated to those in AR and

in FM. Hence, N₂O emissions from N fertilization are reported in FM in a lump. Therefore, this category in AR has been reported as “IE”.

2) N₂O and CH₄ emissions from drainage of soils

Soil drainage in forest land with organic soils is not implemented in Japan. N₂O and CH₄ emissions from organic soils in forest land do not occur and were reported as “NO”.

3) N₂O emissions from N mineralization/immobilization due to carbon loss/gain associated with land-use conversions and management change in mineral soils

Since soil carbon stock changes in AR are reported to be on the increases, according to method under Tier 2 described in *the 2006 IPCC Guidelines*, N₂O emissions from N immobilization associated with gain of soil organic matter were not estimated. Therefore, N₂O emissions from this subcategory in AR land were reported as “NA”. Since “NA” could not be entered in the CRF Reporter for this category, they were reported as “NO” in the CRF-Table NIR 1.

4) Biomass burning

GHG emissions from wild fire exist in Japan as explained in section 6.16.b) 1), Chapter 6 of this report. Since there is no data which directly express biomass burning status in AR land, GHG emissions in AR land are estimated by multiplying GHG emissions due to fire for all forest land by the ratio of AR land area to all forest land area. Carbon released due to fire for all forest land (national forests and private forests) is estimated by multiplying the damaged timber volume due to fire by wood density, biomass expansion factor and carbon fraction of dry matter. Calculations only for non-CO₂ emissions are performed since CO₂ emissions are already included in the calculation of carbon stock change. Moreover, controlled burning activities in forests and land converted from land-use categories other than forest land to forest land are not implemented in Japan because of severe restrictions imposed by the “Waste Management and Public Cleansing Law” and the “Fire Defense Law”.

e) Results

Table 11-13 Net emissions and removals from AR activity

	2013	2014	2015	2016	2017
	[kt-CO ₂ eq.]	[kt-CO ₂ eq.]	[kt-CO ₂ eq.]	[kt-CO ₂ eq.]	[kt-CO ₂ eq.]
AR	-1,607.20	-1,610.25	-1,603.91	-1,598.37	-1,568.98
Above-ground biomass	-921.89	-919.86	-915.53	-909.00	-883.79
Below-ground biomass	-233.64	-233.01	-229.74	-228.14	-226.12
Dead wood	-318.48	-328.79	-335.12	-341.59	-343.64
Litter	-100.71	-96.88	-91.83	-87.07	-81.54
Soils	-32.49	-31.82	-31.72	-32.57	-34.01
Harvested wood products (HWP)	NO	NO	NO	NO	NO
Other gases	0.02	0.11	0.03	0.01	0.12

* CO₂+: Emission, -: Removal

11.5.1.1.b. Deforestation

a) Above-ground biomass, Below-ground biomass

● Methodology

The carbon stock change in living biomass (above-ground biomass and below-ground biomass) in D land is estimated by adding the living biomass loss in forests due to land conversion and carbon stock change due to growth of living biomass in D land after land conversion, in accordance with the *2006 IPCC Guidelines*.

The loss of living biomass of forest due to land conversion is estimated from data in the NFRDB taking into account the status of D land such as tree species and stand ages, and all carbon losses are allocated as emissions in the year of land conversion.

The carbon stock change due to growth of living biomass is estimated depending on land uses after conversion in D land. The land-use categories, except forest land where living biomass growth after conversion is calculated, are only “land converted to grassland” and “land converted to settlements” as explained in Table 6-8b in Chapter 6 of this report. D land which is converted to settlement with growth of living biomass is the land subject to RV practices. This is the land subject to both Article 3.3 and 3.4 activities, and the carbon stock change in this land is reported under D activity. The calculation is performed according to land-use status immediately after conversion in D land with the assumption that D land is seldom converted to other land uses again as explained in section 11.4.2.3.c.

$$\Delta C_{D-LB} = \Delta C_{DG-LB} + \Delta C_{DS-LB}$$

$$\Delta C_{DG-LB} = A_{5,DG} \times C_{G-LB}$$

$$\Delta C_{DS-LB} = \Delta C_{RV-LB} \times RA_{DS-RV}$$

ΔC_{D-LB} : Annual carbon stock change due to living biomass growth after D activity [t-C/yr]

ΔC_{DG-LB} : Carbon stock change due to living biomass growth in grassland subject to D activity [t-C/yr]

ΔC_{DS-LB} : Carbon stock change due to living biomass growth in settlements subject to D activity [t-C/yr]

ΔC_{RV-LB} : Carbon stock change in living biomass due to all RV practices [t-C/yr] (see section 11.5.1.1.f)

$A_{5,DG}$: Area of grassland subject to D activity within the past 5 years [ha]

C_{G-LB} : Carbon stock change per area in grassland [t-C/ha/yr]

RA_{DS-RV} : Ratio of the area subject to both D and RV activities within all areas subject to RV activities

● **Parameters**

Information relating to loss of forest biomass is obtained from the NFRDB. The carbon stock changes due to living biomass growth after D activity in grassland and in settlements were estimated. The default value of living biomass growth increments (Table 6-8b in Chapter 6 of this report) which is provided in the *2006 IPCC Guidelines* and carbon fraction of dry matter (0.47 [tC/td.m.]) for herbaceous biomass in grassland were used. The parameters for estimating carbon stock change due to RV practices are the same as those used for RV activity.

● **Activity data**

The D land area is calculated by the method described in section 11.4.2.3. The D land area where RV practices have been taken place is calculated by the method described in section 11.5.1.1.f.

b) Dead wood, Litter and Soils

The carbon stock change in dead wood, litter and soils associated with D is calculated in accordance with the Tier 2 method in the *2006 IPCC Guidelines*. Japan assumes that all carbon stocks in dead wood and litter are emitted at the time when D activities occur. The carbon stock change in mineral soils is calculated under the assumption that it takes 20 years to reach the soil carbon stocks in non-forest land with linearly increase from carbon stocks in forest land. Carbon stocks before and after conversion are established based on the data in Tables 6-9 to 6-11 in Chapter 6 of this report, and data obtained from the CENTURY-jfos model.

Land-use changes from forest land with organic soils hardly occur in Japan. Therefore, the emissions from organic soils are reported as “NO”.

c) Harvested Wood Products (HWP)

Carbon stock change of HWP in D land was reported as “IO” because HWP from D land was accounted for on the basis of instantaneous oxidation in accordance with the decision 2/CMP.7.

d) Other gases

1) Direct and indirect N₂O emissions from N fertilization

The fertilization in deforestation process has not been implemented in Japan. N₂O emissions from N fertilization in land after conversion are included in the estimation of the agriculture sector. Therefore, the emissions in this category were reported as “IE”.

2) N₂O and CH₄ emissions from drainage of soils

Land-use changes from forest land with organic soils hardly occur in Japan. Therefore, the emissions from organic soils are reported as “NO”.

3) N₂O emissions from N mineralization/immobilization due to carbon loss/gain associated with land-use conversions and management change in mineral soils

N₂O emissions from nitrogen mineralization associated with loss of soil organic matter were calculated by using Tier 1 estimation method described in the 2006 IPCC Guidelines. The estimation equation and parameters used are the same as section 6.14 in Chapter 6 in this NIR. All carbon losses due to deforestation are regarded as annual loss of soil carbon of N mineralized in mineral soils.

4) Biomass burning

In Japan, controlled burning activities are not carried out in deforestation activities and on the lands after conversion because of severe restrictions imposed by the “Waste Management and Public Cleansing Law” and the “Fire Defense Law”. In addition, wild fires do not occur on all land after conversion. Therefore, CH₄, CO, N₂O, and NO_x emissions from biomass burning in D land are reported as “NO”.

e) Results

Table 11-14 Net emissions and removals from D activity

	2013	2014	2015	2016	2017
	[kt-CO ₂ eq.]	[kt-CO ₂ eq.]	[kt-CO ₂ eq.]	[kt-CO ₂ eq.]	[kt-CO ₂ eq.]
D	2,029.02	2,032.14	2,140.82	2,136.71	1,846.26
Above-ground biomass	1,040.05	1,046.78	1,105.99	1,109.11	952.78
Below-ground biomass	254.98	257.18	273.63	274.67	234.84
Dead wood	492.09	491.27	515.69	513.60	440.56
Litter	198.22	198.18	208.94	209.16	180.09
Soils	36.75	32.31	30.31	24.59	31.39
Harvested wood products (HWP)	IO	IO	IO	IO	IO
Other gases	6.93	6.42	6.26	5.58	6.60

* CO₂) +: Emission, -: Removal

11.5.1.1.c. Forest Management

a) Above-ground biomass, Below-ground biomass

- **Methodology**

1. Emissions/removals in all forest lands are estimated from biomass stock data in the NFRDB (based on the stock difference method).
2. Emissions/removals relating to AR and D activities are subtracted from emissions/removals in all forest land. For ikusei-rin forest, emissions/removals in FM land are estimated by applying the FM ratio for each tree species, region and age class^{6,7}. For tennensei-rin forest, the areas of forest land with standing trees subject to practices for protection or conservation activities such as controlling logging activities and land-use change which have been implemented under laws are identified by using the NFRDB, and emissions/removals are estimated.

- **Parameters**

The parameters are the same as those used for AR.

b) Dead wood, Litter and Soils

- **Methodology**

The carbon stock changes in dead wood, litter and mineral soil pools are estimated by the Tier 3 method. It is estimated by multiplying carbon emissions/removals per area in each pool, which are calculated by the CENTURY-jfos model for each type of forest management, by the land area of each type of forest management and then summing them.

$$\Delta C_{dls} = \sum_{k,m,j} \left\{ A_{k,m,j} \times (d_{k,m,j} + l_{k,m,j} + s_{k,m,j}) \right\}$$

ΔC_{dls} : Carbon stock change in dead wood, litter and soil [t-C/yr]

A : Area [ha]

d : Average carbon stock change in dead wood per unit area [t-C/ha/yr]

l : Average carbon stock change in litter per unit area [t-C/ha/yr]

s : Average carbon stock change in mineral soils per unit area [t-C/ha/yr]

k : Type of forest management

m : Age class or forest age

j : Tree species

CO₂ emissions from organic soil do not occur because soil drainage activities for organic soil in forest land were not implemented in Japan. Therefore, this category is reported as “NO”.

- **Parameters**

The average carbon stock changes per unit area for dead wood, litter and soils are calculated by the CENTURY-jfos model, which was the modified version of the CENTURY model (Colorado State

⁶ Only a part of stock losses may be accounted for as FM removals/emissions, when carbon stock changes obtained through the stock change method are multiplied by the FM ratios. In order to avoid this, all stock losses resulted from harvesting are included in the estimation of FM removals/emissions.

⁷ When prefectures and Regional Forest Offices update the Forest Registers, the Registers' data like tree species or areas may be revised in order to reflect the current status of forests. In this case, FM removals/emissions are modified to obtain values based on appropriate carbon stock changes. Without modification, the difference between carbon stock without revision at a time point and carbon stock with revision at another time point would be regarded as the carbon stock change between the two points of time under the stock change method, and it would not reflect the correct removals or emissions.

University) to accommodate for Japanese climate, soil, and vegetation conditions. Detailed explanation of the CENTURY-jfos model is provided in section 6.5.1.b) 2), Chapter 6 of this report.

c) *Harvested Wood Products (HWP)*

HWP under FM is the same of the HWP reporting of LULUCF under the Convention; carbon stock change in sawnwood, wooden board, and plywood used in buildings were estimated by using Tier 3 country-specific method. As for wood used for other than buildings (sawnwood, wooden board, plywood) and paper and paperboard (including waste paper), Tier 2 method described in *the KP Supplement* were used for calculation. The estimation equation, parameters used and activity data are the same as section 6.11 in Chapter 6 in this NIR.

d) *Other gases*

1) *Direct and indirect N₂O emissions from N fertilization*

N₂O emissions from N fertilization exist in Japan as explained in section 6.12, Chapter 6, of this report, even though their quantity is a very little. The amount of nitrogen-based fertilizer applied in Forest land cannot be separated to those in AR and in FM. Hence, N₂O emissions from N fertilization are reported in FM in a lump. With respect to the methodology and parameters applied to this category, see section 6.12, Chapter 6, of this report.

2) *N₂O and CH₄ emissions from drainage of soils*

Soil drainage activity for organic soils in forest land does not occur in Japan, this category is reported as “NO”.

3) *N₂O emissions from N mineralization/immobilization due to carbon loss/gain associated with land-use conversions and management change in mineral soils*

N₂O emissions from N mineralization associated with loss of soil organic matter is estimated by using Tier 1 method described in the *2006 IPCC Guidelines*. The estimation method and parameters are the same as section 6.14 and section 6.15 in Chapter 6 in this NIR. The activity data is gross loss of soil carbon which was extracted from land that soil carbon has reduced by each tree age and tree species in each prefecture.

4) *Biomass burning*

Emissions due to biomass burning are estimated in the same way as in the case of AR by multiplying GHG emissions due to fire for all forest land by the ratio of FM land area to all forest land area. Calculations are performed only for non-CO₂ emissions since CO₂ emissions are already included in the calculation of carbon stock change. 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”.

e) Results

Table 11-15 Net emissions and removals from FM activity

	2013	2014	2015	2016	2017
	[kt-CO ₂ eq.]	[kt-CO ₂ eq.]	[kt-CO ₂ eq.]	[kt-CO ₂ eq.]	[kt-CO ₂ eq.]
FM	-51,065.19	-51,393.96	-49,002.28	-46,463.20	-46,135.04
Above-ground biomass	-41,348.23	-40,760.37	-38,734.64	-36,700.13	-36,306.61
Below-ground biomass	-10,452.43	-10,326.09	-9,785.16	-9,395.19	-9,285.09
Dead wood	2,018.95	2,091.21	2,143.54	2,179.10	2,150.33
Litter	-198.23	-193.89	-182.44	-162.58	-159.64
Soils	-1,518.02	-1,455.79	-1,393.28	-1,330.06	-1,276.39
Harvested wood products (HWP)	337.86	-859.35	-1,150.76	-1,153.83	-1,374.66
Other gases	94.92	110.32	100.46	99.50	117.01

* CO₂+: Emission, -: Removal

11.5.1.1.d. Cropland Management

a) Above-ground biomass, Below-ground biomass

● Methodology

Carbon stock changes in living biomass in orchard were estimated by using Tier 2 stock-difference method described in the *2006 IPCC Guidelines*.

As for estimation equation, parameters used and activity data, see section 6.6.1.b) 1) in Chapter 6 in this NIR.

b) Dead Wood, Litter

Dead wood and litter in rice fields and in upland fields do not occur. In orchards, the practices that accumulate dead organic matter on the soil are not implemented. Therefore, carbon stocks are not changed over time and are not net sources. Hence, the carbon stock changes are treated as "NA" and reported as "NR" in the CRF-NIR table 1.

c) Soils

● Methodology

1) Mineral soil

Carbon stock changes in mineral soils in CM were estimated by applying the tier 3 model (Roth C) estimation method. As described in section 6.6.1.b) 2) in Chapter 6 in this NIR, mesh data have been used as input data of Roth C model and carbon stock changes were calculated by Roth C model in each grid (100 x 100 meter mesh). From the result of grid level calculation, the average carbon stock changes per unit area were estimated by prefecture and by land use subcategory (rice field, upland fields and orchards). This output (carbon stock change per unit area) was multiplied by the area in each prefecture and land use subcategory from statistics, and then the final results of carbon stock change were obtained. For the input parameters and data for Roth C model and annual fluctuation and main drivers of soil carbon stock change in mineral soil in CM, see section 6.6 in Chapter 6 in this NIR.

2) Organic soil

On-site CO₂ emissions from organic soils in rice fields and in upland fields were estimated by applying Tier 1, 2 described in the *2006 IPCC Guidelines*. Off-site CO₂ emissions via waterborne carbon losses from drained inland organic soils in rice fields and upland fields were estimated by applying Tier 1 described in section 2.2.2.1 in the *Wetlands Guidelines*. In Orchard, it was reported as "NO" because tillage and drainage were not implemented. For detailed information on the method, see section 6.6.1.b)

2) in Chapter 6 in this NIR.

● **Parameters**

Parameters used are the same as section 6.6.1.b) 2) in Chapter 6 in this NIR.

● **Activity data**

Regarding area subject to GM activity in current pasture land obtained by using method described in section 11.4.2.6, areas of mineral soil and organic soil were estimated by the ratio of organic soil in each prefecture, and were regarded as activity data, respectively. The area reported under GM activity but currently used as non-pasture land is not included in activity data for the carbon stock change estimation, since the emissions and removals are treated as zero for this land as described in Box 1.1 in *the KP Supplement*. For calculation of ratio of organic soil in pasture land, see section 6.7.1.b) 1) in Chapter 6 in this NIR.

d) Other gases

1) CH₄ emissions from drainage of soils

CH₄ emissions from drainage of organic soils in upland fields were estimated by applying Tier 1 method described in section 2.2.2.1 in the *Wetlands Guidelines*. The estimation equation and parameters used are the same as section 6.13 in Chapter 6 in this NIR. The activity data is the same as section 6.6.1.b) 2) in Chapter 6 in this NIR.

2) N₂O emissions from N mineralization/immobilization due to carbon loss/gain associated with land-use conversions and management change in mineral soils

Since the emissions from cropland converted from other-land use is subject to CM, the emissions calculated for reporting of LULUCF under the Convention are reported. The estimation equation and parameters used and activity data are the same as section 6.14 in Chapter 6 in this NIR.

3) Biomass burning

Since CO₂ emissions are already included in the calculation of carbon stock change, non-CO₂ emissions from burning of pruned branches from orchard trees were reported as part of the GHG emissions in CM land. In addition, emissions from wild fires are not reported, as it is considered almost impossible that wild fires occur under our farmland management system. The estimation method, parameters and activity data are the same as section 6.16.b) 2) in Chapter 6 in this NIR.

e) Results

Table 11-16 Net emissions from CM activity

	1990	2013	2014	2015	2016	2017
	[kt-CO ₂ eq.]	[kt-CO ₂ eq.]	[kt-CO ₂ eq.]	[kt-CO ₂ eq.]	[kt-CO ₂ eq.]	[kt-CO ₂ eq.]
CM	10,281.38	3,625.43	4,370.46	4,290.52	4,764.12	4,514.68
Above-ground biomass	160.75	89.60	85.50	112.27	109.44	105.38
Below-ground biomass	118.80	54.45	51.86	66.36	65.02	63.07
Dead wood	NA	NA	NA	NA	NA	NA
Litter	NA	NA	NA	NA	NA	NA
Soils (mineral)	8,248.58	1,807.20	2,558.04	2,437.15	2,916.03	2,668.11
Soils (organic)	1,652.36	1,613.48	1,614.59	1,614.75	1,614.37	1,617.75
Non-CO ₂ (organic soil)	35.96	34.76	34.76	34.75	34.74	34.87
Non-CO ₂ (N mineralization)	32.80	3.61	3.67	3.57	3.20	4.54
Non-CO ₂ (biomass burning)	32.13	22.33	22.04	21.67	21.32	20.97

* CO₂ +: Emission, -: Removal

11.5.1.1.e. Grazing Land Management

a) Above-ground biomass, Below-ground biomass

- **Methodology**

Carbon stock gain in living biomass in grassland converted from land other than forest land was reported. The estimation equation, parameters used and activity data are the same as sections 6.7.2.b) 1) in Chapter 6 and 11.4.2.6 in Chapter 11 in this NIR.

b) Dead Wood, Litter

It is assumed that carbon stocks in dead wood and litter in grassland do not change in Japan, according to the 2006 IPCC Guidelines. Therefore, the carbon stock changes are treated as “NA” and are reported as “NR” in the CRF-Table NIR 1 because these carbon pools are not net sources of GHGs.

c) Soils

- **Methodology**

1) Mineral soil

Carbon stock changes in mineral soils in GM were estimated by applying the tier 3 model (Roth C) estimation method. For detailed information on the method, see section 6.6.1 b 2) in Chapter 6 in this NIR. For the annual fluctuation and main drivers of soil carbon stock change in mineral soil in GM, see section 6.7 in Chapter 6 in this NIR.

2) Organic soil

On-site CO₂ 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 cropland remaining cropland. Off-site CO₂ emissions via waterborne carbon losses from drained inland organic soils were estimated by applying Tier 1 estimation method described in the Wetlands Guidelines. For detailed information on the method, see section 6.7.1.b) 2) in Chapter 6 in this NIR.

- **Parameters**

Parameters used are the same as section 6.7.1.b) 2) in Chapter 6 in this NIR.

- **Activity data**

Regarding area subject to GM activity in current pasture land obtained by using method described in section 11.4.2.6, areas of mineral soil and organic soil were estimated by using the ratio of organic soil by prefecture, and were used for estimating as activity data, respectively. As explanation described in Box1.1 in the KP Supplement, since emissions and removals are treated as zero, the area subject to GM activity in current non-pasture land is not included in activity data to be used for the estimation. For calculation of ratio of organic soil in pasture land, see section 6.7.1.b) 1) in Chapter 6 in this NIR.

d) Other gases

1) CH₄ emissions from drainage of soils

CH₄ emissions from drainage of organic soils in pasture land were estimated by applying Tier 1 method described in section 2.2.2.1 in the Wetlands Guidelines. The estimation equation and parameters used are the same as section 6.13 in Chapter 6 in this NIR. The activity data is the same as section 6.7.1.b)

1) in Chapter 6 in this NIR.

2) *N₂O emissions from N mineralization/immobilization due to carbon loss/gain associated with land-use conversions and management change in mineral soils*

Estimation equation, parameters used and activity data are the same as section 6.14 in Chapter 6 in this NIR.

3) *Biomass burning*

Emissions from biomass burning in GM were reported as “NO” because open burning in pasture land do not occur in Japan.

e) *Results*

Table 11-17 Emissions and removals from GM activity

	1990	2013	2014	2015	2016	2017
	[kt-CO ₂ eq.]	[kt-CO ₂ eq.]	[kt-CO ₂ eq.]	[kt-CO ₂ eq.]	[kt-CO ₂ eq.]	[kt-CO ₂ eq.]
GM	841.27	-273.16	-95.06	-160.54	-218.83	-257.35
Above-ground biomass	-10.76	-2.63	-2.39	-2.22	-2.29	-3.35
Below-ground biomass	-43.06	-10.52	-9.56	-8.89	-9.14	-13.39
Dead wood	NA	NA	NA	NA	NA	NA
Litter	NA	NA	NA	NA	NA	NA
Soils (mineral)	861.59	-298.40	-126.98	-194.99	-240.37	-273.47
Soils (organic)	28.88	32.25	37.57	39.23	28.54	28.45
Non-CO ₂ (organic soil)	2.26	2.52	2.94	3.07	2.23	2.23
Non-CO ₂ (N mineralization)	2.36	3.62	3.37	3.25	2.19	2.18

* CO₂: +: Emission, -: Removal

11.5.1.1.f. Revegetation

Methodologies for estimating GHG emissions and removals from RV activity are described in two cases: when RV activity is performed on the land where no land conversion has occurred (remaining land) and on the land where land conversion has occurred (Conversion Land).

a) *Remaining land: Above-ground biomass, Below-ground biomass*

Japan estimates the carbon stock change in above-ground biomass and below-ground biomass of tall trees planted in RV lands. Tall trees are consistent with the definition in “Standards for the quality and size of planted trees for the public (draft)”⁸.

● *Methodology*

$$\Delta C_{RVLB} = \sum_i (\Delta C_{LBG,i} - \Delta C_{LBL,i})$$

$$\Delta C_{LBG,i} = \Delta B_{LBG,i}$$

$$\Delta B_{LBG,i} = \sum_j (NT_{i,j} \times C_{Ratei,j})$$

ΔC_{RVLB} : Annual carbon stock changes in living biomass in remaining RV land [t-C/yr]

ΔC_{LBG} : Annual carbon stock changes due to living biomass growth in remaining RV land [t-C/yr]

ΔC_{LBL} : Annual carbon stock changes due to living biomass loss in remaining RV land [t-C/yr]

ΔB_{LBG} : Annual living biomass growth in RV land [t-C/yr]

C_{Rate} : Annual living biomass growth rate per tree [t-C/tree/yr]

⁸ “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.

- NT* : Number of trees
- i* : Type of urban green facilities (Urban parks, Green areas on roads, Green areas at ports, Green areas around sewage treatment facilities, Green areas by greenery promoting systems for private green space, Green areas along rivers and erosion control sites, Green areas around public rental housing and Green areas around government buildings)
- j* : Tree species

● **Parameters⁹**

➤ **Urban parks**

Carbon stock changes due to the loss of living biomass in urban parks are assumed to be zero based on Tier 2b method in the *2006 IPCC Guidelines* (p. 8.9), because the average age of trees is found to be less than or equal to 30 years in the tree survey for sample urban parks¹⁰ (*Parks, Green Spaces and Landscape Division, Ministry of Land, Infrastructure, Transport and Tourism (MLIT), 2014*).

The annual living biomass growth of trees in urban parks is 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* (p. 8.10, Table 8.2) and the country specific annual growth rates of living biomass for the trees in Japan (0.0204 for Japanese zelkova, 0.0103 for ginkgo, 0.0095 for bamboo-leaf oak and 0.0122 t-C/tree/yr for camphor tree) by taking into account the distribution ratio of tree species in sample urban parks¹¹. The annual growth rates of living biomass for Japanese zelkova, ginkgo, bamboo-leaf oak and camphor tree 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 ratio of above-ground biomass/below-ground biomass, the default value (root-to-shoot ratio: 0.26) provided in the *2006 IPCC Guidelines* (p. 8.9) is applied.

➤ **Green areas on roads**

Carbon stock changes due to the loss of living biomass in green areas on roads are assumed to be zero, because the average age of trees is found to be less than or equal to 30 years for those trees planted in randomly extracted green areas on roads.

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 combining the 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, taking into account the distribution ratio of tree species indicated by the surveys

⁹ The Tier 1b method described in the *2006 IPCC Guidelines* and the Tier 2b method with country-specific annual biomass growth rates are applied for the estimation of the annual growth rate of living biomass per tree. Japan will further improve the accuracy of this estimation.

¹⁰ 129 samples were randomly extracted from the urban parks notified after 1 January 1990 and located in Kanagawa prefecture, which is located in Japan's typical climate zone and has various types of urban parks. In addition, the same survey was implemented in 3 urban parks in Chiba prefecture, which is located next to Kanagawa prefecture, in order to cover the park types that did not exist in Kanagawa prefecture.

¹¹ The distribution ratio of tree types was calculated by using tree registers and plantation maps for all urban parks in Kushiro city and Yubari city in Hokkaido and for 321 randomly extracted urban parks in the other prefectures.

in green areas on roads¹².

For the ratio of above-ground biomass/below-ground biomass, the same value used for urban parks is applied.

➤ **Urban green areas other than Urban parks, Green areas on roads and Green areas by greenery promoting systems for private green space**

Carbon stock changes due to the loss of living biomass in these green areas are assumed to be zero, because the standard of planted trees, tree types and their distribution are applied in the same manner as in urban parks.

The annual living biomass growth and the ratio of above-ground biomass/below-ground biomass are the same parameters as for urban parks.

➤ **Green areas by greenery promoting systems for private green space**

Carbon stock changes due to the loss of living biomass in these green areas are assumed to be zero, because the standard of planted trees is selected in the same manner as in urban parks and all facilities have been certified since 2002.

The annual living biomass growth and the ratio of above-ground biomass/below-ground biomass are the same parameters as for urban parks.

● **Activity data**

➤ **Urban parks**

The area of land remaining urban parks is calculated by multiplying the area of urban parks by the area ratio of land conversion for the whole country. The activity data for carbon stock changes in living biomass in urban parks is the number of tall trees planted in urban parks which is calculated by multiplying the area of urban parks obtained from the “Urban Parks Status Survey” by the number of tall trees per area (Hokkaido: 329.5 tree/ha, the other prefectures: 222.3 tree/ha). 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%.¹³

Table 11-18 Area of urban parks which were not classified as forest land on 31 December 1989

At the end of FY2017

	Land-use category	Area ratio of land which has been converted from forest land to settlements from FY1990 to FY2015	Area [ha]	Classified as RV land
Urban parks which have been notified since 1st January 1990 and whose establishment area is 500 m ² or more	Forest	5.42%	3,374.75	No
	Non-forest	94.58%	58,918.55	Yes
	Total	100.00%	62,293.30	-

¹² The distribution ratio of tree types is taken from the *Road Tree Planting Status Survey (The Street tree of Japan VI)*, which covered green areas on roads throughout Japan.

¹³ 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. For Hokkaido, the number of samples was not sufficient to satisfy the significant level of 95% because the tree register has not been developed completely.

Table 11-19 Area of urban parks which have been classified as RV and activity data (remaining land / converted land)

At the end of FY2017

	Land-use category	Area ratio of land which has been converted in the current year	Area [ha]	Activity data [Number of tall trees]
Urban parks which have been notified since 1st January 1990 and whose establishment area is 500 m ² or more (classified as RV land)	Converted (except land converted from forest land)	0.28%	166.09	38,876
	Remaining	99.72%	58,752.45	13,751,975
	Total	100.00%	58,918.55	13,790,851

➤ **Green areas on roads**

The activity data (the number of tall trees) in “Remaining green areas on roads” is calculated by the following procedures.

1. The number of tall trees in all green areas on roads on 31 March 1990 and in the end of each corresponding fiscal year during the commitment period is estimated by using data from the “Road Tree Planting Status Survey” which have been implemented in FY1987, FY1992 and each corresponding fiscal year.
2. The number of tall trees planted after 1 April 1990 was calculated by subtracting the number at 31 March 1990 from the number for the end of each corresponding fiscal year (RV is an activity which takes place after 1 January 1990. However, Japan considers it an activity after 1 April 1990 because it is impossible to estimate the number of tall trees which have been planted between 1 April 1990 and 31 March 1990).
3. The number of tall trees calculated in step 2 is multiplied by the ratio of the number of tall trees planted on roads whose planted area is more than 500 m².
4. The number of tall trees calculated in step 3 is multiplied by the area ratio of green areas on roads, which were classified as “Forest land” on 31 December 1989.
5. The number of tall trees calculated in step 4 is multiplied by the area ratio of “Land remaining settlements”.

Table 11-20 Area of green areas on roads which have been classified as RV

At the end of FY2017

	Area of green areas on roads per tall tree [ha/tree]	Number of planted tall trees [tree]			Area ratio of planted lands which are 500 m ² or more [%]	Area ratio of land which was classified as forest land on 31st December 1989	Area of green areas on roads which was classified as RV land [ha]	Activity data [Number of tall trees]
		31st March 1990	31st March 2018	FY1990 - FY2017				
		a	b	c-b				
General roads (managed by the MLIT, Prefectures, local authorities, public corporations)	0.006237	4,342,070	6,947,097	2,605,027	99.00%	5.42%	15,213	2,439,178
Expressway (managed by now-defunct public corporation)	0.000829903	1,096,380	8,568,448	7,472,068	100.00%	5.42%	5,865	7,067,267
Total	—	5,438,450	15,515,545	10,077,095	—	—	21,078	9,506,445

MLIT: Ministry of Land, Infrastructure, Transport and Tourism

Table 11-21 Area of green areas on roads which have been classified as RV and activity data [number of tall trees] (remaining land / converted land)

At the end of FY2017

	Land-use category	Area ratio of land which has been converted in the current year	Activity data [Number of tall trees]	Area [ha]
Green areas on roads which have been notified since 1st January 1990 and whose establishment area is 500 m ² or more (classified as RV land)	Converted	0.28%	26,799	59.42
	Remaining	99.72%	9,479,646	21,018.87
	Total	100.00%	9,506,445	21,078.29
General roads	Converted	0.28%	6,876	42.89
	Remaining	99.72%	2,432,302	15,170.27
	Total	100.00%	2,439,178	15,213.15
Expressway	Converted	0.28%	19,923	16.53
	Remaining	99.72%	7,047,344	5,848.61
	Total	100.00%	7,067,267	5,865.14

* "Converted": except land converted from forest land.

➤ Green areas at ports

The activity data for carbon stock changes in living biomass in green areas at ports is the number of tall trees planted in green areas at ports. The activity data is calculated by multiplying the service area obtained from complete census by the number of tall trees per unit area of urban parks (329.5 trees/ha for Hokkaido and 222.3 trees/ha for the other prefectures). These values were adopted by taking into account the similarities between the urban parks and the green areas at ports as mentioned above. All green areas at ports are located in "settlements" and judged not being classified as "Forest land" on 31 December 1989.

Table 11-22 Area of green areas at ports and activity data (remaining land / converted land)

At the end of FY2017

Land-use category	Area ratio of land which has been converted in the current year	Area [ha]	Activity data [Number of tall trees]
Converted	0.28%	5.21	1,185
Remaining	99.72%	1,844.45	419,056
Total	100.00%	1,849.66	420,241

➤ Green areas around sewage treatment facilities

The area of land remaining green areas around sewage treatment facilities is calculated in the same manner as for urban parks. The activity data for carbon stock change in living biomass in green areas around sewage treatment facilities are obtained from the "Sewage Treatment Facility Status Survey" for each fiscal year during the commitment period. The number of tall trees planted in green areas around sewage treatment facilities is calculated by multiplying the greening areas by the number of tall trees per greening area (129.8 tree/ha for Hokkaido and 429.2 tree/ha for the other prefectures).¹⁴ All green areas around sewage treatment facilities are located in "settlements".

¹⁴ 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.

Table 11-23 Area of green areas around sewage treatment facilities which were not classified as “Forest land” on 31 December 1989

At the end of FY2017

Land-use category	Area ratio of land which has been converted from forest land to settlements from FY1990 to FY2015	Area (ha) (Green areas)	Classified as RV land
Forest	5.42%	37.75	No
Non-forest	94.58%	659.01	Yes
Total	100.00%	696.76	-

Table 11-24 Area and activity data of “Green areas around sewage treatment facilities” [number of tall trees] (remaining land / converted land)

At the end of FY2017

Land-use category	Area ratio of land has been converted for the current year	Area [ha] (Green areas)	Activity data [Number of tall trees]
Converted (except land converted from forest land)	0.28%	1.86	754
Remaining	99.72%	657.16	266,831
Total	100.00%	659.01	267,585

➤ *Green areas by greenery promoting systems for private green space*

Activity data (the number of tall trees) is available for each facility. Therefore, the total number of tall trees is used as activity data.

Table 11-25 Activity data and area of “Green areas by greenery promoting systems for private green space”

Certification year	Location	Area [m ²]	Breakdown of area [m ²]			Area Wall green area by greenery promoting system for private green space [m ²]	Activity data Number of tall trees [tree]
			Ground	Roof	Wall		
2002	Minato-ku, Tokyo	17,244	1,314	2,042	106	3,356	335
2002	Minato-ku, Tokyo	19,708	3,285	736	0	4,021	147
2002	Minato-ku, Tokyo	52,766	10,679	0	0	10,679	672
2002	Minato-ku, Tokyo	84,780	8,846	9,386	0	18,232	813
2003	Minato-ku, Tokyo	5,519	1,374	280	0	1,654	167
2003	Osaka City	22,282	1,527	3,164	110	4,691	500
2005	Kawaguchi City	1,995	586	164	18	750	153
2006	Kyoto City	3,857	1,271	0	0	1,271	90
2006	Hiroshima City	4,453	130	783	0	913	1
2007	Hiroshima City	14,353	4,058	0	0	4,058	261
2007	Fukuoka City	5,689	773	799	0	1,572	19
2008	Ishikawa Prefecture	7,281	682	1,411	0	2,093	19
2009	Setagaya-ku, Tokyo	5,526	1,116	0	0	1,116	51
2009	Setagaya-ku, Tokyo	6,459	1,370	0	0	1,370	15
Total		251,912	37,011	18,765	234	55,776	3,243

* There were no areas certified from FY2010 to FY2017.

➤ **Green areas along rivers and erosion control sites**

The area of land remaining green areas along rivers and erosion control sites is calculated by multiplying the area of this green area by the area ratio of land conversion for the whole country. The activity data for living biomass (the number of tall trees) is calculated by multiplying this area by the number of tall trees per area (Hokkaido: 1470.8 tree/ha, the other prefectures: 339.0 tree/ha).¹⁵

The green areas along rivers and erosion control sites exclude lands, which were classified as Forest land at the time of survey. Therefore, land conversion from Forest land is not taken into account for the estimation of activity data.

Table 11-26 Activity data and area of “Green areas along rivers and erosion control sites” (remaining land / converted land)

At the end of FY2017

	Land-use category	Area ratio of land which has been converted in the current year	Area [ha]	Activity data [Number of tall trees]
Green areas along rivers and erosion control sites which have been established since 1st January 1990 and whose establishment area is 500 m ² or more (classified as RV land)	Converted (except land converted from forest land)	0.28%	4.90	2,708
	Remaining	99.72%	1,733.69	958,051
	Total	100.00%	1,738.59	960,759

➤ **Green areas around government buildings**

The area of land remaining green area around government buildings is calculated by multiplying the area of this green area by the area ratio of land conversion for the whole country. The activity data for living biomass (the number of tall trees) is calculated by multiplying this area by the number of tall trees per area (all prefecture: 108.8 tree/ha).¹⁶

Table 11-27 Area of “Green areas around government buildings” which were not classified as “Forest land” on 31 December 1989

At the end of FY2017

	Land-use category	Area ratio of land which has been converted from forest land to settlements from FY1990 to FY2015	Area [ha] (Green areas)	Classified as RV land
Green areas around government buildings which have been established since 1st January 1990 and whose establishment area is 500 m ² or more	Forest	5.42%	18.21	No
	Non-forest	94.58%	317.92	Yes
	Total	100.00%	336.13	-

¹⁵ 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.

¹⁶ 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.

Table 11-28 Area and activity data of “Green areas around government buildings”
(remaining land / converted land)

At the end of FY2017

	Land-use category	Area ratio of land which has been converted in the current year	Area [ha]	Activity data [Number of tall trees]
Green areas around government buildings which have been established since 1st January 1990 and whose establishment area is 500 m ² or more (classified as RV land)	Converted (except land converted from forest land)	0.28%	0.90	98
	Remaining	99.72%	317.02	34,492
	Total	100.00%	317.92	34,590

➤ **Green areas around public rental housing**

The area of land remaining green areas around public rental housing is calculated by multiplying the area of this green area by the area ratio of land conversion for the whole country. The activity data for living biomass (the number of tall trees) is calculated by multiplying this area by the number of tall trees per area (all prefecture: 219.9 tree/ha).¹⁷

Table 11-29 Area of “Green areas around public rental housing” which were not classified as “Forest land” on 31 December 1989

At the end of FY2017

	Land-use category	Area ratio of land which has been converted from forest land to settlements from FY1990 to FY2015	Area [ha] (Green areas)	Classified as RV land
Green areas around public rental housing which have been established since 1st January 1990 and whose establishment area is 500 m ² or more	Forest	5.42%	149.87	No
	Non-forest	94.58%	2,616.57	Yes
	Total	100.00%	2,766.44	-

Table 11-30 Area and activity data of “Green areas around public rental housing”
(remaining land / converted land)

At the end of FY2017

	Land-use category	Area ratio of land which has been converted in the current year	Area [ha]	Activity data [Number of tall trees]
Green areas around public rental housing which have been established since 1st January 1990 and whose establishment area is 500 m ² or more (classified as RV land)	Converted (except land converted from forest land)	0.28%	7.38	1,622
	Remaining	99.72%	2,609.19	573,761
	Total	100.00%	2,616.57	575,383

b) Remaining land: Dead wood

➤ **Urban parks**

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”.

¹⁷ 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.

➤ **Green areas on roads**

The number of tall trees used in the estimation of activity data for living biomass is obtained in the survey every 5 years (implemented every year since 2007). These data include the effects of dead wood and complementary planting, thus the carbon stock change in dead wood is included in the carbon stock changes in living biomass. Therefore, this category is reported as “IE”.

➤ **Urban green facilities other than Urban parks and Green areas on roads**

These categories are reported as “IE” based on the same assumption as urban parks.

c) Remaining land: Litter

Carbon stock changes in litter are estimated for urban parks and green areas at ports.

● **Methodology**

$$\Delta C_{RVLit} = \sum_i (A_i \times L_{it,i})$$

ΔC_{RVLit} : Annual carbon stock changes in litter in remaining RV land [t-C/yr]

A : Area of remaining RV land [ha]

L_{it} : Annual carbon stock changes in litter per RV land [t-C/ha/yr]

i : Type of urban green facilities (Urban parks and Green areas at ports)

● **Parameters**

➤ **Urban parks and Green areas at ports**

Carbon stock changes in litter were estimated only in branches and leaves dropped naturally from tall trees. The carbon stock changes in litter per urban park area are calculated by using the annual accumulation of litter per tall tree (all prefectures: 0.0006 t-C/tree/yr) based on the results of a field survey in urban parks¹⁸, the number of tall trees per area and the ratio of litter moved to off-site due to management including cleaning (54.4%). As a result, carbon stock change in litter per urban park area is calculated to be 0.0882 t-C/ha/yr for Hokkaido and 0.0594 t-C/ha/yr for other prefectures. In addition, 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 (p.8.21).

➤ **Urban green facilities other than urban parks and green areas at ports**

Litter in these urban green facilities includes branches and leaves dropped naturally and dead roots. A part of the litter remains on-site and leads to an increase in carbon stocks, although other litter is moved to off-site due to management such as cleaning (such litter is dropped from trees planted after the establishment of green areas). Dead roots also lead to an increase in carbon stocks because they are not moved to off-site.

It is clear that the litter in the urban green facilities other than urban parks and green areas at ports because the input of fallen branches and leaves and dead roots into these facilities increases carbon stocks as mentioned above. However, it is difficult to accurately estimate the carbon stock changes in

¹⁸ The annual accumulation of litter dropped naturally was measured for some tree types by using litter traps installed in Takino Suzuran Kyuryo National Government Park (Hokkaido) and Showa Kinen National Government Park (Tokyo). Litter is defined as branches and leaves dropped on the surface. In the selection of parks for the survey, large-sized and intensively managed national government parks in which continuous monitoring is available and different types of trees have been planted are considered to meet the measurement requirements. In addition, it is also considered that the distribution of tree types differs between Hokkaido and other prefectures. Therefore, Japan selected two parks for the survey, one in Hokkaido and the other in a typical climate zone excluding Hokkaido.

litter in these urban green facilities because of limited information on various managements (such as cleaning). Therefore, as a conservative treatment, these sub-categories are not subject to reporting because they are not sources of GHGs.

- **Activity data**

The activity data is the same as for living biomass.

d) Remaining land: Soils

Urban parks, for which the carbon stock changes in soils per area were determined, and green areas at ports, whose management practices are similar to those for urban parks, are the subject of estimation. In general, soils in RV land are not organic soils (peat soils and muck soils). Therefore, organic soils are reported as “NO”, and only mineral soils are estimated.

- **Methodology**

$$\Delta C_{RVSoils} = \sum_i (\Delta C_{Mineral,i} - L_{Organic,i})$$

$$\Delta C_{Mineral,i} = A_i \times \Delta C_{Soil,i}$$

$\Delta C_{RVSoils}$: Annual carbon stock changes in soils in remaining RV land¹⁹ [t-C/yr]

$\Delta C_{Mineral}$: Annual carbon stock changes in mineral soils in RV land [t-C/yr]

$L_{Organic}$: Annual carbon stock changes in organic soils in RV land (=0) [t-C/yr]

A : Area of remaining RV land [ha]

ΔC_{Soil} : Annual carbon stock changes in soils per area of remaining RV land [t-C/ha/yr]

i : Type of urban green facilities (Urban parks and Green areas at ports)

- **Parameters**

➤ **Urban parks and Green areas at ports**

Carbon stock changes in soils per area of RV land are estimated based on the results of surveys²⁰ conducted in urban parks which have been established within 30 years (1.28t-C/ha/yr for 0~20 years and 1.38t-C/ha/yr for 21~30 years) (Tonosaki et al., 2013; Parks, Green Spaces and Landscape Division, Ministry of Land, Infrastructure, Transport and Tourism (MLIT), 2015)²¹.

This value is applicable to land, which is the subject of revegetation activity and was established within 30 years, because the value is based on the results of surveys conducted in urban parks which have been

¹⁹ Soil organic carbon pools are the subject of estimation of carbon stock changes in soils in RV land.

²⁰ 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.

²¹ 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 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”

Furthermore, 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. The soil carbon stocks of bare area are about 38 t-C/ha when converted from the sample data.

established within 30 years.

➤ ***Urban green facilities other than Urban parks and Green areas at ports***

It is assumed that the patterns of carbon stock changes in soils in these urban green facilities 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 available data. Therefore, as a conservative treatment, these sub-categories are not subject to reporting because they are not sources of GHGs. The estimation for urban green facilities other than urban parks and green areas at ports will be further considered in the future.

● ***Activity data***

The area is as obtained for estimating the activity data for living biomass.

e) Remaining land: Other gases

1) Direct and indirect N₂O emissions from N fertilization

It is assumed that the volume of nitrogen-based fertilizer applied to urban parks is included in the demand for nitrogen-based fertilizers in the Agriculture sector, although fertilization in urban parks has been conducted in Japan. Therefore, these sources have been reported as “IE”.

2) N₂O and CH₄ emissions from drainage of soils

Because soil drainage activity for organic soils in RV does not occur in Japan, this category is reported as “NO”.

3) N₂O emissions from N mineralization/immobilization due to carbon loss/gain associated with land-use conversions and management change in mineral soils

Since soil carbon stock changes in RV are reported to be on the increases, according to method under Tier 2 described in *the 2006 IPCC Guidelines*, N₂O emissions from immobilization associated with gain of soil organic matter were not estimated. Therefore, N₂O emissions in this subcategory is reported as “NA”.

4) Biomass burning

In settlements subjected to RV activities, burning of residues is restricted by the “Waste Management and Public Cleansing Law” and the “Fire Defense Law”. In addition, wild fires do not usually occur in lands subjected to RV activities because these lands are managed. Therefore, biomass burning activities which lead to carbon emissions do not occur and Japan reports this category as “NO”.

f) Land converted from other land-use categories: Above-ground biomass, Below-ground biomass

● ***Methodology***

For RV activities, land conversion occurs due to the establishment or building of “facilities” and all living biomass is basically replaced in one year (In the case of urban parks converted from cropland, new planting in urban parks is carried out after removal of trees in cropland).

In Japan’s basic estimation principles for land converted to RV land, the facilities newly established by

land conversion in the reporting year are defined as “Land converted to RV land”. The estimation methods are shown below.

$$\Delta C_{RVLUC} = \sum_i \left\{ A_i \times (C_{AfterLBi} - C_{BeforeLBi}) + (\Delta C_{RVLUCGi} - \Delta C_{RVLUCLi}) \right\}$$

$$\Delta C_{RVLUCGi} = \Delta B_{RVGi}$$

$$\Delta B_{RVGi} = \sum_j (NT_{i,j} \times C_{Ratei,j})$$

ΔC_{RVLUC} : Annual carbon stock changes in living biomass in converted RV land [t-C/yr]

A : Area of converted RV land [ha/yr]

$C_{AfterLB}$: Carbon stocks in living biomass immediately following land conversion [t-C/ha]

$C_{BeforeLB}$: Carbon stocks in living biomass immediately before land conversion [t-C/ha]

ΔC_{RVLUCG} : Annual carbon stock changes due to living biomass growth in converted RV land [t-C/yr]

ΔC_{RVLUCL} : Annual carbon stock changes due to living biomass loss in converted RV land [t-C/yr]

ΔB_{RVG} : Annual biomass growth in RV land [t-C/yr]

C_{Rate} : Annual living biomass growth per tree [t-C/tree/yr]

NT : Number of trees

i : Type of urban green facilities (Urban parks, Green areas on roads, Green areas at ports, Green areas around sewage treatment facilities, Green areas by greenery promoting systems for private green space, Green areas along rivers and erosion control sites, Green areas around public rental housing and Green areas around government buildings)

j : Tree species

● **Parameters**

➤ **Urban parks**

The carbon stocks in living biomass immediately before conversion [t-C/ha] are the same as those for grassland, cropland, wetlands and other land. The carbon stocks in living biomass immediately after conversion are assumed to be zero (When urban parks classified as RV land are established, planting activities occur and living biomass is stocked. It is assumed that these biomass stocks are zero because they are carried from other fields and they are grown by the RV activities). In addition, it is assumed that all living biomass before conversion is lost due to the establishment of RV land. The other parameters are assumed to be the same as the ones for “Remaining urban parks”.

➤ **Urban green facilities other than Urban parks**

The carbon stocks in living biomass immediately before and after conversion [t-C/ha] are the same as those for urban parks converted from other land uses.

The other parameters are assumed to be the same as the ones for “Remaining green area on roads”, “Remaining green area at ports”, “Remaining green area around sewage treatment facilities”, “Remaining green area along rivers and erosion control sites”, “Remaining green area around public rental housing” and “remaining green area around government buildings”.

● **Activity data**

➤ **Urban parks**

The area of land converted to urban parks is calculated by multiplying the area of urban parks by the area ratio of land conversion for the whole country. The activity data for living biomass (the number of tall trees) is estimated in the same manner as for “remaining urban parks”.

Table 11-31 Area of “Urban parks” and activity data (remaining land /converted land)

At the end of FY2017

	Land-use category before conversion	Area ratio of land which has been converted in the current year	Area [ha]	Activity data [Number of tall trees]
Urban parks which have been notified since 1st January 1990 and whose establishment area is 500 m ² or more	Remaining land	99.72%	58,752.45	13,751,975
	Cropland	0.23%	136.73	32,005
	Grassland	0.05%	29.36	6,872
	Wetlands	IE	IE	IE
	Other land	IE	IE	IE
	Total	100.00%	58,918.55	13,790,852

➤ Green areas on roads

The area of land converted to green area on roads is calculated by multiplying the area of green areas on roads by the area ratio of land conversion for the whole country. The activity data for living biomass (the number of tall trees) is estimated in the same manner as for “remaining green area on roads”.

Table 11-32 Area of “Green areas on roads” and activity data for each land-use category

At the end of FY2017

	Land-use category before conversion	Area ratio of land which has been converted in the current year	Area [ha]	Activity data [Number of tall trees]
Green areas on roads which have been notified since 1st January 1990 and whose establishment area is 500 m ² or more	Remaining	99.72%	21,018.87	9,479,646
	Cropland	0.23%	48.92	22,062
	Grassland	0.05%	10.50	4,737
	Wetlands	IE	IE	IE
	Other land	IE	IE	IE
	Total	100.00%	21,078.29	9,506,445

➤ Green areas at ports

The area of land converted to green areas at ports is calculated by multiplying the service area of green areas at ports by the area ratio of land conversion for the whole country. The activity data for living biomass (the number of tall trees) is estimated in the same manner as for “remaining green areas at ports”.

Table 11-33 Area of “Green areas at ports” and activity data for each land-use category

At the end of FY2017

Land-use category before conversion	Area ratio of land which has been converted in the current year	Area [ha]	Activity data [Number of tall trees]
Remaining land	99.72%	1,844.45	419,056
Cropland	0.23%	4.29	975
Grassland	0.05%	0.92	209
Wetlands	IE	IE	IE
Other land	IE	IE	IE
Total	100.00%	1,849.66	420,240

➤ **Green areas around sewage treatment facilities**

The area of land converted to green areas around sewage treatment facilities is calculated by multiplying the green areas around sewage treatment facilities by the area ratio of land conversion for the whole country. The activity data for living biomass (the number of tall trees) is estimated in the same manner as for “remaining green area around sewage treatment facilities”.

Table 11-34 Area of “green areas around sewage treatment facilities” and activity data for each land-use category

At the end of FY2017

Land-use category before conversion	Area ratio of land which has been converted in the current year	Area [ha]	Activity data [Number of tall trees]
Remaining land	99.72%	657.16	266,831
Cropland	0.23%	1.53	621
Grassland	0.05%	0.33	133
Wetlands	IE	IE	IE
Other land	IE	IE	IE
Total	100.00%	659.01	267,585

➤ **Green areas along rivers and erosion control sites**

The area of land converted to green areas along rivers and erosion control sites is calculated by multiplying the planted land area by the area ratio of land conversion for the whole country. The activity data for living biomass (the number of tall trees) is estimated in the same manner as for “remaining green area along rivers and erosion control sites”.

Table 11-35 Area of “green areas along rivers and erosion control sites” and activity data for each land-use category

At the end of FY2017

Land-use category before conversion	Area ratio of land which has been converted in the current year	Area [ha]	Activity data [Number of tall trees]
Remaining land	99.72%	1,733.69	958,051
Cropland	0.23%	4.03	2,230
Grassland	0.05%	0.87	479
Wetlands	IE	IE	IE
Other land	IE	IE	IE
Total	100.00%	1,738.59	960,760

➤ **Green areas around government buildings**

The area of land converted to green areas around government buildings is calculated by multiplying the “total land area – building area” by the area ratio of land conversion for the whole country. The activity data for living biomass (the number of tall trees) is estimated in the same manner as for “remaining green area around government buildings”.

Table 11-36 Area of “green areas around government buildings” and activity data for each land-use category

At the end of FY2017

Land-use category before conversion	Area ratio of land which has been converted in the current year	Area [ha]	Activity data [Number of tall trees]
Remaining land	99.72%	317.02	34,492
Cropland	0.23%	0.74	80
Grassland	0.05%	0.16	17
Wetlands	IE	IE	IE
Other land	IE	IE	IE
Total	100.00%	317.92	34,589

➤ **Green areas around public rental housing**

The area of land converted to green areas around public rental housing is calculated by multiplying the “total land area – building area” by the area ratio of land conversion for the whole country. The activity data for living biomass (the number of tall trees) is estimated in the same manner as for “remaining green area around public rental housing”.

Table 11-37 Area of “green areas around public rental housing” and activity data for each land-use category

At the end of FY2017

Land-use category before conversion	Area ratio of land which has been converted in the current year	Area [ha]	Activity data [Number of tall trees]
Remaining land	99.72%	2,609.19	573,761
Cropland	0.23%	6.07	1,335
Grassland	0.05%	1.30	287
Wetlands	IE	IE	IE
Other land	IE	IE	IE
Total	100.00%	2,616.57	575,383

g) Land converted from other land use categories: Dead wood

When a RV activity following land-use conversion is implemented, dead wood is removed off-site and supplemental planting is implemented before conversion because almost all of such lands are managed and trees are assumed to be “property”. Therefore, dead wood is not left on the ground immediately before land-use conversion. The carbon stocks in dead wood immediately after conversion are assumed to be zero, the same as living biomass. Therefore, the carbon stocks in dead wood before and after conversion are assumed to be zero.

The carbon stocks in dead wood accumulated for a year after conversion are reported as “IE”, the same as for “Remaining land”.

h) Land converted from other land-use categories: Litter

Likewise the “remaining land”, Japan estimates carbon stock changes in litter in urban parks and green areas at ports only. The other urban green facilities (green areas on roads, green areas around sewage treatment facilities, green areas along rivers and erosion control sites, green areas around public rental

housing and green areas around government buildings) are not the subject of estimation and are not reported (NR), since these facilities are not net sources.

- **Methodology**

$$\Delta C_{LUCRVLit} = \sum_i \{ A_i \times (C_{AfterLit_i} - C_{BeforeLit_i}) + A_i \times Lit_i \}$$

$\Delta C_{LUCRVLit}$: Annual carbon stock changes in litter in land converted to RV land [t-C/yr]

$C_{AfterLit}$: Carbon stocks in litter immediately following land conversion [t-C/ha]

$C_{BeforeLit}$: Carbon stocks in litter immediately before land conversion [t-C/ha]

A : Area of converted RV land [ha/yr]

Lit : Annual carbon stock changes in litter per area of RV land [t-C/ha/yr]

i : Types of urban green facilities (Urban parks and Green areas at ports)

- **Parameters**

- **Urban parks and Green areas at ports**

When urban parks are converted from cropland, grassland or wetlands, soils before conversion are not moved to off-site and in general, these soils are used continuously after conversion or covered by additional soils. Therefore, litters and dead roots accumulated before conversion do not decrease due to the land-use conversion.

In addition, litter in urban parks immediately following conversion is very little, because the parks are newly planted. Therefore, carbon stock changes in litter due to land conversion are assumed to be zero.

The amount of carbon in litter accumulated for a year after conversion is estimated in the same manner as for “Remaining urban parks”.

- **Urban green facilities other than Urban parks and Green areas at ports**

The carbon stock changes in litter due to land-use conversion are assumed to be zero for the same reasons as for urban parks. With respect to after conversion, it is clear that the litter in the urban green facilities other than urban parks and green areas at ports because the input of fallen branches and leaves and dead roots into these facilities increases carbon stocks likewise the “remaining green area on roads”, “remaining green area around sewage treatment facilities”, “remaining green area along rivers and erosion control sites”, “remaining green area around public rental housings” and “remaining green area around government buildings” mentioned above. However, it is difficult to accurately estimate the carbon stock changes in litter in these urban green facilities because of limited information on various managements (such as cleaning). Therefore, as a conservative treatment, these sub-categories are not subject to reporting because they are not sources of GHGs.

- **Activity data**

The activity data is the same as for living biomass.

- i) **Land converted from other land-use categories: Soils**

Likewise the “remaining land”, urban parks and green areas at ports, whose management practices are similar to those in urban parks, are the only subject of estimation.

- **Methodology**

$$\Delta C_{LUCRVSoils} = \sum_i (\Delta C_{LUCMineral_i} - L_{LUCOrganic_i})$$

$$\Delta C_{LUCMineral_i} = \Delta A_i \times (C_{AfterSoil} - C_{BeforeSoil}) + A_i \times \Delta C_{soil_i}$$

- $\Delta C_{LUCRVSoils}$: Annual carbon stock changes in soils in RV land following land-use conversion [t-C/ha]
 $\Delta C_{LUCMineral}$: Annual carbon stock changes in mineral soils in RV land following land conversion [t-C/ha]
 $L_{LUCOrganic}$: Annual carbon stock changes in organic soils in RV land following land conversion (=0) [t-C/ha]
 ΔA : Area of land converted to RV land within a year [ha/yr]
 A : Area of land converted to RV land [ha]
 $C_{AfterSoil}$: Soil carbon stocks immediately after land-use conversion [t-C/ha]
 $C_{BeforeSoil}$: Soil carbon stocks before land-use conversion [t-C/ha]
 ΔC_{Soil} : Annual carbon stock changes in soils per RV land area [t-C/ha/yr]
 i : Types of urban green facilities (urban parks and green areas at ports)

- **Parameters**

- **Urban parks and Green areas at ports**

As mentioned in the section for litter, when urban parks are converted from cropland, grassland or wetlands, soils before conversion are almost never moved to off-site (even if moved to off-site, carbon in these soils are not emitted due to combustion). In general, these soils are used after conversion continuously or covered by additional soils.

Therefore, soil carbon stocks do not change due to land-use conversion (the carbon stocks may increase due to additional soils. However, Japan assumes that soil carbon stocks do not change because additional soils do not lead to carbon sequestration from the atmosphere).

Carbon stock changes in soils within a year after conversion is estimated in the same manner as for the remaining urban parks and green areas at ports.

- **Urban green areas other than Urban parks and Green areas at ports**

The urban green facilities other than urban parks and green areas at ports are not sources of GHGs because of the same reasons as for the “Land converted to urban parks”. Therefore, as a conservative treatment, these sub-categories are not subject to reporting because they are not sources of GHGs.

- **Activity data**

The area is as used for living biomass.

- j) **Land converted from other land-use categories: Other gases**

For reporting each GHG emission, the same way as the RV remaining RV is used.

k) Results

Table 11-38 Emissions and removals from RV activity

	1990	2013	2014	2015	2016	2017
	[kt-CO ₂]	[kt-CO ₂]	[kt-CO ₂]	[kt-CO ₂]	[kt-CO ₂]	[kt-CO ₂]
RV	-79.00	-1,222.70	-1,241.17	-1,261.87	-1,279.58	-1,289.85
Above-ground biomass	-47.29	-746.98	-756.02	-766.21	-775.24	-779.61
Below-ground biomass	-12.30	-194.22	-196.56	-199.22	-201.56	-202.70
Dead wood	IE	IE	IE	IE	IE	IE
Litter	-0.92	-12.93	-13.21	-13.53	-13.76	-13.93
Soils	-18.49	-268.57	-275.38	-282.91	-289.01	-293.61
Other gases	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO	IE,NA,NO

* CO₂+: Emission, -: Removal

For RV activities, various parameters (annual living biomass growth of trees, number of tall trees per area, etc.) which corresponding to specific characteristic of types of urban green facilities (sub-categories) and climatic division (Hokkaido, areas other than Hokkaido), have been applied.

Hence, the total removals per unit of revegetation area in each year are not the same because of composition of the sub-categories are different in each year.

11.5.1.2. Justification when omitting any carbon pool or GHG emissions/removals from activities under Article 3.3, forest management and elected activities under Article 3.4

Some carbon pools under RV activities (litter and soils: green areas on roads, green areas around sewage treatment facilities, green areas by greenery promoting systems for private green space, green areas along river and erosion control sites, green areas around public rental housing and green areas around government buildings) are not included in the reporting. Some intermediate results of the ongoing research project relating to RV land by the MLIT show a clear tendency that those carbon pools have been increasing although more research and analysis are necessary to quantify carbon stock changes in these carbon pools (Handa et al., 2008). This does not lead to over-estimation of removals because these carbon pools are not sources of GHGs, although further information and data are needed for estimating carbon stock changes in these carbon pools.

Carbon pools of dead wood and litter in CM and in GM are not included in the reporting. As described in the relevant sections, carbon stock changes in dead wood and litter in CM and in GM were estimated as zero. This does not lead to over-estimation of removals because these carbon pools are not sources of GHGs.

11.5.1.3. Information relating to exclusions of emission from natural disturbances

Japan does not apply to exclusion of emissions from natural disturbances.

11.5.1.4. Information relating to Harvest Wood Product (HWP)

● Overview and methodologies used

As described in 11.5.1.1.c), for HWP of the reporting of LULUCF under the Convention, carbon stock change in sawnwood, wooden board, and plywood used in buildings were estimated by using Tier 3 country-specific method. As for wood use other than buildings and paper and paperboard (including waste paper), were calculated by using Tier 2 method described in *the KP Supplement*. The estimation equation and used parameters and activity data are the same as section 6.11 in Chapter 6 in this NIR.

In the reporting under the Kyoto Protocol, the values were estimated by deducting the HWP resulting

from deforestation as instantaneous oxidation.

- ***Information on reporting HWP before the second commitment period of the Kyoto Protocol***

As shown in the CRF table 4(KP-I) B.1.1, forest management reference level (FMRL) is not based on a projection in Japan. Therefore, carbon stock changes in the HWP pool before the second commitment period of the Kyoto Protocol were included in the estimation in Japan. The FMRL for reporting five carbon pools (not including HWP) was set as zero in Japan. For the reporting HWP, HWP reference level was set newly based on a projection and reported as technical corrections. For detailed information on setting of HWP reference level, see section 11.7.5.

- ***Information on emissions from HWP calculated already during the first commitment period***

In Japan, emissions from the HWP pool that have been already accounted during the first commitment period of the Kyoto Protocol on the basis of instantaneous oxidation have not been excluded from the accounting for the second commitment period of the Kyoto Protocol, as well as from the HWP reference level. This is because the HWP reference level was set based on a projection. As a result, emissions from the HWP pool that have been accounted for during the first commitment period of the Kyoto Protocol on the basis of instantaneous oxidation has been canceled out and it to be zero.

- ***Information on HWP resulting from D land***

HWP resulting from D have been accounted on the basis of instantaneous oxidation (see section 11.5.1.1.b). For detailed information on methodology, see section 11.5.1.7.

- ***Information on CO₂ emissions from HWP in SWDS and logged wood for energy purpose***

The methodologies used for calculating carbon stock change in HWP are explained in section 6.11 in chapter 6 and the same methodologies are applied for reporting of LULUCF under the Kyoto Protocol. Since CO₂ emissions from HWP in solid waste disposal site (SWDS) are considered to be similar to incineration and not included in the HWP pool. Also, logged wood for energy purpose is not included in the HWP pool subject to accounting; those emissions from HWP have been accounted on the basis of instantaneous oxidation.

- ***Information on imported HWP***

As Production Approach for calculating carbon stock change in HWP was applied, emissions and removals resulting from changes in the HWP pool accounted for do not include imported HWP (see section 6.11 Chapter 6 in this NIR).

11.5.1.5. Information on whether or not indirect and natural GHG emissions and removals have been factored out

Japan does not factor out indirect, natural and pre-1990 effects specified in paragraph 3 in the annex II to decision 2/CMP.8 in estimating emissions/removals from activities under Articles 3.3 and 3.4.

11.5.1.6. QA/QC and verification

- ***General inventory QA/QC procedure***

As for reporting of LULUCF under the Kyoto Protocol, general inventory QC procedures have been conducted in accordance with the 2006 IPCC Guidelines as with reporting of LULUCF under the Convention. The focus of general inventory QC is on the checking of the parameters for activity data and emissions factors and the archiving of reference materials. QA/QC activities are summarized in Chapter 1.

- **Verification of Tier 3 estimation method**

For the calculation using Tier 3 method, the following verification activities have been carried out when applying the Roth C model in Japan.

- **Information on activities of calibration and validation**

Although calibration for Roth C estimation method has not been carried out, it was confirmed that the simulation results of Roth C matched well the measured data with selectively using the three modified versions of the Roth C model adopting to different land uses and soil types (Paddy soils, Andosols and non-Andosols). Regarding the suitability of Roth C model for estimating carbon stock changes in mineral soils in CM and GM, the modification and the verification of plot scale using the measured data in long-term field experiments have been carried out.

- **Demonstration that sites of calibration and validation have covered all of soil species and activities**

First of all, it is necessary to divide soils broadly into paddy soils and non-paddy soils depending on whether or not the soils are waterlogged due to the characteristics of soil carbon dynamics. Furthermore, for non-paddy soils, it is appropriate to divide them into Andosols and non-Andosols from the characteristics of soil carbon dynamics. As a result, it is considered appropriate that all agricultural soils to be divided into these three types above.

- **More detailed information on input data**

More detailed information on input data of Roth C model for estimating was described in a research paper listed below.

For detailed information on calibration and validation and input data of Roth C model, see references; Shirato Y, 2006, Shirato.Y & Taniyama.I, 2003, Shirato. Y et al., 2004, Shirato.Y & Yokozawa.M., 2005, Takata.Y et al., 2011, Shirato. Y et al., 2011, Yagasaki. Y et al., 2014 listed in this chapter.

11.5.1.7. Changes in data and methods since the previous submission (recalculations)

For reporting of LULUCF under the Kyoto Protocol, recalculation described below was carried out. For the impact of the recalculation, refer to Chapter 10.

- **Revision of AR and D areas**

In this submission, Japan revised the ARD ratio. As a result, the AR and D areas were recalculated. Due to this revision, carbon stock changes in above-ground biomass, below-ground biomass, litter, dead wood and mineral soils in AR, D and FM from FY2013 to FY2016 were also recalculated.

In addition, D areas and correspondent Article 3.4 areas which are subject to D and CM, GM, RV activities were recalculated due to this revision; hence, the areas of CM, GM and RV were also recalculated. As a result, carbon stock changes in all carbon pools in CM, GM and RV were also recalculated.

Moreover, ratios of disaggregating damaged timber volume from national to prefecture were estimated by utilizing AR area. Hence, CH₄ and N₂O emissions from biomass burning in AR and FM was recalculated because of revision of the ratios of disaggregating amount of damaged timber volume due to revision of AR area.

- **Revision of methodology for estimating organic soils in CM and GM**

With the revision of the estimation method for area of organic soils in rice fields, upland fields and pasture land, CO₂ and CH₄ emissions by plowing organic soils (on-site emissions), and emissions from water-soluble carbons (off-site emissions) were recalculated. Furthermore, the areas of mineral soil in each land use sub-category were also recalculated, as these were the areas obtained by subtracting the organic soil areas from the each of whole area, so the carbon stock changes in mineral soils in CM and GM were also recalculated.

- **Correction by area of Orchard in CM**

Since the fruit tree area other than the main fruit species was newly included in the calculation, the carbon stock change of living biomass in orchard and CH₄ and N₂O emissions associated with the burning of pruned branches were recalculated.

- **Revisions of activity data and parameters used for calculating carbon stock change in HWP**

In this submission, due to revision of the activity data (Correction of floor area of destroyed buildings) and some parameters (correction of the amount of wood used per unit floor area), carbon stock change in HWP for FY2013- FY2016 were recalculated (see section 6.11 Chapter 6 in this NIR).

- **Revisions of HWP reference level**

HWP reference level was projected by using average value of D area from 2008 to 2012 and also has deducted the inflow resulting from D. Due to the revision of D area as well as some revisions related to AD and EF above mentioned, HWP reference level for FY2013 - FY2016 were recalculated.

11.5.1.8. Uncertainty estimates

The uncertainty of the total emissions/removals from activities under Articles 3.3 and 3.4 in FY2017 has been assessed to be -16% to +16%.

See relevant sections of chapters 6 and 11 for uncertainties of respective parameters of the LULUCF sector. Specifically, see Table 11-39 to 11-43 below for detailed information on disaggregated uncertainties on emission factors and activity data used for estimating GHG emissions from and removals by each KP-LULUCF activity.

Table 11-39 Uncertainty of emissions/removals from activities under Articles 3.3 and 3.4 of KP

Greenhouse gas source and sink activities	GHGs	Emissions/Removals [kt CO ₂ eq.]		Emissions/Removals Uncertainty [%]		Emissions/Removals Uncertainty as % of net removals [%]	
			%	(-)[%]	(+)[%]	(-)[%]	(+)[%]
Article 3.3 activities Afforestation and Reforestation	CO ₂ , N ₂ O, CH ₄	-1,569	-4%	-34%	34%	-1%	1%
Article 3.3 activities Deforestation	CO ₂ , N ₂ O, CH ₄	1,846	4%	-22%	22%	1%	-1%
Article 3.4 activities Forest management	CO ₂ , N ₂ O, CH ₄	-46,135	-108%	-14%	14%	-15%	15%
Article 3.4 activities Cropland management	CO ₂ , N ₂ O, CH ₄	4,515	11%	-33%	33%	3%	-3%
Article 3.4 activities Grazing land management	CO ₂ , N ₂ O, CH ₄	-257	-1%	-11%	11%	0%	0%
Article 3.4 activities Revegetation	CO ₂ , N ₂ O, CH ₄	-1,290	-3%	-33%	33%	-1%	1%
Total		-42,890	-100%	-16%	16%		

11.5.1.8.a. Uncertainties of emissions/removals of afforestation/reforestation activities

Uncertainties of emissions/removals in living biomass resulting from AR activities were estimated by applying Tier 1 – error propagation equation – based on uncertainties in accuracy of AR area identification (activity data), in estimation of carbon stock changes in living biomass in forest land, and in carbon stocks before land conversion. Uncertainties of emissions/removals in litter, dead woods and soils were estimated by applying Monte Carlo Analysis in the CENTURY-jfos Model. As a result, the uncertainty of emissions/removals from AR activities in FY2017 has been assessed to be -34% to +34%.

Table 11-40 Uncertainty of emissions and removals from afforestation and reforestation activities

Greenhouse gas source and sink activities		GHGs	Emissions/Removals [kt CO ₂ eq.]	AD Uncertainty [%]		EF/RF Uncertainty [%]		Combined Uncertainty [%]		Combined Uncertainty as % of emissions/removals [%]		
				(-)[%]	(+)[%]	(-)[%]	(+)[%]	(-)[%]	(+)[%]	(-)[%]	(+)[%]	
Article 3.3 activities Afforestation and Reforestation	Change in carbon pool reported											
		Above-ground biomass	CO ₂	-883.79	-12%	12%	-43%	43%	-45%	45%	-32%	32%
		Below-ground biomass	CO ₂	-226.12	IE	IE	IE	IE	IE	IE	IE	IE
		Litter	CO ₂	-343.64	-	-	-	-	-51%	51%	-11%	11%
		Dead wood	CO ₂	-81.54	-	-	-	-	-22%	22%	-1%	1%
		Soil	CO ₂	-34.01	-	-	-	-	-20%	20%	0%	0%
		Harvested wood products (HWP)	CO ₂	NO	-	-	-	-	-	-	-	-
	Greenhouse gas sources reported											
		Fertilization	N ₂ O	IE	-	-	-	-	-	-	-	-
		N ₂ O emissions from drainage of soils	N ₂ O	NO	-	-	-	-	-	-	-	-
		N ₂ O emissions from N mineralization associated with loss of soil organic matter	N ₂ O	NA	-	-	-	-	-	-	-	-
		Biomass burning	CO ₂	IE	IE	IE	IE	IE	IE	IE	IE	-
			CH ₄	IE	-	-	-	-	-	-51%	51%	0%
		N ₂ O	0.11	-	-	-	-	-	-53%	53%	0%	0%
	Total			-1,568.98					-34%	34%		

11.5.1.8.b. Uncertainties of emissions/removals of deforestation activities

Uncertainties of emissions/removals in living biomass resulting from D activities were estimated, as same as AR activities, by applying Tier 1 – error propagation equation – based on uncertainties in accuracy of D area identification (activity data), in estimation of carbon stock changes in living biomass in forest land, and in growth of living biomass after land conversion. Uncertainties of

emissions/removals in litter, dead woods and soils were estimated by applying Monte Carlo Analysis in the CENTURY-jfos Model. As a result, the uncertainty of emissions/removals from D activities in FY2017 has been assessed to be -22% to +22%.

Table 11-41 Uncertainty of emissions and removals from deforestation activities

Greenhouse gas source and sink activities		GHGs	Emissions/ Removals [kt CO ₂ eq.]	AD Uncertainty [%]		EF/RF Uncertainty [%]		Combined Uncertainty [%]		Combined Uncertainty as % of emissions/ removals [%]		
				(-)[%]	(+)[%]	(-)[%]	(+)[%]	(-)[%]	(+)[%]	(-)[%]	(+)[%]	
Article 3.3 activities	Change in carbon pool reported											
	Deforestation	Above-ground biomass	CO ₂	952.78	-12%	12%	-26%	26%	-28%	28%	-18%	18%
		Below-ground biomass	CO ₂	234.84	IE	IE	IE	IE	IE	IE	IE	IE
		Litter	CO ₂	440.56	-	-	-	-	-51%	51%	-12%	12%
		Dead wood	CO ₂	180.09	-	-	-	-	-22%	22%	-2%	2%
		Soil	CO ₂	31.39	-	-	-	-	-20%	20%	0%	0%
		Harvested wood products (HWP)	CO ₂	IO	-	-	-	-	-	-	-	-
	Greenhouse gas sources reported											
		Fertilization	N ₂ O	IE	-	-	-	-	-	-	-	-
		Drainage of soils under forest management	N ₂ O	NO	-	-	-	-	-	-	-	-
		N ₂ O emissions from N mineralization associated with loss of soil organic matter	N ₂ O	5.39	-	-	-	-	-75%	202%	0%	1%
		Biomass burning	CO ₂	NO	-	-	-	-	-	-	-	-
			CH ₄	NO	-	-	-	-	-	-	-	-
			N ₂ O	NO	-	-	-	-	-	-	-	-
	Total			1,846.26					-22%	22%		

11.5.1.8.c. Uncertainties of emissions/removals of forest management activities

Uncertainties of emissions/removals in living biomass resulting from FM activities were estimated by applying Tier 1 – error propagation equation – based on uncertainties in data on forest areas and FM ratio and in estimation of carbon stock changes in living biomass in forest land. Uncertainties of emissions/removals in litter, dead woods and soils were estimated by applying Monte Carlo Analysis in the CENTURY-jfos Model. As a result, the uncertainty of emissions/removals from FM activities in FY2017 has been assessed to be -14% to +14%.

Table 11-42 Uncertainty of emissions/removals from forest management activities

Greenhouse gas source and sink activities		GHGs	Emissions/ Removals [kt CO ₂ eq.]	AD Uncertainty [%]		EF/RF Uncertainty [%]		Combined Uncertainty [%]		Combined Uncertainty as % of emissions/ removals [%]		
				(-)[%]	(+)[%]	(-)[%]	(+)[%]	(-)[%]	(+)[%]	(-)[%]	(+)[%]	
Article 3.4 activities	Change in carbon pool reported											
	Forest management	Above-ground biomass	CO ₂	-36,306.61	-12%	12%	-8%	8%	-14%	14%	-14%	14%
		Below-ground biomass	CO ₂	-9,285.09	IE	IE	IE	IE	IE	IE	IE	IE
		Litter	CO ₂	2,150.33	-	-	-	-	-51%	51%	2%	-2%
		Dead wood	CO ₂	-159.64	-	-	-	-	-22%	22%	0%	0%
		Soil	CO ₂	-1,276.39	-	-	-	-	-20%	20%	-1%	1%
		Harvested wood products (HWP)	CO ₂	-1,374.66	-	-	-	-	-30%	30%	-1%	1%
	Greenhouse gas sources reported											
		Fertilization	N ₂ O	0.54	-	-	-	-	-31%	31%	0%	0%
		Drainage of soils under forest management	N ₂ O	NO	-	-	-	-	0%	0%	-	-
		N ₂ O emissions from N mineralization associated with loss of soil organic matter	N ₂ O	81.01	-	-	-	-	-75%	202%	0%	0%
		Biomass burning	CO ₂	IE	IE	IE	IE	IE	IE	IE	-	-
			CH ₄	15.68	-	-	-	-	-29%	29%	0%	0%
			N ₂ O	1.28	-	-	-	-	-32%	32%	0%	0%
	Total			-46,135.04					-14%	14%		

11.5.1.8.d. Uncertainties of emissions/removals of cropland management

For the uncertainties of activity data for living biomass in orchards, the uncertainties of statistics and the default values given in the 2006 IPCC Guidelines are applied. For the uncertainties of mineral soil, the comparison of simulation results and actual measurement, when both data are available, revealed that the uncertainty due to model structure was estimated about 10%. The uncertainties caused by input

values have not been quantified yet and remain as an issue to be solved. For the uncertainties of organic soil, the uncertainties of statistical data and default values given in the *Wetlands Guidelines* are used. As a result, the uncertainty of emissions and removals accompanied by cropland management was evaluated to be -33% to +33%.

11.5.1.8.e. Uncertainties of emissions/removals of grazing land management

The method used is omitted because uncertainties of carbon stock change in mineral soil are the same as CM. Uncertainties of existing statistics and the default values described in the *Wetlands Guidelines* were applied to the estimation of CO₂ emissions from organic soil. As a result, the uncertainty of emissions and removals accompanied by grazing land management was evaluated to be -11% to +11%.

11.5.1.8.f. Uncertainties of emissions/removals of revegetation activities

Uncertainties of emissions/removals resulting from RV activities were estimated by following processes of estimating carbon stock changes in 8 sub-categories. First, uncertainties of each carbon pool (living biomass, litter and soils) in the 8 sub-categories were estimated by combining uncertainties of parameters and activity data (areas and the number of tall trees) used for estimating carbon stock changes. Next, an uncertainty of emissions/removals resulting from RV activities as a whole was estimated by applying Tier 1 – error propagation equation – based on the carbon stock changes in the 8 sub-categories. As a result, the uncertainty of emissions/removals from RV activities in FY2017 has been assessed at -33% to +33%.

Table 11-43 Uncertainty of emissions/removals from revegetation activities

Greenhouse gas source and sink activities		GHGs	Emissions/ Removals [kt CO ₂ eq.]	AD Uncertainty [%]		EF/RF Uncertainty [%]		Combined Uncertainty [%]		Combined Uncertainty as % of emissions/ removals [%]	
				(-)[%]	(+)[%]	(-)[%]	(+)[%]	(-)[%]	(+)[%]	(-)[%]	(+)[%]
Article 3.4 activities	Change in carbon pool reported										
	Revegetation										
	Above-ground biomass	CO ₂	-779.61	-	-	-	-	-42%	42%	-32%	32%
	Below-ground biomass	CO ₂	-202.70	IE	IE	IE	IE	IE	IE	IE	IE
	Litter	CO ₂	-13.93	-	-	-	-	-61%	61%	-1%	1%
	Dead wood	CO ₂	IE	-	-	-	-	-	-	-	-
	Soil	CO ₂	-293.61	-	-	-	-	-38%	38%	-9%	9%
	Total		-1,289.85					-33%	33%		

11.5.1.9. Information on other methodological issues (methods dealing with the effects of natural disturbances²²)

11.5.1.9.a. Afforestation/Reforestation and Deforestation

The effects of natural disturbances have been reflected in forest resources data when Forest Registers are updated every 5 years in each planning area.

11.5.1.9.b. Forest Management

The effects of natural disturbances have been reflected in forest resources data when Forest Registers are updated every 5 years in each planning area.

²² Including fires, windstorms, insects, droughts, flooding and ice storms, etc.

11.5.1.9.c. Revegetation

It is considered that windstorms, floods and insects are natural disturbances which have a considerable impact on carbon stock changes in RV land. However, all land classified as RV is under human-induced management by administration etc. In addition, when tall trees disappear and outflow of soils occur in RV land located in settlements, the business budget is often appropriated and urgent restoration measures are administered from the viewpoint of safety and view.

Consequently, the effects of natural disturbances are not considered in the estimation because it looks that carbon stocks do not change. Furthermore, carbon stock change due to post-disaster restoration practices which are not implemented in the year when the disaster occurred does not lead to double-counting because it is not considered in this reporting.

11.5.1.10. The year of the onset of an activity

In this submission, all units of land and lands which start to be subject to activities under Article 3.3, Article 3.4 and any elected activities under Article 3.4 until 2017 are reported. The emissions and removals from the units of land and the lands which activities started in FY2017 for the first time are not included in the calculated emissions and removals in FY2016. The areas of such lands are shown below.

Table 11-44 Areas of afforestation/reforestation, deforestation and forest management

Area of activities	Afforestation/R eforestation [kha]	Deforestation [kha]	Forest Management [kha]		
			Ikusei-rin forest	Tennensei- rin forest	Total
FY1990-2016	108.2	314.6	8,813.5	7,012.3	15,825.8
(FY2016)	—	6.9	—	—	—

Table 11-45 Areas of revegetation

Categories	Urban parks [ha]	Green areas on roads [ha]	Green areas at ports [ha]	Green areas around sewage treatment facilities [ha]	Green areas by greenery promoting systems for private green space [ha]
FY1990	3,743	1,623	198	44	0
FY1990-FY2017	58,919	21,078	1,850	659	6
(FY2017)	750	21078	9	-1	0
Categories	Green areas along rivers and erosion control sites [ha]	Green areas around government buildings [ha]	Green areas around public rental housing [ha]	Total [ha]	
FY1990	58	13	214	5,891	
FY1990-FY2017	1,739	318	2,617	87,184	
(FY2017)	0	10	-3	739	

11.6. Article 3.3

11.6.1. Information that demonstrates that activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2020 and are direct human-induced

Japan identifies AR and D by detecting changes of the forest cover which has occurred since 1 January 1990 using orthophotos taken at the end of 1989 and recent satellite images. At that time, AR and forest restoration through natural succession are distinguished by judging through imagery interpretation 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.

11.6.2. Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation

In Japan, land conversion from forest land to other land use means 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 be considered to be subject not to D but to temporary loss of biomass stock, and in Forest Registers would be distinguished from D which means conversion to other land use.

Japan identifies forest cover change as D only in the case when land form transformation or artificial construction are observed or obvious conversion to non-forest land such as cropland are detected through imagery interpretation using aerial photos and satellite images. By this methodology, D 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 accuracy of D interpretation is approximately 90% on average.

The total area of forest land that has temporarily lost forest cover due to harvesting or disturbance and which are not classified as deforested but as “cut-over forests” in Forest Registers was about 95 thousand ha in 2017.

The period for tree planting after a harvest event is determined as being within two years at the latest under the standard based on the Forest Law. In the case of natural regeneration, it is expected that trees are established within five years following a harvest event.

11.7. Article 3.4

11.7.1. Information that demonstrates that activities under Article 3.4 have occurred since 1 January 1990 and are human-induced

11.7.1.1. Forest Management

The status of FM activities since 1 January 1990 has been investigated since FY2007 by sample surveys including field surveys, interviews with forest owners' associations and detection of administrative information on subsidies for forest practices, of ikusei-rin forests throughout the country. The results of the survey have been used to estimate the FM ratio.

With respect to Tennensei-rin forests, the measures described in detail in section 11.4.2.4.a.b) have been applied to the Tennensei-rin forests continuously after January 1, 1990.

11.7.1.2. Cropland Management

Cropland is land which anthropogenic management practices such fertilization management is implemented and CM land is subject to direct human induced activities from January 1, 1990 onward.

11.7.1.3. Grazing Land Management

Pasture land is land which anthropogenic management practices such fertilization management is implemented and GM land is subject to direct human induced activities from January 1, 1990 onward.

11.7.1.4. Revegetation

Japan demonstrates that RV activities have occurred since 1990 and are human induced based on the following reasons.

Table 11-46 Information that demonstrates that revegetation activities have occurred since 1 January 1990 and are human induced

Urban green facilities	Information that demonstrates that Revegetation activities have occurred since 1 January 1990 and are human induced
Urban parks	<p><u>Extraction of activities which have occurred since 1 January 1990</u> MLIT has implemented the “Urban Parks Status Survey” and has collected data on the notification year of urban parks. In the reporting, only urban parks which have been notified since 1 January 1990 are included. Although some urban parks were established before the notification year, Japan considers that RV activities have occurred since the notification year under the “Urban Park Act”. <u>Demonstration that activities are human induced</u> Activity data (the number of tall trees) is calculated based on the number of tall trees per land area (tree/ha) which is developed by using data on planted tall trees. Its calculation procedure ensures that Japan extracts human-induced activities.</p>
Green areas on roads	<p><u>Extraction of activities which have occurred since 1 January 1990</u> MLIT has implemented the “Road Tree Planting Status Survey” every 5 years (implemented every year since 2007) and has collected data on the number of planted tall trees. Activity data after 1990 is calculated by extrapolating or interpolating these data. <u>Demonstration that activities are human induced</u> In the “Road Tree Planting Status Survey”, only planted tall trees have been measured. Their measurement procedure ensures that Japan extracts human induced activities.</p>
Green areas at ports	<p><u>Extraction of activities which have occurred since 1 January 1990</u> MLIT has implemented complete census since 2006 and has collected relevant data (year of establishment and service area) for green areas at ports which had been established since 1990. <u>Demonstration that activities are human induced</u> Activity data (the number of tall trees) is calculated by using parameters of urban parks which are based on human-induced activities data.</p>
Green areas around sewage treatment facilities	<p><u>Extraction of activities which have occurred since 1 January 1990</u> MLIT has implemented the “Sewage treatment Facility Status Survey” since 2006 and has collected relevant data (year of establishment and greening area) for green areas around sewage treatment facilities which had been established since 1990. <u>Demonstration that activities are human induced</u> Activity data (the number of tall trees) is calculated based on the number of tall trees per land area (tree/ha) which is developed by using data on planted tall trees. Its calculation procedure ensures that Japan extracts human-induced activities.</p>
Green areas by greenery promoting systems for private green space	<p><u>Extraction of activities which have occurred since 1 January 1990</u> It is clear that all green areas by greenery promoting systems for private green space have been established since 1 January 1990 because greenery promoting systems have been implemented since 2001. Existing tall trees before 1990 in some green areas are reported when it have been notified by the local authority mayor. They are excluded from RV land area. <u>Demonstration that activities are human induced</u> All green areas by greenery promoting systems for private green space have been established by human-induced activities.</p>

(continued) Green areas along rivers and erosion control sites	<u>Extraction of activities which have occurred since 1 January 1990</u> MLIT has implemented the “Survey on carbon dioxide absorption at source in river works” since 2007 and has collected relevant data (name, location, year of establishment, planted land area [projected area] and the number of tall trees) for river works and erosion and sediment control works which had been implemented since 1990. <u>Demonstration that activities are human induced</u> Activity data (the number of tall trees) is calculated based on the number of tall trees per land area (tree/ha) which is developed by using data on planted tall trees. Its calculation procedure ensures that Japan extracts human-induced activities
Green areas around government buildings	<u>Extraction of activities which have occurred since 1 January 1990</u> MLIT has implemented complete census since 2007 and has collected relevant data (name, location, year of establishment, total land area and building area) for government buildings which had been established since 1990. <u>Demonstration that activities are human induced</u> Activity data (the number of tall trees) is calculated based on the number of tall trees per land area (tree/ha) which is developed by using data on planted tall trees. Its calculation procedure ensures that Japan extracts human-induced activities.
Green areas around public rental housing	<u>Extraction of activities which have occurred since 1 January 1990</u> MLIT has implemented the “Progress survey on tree planting for public rental housing” since 2007 and has collected relevant data (name, location, year of establishment, total land area and building area) for public rental housing which had been established since 1990. <u>Demonstration that activities are human induced</u> Activity data (the number of tall trees) is calculated based on the number of tall trees per land area (tree/ha) which is developed by using data on planted tall trees. Its calculation procedure ensures that Japan extracts human-induced activities.

11.7.2. Information relating to cropland management, grazing land management and revegetation for the base year and the commitment period

The anthropogenic greenhouse gas emissions/removals in “Cropland management”, “Grazing land management” and “Revegetation” for the base year are those from CM, GM and RV area in 1990. The anthropogenic greenhouse gas emissions/removals in “Cropland management”, “Grazing land management” and “Revegetation” for the commitment period are those from CM, GM and RV area in each year. Those emissions/removals are reported within the relevant geographical location. The data and the methodologies used are provided in sections 11.4.2.5 through 11.4.2.7 and 11.5.1.1.d through 11.5.1.1.f.

11.7.3. Information that demonstrates the emissions and removals resulting from elected Article 3.4 activities are not accounted for under activities under Article 3.3 activities

11.7.3.1. Information on emissions and removals by FM activities are not accounted for under Article 3.3 activities

AR and D are of higher hierarchy than FM in the land classification system of Articles 3.3 and 3.4 in Japan. Emissions and removals by AR and D are estimated in the first step, then emissions and removals by FM are estimated by subtracting emissions and removals by AR and D from emissions and removals in managed forests as explained in section 11.4.2.2 (see Figure 11-1). Therefore, emissions and removals by FM could not be included in those by AR nor D.

11.7.3.2. Information on emissions and removals from CM activities are not accounted under Article 3.3 activities

As described in definition of CM in section 11.3.2.2 and identifying method of CM area in section 11.4.2.5, the land that does not fall under AR can be classified as CM. In addition, in the cropland, the land that fall under D was excluded from land subject to CM.

11.7.3.3. Information on emissions and removals from GM activities are not accounted under Article 3.3 activities

As described in definition of GM in section 11.3.2.3 and identifying method of GM area in section 11.4.2.6, land that does not fall under AR can be classified as GM. In addition, in the pasture land, the land that fall under D was excluded from land subject to GM.

11.7.3.4. Information on emissions and removals from RV activities are not accounted under Article 3.3 activities

RV land is defined as the land which is not included in AR land as described in the definition section 11.3.2.4. Therefore, emissions and removals from RV could not be included in those from AR theoretically.

The area of D land which would otherwise be included in RV lands is reported in the CRF Table 4(KP-I) A.2.1. Since this land is classified as D land and is not included in RV land, all emissions and removals from this land are reported under D activity as described in the explanation of methodologies of D in section 11.5.1.1.b and those of RV in section 11.5.1.1.f. Therefore, there is no double count between D and RV and emissions and removals from RV could not be included in those from D.

11.7.4. Information relating to the conversion of natural forests to planted forests

Since the conversion of natural forests to planted forests are accounted as practices subject FM activity if such activities occur, emissions arising from the conversion of natural forests to planted forests are all included in FM estimation.

11.7.5. Information on forest reference level (Consistency)

As for reporting FM, forest management reference level (FMRL) was set as zero in Japan. For estimating five carbon pools and GHG emissions and treatment of natural disturbances, methodological consistency between the FMRL and actual calculation is ensured. Regarding the reporting HWP, reference level was set newly by following methodology, and is reported by carrying out technical corrections.

● *Setting of HWP reference level*

As for setting HWP reference level, prediction values by sub-categories based on the historical trend until 2012 were applied. As for the prediction, floor area of construction, production of wooden board from 2013 to 2020 were estimated by extrapolation their trend from 1993 to 2012; floor area of destroyed building, production of lumber and production of paper and paper board from 2013 to 2020 were estimated by extrapolation their trend from 2003 to 2012. As for rate of domestic logs, average values from 2003 to 2012 were applied. The HWP inflow resulting from D from 2013 to 2020, which were estimated from the average value of deforestation area from 2008 to 2012, were deducted from HWP reference level.

11.7.6. Information relating forest management reference (technical correction)

In reporting carbon stock changes of HWP pool in FM, technical correction was submitted. .

11.7.7. Information on newly established forest will reach at least the equivalent carbon stock

Japan does not apply the provision of Carbon Equivalent Forests (in paragraphs 37-39 of Annex to Decision/CMP.7).

11.8. Other information

11.8.1. Key category analysis for Article 3.3 activities and any elected activities under Article 3.4

In accordance with section 2.3.6 of *the KP Supplement* as well as section 4.3.3 in Volume 1 of the 2006 *IPCC Guidelines*, the activity which meets the following requirements is considered as a key category.

- The activities that associated categories identified as key under the UNFCCC inventory.
- The activities that of emissions/removals are greater than the smallest category identified as key in the tier 1 level assessment under the UNFCCC inventory.

- **Corresponding key categories under the UNFCCC**

Japan's LULUCF key categories under the UNFCCC for FY2017 (Annex 1 of this report) are as follows;

- 4.A.1. Forest land remaining forest land (CO₂)
- 4.A.2. Land converted to Forest land (CO₂)
- 4.B.1. Cropland remaining cropland (CO₂)
- 4.E.2. Land converted to settlements (CO₂)

In accordance with the *KP Supplement*, AR, D, FM, CM and RV may be identified as key categories under the Kyoto Protocol.

Table 11-47 Relationship between UNFCCC categories and Kyoto Protocol activities

UNFCCC category under the Convention	Kyoto Protocol category
4.A.1. Forest land remaining forest land	FM
4.A.2. Land converted to forest land	AR
4.B.1. Cropland remaining cropland	CM
4.B.2. Land converted to cropland	D
4.C.1. Grassland remaining grassland	GM
4.C.2. Land converted to grassland	D
4.D.1. Wetlands remaining wetlands	
4.D.2. Land converted to wetlands	D
4.E.1. Settlements remaining settlements	RV
4.E.2. Land converted to settlements	D, RV
4.F.1. Other land remaining other land	—
4.F.2. Land converted to other land	D

The relationship between the Convention categories and the Kyoto categories in this table is based on the Table 2.1.1 of the *KP Supplement*, and the definitions of Articles 3.3 and 3.4 activities in Japan. Shade indicates the key categories under the UNFCCC.

- **Comparison with the smallest key category under the UNFCCC**

The smallest category for the UNFCCC (Approach 1 level assessment) for FY2017 was 2.C.1. Iron and Steel Production (CO₂). As a result of the comparison, only FM activity was greater than this category.

Therefore, AR, D, FM, CM and RV activities (CO₂) are identified as key activities for FY2017.

11.8.2. Further improvements

Methodological issues relating to Articles 3.3 and 3.4 are identified under the committee for greenhouse gas emissions estimation methods- breakout group on LULUCF. They are updated every year along with the progress of the inventory-related work and issues identified by the expert review team. Many

of the improvement plans on LULUCF reporting under the Convention described in Chapter 6 of this report are closely linked to activities under Articles 3.3 and 3.4 of the Kyoto Protocol. Therefore, both the reporting under the Convention and the reporting under the Kyoto Protocol are discussed together. Major issues to be improved are as follows:

- Improvement of methodology and data to estimate carbon stock change in soil due to land-use conversion which reflects changes in management practices more properly is under discussion in Japan.
- With regard to the annual growth rate of living biomass per tree in RV land, Japan plans to improve the accuracy when new country-specific data by tree species become available.
- Except for urban parks and green areas at ports, carbon stock change in soils is not included in the reporting because soils are not sources of GHGs under RV activities. Collecting fundamental information on soil carbon and development estimation methods will be continued.
- With respect to uncertainties on KP-LULUCF activities, disaggregated uncertainties area shown in section 11.5.1.8 in chapter 11, and additional information in description on each category in Chapter 6 are provided. The method to show more detailed information on uncertainties systematically than in current NIR is regarded as a long-term issue.

11.9. Information relating to Article 6

Japan has not carried out any projects under Article 6 of the Kyoto Protocol. Therefore, a special indication of whether the boundary of the geographical location encompasses land subject to the Article 6 project is not prepared.

11.10. Information on the reporting status of the Annex II to decision 2/CMP.8

The requirements for reporting about Articles 3.3 and 3.4 which are set out in the annex II to decision 2/CMP.8 are provided in sections shown in Table 11-48.

Table 11-48 List of reference sections for the requirements set in the annex II to decision 2/CMP.8

Checklist for KP reporting (paragraphs 1-5 in the annex to decision 2/CMP.8)	Paragraph	Main sections of Chapter 11 providing relevant information
Information on how inventory methodologies have been applied taking into account <i>the KP Supplement</i> and decision 16/CMP.1	2 (a)	Detailed information is provided in each section
Information on the geographical location of the boundaries of areas that encompass:	2 (b)	11.4.3, 11.4.2
Units of land subject to activities under Article 3.3	2 (b) (i)	11.4.3, 11.4.2
Units of land subject to activities under Article 3.3, which would otherwise be included in land subject to elected activities under Article 3.4	2 (b) (ii)	11.4.3, 11.4.2 and CRF table 4(KP-I)A.2.1
Land subject to elected activities under Article 3.4	2 (b) (iii)	11.4.3, 11.4.2
Information on the spatial assessment unit for determining the area of accounting for ARD	2 (c)	11.4.1
GHG emissions by sources and removals by sinks from LULUCF activities under Articles 3.3 and 3.4:		
Emissions by sources and removals by sinks are clearly distinguished from emissions from Annex A sources	1	11.5.1: Methodology
Emissions by sources and removals by sinks are reported for all geographical locations reported in current and previous years	2 (d)	11.4.2.3, 11.4.2.4, 11.4.2.5, 11.4.2.6, 11.4.2.7

Checklist for KP reporting (paragraphs 1-5 in the annex to decision 2/CMP.8)	Paragraph	Main sections of Chapter 11 providing relevant information
Emissions/removals from Articles 3.3 or (elected) 3.4 activities are reported since the beginning of the commitment period or the onset of the activity	2 (d)	11.5.1.10
Information on which pools (above-ground / below-ground biomass, litter, dead wood and soil organic carbon) were not accounted for	2 (e)	11.5.1.2
Information on how emissions from natural disturbance are considered	2 (f)	11.5.1.3
Information on GHG emissions /removals from the harvested wood products pool	2 (g)	11.5.1.4
Activity data for the HWP categories used for estimating the pool removed from domestic forests, for domestic consumption and for export	2(g)(i)	11.5.1.4
Half-lives used in estimating emissions/removals for the HWP categories when the first-order decay method was used	2(g)(ii)	11.5.1.4
Whether emissions from HWP originating from forests prior to the start of the second commitment period have been included in the accounting, if the forest management reference level is based on a projection	2(g)(iii)	11.5.1.4
How emissions from the HWP pool accounted for in the first commitment period on the basis of instantaneous oxidation have been excluded from the accounting for the second commitment period	2(g)(iv)	11.5.1.4
How the HWP resulting from deforestation have been accounted on the basis of instantaneous oxidation	2(g)(v)	11.5.1.4
How CO ₂ emissions from HWP in SWDS and from wood harvested for energy purposes have been accounted on the basis of instantaneous oxidation	2(g)(vi)	11.5.1.4
How emissions/removals from changes in the HWP pool accounted for do not include imported harvested wood products	2(g)(vii)	11.5.1.4
Information on whether Articles 3.3 and (elected) 3.4 emissions/removals factor out removals from (i) elevated CO ₂ concentrations above pre-industrial levels; (ii) indirect N deposition; and (iii) dynamic effects of age structure resulting from pre-1 January 1990 activities	3	11.5.1.5
Specific information to be reported for Article 3.3 activities		
Information that activities under Article 3.3 began on or after 1 January 1990 and before 31 December of the last year of the commitment period	4 (a)	11.6.1
Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation	4 (b)	11.6.2
Specific information to be reported for Article 3.4 activities		
Information that activities under Article 3.4 occurred since 1 January 1990 and are human induced.	5 (a)	11.7.1
CM, GM, RV: emissions/removals reported for each year of the commitment period and for the base year for each of the elected activities on the geographical locations reported	5 (b)	11.7.2, 11.4.2.5, 11.4.2.6, 11.4.2.7, 11.5.1.1.d, 11.5.1.1.e, 11.5.11.f
Information that emissions/removals from Article 3.4 activities are not accounted for under activities under Article 3.3	5 (c)	11.7.3
Information how all emissions arising from the conversion of natural forests to planted forests are accounted for	5 (d)	11.7.4
Information that demonstrates methodological consistency between the reference level and reporting for FM during the second commitment period	5 (e)	11.7.5
Information on technical corrections between the reference level and reporting for FM during the second commitment period	5 (f)	11.7.6
Information on newly established forest will reach at least the equivalent carbon stock	5 (g)	11.7.7

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. FAO, *Global Forest Resources Assessment Country Reports 2005*, 2006.
5. UNFCCC, “*Land use, land-use change and forestry*”, (Decision 16/CMP.1), (FCCC/KP/CMP/2005/8/Add.3), 2006.
6. UNFCCC, “*Land use, Land-use changes and forestry*”, (Decision 2/CMP.7), (FCCC/KP/CMP/2011/10/Add. 1), 2012.
7. UNFCCC, “*Implications of the implementation of decisions 2/CMP.7 to 5/CMP.7 on the previous decisions on methodological issues related to the Kyoto Protocol, including those relating to Articles 5, 7 and 8 of the Kyoto Protocol*”, (Decision 2/CMP.8), (FCCC/KP/CMP/2012/13/Add.1), 2013.
8. UNFCCC, “*Guidance for reporting information on activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol*”, (Decision 6/CMP.9), (FCCC/KP/CMP/2013/9/Add.1), 2014.
9. UNFCCC, *Implications of the implementation of decisions 2/CMP.7 to 4/CMP.7 and 1/CMP.8 on the previous decisions on methodological issues related to the Kyoto Protocol, including those relating to Articles 5, 7 and 8 of the Kyoto Protocol (Decision 3/CMP.11)*, (FCCC/KP/CMP/2015/8/Add.1), 2015.
10. Ministry of Land, Infrastructure, Transport and Tourism, *Basic Data Collection Survey on Tall Tree Planting on the Road*.
11. Ministry of Land, Infrastructure, Transport and Tourism, *Road Tree Planting Status Survey*.
12. Ministry of Land, Infrastructure, Transport and Tourism, *Sewage Treatment Facility Status Survey*.
13. Ministry of Land, Infrastructure, Transport and Tourism, *Survey on Carbon Dioxide Absorption at Source in River Works*.
14. Ministry of Land, Infrastructure, Transport and Tourism, *Progress Survey on Tree Planting for Public Rental Housing*.
15. Ministry of Land, Infrastructure, Transport and Tourism, *Urban Parks Status Survey*.
16. Ministry of Land, Infrastructure, Transport and Tourism, *Urban Greening Status Survey*.
17. Parks and Green Spaces Division of the Ministry of Land, Infrastructure and Transport, *FY2004 Survey on evaluation techniques for the effectiveness of greening in urban parks for preventing global warming*, March, 2005.
18. Parks, Green Spaces and Landscape Division of the Ministry of Land, Infrastructure, Transport and Tourism, *Survey on policies of sinks measures by urban planting for the next framework*, 2014.
19. Parks, Green Spaces and Landscape Division of the Ministry of Land, Infrastructure, Transport and Tourism, *FY 2014 Survey on promotion of greenhouse gas sink measures by urban planting*, 2015.
20. National Institute for Land and Infrastructure Management, Ministry of Land, Infrastructure, Transport and Tourism, Japan, *Technical note of National Institute for Land and Infrastructure*

- Management No.506 The Street tree of Japan VI*, 2009.
21. Ministry of Agriculture, Forestry and Fisheries, *World Census of Agriculture and Forestry*.
 22. Ministry of Agriculture, Forestry and Fisheries, *Statistics of Cultivated and Planted Area* (Survey of Cropland area).
 23. Ministry of Agriculture, Forestry and Fisheries, *A move and conversion of Cropland*.
 24. Forestry Agency, *National Forest Resources Database*.
 25. Forestry Agency, *Handbook of Forestry Statistics*.
 26. Ministry of Agriculture, Forestry and Fisheries, “*Report on Forest GHG Inventory Information Development Project*” (in Japanese), 2017.
 27. Ministry of Agriculture, Forestry and Fisheries, “*Report on Forest GHG Inventory Information Development Project*” (in Japanese), 2018.
 28. Coleman, K. and D. S. Jenkinson, “*RothC-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 and J. U. Smith, p. 237-246, Springer, Berlin, 1996
 29. Yasuhito Shirato, “*Validation and Modification of Soil Organic Matter Models in Arable Soils in Japan and Thailand*”, Bull. Natl. Inst. Agro-Environ. Sci., 24, 23-94, 2006
 30. Sakai, H., Hashimoto, S., Ishizuka, S., Kaneko, S., Takahashi, M., “*Estimation of the effect of forest management on the carbon stocks in Japanese planted forests using CENTURY-jfos: a modified CENTURY model.*”, The International Forestry Review,12(5):31-32(Forests for the Future: Sustaining Society and the Environment XXIII IUFRO World Congress, Republic of Korea Abstracts), 2010.
 31. Shirato.Y & Taniyama.I, “*Testing the suitability of the Rothamsted Carbon model for long-term experiments on Japanese non-volcanic upland soils*”, Soil Science and Plant Nutrition, 49(6). 921-925, 2003.
 32. Shirato.Y, Hakamata.T & Taniyama.I., “*Modified rothamsted carbon model for andosols and its validation: changing humus decomposition rate constant with pyrophosphate-extractable Al*”, Soil Science and Plant Nutrition, 50(1). 149-158, 2004.
 33. Shirato.Y & Yokozawa.M., “*Applying the Rothamsted Carbon Model for Long-Term Experiments on Japanese Paddy Soils and Modifying It by Simple Tuning of the Decomposition Rate*”, Soil Science and Plant Nutrition, 51(3). 405-415, 2005.
 34. Shirato.Y, Yagasaki.Y & Nishida.M., “*Using different versions of the Rothamsted Carbon Model to simulate soil carbon in long-term experimental plots subjected to paddy-upland rotation in Japan*”, Soil Science and Plant Nutrition, 57, 597-606, 2011.
 35. Takata.Y, Ito.T, Ohkura.T, Obara.H, Kohyama.K & Shirato.Y., “*Phosphate adsorption coefficient can improve the validity of Roth C model for Andosols*”, Soil Science and Plant Nutrition, 57, 421-428, 2011.
 36. Tonosaki K., Murayama K., Imai K., Nagino Y., “*Estimation of Soil Carbon Accumulation Rate in Urban Parks*”, Journal of the Japanese Society of Revegetation Technology, Vol. 38 (3), 373-380, 2013.
 37. Hayashi M., Hori S., Awaya Y., Matsumoto M., Iehara T., “*Evaluation of ARD monitoring method under Article 3.3 of the Kyoto Protocol*”, Journal of the Japan Society of Photogrammetry and Remote Sensing, Vol. 47 (3), 48-58, 2008.

38. Handa M., Tonosaki K., Imai K., Goto S., “A study to estimate the amount of Carbon stocks of soil and litter in revegetation areas”, *Urban Green Technology*, No 69, 18-22, 2008.
39. Hatano Ryusuke, “Project Title: Survey on actual situation of grassland management for feed”, Project Report of Livestock Industry Promotion by Japan Racing Association in FY2016, 2017.
40. Matsue M., Nagahama Y., Iizuka Y., Murata M., Fujiwara N., “Estimation equations for the amount of CO₂ fixed by planted trees in cities in Japan”, *Journal of the Japanese Society of Revegetation Technology*, Vol. 35 (2), 318-324, 2009.
41. Yagasaki, Y. and Shirato, Y., “Assessment on the rates and potentials of soil organic carbon sequestration in agricultural lands in Japan using a process-based model and spatially explicit land-use change inventories –Part 1: Historical trend and validation based on nation-wide soil monitoring”, *Biogeosciences*, 11, 4429-4442, doi:10.5194/bg-11-4429-2014, 2014.

Chapter 12. Information on accounting of Kyoto units

In line with paragraph 10 of the annex to decision 15/CMP.1 and paragraph 14 of decision 3/CMP.11, Japan reports the information on holdings and transactions of Kyoto units (ERUs, CERs, ICERs, tCERs, AAUs and RMUs)¹. For the reporting, in accordance with paragraph 11 of annex of decision 15/CMP.1, Japan uses Standard electronic format (SEF) defined in the annex of decision 14/CMP.1. Apart from this NIR, SEF is submitted to the UNFCCC Secretariat with the file name “RREG1_JP_2018_1_1.xlsx”.

12.1. Summary of information reported in the SEF tables

For information on Kyoto units in Japan’s National Registry, see the annex of the NIR “Standard Electric Format for Reporting of Information on Kyoto Protocol Units” (RREG1_JP_2018_1_1.xlsx) submitted on the basis of Decision 14/CMP. 1.

Japan also submits “RREG1_JP_2018_2_1.xlsx”.

12.2. Discrepancies and notifications

Regarding Japan’s national registry, discrepancies and notifications to be reported in accordance with paragraphs 12-17 of annex to decision 15/CMP.1 are as follows.

Table 12-1 Discrepancies and notifications

Reporting item	Description
Para. 12 of the annex to decision 15/CMP.1 Discrepancies	There was no discrepancy to be reported.
Para. 13 of the annex to decision 15/CMP.1 Notification from Executive Board of CDM	There was no notification regarding ICERs to be replaced due to a reversal of storage.
Para. 14 of the annex to decision 15/CMP.1 Failure of certification	There was no notification regarding ICERs to be replaced due to non-submission of certification report.
Para. 15 of the annex to decision 15/CMP.1 List of non-replacements	There was no record of non-replacement identified by the transaction log.
Para. 16 of the annex to decision 15/CMP.1 Invalid Kyoto units	There were no units that are invalid for use towards compliance with commitments.
Para. 17 of the annex to decision 15/CMP.1 Discrepant transaction that needs actions to correct problem	There was no discrepant transaction that needs actions to correct problem.

12.3. Publicly accessible information

As presented in the section IV of Part 2 of “Report on Japan’s Assigned Amount”, a list of the information publicly accessible by means of the user interface to the national registry is as below:

- Account information as required by paragraph 45, annex, Decision 13/CMP.1

¹ Kyoto units are: emission reduction units (ERU) from joint implementation (JI) projects, certified emission reductions (CERs) from clean development mechanism (CDM) projects, temporary certified emission reductions (tCERs) and long-term certified emission reductions (ICERs) from afforestation/reforestation CDM projects, assigned amount units (AAUs) and removal units (RMUs) from KP-LULUCF activities within Annex I Parties.

- Article 6 project information as required by paragraph 46, annex, Decision 13/CMP.1
- Kyoto units information as required by paragraph 47, annex, Decision 13/CMP.1
- Legal entities as required by paragraph 48, annex, Decision 13/CMP.1
- The serial numbers of the units in the retirement account at the end of the true-up period as required by paragraph 49(b), annex, Decision 13/CMP.1
- The serial numbers of the units requested to be carried over as required by paragraph 49(c), annex, Decision 13/CMP.1

The information is provided in “Publicly Accessible Information” of Japan’s national registry website.

- URL of the Japan’s national registry system: http://www.registry.go.jp/index_e.html
- Publicly Accessible Information: http://www.registry.go.jp/public_info_en.html

The following information is not published due to confidentiality concerns:

- Unit holdings at an individual account level
- Identity of accounts to which Japan’s national registry transferred units and those from which it acquired units.

In addition, for better readability, information on units is not associated with their respective serial numbers.

12.4. Calculation of the commitment period reserve (CPR)

Since Japan does not have a quantified emission limitation or reduction commitment for the second commitment period, it does not have a commitment period reserve.

Chapter 13. Information on changes in national system

In line with paragraph 50 (J) of the UNFCCC Inventory Reporting Guidelines, and paragraph 21 of the annex to decision 15/CMP.1, Japan reports the changes in its national system from the previous inventory submission.

- No changes have been made since the previous inventory submission.

Chapter 14. Information on changes in national registry

In line with paragraph 22 of the Annex to decision 15/CMP.1 and paragraph 14 of decision 3/CMP.11, Japan reports changes in the national registry of Japan from the previous inventory submission.

14.1. Summary of changes made on national registry of Japan in 2018

Table 14-1 Summary of changes made on national registry of Japan in 2018

Reporting Items	Descriptions of Changes
15/CMP.1, annex II, para 32. (a) Change of name or contact	Contact of the registry system administrator (RSA) of Japan was changed to follows: (Before) Mr. Kazuhisa Koakutsu Mr. Akira Izumo Mr. Kohei Tamura (After) Mr. Kazuhisa Koakutsu Mr. Akira Izumo
15/CMP.1, annex II, para 32. (b) Change of cooperation arrangement	No change
15/CMP.1, annex II, para 32. (c) Change to database or the capacity of national registry	No change
15/CMP.1, annex II, para 32. (d) Change of conformance to technical standards	No change
15/CMP.1, annex II, para 32. (e) Change of procedures to minimize discrepancies	No change
15/CMP.1, annex II, para 32. (f) Change of security measures	No change
15/CMP.1, annex II, para 32. (g) Change of a list of publicly accessible information	Information on unit holdings and transactions is made publicly available on the basis of Standard Electronic Format (SEF) to meet the requirement specified in decision 14/CMP.1. In June 2018, the information for 2017 was published. The following information was not published due to confidentiality concerns: - Unit holdings at an individual account level - Identity of accounts to which national registry of Japan transferred units and those from which it acquired units. In addition, for better readability, information on units was not associated with their respective serial numbers.
15/CMP.1, annex II, para 32. (h) Change of the internet address	No change
15/CMP.1, annex II, para 32. (i) Change of measures for ensuring data integrity	No change
15/CMP.1, annex II, para 32. (j) Change of test results	No change

14.2. Information relevant to the changes made on national registry of Japan

Following changes were made to national registry of Japan. There was no impact on the functions of the ITL and other national registries.

- In January 2018, the log rotation setting was changed.
- In March 2018, the registry administrator's PCs were updated with security patches.
- In May 2018, the web server was updated with security patches.

- In May 2018, the DNS server was updated with security patches.
- In May 2018, the network device was updated with security patches.
- In May 2018, the web server was updated for enhanced encryption.
- In June 2018, public information on the unit holdings and transactions conducted was updated on the basis of the SEF for 2017, for the purpose of meeting the requirement specified in decision 13/CMP.1. The following information, which is requested to be made publicly available in decision 13/CMP.1, has not been made so due mostly to confidentiality concerns (relevant paragraph numbers of the annex to decision 13/CMP.1 are indicated in parentheses):
 - The full name of the representative of the account holder (paragraph 45(e))
 - Serial numbers of ERUs, CERs, AAUs and RMUs those are subject of this public information (paragraph 47)
 - The total quantity of ERUs, CERs, AAUs and RMUs in each account at the beginning of the year (the total quantity is only available by account type) (paragraph 47(a))
 - The identity of the transferring accounts from which ERUs, CERs, AAUs and RMUs were acquired by national registry of Japan during the year (the identity of the transferring registries is available) (paragraph 47(d))
 - The identity of the acquiring accounts to which ERUs, CERs, AAUs and RMUs were transferred from national registry of Japan during the year (the identity of the acquiring registries is available) (paragraph 47(g))
 - Current holdings of ERUs, CERs, AAUs and RMUs in each account (the current holdings are only available by account type) (paragraph 47(l))
- In July 2018, the DNS server was upgraded.
- In July 2018, the network device was upgraded.
- In December 2018, the web server was updated with security patches.
- In December 2018, the DNS server was updated with security patches.
- In December 2018, the network device was updated with security patches.
- In December 2018, the network device was changed.

Chapter 15. Information on minimization of adverse impacts in accordance with Article 3, paragraph 14

In line with paragraphs 23-25 of the Annex to decision 15/CMP.1 and paragraph 4 of Annex III to decision 1/CMP.11, Japan reports the information on minimization of adverse impacts in accordance with Article 3, paragraph 14. Changes made since the last submission are indicated with underlines.

15.1. Overview

Japan takes actions, taking into account the importance to make effort to minimize adverse impacts in accordance with Article 3, paragraph 14. On the other hand, it should be noted that we have difficulty in accurately assessing specific adverse impacts due to the implementation of response measures to address climate change issues. For example, the fluctuations in crude oil prices are caused by balance between supply and demand as well as numerous other factors (e.g., trend in crude oil futures market or economic fluctuation), and it is uncertain whether there exists a causal link or, if so, to what extent it results from adverse impacts of climate change policy and measures.

In addition, it is necessary to change the perception of response measures in order to address climate change issues effectively, and sustainable development could be the one of the key options. For instance, the introduction of renewable energy leads to improve energy access, prepare for a disaster and create employment through development of a new industry, as well as contributes to reducing GHG emissions. As discussed in international community including COP, the transition to green economy and the attainment of low-carbon growth are the key elements in order to address climate change and to achieve the sustainable development which strikes a balance between environment and economy. In order to facilitate the achievement of an agreement at COP21, Japan announced its new policies of contribution called “Actions for Cool Earth 2.0 (ACE 2.0)” which consists of two pillars: (1) providing support to developing countries worth of about 1.3 trillion yen in 2020 and (2) promoting innovation. In October 2017, ahead of COP23, Japan announced Japan’s Assistance Initiatives to Address Climate Change 2017 (Initiative 2017), which includes Japan’s visions and activities. The key concept of this initiative is "co-innovation" that enhances the collaboration with developing countries by utilizing its advanced technology and know-how. In March 2018, Japan announced “Vision for International Cooperation on Climate Change Mitigation” that presents Japan’s pursuit of international cooperation to reduce greenhouse gas emissions tremendously and to lead global decarbonization towards the Paris Agreement goals. Japan continues to proactively contribute to the international community in these fields.

15.2. Actions to minimize adverse impacts in accordance with Article 3, paragraph 14

Japan has given a priority to the efforts below, taking into consideration that these efforts are important to minimize adverse social, environmental and economic impacts on developing country Parties, particularly those identified in Article 4, paragraphs 8 and 9, of the Convention in implementing the commitments under Article 3, paragraph 1 of the Kyoto Protocol.

At the same time, it should be noted that it is impossible to evaluate these efforts since the method of evaluation has not been established internationally.

● ***Technical assistance in the energy and environmental sectors***

Japan has provided technical assistance in the field of energy and environment throughout the world and has contributed to the sustainable economic growth of developing countries taking into consideration their needs. For example, Japan has provided cooperation for development and operation of institutions related to energy-saving and renewable energy through capacity building such as accepting technical training participants from, and sending experts to developing countries. Moreover, from the view point of deployment of renewable energy in small island nations particularly vulnerable to climate change, Japan supports introduction of hybrid power generation system in the Pacific region. Japan also supports policy development and system introduction of renewable energy in Middle East and Africa.

● ***Development of carbon capture and storage (CCS) technologies***

Recognizing that CCS is an important technology for global warming countermeasures, Japan has been implementing large-scale demonstration projects toward practical use of CCS by around 2020, research and development activities on cost reductions and safety improvements, evaluations of environmental impacts in the CO₂ capture process, and geological surveys to identify potential CO₂ offshore storage sites in Japan. Also, Japan has actively conducted information exchange and joint research on CCS technologies with other countries such as the United States of America and European countries through multilateral and bilateral cooperation.

Annex 1. Key Categories

A1.1. Outline of Key Category Analysis

The *UNFCCC Inventory Reporting Guidelines*¹ require the application of the *2006 IPCC Guidelines*, and the key category analysis given in the Guidelines. The key category analyses were done for both data of FY2017 (the latest reported year) and of FY1990 (the base year for the UNFCCC). 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).

The key category for LULUCF sector was identified for the inventory excluding LULUCF first, and then the key category analysis was repeated for the full inventory including the LULUCF categories.

As a result, 44 and 40 sources and sinks were detected as the key categories for FY2017 and FY1990, respectively (Table A1-1 and A1-2).

¹ Revision of the UNFCCC reporting guidelines on annual inventories for Parties included in Annex I to the Convention (Decision 24/CP.19)

Table A1-1 Japan's key categories (FY2017)

	A IPCC Code	B IPCC Category	C GHGs	Ap1-L	Ap1-T	Ap2-L	Ap2-T
#1	1.A.1.	Energy Industries	Solid Fuels	CO2	#1	#1	#1
#2	1.A.3.	Transport	b. Road Transportation	CO2	#2		#3
#3	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO2	#3	#7	#2
#4	1.A.1.	Energy Industries	Gaseous Fuels	CO2	#4	#3	#6
#5	1.A.4.	Other Sectors	Liquid Fuels	CO2	#5	#5	#5
#6	1.A.1.	Energy Industries	Liquid Fuels	CO2	#6	#2	#7
#7	4.A	Forest Land	1. Forest Land remaining Forest Land	CO2	#7	#12	#4
#8	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO2	#8	#4	#11
#9	1.A.4.	Other Sectors	Gaseous Fuels	CO2	#9	#8	#23
#10	2.F	Product uses as substitutes for ODS	1. Refrigeration and Air conditioning	HFCs	#10	#6	#10
#11	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO2	#11	#9	#31
#12	2.A	Mineral Product	1. Cement Production	CO2	#12	#11	#24
#13	3.C	Rice Cultivation		CH4	#13		#28
#14	5.C	Incineration and Open Burning of Waste		CO2	#14		#14
#15	1.A.3.	Transport	d. Domestic Navigation	CO2	#15	#21	
#16	1.A.3.	Transport	a. Domestic Aviation	CO2	#16	#23	
#17	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO2	#17	#18	#13
#18	1.A.4.	Other Sectors	Other Fossil Fuels	CO2	#18		#18
#19	3.A	Enteric Fermentation		CH4	#19		#12
#20	2.C	Metal Production	1. Iron and Steel Production	CO2	#20		#21
#21	4.B	Cropland	1. Cropland remaining Cropland	CO2		#16	#20
#22	3.B	Manure Management		N2O			#9
#23	3.D	Agricultural Soils	1. Direct Emissions	N2O			#27
#24	5.A	Solid Waste Disposal		CH4		#15	#12
#25	2.D	Non-energy Products from Fuels and Solvent Use		CO2			#15
#26	2.F	Product uses as substitutes for ODS	2. Foam Blowing Agents	HFCs		#25	#19
#27	2.B	Chemical Industry	Other products except Ammonia	CO2			#17
#28	1.A.1.	Energy Industries		N2O			#27
#29	5.D	Wastewater Treatment and Discharge		N2O			#30
#30	2.E	Electronics Industry		PFCs			#16
#31	3.D	Agricultural Soils	2. Indirect Emissions	N2O			#8
#32		Indirect CO2	from IPPU sector	Ind CO2		#24	#29
#33	2.G	Other Product Manufacture and Use		SF6		#13	#21
#34	2.F	Product uses as substitutes for ODS	5. Solvents	PFCs		#22	
#35	1.A.3.	Transport	b. Road Transportation	N2O			#26
#36	5.C	Incineration and Open Burning of Waste		N2O			#22
#37	4.E	Settlements	2. Land converted to Settlements	CO2		#26	
#38	4.A	Forest Land	2. Land converted to Forest Land	CO2		#17	#19
#39	1.B	Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	CH4		#19	
#40	2.E	Electronics Industry		SF6			#25
#41	2.B	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N2O			#11
#42	2.B	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	HFCs		#10	#30
#43	2.B	Chemical Industry	3. Adipic Acid Production	N2O		#14	#20
#44	2.B	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	SF6		#20	

N.B.1) Ap1-L: Approach1-Level Assessment, Ap1-T: Approach1-Trend Assessment,
Ap2-L: Approach2-Level Assessment, Ap2-T: Approach2-Trend Assessment

N.B.2) 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)

A IPCC Code	B IPCC Category	C GHGs	Ap1-L	Ap2-L	
#1	1.A.2. Manufacturing Industries and Construction	Solid Fuels	CO2	#1	#1
#2	1.A.3. Transport	b. Road Transportation	CO2	#2	#3
#3	1.A.1. Energy Industries	Liquid Fuels	CO2	#3	#4
#4	1.A.2. Manufacturing Industries and Construction	Liquid Fuels	CO2	#4	#6
#5	1.A.4. Other Sectors	Liquid Fuels	CO2	#5	#8
#6	1.A.1. Energy Industries	Solid Fuels	CO2	#6	#7
#7	1.A.1. Energy Industries	Gaseous Fuels	CO2	#7	#19
#8	4.A Forest Land	1. Forest Land remaining Forest Land	CO2	#8	#2
#9	2.A Mineral Product	1. Cement Production	CO2	#9	#21
#10	1.A.4. Other Sectors	Gaseous Fuels	CO2	#10	
#11	2.B Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	HFCs	#11	
#12	1.A.3. Transport	d. Domestic Navigation	CO2	#12	
#13	3.C Rice Cultivation		CH4	#13	#32
#14	5.C Incineration and Open Burning of Waste		CO2	#14	#17
#15	1.A.2. Manufacturing Industries and Construction	Gaseous Fuels	CO2	#15	
#16	4.B Cropland	1. Cropland remaining Cropland	CO2	#16	#10
#17	5.A Solid Waste Disposal		CH4	#17	#15
#18	3.A Enteric Fermentation		CH4	#18	#14
#19	2.G Other Product Manufacture and Use		SF6	#19	#5
#20	2.C Metal Production	1. Iron and Steel Production	CO2	#20	
#21	2.B Chemical Industry	3. Adipic Acid Production	N2O	#21	
#22	1.A.3. Transport	a. Domestic Aviation	CO2	#22	
#23	4.A Forest Land	2. Land converted to Forest Land	CO2	#23	#30
#24	1.A.4. Other Sectors	Other Fossil Fuels	CO2	#24	#22
#25	2.A Mineral Product	2. Lime Production	CO2	#25	
#26	1.B Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	CH4	#26	#11
#27	3.D Agricultural Soils	1. Direct Emissions	N2O	#27	#24
#28	Indirect CO2	from IPPU sector	Ind CO2		#16
#29	1.A.2. Manufacturing Industries and Construction	Other Fossil Fuels	CO2		#31
#30	3.B Manure Management		N2O		#12
#31	4.E Settlements	2. Land converted to Settlements	CO2		#29
#32	2.B Chemical Industry	Other products except Ammonia	CO2		#18
#33	1.A.3. Transport	b. Road Transportation	N2O		#13
#34	3.D Agricultural Soils	2. Indirect Emissions	N2O		#9
#35	5.D Wastewater Treatment and Discharge		N2O		#28
#36	2.D Non-energy Products from Fuels and Solvent Use		CO2		#25
#37	2.B Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N2O		#20
#38	2.E Electronics Industry		PFCs		#26
#39	5.C Incineration and Open Burning of Waste		N2O		#27
#40	2.E Electronics Industry		SF6		#23

N.B.1) Ap1-L: Approach1-Level Assessment, Ap2-L: Approach2-Level Assessment

N.B.2) Figures recorded in the Level and Trend columns indicate the ranking of individual level and trend 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, 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.

The key category analysis was first conducted for the inventory excluding LULUCF and the key categories for source sectors were identified (1). Then the key category analysis was repeated again for the full inventory including the LULUCF categories and key categories for LULUCF sector were identified (2). A source category, which was identified as key in (1) but not in (2), was still regarded as

key; while a source category, which was not identified as key in (1) but was done in (2), was not regarded as key (gray rows in tables below).

Approach 1 level assessment of the latest emissions and removals (FY2017) gives the following 20 sub-categories as the key categories (Table A1-3). Approach 2 level assessment of the latest emissions and removals (FY2017) gives the following 31 sub-categories as the key categories (Table A1-4).

Table A1-3 Results of Approach 1 level assessment (FY2017)

	A IPCC Code	B IPCC Category	C GHGs	F Current Year Estimate [Gg-CO2 eq.]	H Ap1-L	I % Ap1-L Contrib.	Cumulative contrib.	
#1	1.A.1.	Energy Industries	Solid Fuels	CO2	273,827.66	0.201	20.1%	20.1%
#2	1.A.3.	Transport	b. Road Transportation	CO2	183,879.73	0.135	13.5%	33.6%
#3	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO2	174,831.12	0.128	12.8%	46.4%
#4	1.A.1.	Energy Industries	Gaseous Fuels	CO2	163,791.95	0.120	12.0%	58.5%
#5	1.A.4.	Other Sectors	Liquid Fuels	CO2	86,983.32	0.064	6.4%	64.8%
#6	1.A.1.	Energy Industries	Liquid Fuels	CO2	69,421.68	0.051	5.1%	69.9%
#7	4.A	Forest Land	1. Forest Land remaining Forest Land	CO2	-59,813.72	0.044	4.4%	74.3%
#8	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO2	55,984.11	0.041	4.1%	78.4%
#9	1.A.4.	Other Sectors	Gaseous Fuels	CO2	46,003.21	0.034	3.4%	81.8%
#10	2.F	Product uses as substitutes for ODS	1. Refrigeration and Air conditioning	HFCs	41,098.30	0.030	3.0%	84.8%
#11	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO2	32,244.74	0.024	2.4%	87.2%
#12	2.A	Mineral Product	1. Cement Production	CO2	26,428.78	0.019	1.9%	89.1%
#13	3.C	Rice Cultivation		CH4	13,627.04	0.010	1.0%	90.1%
#14	5.C	Incineration and Open Burning of Waste		CO2	10,807.65	0.008	0.8%	90.9%
#15	1.A.3.	Transport	d. Domestic Navigation	CO2	10,447.11	0.008	0.8%	91.7%
#16	1.A.3.	Transport	a. Domestic Aviation	CO2	10,400.11	0.008	0.8%	92.5%
#17	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO2	9,619.73	0.007	0.7%	93.2%
#18	1.A.4.	Other Sectors	Other Fossil Fuels	CO2	7,716.91	0.006	0.6%	93.7%
#19	3.A	Enteric Fermentation		CH4	7,282.58	0.005	0.5%	94.3%
#20	2.C	Metal Production	1. Iron and Steel Production	CO2	5,723.09	0.004	0.4%	94.7%
#21	2.A	Mineral Product	2. Lime Production	CO2	5,554.58	0.004	0.4%	95.1%

Table A1-4 Results of Approach 2 level assessment (FY2017)

	A IPCC Code	B IPCC Category	C GHGs	F Current Year Estimate [Gg-CO2 eq.]	L Source/Sink Uncertainty	N % Ap2-L Contrib.	Cumulative contrib.	
#1	1.A.1.	Energy Industries	Solid Fuels	CO2	273,827.66	6%	15.5%	15.5%
#2	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO2	174,831.12	6%	9.9%	25.5%
#3	1.A.3.	Transport	b. Road Transportation	CO2	183,879.73	5%	8.7%	34.2%
#4	4.A	Forest Land	1. Forest Land remaining Forest Land	CO2	-59,813.72	12%	7.5%	41.7%
#5	1.A.4.	Other Sectors	Liquid Fuels	CO2	86,983.32	5%	4.1%	45.8%
#6	1.A.1.	Energy Industries	Gaseous Fuels	CO2	163,791.95	2%	3.9%	49.7%
#7	1.A.1.	Energy Industries	Liquid Fuels	CO2	69,421.68	5%	3.3%	53.0%
#8	3.D	Agricultural Soils	2. Indirect Emissions	N2O	1,836.42	164%	3.0%	56.0%
#9	3.B	Manure Management		N2O	3,915.59	75%	3.0%	58.9%
#10	2.F	Product uses as substitutes for ODS	1. Refrigeration and Air conditioning	HFCs	41,098.30	7%	2.9%	61.8%
#11	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO2	55,984.11	5%	2.6%	64.5%
#12	3.A	Enteric Fermentation		CH4	7,282.58	26%	1.9%	66.4%
#13	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO2	9,619.73	19%	1.8%	68.2%
#14	5.C	Incineration and Open Burning of Waste		CO2	10,807.65	16%	1.8%	70.0%
#15	2.D	Non-energy Products from Fuels and Solvent Use		CO2	2,899.23	55%	1.6%	71.6%
#16	2.E	Electronics Industry		PFCs	1,931.11	81%	1.6%	73.1%
#17	2.B	Chemical Industry	Other products except Ammonia	CO2	2,759.43	55%	1.5%	74.7%
#18	1.A.4.	Other Sectors	Other Fossil Fuels	CO2	7,716.91	19%	1.5%	76.1%
#19	2.F	Product uses as substitutes for ODS	2. Foam Blowing Agents	HFCs	2,801.39	50%	1.4%	77.5%
#20	4.B	Cropland	1. Cropland remaining Cropland	CO2	4,456.34	31%	1.4%	79.0%
#21	2.G	Other Product Manufacture and Use		SF6	1,485.60	76%	1.1%	80.1%
#22	5.C	Incineration and Open Burning of Waste		N2O	1,420.64	79%	1.1%	81.2%
#23	1.A.4.	Other Sectors	Gaseous Fuels	CO2	46,003.21	2%	1.1%	82.3%
#24	2.A	Mineral Product	1. Cement Production	CO2	26,428.78	4%	1.1%	83.4%
#25	2.E	Electronics Industry		SF6	362.61	300%	1.1%	84.5%
#26	1.A.3.	Transport	b. Road Transportation	N2O	1,454.83	72%	1.1%	85.6%
#27	3.D	Agricultural Soils	1. Direct Emissions	N2O	3,571.75	27%	1.0%	86.5%
#28	3.C	Rice Cultivation		CH4	13,627.04	6%	0.8%	87.3%
#29		Indirect CO2	from IPPU sector	Ind CO2	1,650.26	48%	0.8%	88.1%
#30	5.D	Wastewater Treatment and Discharge		N2O	2,034.23	38%	0.8%	88.9%
#31	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO2	32,244.74	2%	0.8%	89.7%
#32	1.A.1.	Energy Industries		N2O	2,333.25	30%	0.7%	90.4%

Approach1 level assessment of the base year emissions and removals (FY1990) gives the following 27 sub-categories as the key categories (Table A1-5). Approach2 level assessment of the base year emissions and removals (FY1990) gives the following 32 sub-categories as the key categories (Table A1-6).

Table A1-5 Results of Approach 1 level assessment (FY1990)

	A IPCC Code	B IPCC Category		C GHGs	D FY1990 Estimate [Gg-CO ₂ e _{q.}]	H Ap1-L	I % Ap1-L Contrib.	Cumulative contrib.
#1	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO ₂	199,587.36	0.145	14.5%	14.5%
#2	1.A.3.	Transport	b. Road Transportation	CO ₂	179,212.93	0.130	13.0%	27.6%
#3	1.A.1.	Energy Industries	Liquid Fuels	CO ₂	178,959.74	0.130	13.0%	40.6%
#4	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO ₂	134,022.54	0.097	9.7%	50.3%
#5	1.A.4.	Other Sectors	Liquid Fuels	CO ₂	130,347.42	0.095	9.5%	59.8%
#6	1.A.1.	Energy Industries	Solid Fuels	CO ₂	109,537.93	0.080	8.0%	67.8%
#7	1.A.1.	Energy Industries	Gaseous Fuels	CO ₂	80,030.95	0.058	5.8%	73.6%
#8	4.A	Forest Land	1. Forest Land remaining Forest Land	CO ₂	-72,383.99	0.053	5.3%	78.9%
#9	2.A	Mineral Product	1. Cement Production	CO ₂	38,701.10	0.028	2.8%	81.7%
#10	1.A.4.	Other Sectors	Gaseous Fuels	CO ₂	22,241.56	0.016	1.6%	83.3%
#11	2.B	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	HFCs	15,930.24	0.012	1.2%	84.5%
#12	1.A.3.	Transport	d. Domestic Navigation	CO ₂	13,674.88	0.010	1.0%	85.4%
#13	3.C	Rice Cultivation		CH ₄	12,770.99	0.009	0.9%	86.4%
#14	5.C	Incineration and Open Burning of Waste		CO ₂	12,429.49	0.009	0.9%	87.3%
#15	1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO ₂	11,894.05	0.009	0.9%	88.1%
#16	4.B	Cropland	1. Cropland remaining Cropland	CO ₂	10,116.51	0.007	0.7%	88.9%
#17	5.A	Solid Waste Disposal		CH ₄	9,570.42	0.007	0.7%	89.6%
#18	3.A	Enteric Fermentation		CH ₄	9,351.06	0.007	0.7%	90.3%
#19	2.G	Other Product Manufacture and Use		SF ₆	8,814.04	0.006	0.6%	90.9%
#20	2.C	Metal Production	1. Iron and Steel Production	CO ₂	7,244.20	0.005	0.5%	91.4%
#21	2.B	Chemical Industry	3. Adipic Acid Production	N ₂ O	7,210.88	0.005	0.5%	92.0%
#22	1.A.3.	Transport	a. Domestic Aviation	CO ₂	7,162.41	0.005	0.5%	92.5%
#23	4.A	Forest Land	2. Land converted to Forest Land	CO ₂	-6,690.45	0.005	0.5%	93.0%
#24	1.A.4.	Other Sectors	Other Fossil Fuels	CO ₂	6,678.58	0.005	0.5%	93.4%
#25	2.A	Mineral Product	2. Lime Production	CO ₂	6,674.45	0.005	0.5%	93.9%
#26	1.B	Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	CH ₄	4,760.38	0.003	0.3%	94.3%
#27	3.D	Agricultural Soils	1. Direct Emissions	N ₂ O	4,704.38	0.003	0.3%	94.6%
#28	2.F	Product uses as substitutes for ODS	5. Solvents	PFCs	4,549.94	0.003	0.3%	95.0%
#29		Indirect CO ₂	from IPPU sector	Ind CO ₂	4,446.23	0.003	0.3%	95.3%

Table A1-6 Results of Approach 2 level assessment (FY1990)

	A IPCC Code	B IPCC Category	C GHGs	D FY1990 Estimate [Gg-CO ₂ e _{q.}]	L Source/Sink Uncertainty	N % Ap2-L Contrib.	Cumulative contrib.	
#1	1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO ₂	199,587.36	6%	9.6%	9.6%
#2	4.A.	Forest Land	1. Forest Land remaining Forest Land	CO ₂	-72,383.99	12%	7.7%	17.4%
#3	1.A.3.	Transport	b. Road Transportation	CO ₂	179,212.93	5%	7.2%	24.6%
#4	1.A.1.	Energy Industries	Liquid Fuels	CO ₂	178,959.74	5%	7.2%	31.8%
#5	2.G.	Other Product Manufacture and Use		SF ₆	8,814.04	76%	5.7%	37.5%
#6	1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO ₂	134,022.54	5%	5.4%	42.9%
#7	1.A.1.	Energy Industries	Solid Fuels	CO ₂	109,537.93	6%	5.3%	48.1%
#8	1.A.4.	Other Sectors	Liquid Fuels	CO ₂	130,347.42	5%	5.2%	53.4%
#9	3.D.	Agricultural Soils	2. Indirect Emissions	N ₂ O	2,416.19	164%	3.4%	56.8%
#10	4.B.	Cropland	1. Cropland remaining Cropland	CO ₂	10,116.51	31%	2.7%	59.5%
#11	1.B.	Fugitive Emission from Fuel	1.Fugitive emissions from Solid Fuels	CH ₄	4,760.38	65%	2.7%	62.1%
#12	3.B.	Manure Management		N ₂ O	4,114.42	75%	2.6%	64.8%
#13	1.A.3.	Transport	b. Road Transportation	N ₂ O	3,457.24	72%	2.1%	66.9%
#14	3.A.	Enteric Fermentation		CH ₄	9,351.06	26%	2.1%	69.0%
#15	5.A.	Solid Waste Disposal		CH ₄	9,570.42	22%	1.8%	70.8%
#16		Indirect CO ₂	from IPPU sector	Ind CO ₂	4,446.23	48%	1.8%	72.6%
#17	5.C.	Incineration and Open Burning of Waste		CO ₂	12,429.49	16%	1.8%	74.4%
#18	2.B.	Chemical Industry	Other products except Ammonia	CO ₂	3,623.06	55%	1.7%	76.1%
#19	1.A.1.	Energy Industries	Gaseous Fuels	CO ₂	80,030.95	2%	1.6%	77.7%
#20	2.B.	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N ₂ O	1,672.86	99%	1.4%	79.1%
#21	2.A.	Mineral Product	1. Cement Production	CO ₂	38,701.10	4%	1.4%	80.5%
#22	1.A.4.	Other Sectors	Other Fossil Fuels	CO ₂	6,678.58	19%	1.1%	81.6%
#23	2.E.	Electronics Industry		SF ₆	418.70	300%	1.1%	82.6%
#24	3.D.	Agricultural Soils	1. Direct Emissions	N ₂ O	4,704.38	27%	1.1%	83.7%
#25	2.D.	Non-energy Products from Fuels and Solvent Use		CO ₂	2,163.76	55%	1.0%	84.7%
#26	2.E.	Electronics Industry		PFCs	1,454.78	81%	1.0%	85.7%
#27	5.C.	Incineration and Open Burning of Waste		N ₂ O	1,438.04	79%	1.0%	86.7%
#28	5.D.	Wastewater Treatment and Discharge		N ₂ O	2,387.11	38%	0.8%	87.5%
#29	4.E.	Settlements	2. Land converted to Settlements	CO ₂	4,025.65	21%	0.7%	88.2%
#30	4.A.	Forest Land	2. Land converted to Forest Land	CO ₂	-6,690.45	12%	0.7%	88.9%
#31	1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO ₂	4,199.02	19%	0.7%	89.6%
#32	3.C.	Rice Cultivation		CH ₄	12,770.99	6%	0.7%	90.3%

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, 90% for Approach 2. At this point, these categories are defined as the key categories. 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.

The key category analysis was first conducted for the inventory excluding LULUCF and the key categories for source sectors were identified (1). Then the key category analysis was repeated again for the full inventory including the LULUCF categories and key categories for LULUCF sector were identified (2). A source category, which was identified as key in (1) but not in (2), was still regarded as key; while a source category, which was not identified as key in (1) but was done in (2), was not regarded as key (gray rows in tables below).

Approach 1 trend assessment of the latest emissions and removals (FY2017) gives the following 26 sub-categories as the key categories (Table A1-7). Approach 2 trend assessment of the latest emissions and removals (FY2017) gives the following 30 sub-categories as the key categories (Table A1-8).

Table A1-7 Results of Approach 1 trend assessment (FY2017)

A IPCC Code	B IPCC Category	C GHGs	D FY1990 Estimate [Gg-CO ₂ e q.]	F Current Year Estimate [Gg-CO ₂ e q.]	J Ap1-T	K % Ap1-T Contrib.	Cumulative contrib.	
#1	1.A.1. Energy Industries	Solid Fuels	CO ₂	109,537.93	273,827.66	0.118	22.0%	22.0%
#2	1.A.1. Energy Industries	Liquid Fuels	CO ₂	178,959.74	69,421.68	0.082	15.2%	37.2%
#3	1.A.1. Energy Industries	Gaseous Fuels	CO ₂	80,030.95	163,791.95	0.060	11.2%	48.4%
#4	1.A.2. Manufacturing Industries and Construction	Liquid Fuels	CO ₂	134,022.54	55,984.11	0.058	10.8%	59.2%
#5	1.A.4. Other Sectors	Liquid Fuels	CO ₂	130,347.42	86,983.32	0.033	6.1%	65.4%
#6	2.F. Product uses as substitutes for ODS	1. Refrigeration and Air conditioning	HFCs	0.00	41,098.30	0.030	5.6%	71.0%
#7	1.A.2. Manufacturing Industries and Construction	Solid Fuels	CO ₂	199,587.36	174,831.12	0.020	3.8%	74.7%
#8	1.A.4. Other Sectors	Gaseous Fuels	CO ₂	22,241.56	46,003.21	0.017	3.2%	77.9%
#9	1.A.2. Manufacturing Industries and Construction	Gaseous Fuels	CO ₂	11,894.05	32,244.74	0.015	2.7%	80.6%
#10	2.B. Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	HFCs	15,930.24	133.43	0.012	2.2%	82.8%
#11	2.A. Mineral Product	1. Cement Production	CO ₂	38,701.10	26,428.78	0.009	1.7%	84.5%
#12	4.A. Forest Land	1. Forest Land remaining Forest Land	CO ₂	-72,383.99	-59,813.72	0.008	1.6%	86.1%
#13	2.G. Other Product Manufacture and Use		SF ₆	8,814.04	1,485.60	0.005	1.0%	87.1%
#14	2.B. Chemical Industry	3. Adipic Acid Production	N ₂ O	7,210.88	90.30	0.005	1.0%	88.1%
#15	5.A. Solid Waste Disposal		CH ₄	9,570.42	3,080.66	0.005	0.9%	89.0%
#16	4.B. Cropland	1. Cropland remaining Cropland	CO ₂	10,116.51	4,456.34	0.004	0.8%	89.8%
#17	4.A. Forest Land	2. Land converted to Forest Land	CO ₂	-6,690.45	-1,040.56	0.004	0.8%	90.5%
#18	1.A.2. Manufacturing Industries and Construction	Other Fossil Fuels	CO ₂	4,199.02	9,619.73	0.004	0.7%	91.2%
#19	1.B. Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	CH ₄	4,760.38	520.78	0.003	0.6%	91.8%
#20	2.B. Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	SF ₆	3,470.78	40.70	0.003	0.5%	92.3%
#21	1.A.3. Transport	d. Domestic Navigation	CO ₂	13,674.88	10,447.11	0.003	0.5%	92.8%
#22	2.F. Product uses as substitutes for ODS	5. Solvents	PFCs	4,549.94	1,483.85	0.002	0.4%	93.2%
#23	1.A.3. Transport	a. Domestic Aviation	CO ₂	7,162.41	10,400.11	0.002	0.4%	93.6%
#24		Indirect CO ₂	Ind CO ₂	4,446.23	1,650.26	0.002	0.4%	94.0%
#25	2.F. Product uses as substitutes for ODS	2. Foam Blowing Agents	HFCs	1.34	2,801.39	0.002	0.4%	94.4%
#26	4.E. Settlements	2. Land converted to Settlements	CO ₂	4,025.65	1,392.85	0.002	0.4%	94.7%
#27	1.A.4. Other Sectors	Solid Fuels	CO ₂	353.86	2,697.36	0.002	0.3%	95.1%

Table A1-8 Results of Approach 2 trend assessment (FY2017)

A IPCC Code	B IPCC Category	C GHGs	D FY1990 Estimate [Gg-CO ₂ e q.]	F Current Year Estimate [Gg-CO ₂ e q.]	L Source/Sin k Uncertainty	O Ap2-T	P % Ap2-T Contrib.	Cumulative contrib.	
#1	1.A.1. Energy Industries	Solid Fuels	CO ₂	109,537.93	273,827.66	6%	6.67	15.2%	15.2%
#2	2.G. Other Product Manufacture and Use		SF ₆	8,814.04	1,485.60	76%	4.11	9.4%	24.6%
#3	1.A.1. Energy Industries	Liquid Fuels	CO ₂	178,959.74	69,421.68	5%	3.84	8.8%	33.4%
#4	1.A.2. Manufacturing Industries and Construction	Liquid Fuels	CO ₂	134,022.54	55,984.11	5%	2.74	6.3%	39.7%
#5	2.F. Product uses as substitutes for ODS	1. Refrigeration and Air conditioning	HFCs	0.00	41,098.30	7%	2.08	4.7%	44.4%
#6	1.B. Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	CH ₄	4,760.38	520.78	65%	2.04	4.7%	49.1%
#7	1.A.4. Other Sectors	Liquid Fuels	CO ₂	130,347.42	86,983.32	5%	1.55	3.5%	52.6%
#8	1.A.1. Energy Industries	Gaseous Fuels	CO ₂	80,030.95	163,791.95	2%	1.43	3.3%	55.9%
#9	4.B. Cropland	1. Cropland remaining Cropland	CO ₂	10,116.51	4,456.34	31%	1.33	3.0%	58.9%
#10	1.A.2. Manufacturing Industries and Construction	Solid Fuels	CO ₂	199,587.36	174,831.12	6%	1.14	2.6%	61.5%
#11	1.B. Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	N ₂ O	1,672.86	162.97	99%	1.10	2.5%	64.0%
#12	5.A. Solid Waste Disposal		CH ₄	9,570.42	3,080.66	22%	1.08	2.5%	66.5%
#13	1.A.3. Transport	b. Road Transportation	N ₂ O	3,457.24	1,454.83	72%	1.07	2.5%	69.0%
#14	4.A. Forest Land	1. Forest Land remaining Forest Land	CO ₂	-72,383.99	-59,813.72	12%	1.04	2.4%	71.3%
#15	2.F. Product uses as substitutes for ODS	2. Foam Blowing Agents	HFCs	1.34	2,801.39	50%	1.02	2.3%	73.7%
#16		Indirect CO ₂	Ind CO ₂	4,446.23	1,650.26	48%	0.99	2.3%	75.9%
#17	1.A.2. Manufacturing Industries and Construction	Other Fossil Fuels	CO ₂	4,199.02	9,619.73	19%	0.74	1.7%	77.6%
#18	3.D. Agricultural Soils	2. Indirect Emissions	N ₂ O	2,416.19	1,836.42	164%	0.73	1.7%	79.3%
#19	4.A. Forest Land	2. Land converted to Forest Land	CO ₂	-6,690.45	-1,040.56	12%	0.50	1.1%	80.4%
#20	2.B. Chemical Industry	3. Adipic Acid Production	N ₂ O	7,210.88	90.30	9%	0.48	1.1%	81.6%
#21	3.A. Enteric Fermentation		CH ₄	9,351.06	7,282.58	26%	0.42	0.9%	82.5%
#22	4.E. Settlements	2. Land converted to Settlements	CO ₂	4,025.65	1,392.85	21%	0.41	0.9%	83.4%
#23	1.A.4. Other Sectors	Gaseous Fuels	CO ₂	22,241.56	46,003.21	2%	0.41	0.9%	84.4%
#24	2.A. Mineral Product	1. Cement Production	CO ₂	38,701.10	26,428.78	4%	0.39	0.9%	85.2%
#25	2.B. Chemical Industry	Other products except Ammonia	CO ₂	3,623.06	2,759.43	55%	0.37	0.8%	86.1%
#26	1.A.2. Manufacturing Industries and Construction	Gaseous Fuels	CO ₂	11,894.05	32,244.74	2%	0.35	0.8%	86.9%
#27	1.A.1. Energy Industries		N ₂ O	889.46	2,333.25	30%	0.31	0.7%	87.6%
#28	2.D. Non-energy Products from Fuels and Solvent Use		CO ₂	2,163.76	2,899.23	55%	0.28	0.6%	88.2%
#29	2.E. Electronics Industry		PFCs	1,454.78	1,931.11	81%	0.27	0.6%	88.8%
#30	3.D. Agricultural Soils	1. Direct Emissions	N ₂ O	4,704.38	3,571.75	27%	0.23	0.5%	89.4%
#31	2.B. Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	HFCs	15,930.24	133.43	2%	0.23	0.5%	89.9%
#32	2.F. Product uses as substitutes for ODS	5. Solvents	PFCs	4,549.94	1,483.85	10%	0.23	0.5%	90.4%

Data utilized for the key category analysis are shown in Table A1-9 and A1-10 as references.

Table A1-9 Data used for the key category analysis (FY2017)

A Code	B IPCC 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	CO2 178,959.74	69,421.68	0.051	5.1%	0.0817	15.2%	5%	0.033	3.3%	3.84	8.8%
1.A.1.	Energy Industries	Solid Fuels	CO2 109,537.93	273,827.66	0.201	20.1%	0.1183	22.0%	6%	0.155	15.5%	6.67	15.2%
1.A.1.	Energy Industries	Gaseous Fuels	CO2 80,030.95	163,791.95	0.120	12.0%	0.0600	11.2%	2%	0.039	3.9%	1.43	3.3%
1.A.1.	Energy Industries	Other Fossil Fuels	CO2 0.00	48.72	0.000	0.0%	0.0000	0.0%	19%	0.000	0.0%	0.01	0.0%
1.A.1.	Energy Industries		CH4 459.35	209.59	0.000	0.0%	0.0002	0.0%	49%	0.001	0.1%	0.09	0.2%
1.A.1.	Energy Industries		N2O 889.46	2,333.25	0.002	0.2%	0.0010	0.2%	30%	0.007	0.7%	0.31	0.7%
1.A.2.	Manufacturing Industries and Construction	Liquid Fuels	CO2 134,022.54	55,984.11	0.041	4.1%	0.0583	10.8%	5%	0.026	2.6%	2.74	6.3%
1.A.2.	Manufacturing Industries and Construction	Solid Fuels	CO2 199,587.36	174,831.12	0.128	12.8%	0.0203	3.8%	6%	0.099	9.9%	1.14	2.6%
1.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	CO2 11,894.05	32,244.74	0.024	2.4%	0.0147	2.7%	2%	0.008	0.8%	0.35	0.8%
1.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	CO2 4,199.02	9,619.73	0.007	0.7%	0.0039	0.7%	19%	0.018	1.8%	0.74	1.7%
1.A.2.	Manufacturing Industries and Construction		CH4 359.71	492.47	0.000	0.0%	0.0001	0.0%	49%	0.002	0.2%	0.05	0.1%
1.A.2.	Manufacturing Industries and Construction		N2O 1,258.65	1,650.47	0.001	0.1%	0.0003	0.1%	30%	0.005	0.5%	0.08	0.2%
1.A.3.	Transport	a. Domestic Aviation	CO2 7,162.41	10,400.11	0.008	0.8%	0.0023	0.4%	5%	0.005	0.5%	0.11	0.2%
1.A.3.	Transport	a. Domestic Aviation	CH4 5.64	1.49	0.000	0.0%	0.0000	0.0%	79%	0.000	0.0%	0.00	0.0%
1.A.3.	Transport	a. Domestic Aviation	N2O 64.02	90.90	0.000	0.0%	0.0000	0.0%	110%	0.001	0.1%	0.02	0.0%
1.A.3.	Transport	b. Road Transportation	CO2 179,212.93	183,879.73	0.135	13.5%	0.0014	0.3%	5%	0.007	0.7%	0.06	0.1%
1.A.3.	Transport	b. Road Transportation	CH4 252.59	108.33	0.000	0.0%	0.0001	0.0%	70%	0.001	0.1%	0.08	0.2%
1.A.3.	Transport	b. Road Transportation	N2O 3,457.24	1,454.83	0.001	0.1%	0.0015	0.3%	72%	0.011	1.1%	1.07	2.5%
1.A.3.	Transport	c. Railways	CO2 935.40	498.78	0.000	0.0%	0.0003	0.1%	5%	0.000	0.0%	0.02	0.0%
1.A.3.	Transport	c. Railways	CH4 1.34	0.70	0.000	0.0%	0.0000	0.0%	105%	0.000	0.0%	0.00	0.0%
1.A.3.	Transport	c. Railways	N2O 109.95	57.60	0.000	0.0%	0.0000	0.0%	125%	0.001	0.1%	0.05	0.1%
1.A.3.	Transport	d. Domestic Navigation	CO2 13,674.88	10,447.11	0.008	0.8%	0.0025	0.5%	5%	0.005	0.5%	0.12	0.3%
1.A.3.	Transport	d. Domestic Navigation	CH4 31.73	23.31	0.000	0.0%	0.0000	0.0%	52%	0.000	0.0%	0.00	0.0%
1.A.3.	Transport	d. Domestic Navigation	N2O 108.07	79.38	0.000	0.0%	0.0000	0.0%	91%	0.001	0.1%	0.02	0.0%
1.A.4.	Other Sectors	Liquid Fuels	CO2 130,347.42	86,983.32	0.064	6.4%	0.0330	6.1%	5%	0.041	4.1%	1.55	3.5%
1.A.4.	Other Sectors	Solid Fuels	CO2 353.86	2,697.36	0.002	0.2%	0.0017	0.3%	6%	0.002	0.2%	0.10	0.2%
1.A.4.	Other Sectors	Gaseous Fuels	CO2 22,241.56	46,003.21	0.034	3.4%	0.0170	3.2%	2%	0.011	1.1%	0.41	0.9%
1.A.4.	Other Sectors	Other Fossil Fuels	CO2 6,678.58	7,716.91	0.006	0.6%	0.0007	0.1%	19%	0.015	1.5%	0.13	0.3%
1.A.4.	Other Sectors		CH4 239.23	218.37	0.000	0.0%	0.0000	0.0%	49%	0.001	0.1%	0.01	0.0%
1.A.4.	Other Sectors		N2O 709.45	636.52	0.000	0.0%	0.0001	0.0%	30%	0.002	0.2%	0.02	0.0%
1.B	Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	CO2 5.32	0.48	0.000	0.0%	0.0000	0.0%	68%	0.000	0.0%	0.00	0.0%
1.B	Fugitive Emission from Fuel	1. Fugitive emissions from Solid Fuels	CH4 4,760.38	520.78	0.000	0.0%	0.0031	0.6%	65%	0.003	0.3%	2.04	4.7%
1.B	Fugitive Emission from Fuel	2.a. Oil	CO2 0.03	0.02	0.000	0.0%	0.0000	0.0%	89%	0.000	0.0%	0.00	0.0%
1.B	Fugitive Emission from Fuel	2.a. Oil	CH4 25.37	19.56	0.000	0.0%	0.0000	0.0%	69%	0.000	0.0%	0.00	0.0%
1.B	Fugitive Emission from Fuel	2.b. Natural Gas	CO2 0.63	0.92	0.000	0.0%	0.0000	0.0%	80%	0.000	0.0%	0.00	0.0%
1.B	Fugitive Emission from Fuel	2.b. Natural Gas	CH4 174.24	246.26	0.000	0.0%	0.0001	0.0%	73%	0.002	0.2%	0.04	0.1%
1.B	Fugitive Emission from Fuel	2.c. Venting & Flaring	CO2 81.17	264.67	0.000	0.0%	0.0001	0.0%	14%	0.000	0.0%	0.02	0.0%
1.B	Fugitive Emission from Fuel	2.c. Venting & Flaring	CH4 7.96	4.07	0.000	0.0%	0.0000	0.0%	49%	0.000	0.0%	0.00	0.0%
1.B	Fugitive Emission from Fuel	2.c. Venting & Flaring	N2O 0.11	0.08	0.000	0.0%	0.0000	0.0%	32%	0.000	0.0%	0.00	0.0%
1.B	Fugitive Emission from Fuel	2.d. Other (Geothermal)	CO2 104.42	210.49	0.000	0.0%	0.0001	0.0%	17%	0.000	0.0%	0.01	0.0%
1.B	Fugitive Emission from Fuel	2.d. Other (Geothermal)	CH4 5.21	10.29	0.000	0.0%	0.0000	0.0%	17%	0.000	0.0%	0.00	0.0%
2.A	Mineral Product	1. Cement Production	CO2 38,701.10	26,428.78	0.019	1.9%	0.0094	1.7%	4%	0.011	1.1%	0.39	0.9%
2.A	Mineral Product	2. Lime Production	CO2 6,674.45	5,554.58	0.004	0.4%	0.0009	0.2%	4%	0.002	0.2%	0.03	0.1%
2.A	Mineral Product	3. Glass Production	CO2 312.88	194.15	0.000	0.0%	0.0001	0.0%	6%	0.000	0.0%	0.01	0.0%
2.A	Mineral Product	4. Other Process Uses of Carbonates	CO2 3,542.02	1,884.04	0.001	0.1%	0.0012	0.2%	6%	0.001	0.1%	0.07	0.2%
2.B	Chemical Industry	1. Ammonia Production	CO2 3,417.74	1,725.66	0.001	0.1%	0.0013	0.2%	1%	0.000	0.0%	0.02	0.0%
2.B	Chemical Industry	Other products except Ammonia	CO2 3,623.06	2,759.43	0.002	0.2%	0.0007	0.1%	55%	0.015	1.5%	0.37	0.8%
2.B	Chemical Industry	2. Nitric Acid Production	N2O 736.06	345.95	0.000	0.0%	0.0003	0.1%	73%	0.003	0.3%	0.21	0.5%
2.B	Chemical Industry	3. Adipic Acid Production	N2O 7,210.88	90.30	0.000	0.0%	0.0053	1.0%	9%	0.000	0.0%	0.48	1.1%
2.B	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid	N2O 1,672.86	162.97	0.000	0.0%	0.0011	0.2%	99%	0.002	0.2%	1.10	2.5%
2.B	Chemical Industry	9. Fluorochemical Production (Fugitive)	HFCs 15,990.24	133.43	0.000	0.0%	0.0117	2.2%	2%	0.000	0.0%	0.23	0.5%
2.B	Chemical Industry	9. Fluorochemical Production (Fugitive)	PFCs 330.92	77.66	0.000	0.0%	0.0002	0.0%	2%	0.000	0.0%	0.00	0.0%
2.B	Chemical Industry	9. Fluorochemical Production (Fugitive)	SF6 3,470.78	40.70	0.000	0.0%	0.0025	0.5%	2%	0.000	0.0%	0.05	0.1%
2.B	Chemical Industry	9. Fluorochemical Production (Fugitive)	NF3 2.79	234.09	0.000	0.0%	0.0002	0.0%	2%	0.000	0.0%	0.00	0.0%
2.B	Chemical Industry	Whole of Chemical Industries	CH4 37.49	25.26	0.000	0.0%	0.0000	0.0%	55%	0.000	0.0%	0.01	0.0%
2.C	Metal Production	1. Iron and Steel Production	CO2 7,244.20	5,723.09	0.004	0.4%	0.0012	0.2%	4%	0.002	0.2%	0.04	0.1%
2.C	Metal Production	1. Iron and Steel Production	CH4 18.42	14.76	0.000	0.0%	0.0000	0.0%	163%	0.000	0.0%	0.00	0.0%
2.C	Metal Production	2. Ferroalloys Production	CH4 4.63	2.68	0.000	0.0%	0.0000	0.0%	163%	0.000	0.0%	0.00	0.0%
2.C	Metal Production	3. Aluminium Production	PFCs 203.66	0.00	0.000	0.0%	0.0002	0.0%	44%	0.000	0.0%	0.07	0.2%
2.C	Metal Production	4. SF6 Used in Aluminium and Magnesium	HFCs 0.00	1.43	0.000	0.0%	0.0000	0.0%	5%	0.000	0.0%	0.00	0.0%
2.C	Metal Production	4. SF6 Used in Aluminium and Magnesium	SF6 146.54	246.24	0.000	0.0%	0.0001	0.0%	5%	0.000	0.0%	0.00	0.0%
2.D	Non-energy Products from Fuels and Solvent Use		CO2 2,163.76	2,899.23	0.002	0.2%	0.0005	0.1%	55%	0.016	1.6%	0.28	0.6%
2.E	Electronics Industry		HFCs 0.73	125.04	0.000	0.0%	0.0001	0.0%	100%	0.001	0.1%	0.09	0.2%
2.E	Electronics Industry		PFCs 1,454.78	1,931.11	0.001	0.1%	0.0003	0.1%	81%	0.016	1.6%	0.27	0.6%
2.E	Electronics Industry		SF6 418.70	362.61	0.000	0.0%	0.0000	0.0%	300%	0.011	1.1%	0.14	0.3%
2.E	Electronics Industry		NF3 29.82	215.68	0.000	0.0%	0.0001	0.0%	71%	0.002	0.2%	0.10	0.2%
2.F	Product uses as substitutes for ODS	1. Refrigeration and Air conditioning	HFCs 0.00	41,098.30	0.030	3.0%	0.0299	5.6%	7%	0.029	2.9%	2.08	4.7%
2.F	Product uses as substitutes for ODS	2. Foam Blowing Agents	HFCs 1.34	2,801.39	0.002	0.2%	0.0020	0.4%	50%	0.014	1.4%	1.02	2.3%
2.F	Product uses as substitutes for ODS	3. Fire Extinguishers	HFCs 0.00	9.72	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	600.23	0.000	0.0%	0.0004	0.1%	10%	0.001	0.1%	0.04	0.1%
2.F	Product uses as substitutes for ODS	5. Solvents	HFCs 0.00	115.84	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 4,549.94	1,483.85	0.001	0.1%	0.0023	0.4%	10%	0.001	0.1%	0.23	0.5%
2.G	Other Product Manufacture and Use		N2O 290.86	415.77	0.000	0.0%	0.0001	0.0%	4%	0.000	0.0%	0.00	0.0%
2.G	Other Product Manufacture and Use		PFCs 0.00	19.53	0.000	0.0%	0.0000	0.0%	10%	0.000	0.0%	0.00	0.0%
2.G	Other Product Manufacture and Use		SF6 8,814.04	1,485.60	0.001	0.1%	0.0054	1.0%	76%	0.011	1.1%	4.11	9.4%
2.H	Other	Use of Dry Ice	CO2 64.27	85.07	0.000	0.0%	0.0000	0.0%	5%	0.000	0.0%	0.00	0.0%
3.A	Enteric Fermentation		CH4 9,351.06	7,282.58	0.005	0.5%	0.0016	0.3%	26%	0.019	1.9%	0.42	0.9%
3.B	Manure Management		CH4 3,120.55	2,322.96	0.002	0.2%	0.0006	0.1%	17%	0.004	0.4%	0.11	0.2%
3.B	Manure Management		N2O 4,114.42	3,915.59	0.003	0.3%	0.0002	0.0%	75%	0.030	3.0%	0.14	0.3%
3.C	Rice Cultivation		CH4										

Table A1-9 Data used for the key category analysis (FY2017) (Continued)

A IPCC Code	B IPCC Category	C GHGs	E Absolute Value of FY1990 Estimate [Gg- CO2eq.]	G Absolute Value of Current Year Estimate [Gg-CO2eq.]	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		72,383.99	59,813.72	0.044	4.4%	0.0083	1.6%	12%	0.075	7.5%	1.04	2.4%
4.A	Forest Land	1. Forest Land remaining Forest Land											
4.A	Forest Land	2. Land converted to Forest Land	6,690.45	1,040.56	0.001	0.1%	0.0040	0.8%	12%	0.001	0.1%	0.50	1.1%
4.B	Cropland		10,116.51	4,456.34	0.003	0.3%	0.0042	0.8%	31%	0.014	1.4%	1.33	3.0%
4.B	Cropland	1. Cropland remaining Cropland											
4.B	Cropland	2. Land converted to Cropland	1,601.68	65.38	0.000	0.0%	0.0011	0.2%	18%	0.000	0.0%	0.21	0.5%
4.C	Grassland		881.40	251.03	0.000	0.0%	0.0008	0.2%	9%	0.000	0.0%	0.08	0.2%
4.C	Grassland	1. Grassland remaining Grassland											
4.C	Grassland	2. Land converted to Grassland	171.53	94.49	0.000	0.0%	0.0001	0.0%	20%	0.000	0.0%	0.01	0.0%
4.D	Wetlands		0.00	0.00	0.000	0.0%	0.0000	0.0%	21%	0.000	0.0%	0.00	0.0%
4.D	Wetlands	1.1 Peat Extraction Remaining Peat											
4.D	Wetlands	1.2 Flooded Land Remaining Flooded Land											
4.D	Wetlands	1.3 Other Wetlands Remaining Other											
4.D	Wetlands	2. Land converted to Wetlands	90.39	46.83	0.000	0.0%	0.0000	0.0%	21%	0.000	0.0%	0.01	0.0%
4.E	Settlements		1,380.72	1,504.00	0.001	0.1%	0.0001	0.0%	34%	0.005	0.5%	0.04	0.1%
4.E	Settlements	1. Settlements remaining Settlements											
4.E	Settlements	2. Land converted to Settlements	4,025.65	1,392.85	0.001	0.1%	0.0020	0.4%	21%	0.003	0.3%	0.41	0.9%
4.F	Other Land		0.00	0.00	0.000	0.0%	0.0000	0.0%	18%	0.000	0.0%	0.00	0.0%
4.F	Other Land	1. Other Land remaining Other Land											
4.F	Other Land	2. Land converted to Other Land	1,155.15	188.01	0.000	0.0%	0.0007	0.1%	18%	0.000	0.0%	0.13	0.3%
4.G	Harvested Wood Products		365.43	1,370.04	0.001	0.1%	0.0007	0.1%	30%	0.004	0.4%	0.22	0.5%
4.(I)	Direct N2O emissions from N inputs to managed soils		0.84	0.54	0.000	0.0%	0.0000	0.0%	31%	0.000	0.0%	0.00	0.0%
4.(II)	Drainage and rewetting		0.00	0.00	0.000	0.0%	0.0000	0.0%	0%	0.000	0.0%	0.00	0.0%
4.(II)	Drainage and rewetting		38.23	37.14	0.000	0.0%	0.0000	0.0%	115%	0.000	0.0%	0.00	0.0%
4.(II)	Drainage and rewetting		0.00	0.00	0.000	0.0%	0.0000	0.0%	0%	0.000	0.0%	0.00	0.0%
4.(III)	Direct N2O emissions from N		153.48	135.09	0.000	0.0%	0.0000	0.0%	138%	0.002	0.2%	0.02	0.0%
4.(IV)	Indirect N2O Emissions from Managed Soils		41.13	32.27	0.000	0.0%	0.0000	0.0%	318%	0.001	0.1%	0.02	0.1%
4.(V)	Biomass Burning		0.00	0.00	0.000	0.0%	0.0000	0.0%	0%	0.000	0.0%	0.00	0.0%
4.(V)	Biomass Burning		47.20	51.99	0.000	0.0%	0.0000	0.0%	28%	0.000	0.0%	0.00	0.0%
4.(V)	Biomass Burning		22.15	20.61	0.000	0.0%	0.0000	0.0%	296%	0.001	0.1%	0.00	0.0%
5.A	Solid Waste Disposal		9,570.42	3,080.66	0.002	0.2%	0.0048	0.9%	22%	0.007	0.7%	1.08	2.5%
5.B	Biological Treatment of Solid Waste		53.99	103.33	0.000	0.0%	0.0000	0.0%	84%	0.001	0.1%	0.03	0.1%
5.B	Biological Treatment of Solid Waste		180.77	343.95	0.000	0.0%	0.0001	0.0%	170%	0.006	0.6%	0.20	0.5%
5.C	Incineration and Open Burning of Waste		12,429.49	10,807.65	0.008	0.8%	0.0013	0.2%	16%	0.018	1.8%	0.22	0.5%
5.C	Incineration and Open Burning of Waste		27.78	9.58	0.000	0.0%	0.0000	0.0%	163%	0.000	0.0%	0.02	0.1%
5.C	Incineration and Open Burning of Waste		1,438.04	1,420.64	0.001	0.1%	0.0000	0.0%	79%	0.011	1.1%	0.02	0.1%
5.D	Wastewater Treatment and Discharge		2,941.55	1,673.33	0.001	0.1%	0.0010	0.2%	22%	0.004	0.4%	0.21	0.5%
5.D	Wastewater Treatment and Discharge		2,387.11	2,034.23	0.001	0.1%	0.0003	0.1%	38%	0.008	0.8%	0.11	0.2%
5.E	Other		702.83	636.47	0.000	0.0%	0.0001	0.0%	10%	0.001	0.1%	0.01	0.0%
		Indirect CO2 from Energy sector	1,027.51	467.59	0.000	0.0%	0.0004	0.1%	32%	0.001	0.1%	0.13	0.3%
		Indirect CO2 from IPPU sector	4,446.23	1,650.26	0.001	0.1%	0.0021	0.4%	48%	0.008	0.8%	0.99	2.3%
		Absolute Figure Total (including LULUCF)	1,374,643.28	1,362,249.32	1.00	100.0%	0.54	100%		1.00	100.0%	43.8	100.0%

Table A1-10 Data used for the key category analysis (FY1990)

A IPCC Code	B IPCC Category	C GHGs	E Absolute Value of FY1990 Estimate	H Ap1-L	I % Ap1-L Contrib.	L Source/Sink Uncertainty	M Ap2-L	N % Ap2-L Contrib.
I.A.1.	Energy Industries	Liquid Fuels	178,959.74	0.130	13.0%		5%	0.072
I.A.1.	Energy Industries	Solid Fuels	109,537.93	0.080	8.0%		6%	0.053
I.A.1.	Energy Industries	Gaseous Fuels	80,030.95	0.058	5.8%		2%	0.016
I.A.1.	Energy Industries	Other Fossil Fuels	0.00	0.000	0.0%		19%	0.000
I.A.1.	Energy Industries		459.35	0.000	0.0%		49%	0.002
I.A.1.	Energy Industries		889.46	0.001	0.1%		30%	0.002
I.A.2.	Manufacturing Industries and Construction	Liquid Fuels	134,022.54	0.097	9.7%		5%	0.054
I.A.2.	Manufacturing Industries and Construction	Solid Fuels	199,587.36	0.145	14.5%		6%	0.096
I.A.2.	Manufacturing Industries and Construction	Gaseous Fuels	11,894.05	0.009	0.9%		2%	0.002
I.A.2.	Manufacturing Industries and Construction	Other Fossil Fuels	4,199.02	0.003	0.3%		19%	0.007
I.A.2.	Manufacturing Industries and Construction		359.71	0.000	0.0%		49%	0.002
I.A.2.	Manufacturing Industries and Construction		1,258.65	0.001	0.1%		30%	0.003
I.A.3.	Transport	a. Domestic Aviation	7,162.41	0.005	0.5%		5%	0.003
I.A.3.	Transport	a. Domestic Aviation	5.64	0.000	0.0%		79%	0.000
I.A.3.	Transport	a. Domestic Aviation	64.02	0.000	0.0%		110%	0.001
I.A.3.	Transport	b. Road Transportation	179,212.93	0.130	13.0%		5%	0.072
I.A.3.	Transport	b. Road Transportation	252.59	0.000	0.0%		70%	0.002
I.A.3.	Transport	b. Road Transportation	3,457.24	0.003	0.3%		72%	0.021
I.A.3.	Transport	c. Railways	935.40	0.001	0.1%		5%	0.000
I.A.3.	Transport	c. Railways	1.34	0.000	0.0%		105%	0.000
I.A.3.	Transport	c. Railways	109.95	0.000	0.0%		125%	0.001
I.A.3.	Transport	d. Domestic Navigation	13,674.88	0.010	1.0%		5%	0.005
I.A.3.	Transport	d. Domestic Navigation	31.73	0.000	0.0%		52%	0.000
I.A.3.	Transport	d. Domestic Navigation	108.07	0.000	0.0%		91%	0.001
I.A.4.	Other Sectors	Liquid Fuels	130,347.42	0.095	9.5%		5%	0.052
I.A.4.	Other Sectors	Solid Fuels	353.86	0.000	0.0%		6%	0.000
I.A.4.	Other Sectors	Gaseous Fuels	22,241.56	0.016	1.6%		2%	0.005
I.A.4.	Other Sectors	Other Fossil Fuels	6,678.58	0.005	0.5%		19%	0.011
I.A.4.	Other Sectors		239.23	0.000	0.0%		49%	0.001
I.A.4.	Other Sectors		709.45	0.001	0.1%		30%	0.002
I.B	Fugitive Emission from Fuel	1.Fugitive emissions from Solid Fuels	5.32	0.000	0.0%		68%	0.000
I.B	Fugitive Emission from Fuel	1.Fugitive emissions from Solid Fuels	4,760.38	0.003	0.3%		65%	0.027
I.B	Fugitive Emission from Fuel	2.a. Oil	0.03	0.000	0.0%		89%	0.000
I.B	Fugitive Emission from Fuel	2.a. Oil	25.37	0.000	0.0%		69%	0.000
I.B	Fugitive Emission from Fuel	2.b. Natural Gas	0.63	0.000	0.0%		80%	0.000
I.B	Fugitive Emission from Fuel	2.b. Natural Gas	174.24	0.000	0.0%		73%	0.001
I.B	Fugitive Emission from Fuel	2.c. Venting & Flaring	81.17	0.000	0.0%		14%	0.000
I.B	Fugitive Emission from Fuel	2.c. Venting & Flaring	7.96	0.000	0.0%		49%	0.000
I.B	Fugitive Emission from Fuel	2.c. Venting & Flaring	0.11	0.000	0.0%		32%	0.000
I.B	Fugitive Emission from Fuel	2.d. Other (Geothermal)	104.42	0.000	0.0%		17%	0.000
I.B	Fugitive Emission from Fuel	2.d. Other (Geothermal)	5.21	0.000	0.0%		17%	0.000

Table A1-10 Data used for the key category analysis (FY1990) (Continued)

A IPCC Code	B IPCC Category	C GHGs	E Absolute Value of FY1990 Estimate	H Ap1-L	I % Ap1-L Contrib.	L Source/Sink Uncertainty	M Ap2-L	N % Ap2-L Contrib.	
2.A	Mineral Product	1. Cement Production	CO2	38,701.10	0.028	2.8%	4%	0.014	1.4%
2.A	Mineral Product	2. Lime Production	CO2	6,674.45	0.005	0.5%	4%	0.002	0.2%
2.A	Mineral Product	3. Glass Production	CO2	312.88	0.000	0.0%	6%	0.000	0.0%
2.A	Mineral Product	4. Other Process Uses of Carbonates	CO2	3,542.02	0.003	0.3%	6%	0.002	0.2%
2.B	Chemical Industry	1. Ammonia Production	CO2	3,417.74	0.002	0.2%	1%	0.000	0.0%
2.B	Chemical Industry	Other products except Ammonia	CO2	3,623.06	0.003	0.3%	55%	0.017	1.7%
2.B	Chemical Industry	2. Nitric Acid Production	N2O	736.06	0.001	0.1%	73%	0.005	0.5%
2.B	Chemical Industry	3. Adipic Acid Production	N2O	7,210.88	0.005	0.5%	9%	0.006	0.6%
2.B	Chemical Industry	4. Caprolactam, Glyoxal and Glyoxylic Acid Production	N2O	1,672.86	0.001	0.1%	99%	0.014	1.4%
2.B	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	HFCs	15,930.24	0.012	1.2%	2%	0.003	0.3%
2.B	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	PFCs	330.92	0.000	0.0%	2%	0.000	0.0%
2.B	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	SF6	3,470.78	0.003	0.3%	2%	0.001	0.1%
2.B	Chemical Industry	9. Fluorochemical Production (Fugitive Emissions)	NF3	2.79	0.000	0.0%	2%	0.000	0.0%
2.B	Chemical Industry	Whole of Chemical Industries	CH4	37.49	0.000	0.0%	55%	0.000	0.0%
2.C	Metal Production	1. Iron and Steel Production	CO2	7,244.20	0.005	0.5%	4%	0.002	0.2%
2.C	Metal Production	1. Iron and Steel Production	CH4	18.42	0.000	0.0%	163%	0.000	0.0%
2.C	Metal Production	2. Ferroalloys Production	CH4	4.63	0.000	0.0%	163%	0.000	0.0%
2.C	Metal Production	3. Aluminium Production	PFCs	203.66	0.000	0.0%	44%	0.001	0.1%
2.C	Metal Production	4. SF6 Used in Aluminium and Magnesium foundries	HFCs	0.00	0.000	0.0%	5%	0.000	0.0%
2.C	Metal Production	4. SF6 Used in Aluminium and Magnesium foundries	SF6	146.54	0.000	0.0%	5%	0.000	0.0%
2.D	Non-energy Products from Fuels and Solvent Use		CO2	2,163.76	0.002	0.2%	55%	0.010	1.0%
2.E	Electronics Industry		HFCs	0.73	0.000	0.0%	100%	0.000	0.0%
2.E	Electronics Industry		PFCs	1,454.78	0.001	0.1%	81%	0.010	1.0%
2.E	Electronics Industry		SF6	418.70	0.000	0.0%	300%	0.011	1.1%
2.E	Electronics Industry		NF3	29.82	0.000	0.0%	71%	0.000	0.0%
2.F	Product uses as substitutes for ODS	1. Refrigeration and Air conditioning	HFCs	0.00	0.000	0.0%	7%	0.000	0.0%
2.F	Product uses as substitutes for ODS	2. Foam Blowing Agents	HFCs	1.34	0.000	0.0%	50%	0.000	0.0%
2.F	Product uses as substitutes for ODS	3. Fire Extinguishers	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	4,549.94	0.003	0.3%	10%	0.004	0.4%
2.G	Other Product Manufacture and Use		N2O	290.86	0.000	0.0%	4%	0.000	0.0%
2.G	Other Product Manufacture and Use		PFCs	0.00	0.000	0.0%	10%	0.000	0.0%
2.G	Other Product Manufacture and Use		SF6	8,814.04	0.006	0.6%	76%	0.057	5.7%
2.H	Other	Use of Dry Ice	CO2	64.27	0.000	0.0%	5%	0.000	0.0%
3.A	Enteric Fermentation		CH4	9,351.06	0.007	0.7%	26%	0.021	2.1%
3.B	Manure Management		CH4	3,120.55	0.002	0.2%	17%	0.005	0.5%
3.B	Manure Management		N2O	4,114.42	0.003	0.3%	75%	0.026	2.6%
3.C	Rice Cultivation		CH4	12,770.99	0.009	0.9%	6%	0.007	0.7%
3.D	Agricultural Soils	1. Direct Emissions	N2O	4,704.38	0.003	0.3%	27%	0.011	1.1%
3.D	Agricultural Soils	2. Indirect Emissions	N2O	2,416.19	0.002	0.2%	164%	0.034	3.4%
3.F	Field Burning of Agricultural Residues		CH4	127.03	0.000	0.0%	296%	0.003	0.3%
3.F	Field Burning of Agricultural Residues		N2O	39.26	0.000	0.0%	300%	0.001	0.1%
3.G	Liming		CO2	550.24	0.000	0.0%	50%	0.002	0.2%
3.H	Urea Application		CO2	58.64	0.000	0.0%	50%	0.000	0.0%
4.A	Forest Land	1. Forest Land remaining Forest Land	CO2	72,383.99	0.053	5.3%	12%	0.077	7.7%
4.A	Forest Land	2. Land converted to Forest Land	CO2	6,690.45	0.005	0.5%	12%	0.007	0.7%
4.B	Cropland	1. Cropland remaining Cropland	CO2	10,116.51	0.007	0.7%	31%	0.027	2.7%
4.B	Cropland	2. Land converted to Cropland	CO2	1,601.68	0.001	0.1%	18%	0.002	0.2%
4.C	Grassland	1. Grassland remaining Grassland	CO2	881.40	0.001	0.1%	9%	0.001	0.1%
4.C	Grassland	2. Land converted to Grassland	CO2	171.53	0.000	0.0%	20%	0.000	0.0%
4.D	Wetlands	1.1 Peat Extraction Remaining Peat Extraction	CO2	0.00	0.000	0.0%	21%	0.000	0.0%
4.D	Wetlands	1.2 Flooded Land Remaining Flooded Land	CO2	0.00	0.000	0.0%	21%	0.000	0.0%
4.D	Wetlands	1.3 Other Wetlands Remaining Other Wetlands	CO2	0.00	0.000	0.0%	21%	0.000	0.0%
4.D	Wetlands	2. Land converted to Wetlands	CO2	90.39	0.000	0.0%	21%	0.000	0.0%
4.E	Settlements	1. Settlements remaining Settlements	CO2	1,380.72	0.001	0.1%	34%	0.004	0.4%
4.E	Settlements	2. Land converted to Settlements	CO2	4,025.65	0.003	0.3%	21%	0.007	0.7%
4.F	Other Land	1. Other Land remaining Other Land	CO2	0.00	0.000	0.0%	18%	0.000	0.0%
4.F	Other Land	2. Land converted to Other Land	CO2	1,155.15	0.001	0.1%	18%	0.002	0.2%
4.G	Harvested Wood Products		CO2	365.43	0.000	0.0%	30%	0.001	0.1%
4.(I)	Direct N2O emissions from N inputs to managed soils		N2O	0.84	0.000	0.0%	31%	0.000	0.0%
4.(II)	Drainage and rewetting		CO2	0.00	0.000	0.0%	0%	0.000	0.0%
4.(II)	Drainage and rewetting		CH4	38.23	0.000	0.0%	115%	0.000	0.0%
4.(II)	Drainage and rewetting		N2O	0.00	0.000	0.0%	0%	0.000	0.0%
4.(III)	Direct N2O emissions from N mineralization/immobilization		N2O	153.48	0.000	0.0%	138%	0.002	0.2%
4.(IV)	Indirect N2O Emissions from Managed Soils		N2O	41.13	0.000	0.0%	318%	0.001	0.1%
4.(V)	Biomass Burning		CO2	0.00	0.000	0.0%	0%	0.000	0.0%
4.(V)	Biomass Burning		CH4	47.20	0.000	0.0%	28%	0.000	0.0%
4.(V)	Biomass Burning		N2O	22.15	0.000	0.0%	296%	0.001	0.1%
5.A	Solid Waste Disposal		CH4	9,570.42	0.007	0.7%	22%	0.018	1.8%
5.B	Biological Treatment of Solid Waste		CH4	53.99	0.000	0.0%	84%	0.000	0.0%
5.B	Biological Treatment of Solid Waste		N2O	180.77	0.000	0.0%	170%	0.003	0.3%
5.C	Incineration and Open Burning of Waste		CO2	12,429.49	0.009	0.9%	16%	0.018	1.8%
5.C	Incineration and Open Burning of Waste		CH4	27.78	0.000	0.0%	163%	0.000	0.0%
5.C	Incineration and Open Burning of Waste		N2O	1,438.04	0.001	0.1%	79%	0.010	1.0%
5.D	Wastewater Treatment and Discharge		CH4	2,941.55	0.002	0.2%	22%	0.005	0.5%
5.D	Wastewater Treatment and Discharge		N2O	2,387.11	0.002	0.2%	38%	0.008	0.8%
5.E	Other		CO2	702.83	0.001	0.1%	10%	0.001	0.1%
	Indirect CO2	from Energy sector	Ind CO2	1,027.51	0.001	0.1%	32%	0.003	0.3%
	Indirect CO2	from IPPU sector	Ind CO2	4,446.23	0.003	0.3%	48%	0.018	1.8%
Total (including LULUCF)				1,374,643.28	1.00	100.0%		1.00	100%

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 15 and 42 in the “UNFCCC reporting guidelines on annual greenhouse gas inventories” (Decision 24/CP.19 Annex I), 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, uncertainty assessments have been reviewed by the Committee for the Greenhouse Gases Emissions Estimation Methods in FY2001, FY2006, FY2012 and FY2014. For the National Inventory Reports submitted this time, the uncertainties in emission/removal inventories were assessed based on the country-specific guidelines revised in 2013.

A2.2. Results of Uncertainty Assessment

A2.2.1. Uncertainty of Japan’s Total Emissions

In FY2017, total net emissions in Japan were approximately 1,234 million tons (carbon dioxide equivalents). Uncertainty of total net emissions in FY2017 has been assessed at -4% to +2% and uncertainty introduced into the trend in total net emissions has been assessed at -5% to +3%. Thus, the uncertainty level was low in Japan, mainly because CO₂ emissions from low-uncertainty fuel combustion (1.A.) accounted for 92% of the net emissions.

Table A2-1 Uncertainty of Japan’s total net emissions

Category	A	B	C	D	G-1990		G-2017		I	J	
					GHGs	Base year emissions / removals	2017 emissions / removals	Combined uncertainty in 1990		Combined uncertainty in 2017	Inventory trend in national emissions for 2017 increase with respect to 1990
			kt-CO ₂ eq.	kt-CO ₂ eq.	(-) %	(+) %	(-) %	(+) %	%	(-) %	(+) %
1A. Fuel Combustion (CO ₂)		CO ₂	1,078,839	1,128,396	-5%	+2%	-4%	+2%	4.6%	-5.1%	+2.7%
1A. Fuel Combustion (Stationary:CH ₄ ,N ₂ O)		CH ₄ , N ₂ O	3,916	5,541	-23%	+29%	-25%	+28%	41.5%	0.0%	+0.0%
1A. Fuel Combustion (Transport:CH ₄ ,N ₂ O)		CH ₄ , N ₂ O	4,031	1,817	-32%	+92%	-30%	+87%	-54.9%	0.0%	+0.0%
1B. Fugitive Emissions from Fuels		CO ₂ , CH ₄ , N ₂ O	5,165	1,278	-40%	+80%	-22%	+39%	-75.3%	0.0%	+0.0%
2. IPPU (CO ₂ ,CH ₄ ,N ₂ O)		CO ₂ , CH ₄ , N ₂ O	75,715	48,312	-4%	+4%	-5%	+5%	-36.2%	-0.1%	+0.1%
2. IPPU (HFCs,PFCs,SF ₆ ,NF ₃)		HFCs, PFCs, SF ₆ , NF ₃	35,354	50,982	-7%	+33%	-7%	+8%	44.2%	-0.5%	+0.5%
3. Agriculture		CO ₂ , CH ₄ , N ₂ O	37,253	33,196	-10%	+24%	-9%	+20%	-10.9%	0.0%	+0.0%
4. LULUCF		CO ₂ , CH ₄ , N ₂ O	-62,475	-57,458	-15%	+15%	-13%	+13%	-8.0%	-0.4%	+0.4%
5. Waste		CO ₂ , CH ₄ , N ₂ O	29,732	20,110	-10%	+11%	-12%	+12%	-32.4%	-0.2%	+0.2%
Indirect CO ₂		Ind CO ₂	5,474	2,118	-28%	+50%	-27%	+48%	-61.3%	0.0%	+0.0%
Total Net Emissions			1,213,002	1,234,291	-4.5%	+2.2%	-3.7%	+2.1%	1.8%	-5.2%	+2.7%

Data used for estimating emissions in each category are as follows:

Table A2-2 Data used for uncertainty assessment (Energy)

Category	A	B	C	D	E		F	G		H-1990		H-2017		T	I	J	K		L		M		
					Input Data	Activity data uncertainty		Input Data	Input Data	(-) %	(+) %	(-) %	(+) %				(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(-) %
Total			1,213,002	1,234,291																			
I.A. Fuel Combustion			644,312	417,488	-8%	-2%																	
I.A. Fuel Combustion			309,482	451,360	-7%	+5%																	
I.A. Fuel Combustion			114,167	242,163	-3%	+1%																	
I.A. Fuel Combustion			10,878	17,385	-	-																	
I.A. Stationary Combustion			1,058	920	-	-																	
I.A. Stationary Combustion			2,858	4,620	-	-																	
I.A.3. Transport			6	1	-5%	+5%																	
I.A.3. Transport			64	91	-5%	+5%																	
I.A.3. Transport			253	108	-	-																	
I.A.3. Transport			3,457	1,455	-	-																	
I.A.3. Transport			1	1	-5%	+5%																	
I.A.3. Transport			110	58	-5%	+5%																	
I.A.3. Transport			32	23	-13%	+13%																	
I.A.3. Transport			108	79	-13%	+13%																	
I.B Fugitive Emission from Fuel			5	0	-	-																	
I.B Fugitive Emission from Fuel			4,760	521	-	-																	
I.B Fugitive Emission from Fuel			0	0	-	-																	
I.B Fugitive Emission from Fuel			25	20	-	-																	
I.B Fugitive Emission from Fuel			1	1	-	-																	
I.B Fugitive Emission from Fuel			174	246	-	-																	
I.B Fugitive Emission from Fuel			81	265	-	-																	
I.B Fugitive Emission from Fuel			8	4	-	-																	
I.B Fugitive Emission from Fuel			0	0	-	-																	
I.B Fugitive Emission from Fuel			104	210	-7%	+7%																	
I.B Fugitive Emission from Fuel			5	10	-7%	+7%																	

Table A2-3 Data used for uncertainty assessment (Industrial processes and product use)

Category	A	B	C	D	E	F	G	H-1990	H-2017	T	I	J	K	L	M
			Input Data	Input Data	Input Data	Input Data	(E², F²) x 1/2	G°CΣC	G*D ΣD	D/C	Note A	D/ΣC	I*F	J*E*√2	(K²+L²) x 1/2
			(+) %	(-) %	(+) %	(-) %	(+) %	(+) %	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	(-) %
2.A Mineral Product	CO2	38,701	-2%	-2%	-4%	+4%	-4%	-0.1%	0.1%	-31.7%	0.0%	2.2%	0.0%	0.1%	0.1%
2.A Mineral Product	CO2	6,674	-3%	-3%	-2%	+2%	-4%	0.0%	0.0%	-16.8%	0.0%	0.5%	0.0%	0.0%	0.0%
2.A Mineral Product	CO2	313	-3%	-3%	-5%	+5%	-6%	0.0%	0.0%	-37.9%	0.0%	0.0%	0.0%	0.0%	0.0%
2.A Mineral Product	CO2	3,542	-3%	-3%	-3%	+3%	-6%	0.0%	0.0%	-46.8%	0.0%	0.2%	0.0%	0.0%	0.0%
2.B Chemical Industry	CO2	3,418	-	-	-	-	-2%	+1%	0.0%	-49.5%	0.0%	0.1%	NA	NA	0.0%
2.B Chemical Industry	CO2	3,623	-	-	-	-	-55%	-0.2%	0.2%	-23.8%	0.0%	0.2%	0.0%	0.0%	0.0%
2.B Chemical Industry	N2O	736	-2%	-2%	-73%	+73%	-73%	0.0%	0.0%	-53.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.B Chemical Industry	N2O	7,211	-2%	-2%	-9%	+9%	-9%	-0.1%	0.1%	-98.7%	0.0%	0.0%	0.0%	0.0%	0.0%
2.B Chemical Industry	N2O	1,673	-2%	-2%	-99%	+99%	-99%	-0.1%	0.1%	-32.6%	0.0%	0.0%	0.0%	0.0%	0.0%
2.B Chemical Industry	CH4	37	-	-	-	-	+51%	0.0%	0.0%	-90.3%	0.0%	0.0%	0.0%	0.0%	0.0%
2.B Chemical Industry	CO2	7,244	-	-	-	-	-4%	0.0%	0.0%	-21.0%	0.0%	0.5%	0.0%	0.0%	0.0%
2.C Metal Production	CH4	18	-5%	-5%	-163%	+163%	-163%	0.0%	0.0%	-19.9%	0.0%	0.0%	0.0%	0.0%	0.0%
2.C Metal Production	CO2	5	-5%	-5%	-163%	+163%	-163%	0.0%	0.0%	-42.2%	0.0%	0.0%	0.0%	0.0%	0.0%
2.C Metal Production	CO2	2,164	-	-	-	-	-55%	-0.1%	0.1%	34.0%	0.0%	0.2%	NA	NA	0.0%
2.D Non-energy Products from Fuels and Solvent Use	N2O	291	-	-	-	-	-4%	0.0%	0.0%	42.9%	0.0%	0.0%	NA	NA	0.0%
2.D Non-energy Products from Fuels and Solvent Use	CO2	64	-5%	-5%	-	-	-5%	0.0%	0.0%	32.4%	0.0%	0.0%	NA	NA	0.0%
2.D Non-energy Products from Fuels and Solvent Use	CO2	15,929	-	-	-	-	-2%	0.0%	0.0%	-99.8%	0.0%	0.0%	NA	NA	0.0%
2.D Non-energy Products from Fuels and Solvent Use	HFCs	2	-	-	-	-	-2%	0.0%	0.0%	6185.0%	0.0%	0.0%	NA	NA	0.0%
2.D Non-energy Products from Fuels and Solvent Use	PFCs	331	-	-	-	-	-2%	0.0%	0.0%	-76.5%	0.0%	0.0%	NA	NA	0.0%
2.D Non-energy Products from Fuels and Solvent Use	SF6	3,471	-	-	-	-	-2%	0.0%	0.0%	-98.8%	0.0%	0.0%	NA	NA	0.0%
2.D Non-energy Products from Fuels and Solvent Use	NF3	3	-	-	-	-	-2%	0.0%	0.0%	8292.8%	0.0%	0.0%	NA	NA	0.0%
2.D Non-energy Products from Fuels and Solvent Use	PFCs	204	-2%	-2%	-44%	+44%	-44%	0.0%	0.0%	-100.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.D Non-energy Products from Fuels and Solvent Use	HFCs	0	-	-	-	-	-5%	0.0%	0.0%	NA	0.0%	0.0%	NA	NA	0.0%
2.D Non-energy Products from Fuels and Solvent Use	SF6	147	-	-	-	-	-5%	0.0%	0.0%	68.0%	0.0%	0.0%	NA	NA	0.0%
2.E Electronics Industry	HFCs	1	-10%	-10%	-100%	+100%	-100%	0.0%	0.0%	16979%	0.0%	0.0%	0.0%	0.0%	0.0%
2.E Electronics Industry	PFCs	1,455	-10%	-10%	-80%	+80%	-81%	-0.1%	0.1%	32.7%	0.0%	0.2%	0.0%	0.0%	0.0%
2.E Electronics Industry	SF6	419	-10%	-10%	-300%	+300%	-300%	-0.1%	0.1%	-13.4%	0.0%	0.0%	0.0%	0.0%	0.0%
2.E Electronics Industry	NF3	30	-10%	-10%	-70%	+70%	-71%	0.0%	0.0%	623.3%	0.0%	0.0%	0.0%	0.0%	0.0%
2.E Electronics Industry	HFCs	0	-	-	-	-	-7%	0.0%	0.0%	NA	0.0%	3.4%	0.0%	0.5%	0.5%
2.E Electronics Industry	HFCs	1	-	-	-	-	-50%	+0.0%	-0.1%	208657%	0.0%	0.2%	NA	NA	0.0%
2.E Electronics Industry	HFCs	NO	-	-	-	-	-16%	+16%	NA	NA	0.0%	0.0%	NA	NA	0.0%
2.E Electronics Industry	HFCs	0	-	-	-	-	-10%	+10%	0.0%	0.0%	0.0%	0.0%	NA	NA	0.0%
2.E Electronics Industry	HFCs	0	-	-	-	-	-11%	+11%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
2.E Electronics Industry	PFCs	4,550	-10%	-10%	-	-	-10%	+10%	0.0%	0.0%	0.0%	0.1%	NA	NA	0.0%
2.E Electronics Industry	PFCs	0	-10%	-10%	-	-	-10%	+10%	0.0%	0.0%	0.0%	0.0%	NA	NA	0.0%
2.E Electronics Industry	SF6	8,814	-10%	-10%	-	-	-20%	+131%	-0.1%	1.0%	0.0%	0.1%	0.0%	0.0%	0.0%

Table A2-4 Data used for uncertainty assessment (Agriculture)

Category	A	B	C	D	E	F	G	H-1990		H-2017	T	I	J	K	L	M
								Combined Uncertainty as % of Total National Emissions in 1990	Combined Uncertainty as % of Total National Emissions in 2017							
			Input Data	Input Data	Input Data	Input Data	$(\sigma^2 + F^2) \times 1/2$	G/C	G/D	D/C	Note A	D/S/C	F/F	$J^*E^2/2$	$(\sigma^2 + L^2) \times 1/2$	
			kr-CO ₂ eq.	kr-CO ₂ eq.	(-) % (+) %	(-) % (+) %	(-) % (+) %	(-) % (+) %	(-) % (+) %	%	%	(-) % (+) %	(-) % (+) %	(-) % (+) %	(-) % (+) %	
3.A Enteric Fermentation		CH4	4810	3,336	-1%	+1%	-26%	+32%	-0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.A Enteric Fermentation		CH4	4085	3,585	-1%	+1%	-40%	+49%	-0.1%	0.2%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.A Enteric Fermentation		CH4	4	4	-9%	+9%	-51%	+51%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.A Enteric Fermentation		CH4	397	322	-1%	+1%	-69%	+69%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.A Enteric Fermentation		CH4	56	37	-9%	+9%	-51%	+51%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B Manure Management		CH4	2,667	1,996	-1%	+1%	-20%	+20%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B Manure Management		CH4	632	681	-1%	+1%	-71%	+12%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B Manure Management		CH4	108	136	-1%	+1%	-20%	+20%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B Manure Management		N2O	836	849	-1%	+1%	-71%	+12%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B Manure Management		CH4	0	0	-9%	+9%	-30%	+30%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B Manure Management		N2O	NO	NO	-9%	+9%	-71%	+12%	NA	NA	NA	NA	NA	NA	NA	0.0%
3.B Manure Management		CH4	278	118	-1%	+1%	-20%	+20%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B Manure Management		CH4	894	1,137	-1%	+1%	-71%	+12%	-0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B Manure Management		CH4	58	69	-9%	+9%	-20%	+20%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B Manure Management		N2O	411	356	-9%	+9%	-71%	+12%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B Manure Management		CH4	10	5	-9%	+9%	-30%	+30%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B Manure Management		N2O	8	1	-9%	+9%	-71%	+12%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.B Manure Management		N2O	1,333	892	-9%	+9%	-106%	+447%	-106%	+447%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.C Rice Cultivation		CH4	12,771	13,627	-1%	+1%	-6%	+6%	-0.1%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.D Agricultural Soils		N2O	1,843	1,212	-1%	+1%	-31%	+31%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.D Agricultural Soils		N2O	1,574	1,276	-	-	-24%	+24%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.D Agricultural Soils		N2O	55	42	-1%	+1%	-65%	+200%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.D Agricultural Soils		N2O	707	564	-1%	+1%	-70%	+200%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.D Agricultural Soils		N2O	407	360	-1%	+1%	-31%	+31%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.D Agricultural Soils		N2O	120	117	-1%	+1%	-75%	+200%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.D Agricultural Soils		N2O	793	604	-9%	+9%	-106%	+447%	-106%	+447%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.D Agricultural Soils		N2O	1,623	1,232	-1%	+1%	-115%	+287%	-115%	+287%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.F Field Burning of Agricultural Residues		CH4	127	67	-1%	+1%	-296%	+296%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.F Field Burning of Agricultural Residues		N2O	39	21	-1%	+1%	-300%	+300%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.G Liming		CO2	550	363	-1%	+1%	-50%	+50%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
3.H Urea Application		CO2	59	189	-1%	+1%	-50%	+50%	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)

Category	A	B	C	D	E	F	G	H-1990		H-2017		I	J	K	L	M					
								Combined Uncertainty as % of Total National Emissions in 1990		Combined Uncertainty as % of Total National Emissions in 2017							Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by factor/estimation parameter uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions
								(-) %	(+) %	(-) %	(+) %										
4.A Forest Land																					
4.A Forest Land																					
4.A Forest Land																					
4.B Cropland																					
4.B Cropland																					
4.B Cropland																					
4.C Grassland																					
4.C Grassland																					
4.C Grassland																					
4.D Wetlands																					
4.D Wetlands																					
4.D Wetlands																					
4.E Settlements																					
4.E Settlements																					
4.E Settlements																					
4.F Other Land																					
4.F Other Land																					
4.F Other Land																					
4.G Harvested Wood Products																					
4(G). Direct N2O emissions from N inputs to managed soils																					
4(D). Emissions and removals from drainage and rewetting																					
4(D). Emissions and removals from drainage and rewetting																					
4(D). Emissions and removals from drainage and rewetting																					
4(III). Direct N2O emissions from N mineralization/immobilization																					
4(III). Direct N2O emissions from N mineralization/immobilization																					
4(III). Direct N2O emissions from N mineralization/immobilization																					
4(IV). Indirect N2O emissions from N mineralization/immobilization																					
4(IV). Indirect N2O emissions from N mineralization/immobilization																					
4(IV). Indirect N2O emissions from N mineralization/immobilization																					
4(IV). Indirect N2O emissions from Managed Soils																					
4(IV). Indirect N2O emissions from Managed Soils																					
4(IV). Indirect N2O emissions from Managed Soils																					
4(V). Biomass Burning																					
4(V). Biomass Burning																					
4(V). Biomass Burning																					
4(V). Biomass Burning																					
4(V). Biomass Burning																					
4(V). Biomass Burning																					
4(V). Biomass Burning																					
4(V). Biomass Burning																					
4(V). Biomass Burning																					
4(V). Biomass Burning																					

Table A2-6 Data used for uncertainty assessment (Waste, Indirect CO₂)

Category	A	B	C	D	E	F	G	H-1990		H-2017		T	I	J	K	L	M
								Combined Uncertainty as % of Total National Emissions in 1990	GFC/ΣC	Combined Uncertainty as % of Total National Emissions in 2017	C* Δ /ΣD						
	Input Data	Input Data	Input Data	Input Data	Input Data	Input Data	Input Data	Input Data	Input Data	Input Data	Input Data	Input Data	Note A	D/ΣC	*F	JPE*/Σ2	(σ^2_{L+J+M})/Σ2
	kt-CO ₂ eq.	kt-CO ₂ eq.	kt-CO ₂ eq.	kt-CO ₂ eq.	kt-CO ₂ eq.	kt-CO ₂ eq.	kt-CO ₂ eq.	kt-CO ₂ eq.	kt-CO ₂ eq.	kt-CO ₂ eq.	kt-CO ₂ eq.	%	%	%	%	%	%
5.A Solid Waste Disposal	5,919	CH4	1,787	-	-	-	-32%	+32%	0.2%	0.0%	0.0%	-69.8%	0.0%	0.1%	0.0%	0.0%	0.0%
5.A Solid Waste Disposal	3,643	CH4	1,254	-	-	-	-29%	+29%	-0.1%	0.0%	0.0%	-65.6%	0.0%	0.0%	0.0%	0.0%	0.0%
5.A Solid Waste Disposal	9	CH4	40	-60%	+60%	-42%	+41%	+73%	0.0%	0.0%	0.0%	357.6%	0.0%	0.1%	0.0%	0.0%	0.0%
5.B Biological Treatment of Solid Waste	54	CH4	103	-30%	+30%	-79%	+79%	+84%	0.0%	0.0%	0.0%	91.4%	0.0%	0.0%	0.0%	0.0%	0.0%
5.B Biological Treatment of Solid Waste	181	N2O	344	-30%	+30%	-167%	+167%	+170%	0.0%	0.0%	0.0%	90.3%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C Incineration and Open Burning of Waste	5,704	CO2	2,028	-	-	-	-8%	+10%	0.0%	0.0%	0.0%	-64.4%	0.0%	0.2%	0.0%	0.0%	0.0%
5.C Incineration and Open Burning of Waste	3,670	CO2	3,803	-30%	+30%	-2%	+30%	+30%	-0.1%	0.1%	0.1%	3.6%	0.0%	0.3%	0.0%	-0.1%	0.1%
5.C Incineration and Open Burning of Waste	2,134	CO2	3,696	-60%	+60%	-2%	+2%	+60%	0.0%	-0.1%	0.1%	39.8%	0.0%	0.1%	0.0%	-0.1%	0.1%
5.C Incineration and Open Burning of Waste	916	CO2	1,281	-30%	+30%	-2%	+2%	+30%	0.0%	0.0%	0.0%	-99.4%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C Incineration and Open Burning of Waste	5	CO2	0	-30%	+30%	-2%	+2%	+30%	0.0%	0.0%	0.0%	-92.2%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C Incineration and Open Burning of Waste	12	CH4	1	-	-	-	-29%	+52%	0.0%	0.0%	0.0%	0.0%	0.0%	NA	NA	NA	NA
5.C Incineration and Open Burning of Waste	0	CH4	0	-30%	+30%	-100%	+181%	+184%	0.0%	0.0%	0.0%	-10%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C Incineration and Open Burning of Waste	2	CH4	0	-30%	+30%	-100%	+201%	+203%	0.0%	0.0%	0.0%	-87.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C Incineration and Open Burning of Waste	0	CH4	2	-	-	-	-84%	+334%	0.0%	0.0%	0.0%	217.4%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C Incineration and Open Burning of Waste	0	CH4	0	-60%	+60%	-100%	+216%	+224%	0.0%	0.0%	0.0%	372.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C Incineration and Open Burning of Waste	12	CH4	0	-30%	+30%	-100%	+100%	+104%	0.0%	0.0%	0.0%	-98.7%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C Incineration and Open Burning of Waste	306	N2O	90	-	-	-	-27%	+27%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C Incineration and Open Burning of Waste	5	N2O	26	-30%	+30%	-76%	+76%	+81%	0.0%	0.0%	0.0%	471.2%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C Incineration and Open Burning of Waste	1,056	N2O	1,258	-30%	+30%	-84%	+84%	+89%	-0.1%	0.1%	0.1%	19.2%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C Incineration and Open Burning of Waste	64	N2O	36	-	-	-	-50%	+50%	0.0%	0.0%	0.0%	-44.3%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C Incineration and Open Burning of Waste	6	N2O	11	-60%	+60%	-44%	+44%	+74%	0.0%	0.0%	0.0%	84.9%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C Incineration and Open Burning of Waste	3	N2O	0	-30%	+30%	-100%	+104%	+104%	0.0%	0.0%	0.0%	-98.7%	0.0%	0.0%	0.0%	0.0%	0.0%
5.C Incineration and Open Burning of Waste	216	CH4	315	-5%	+5%	-31%	+31%	+31%	0.0%	0.0%	0.0%	46.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D Wastewater Treatment and Discharge	759	CH4	814	-	-	-	-31%	+31%	0.0%	0.0%	0.0%	7.2%	0.0%	0.1%	0.0%	0.0%	0.0%
5.D Wastewater Treatment and Discharge	131	CH4	9	-10%	+10%	-84%	+84%	+84%	0.0%	0.0%	0.0%	-92.8%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D Wastewater Treatment and Discharge	1,543	CH4	393	-10%	+10%	-58%	+58%	+59%	-0.1%	0.1%	0.1%	-74.5%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D Wastewater Treatment and Discharge	56	CH4	42	-30%	+30%	-60%	+60%	+66%	0.0%	0.0%	0.0%	-24.3%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D Wastewater Treatment and Discharge	206	CH4	93	-30%	+30%	-58%	+58%	+66%	0.0%	0.0%	0.0%	-54.9%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D Wastewater Treatment and Discharge	31	CH4	6	-100%	+100%	-39%	+39%	+107%	0.0%	0.0%	0.0%	-80.2%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D Wastewater Treatment and Discharge	416	N2O	461	-5%	+5%	-100%	+146%	+146%	0.0%	0.0%	0.1%	11.0%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D Wastewater Treatment and Discharge	453	N2O	490	-	-	-	-42%	+42%	0.0%	0.0%	0.0%	8.2%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D Wastewater Treatment and Discharge	67	N2O	4	-10%	+10%	-87%	+87%	+88%	0.0%	0.0%	0.0%	-95.9%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D Wastewater Treatment and Discharge	830	N2O	576	-10%	+10%	-58%	+58%	+59%	0.0%	0.0%	0.0%	-30.6%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D Wastewater Treatment and Discharge	298	N2O	336	-30%	+30%	-95%	+95%	+100%	0.0%	0.0%	0.0%	12.9%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D Wastewater Treatment and Discharge	316	N2O	165	-30%	+30%	-58%	+58%	+66%	0.0%	0.0%	0.0%	-47.7%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D Wastewater Treatment and Discharge	8	N2O	2	-100%	+100%	-39%	+39%	+107%	0.0%	0.0%	0.0%	-80.2%	0.0%	0.0%	0.0%	0.0%	0.0%
5.D Wastewater Treatment and Discharge	703	CO2	636	-10%	+10%	-1%	+1%	+10%	0.0%	0.0%	0.0%	-9.4%	0.0%	0.1%	0.0%	0.0%	0.0%
5.E Other																	
Indirect CO ₂	1,028	Ind CO ₂	468	-	-	-	-23%	+40%	0.0%	0.0%	0.0%	-54.5%	0.0%	0.0%	NA	NA	0.0%
Indirect CO ₂	4,446	Ind CO ₂	1,650	-	-	-	-35%	+61%	-0.1%	0.2%	0.0%	-62.9%	0.0%	0.1%	NA	NA	0.0%

Note A: 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 the table A2

$\sum C_i, \sum D_i$ = sum of column C and D respectively

References

1. IPCC, *2006 IPCC Guidelines for National Greenhouse Inventories*, (2006)
2. UNFCCC, *UNFCCC reporting guidelines on annual greenhouse gas inventories* (Decision 24/CP.19 Annex I), 2013
3. Ministry of the Environment, *Guidelines for Uncertainty Assessment of GHG inventories in Japan*, 2013

Annex 3. Detailed Methodological Descriptions for Individual Source or Sink Categories

A3.1. Methodology for Estimating Emissions of Precursors

In addition to the mandatory greenhouse gases (CO₂, CH₄, N₂O, HFCs, PFCs, SF₆, NF₃), Japan reports on the emissions of precursors (NO_x, CO, Non-Methane Volatile Organic Compounds [NMVOCs], and SO_x¹) calculated by established methods. This section explains the categories for which estimation methodologies were established, and emissions are reported.

A3.1.1 Energy Sector

A3.1.1.1. Stationary Combustion (1.A.1., 1.A.2., 1.A.4.: NO_x, CO, NMVOCs, and SO_x)

A3.1.1.1.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 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 format (CRF), 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]

¹ Most SO_x consists of SO₂. For major sources, SO₂ emissions are estimated.

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 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 A3.1.2.1. 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 in the *Report on Emission Factor Results for Combustion Facilities* (Japan Society for Atmospheric Environment, 1997).

NMVOC emission factors for each facility by fuel type were established by multiplying the CH₄ emission factor by the ratio of the NMVOC emission factor to the CH₄ emission factor. The CH₄ emission factors are elaborated in Chapter 3. The NMVOC/CH₄ emission ratios were determined from the *Report on Screening Survey Regarding Measures to Counter Global Warming (Atmospheric Management)* (Japan Environmental Sanitation Center), *Study of Establishment of Methodology for Estimation of Hydrocarbon Emissions* (Institute of Behavioral Science), and *Compilation of Air Pollutant Emission Factors (AP-42)* (United States Environmental Protection Agency).

- **Activity data**

Energy consumption calculated for estimation of CH₄ and N₂O was used for activity data. (see Chapter 3.)

A3.1.1.1.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 (steam coal and coal briquettes) and biomass, 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 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 (steam coal, and coal briquettes), and biomass, 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 reports by *Report of the Research on the Indirect Greenhouse Gas Emission Inventory in FY1996*, Institute of Behavioral Science, 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 (steam coal and coal briquettes), liquid fuels (kerosene), gaseous fuels (LPG and city gas), and biomass, 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 (steam coal and coal briquettes), and biomass, 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 steam coal, 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* (The Energy Data and Modeling Center) is used.

A3.1.1.1.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 in the data input cells for “Other fossil fuels” under the relevant subcategories of 1.A.1 and 1.A.2. Explanations for estimation method, emission factors, and activity data are all given in the section “A3.1.5 Waste”.

A3.1.1.2. Mobile Combustion (1.A.3: NO_x, CO, NMVOCs, and SO_x)

A3.1.1.2.a. Domestic Aviation (1.A.3.a: NO_x, CO, and NMVOCs)

a) Category Description

This section provides the estimation methods for emissions of precursors (NO_x, 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 3-1 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}

Source: *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**

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) are used.

c) Completeness

For aviation gasoline, emissions of NO_x, CO, and NMVOCs are reported as “NE”.

A3.1.1.2.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* (Ministry of the Environment, 2002) and the *Survey for Consideration of Estimation of Emission Factors and Total Emissions of Exhaust Gas from Automobiles* (Ministry of the Environment, 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 the Ministry of the Environment).

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 3-5 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 CH₄ and N₂O emissions, are used. (See Chapter 3)

Table A 3-2 NO_x emission factors for automobiles

Fuel	Vehicle type	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Gasoline	Light vehicle	g-NOx/km	0.23	0.16	0.16	0.08	0.06	0.04	0.15	0.12	0.12	0.10	0.08	0.06	0.09	0.07
	Passenger vehicle (including LPG)	g-NOx/km	0.24	0.20	0.20	0.08	0.05	0.04	0.14	0.12	0.09	0.07	0.06	0.05	0.09	0.06
	Light cargo truck	g-NOx/km	0.87	0.66	0.38	0.20	0.15	0.13	0.27	0.23	0.27	0.23	0.19	0.18	0.32	0.25
	Small cargo truck	g-NOx/km	1.12	0.90	0.48	0.09	0.05	0.04	0.15	0.11	0.09	0.08	0.07	0.06	0.14	0.09
	Regular cargo truck	g-NOx/km	1.83	1.09	0.56	0.16	0.06	0.05	0.33	0.26	0.25	0.23	0.23	0.20	0.24	0.19
	Bus	g-NOx/km	4.45	3.65	2.44	0.09	0.07	0.06	0.15	0.09	0.07	0.06	0.06	0.05	0.08	0.24
	Special-purpose vehicle	g-NOx/km	1.47	0.87	0.43	0.12	0.05	0.04	0.32	0.26	0.19	0.17	0.15	0.12	0.31	0.29
	Special-purpose vehicle	g-NOx/km	1.47	0.87	0.43	0.12	0.05	0.04	0.32	0.26	0.19	0.17	0.15	0.12	0.31	0.29
Diesel	Passenger vehicle	g-NOx/km	0.64	0.53	0.44	0.45	0.39	0.37	0.47	0.46	0.44	0.38	0.34	0.26	0.40	0.35
	Small cargo truck	g-NOx/km	1.33	1.10	1.01	1.00	0.86	0.81	1.06	1.00	0.93	0.89	0.79	0.73	1.87	1.70
	Regular cargo truck	g-NOx/km	5.35	4.59	4.33	4.50	4.27	4.06	3.26	3.09	2.86	2.73	2.64	2.40	3.05	2.84
	Bus	g-NOx/km	4.23	3.83	3.60	4.07	3.75	3.52	3.38	3.48	3.39	3.23	3.13	2.96	3.74	3.56
	Special-purpose vehicle	g-NOx/km	3.38	2.76	2.15	3.63	3.16	2.99	2.97	2.75	2.50	2.41	2.24	2.05	3.21	3.02
	Special-purpose vehicle	g-NOx/km	3.38	2.76	2.15	3.63	3.16	2.99	2.97	2.75	2.50	2.41	2.24	2.05	3.21	3.02

Table A 3-3 CO emission factors for automobiles

Fuel	Vehicle Type	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Gasoline	Light vehicle	g-CO/km	1.75	1.55	1.54	0.97	0.80	0.72	1.51	1.33	1.47	1.22	1.08	0.94	1.39	1.27
	Passenger vehicle (including LPG)	g-CO/km	2.32	2.06	2.03	0.94	0.67	0.58	1.37	1.19	1.07	0.92	0.81	0.75	1.33	1.18
	Light cargo truck	g-CO/km	10.42	8.54	5.51	2.77	2.24	2.10	2.87	2.41	3.17	2.76	2.38	2.27	2.46	2.01
	Small cargo truck	g-CO/km	9.66	10.08	8.31	2.05	1.32	1.08	2.73	2.13	1.85	1.61	1.40	1.25	1.67	1.38
	Regular cargo truck	g-CO/km	12.62	10.60	8.95	3.62	1.95	1.67	7.53	5.73	5.67	5.04	4.77	4.36	4.18	3.76
	Bus	g-CO/km	26.21	25.08	21.94	2.07	1.71	1.45	2.62	1.88	1.77	1.78	1.65	1.57	1.79	3.28
	Special-purpose vehicle	g-CO/km	12.47	10.67	8.92	2.30	1.39	1.19	5.34	4.24	3.69	3.44	3.09	2.76	3.51	3.27
	Special-purpose vehicle	g-CO/km	12.47	10.67	8.92	2.30	1.39	1.19	5.34	4.24	3.69	3.44	3.09	2.76	3.51	3.27
Diesel	Passenger vehicle	g-CO/km	0.48	0.43	0.43	0.37	0.33	0.30	0.39	0.37	0.36	0.29	0.22	0.17	0.24	0.21
	Small cargo truck	g-CO/km	0.98	0.90	0.81	0.59	0.41	0.37	0.45	0.42	0.36	0.34	0.30	0.25	0.54	0.46
	Regular cargo truck	g-CO/km	3.22	2.99	2.44	2.04	1.65	1.47	1.10	0.97	0.80	0.72	0.65	0.55	0.50	0.41
	Bus	g-CO/km	2.58	2.53	2.20	2.03	1.64	1.44	1.24	1.18	1.14	1.05	0.98	0.89	0.86	0.74
	Special-purpose vehicle	g-CO/km	2.11	1.89	1.30	1.60	1.14	1.00	0.93	0.79	0.63	0.58	0.50	0.43	0.53	0.46
	Special-purpose vehicle	g-CO/km	2.11	1.89	1.30	1.60	1.14	1.00	0.93	0.79	0.63	0.58	0.50	0.43	0.53	0.46

Table A 3-4 NMVOC emission factors for automobiles

Fuel	Vehicle Type	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Gasoline	Light vehicle	g-NMVOC/km	0.08	0.03	0.03	0.03	0.02	0.02	0.08	0.07	0.06	0.05	0.04	0.04	0.05	0.04
	Passenger vehicle (including LPG)	g-NMVOC/km	0.11	0.07	0.06	0.02	0.01	0.01	0.06	0.05	0.04	0.04	0.03	0.03	0.06	0.06
	Light cargo truck	g-NMVOC/km	0.64	0.37	0.16	0.09	0.07	0.06	0.14	0.13	0.13	0.12	0.10	0.10	0.12	0.09
	Small cargo truck	g-NMVOC/km	0.71	0.53	0.21	0.04	0.02	0.02	0.07	0.06	0.05	0.04	0.04	0.03	0.10	0.07
	Regular cargo truck	g-NMVOC/km	0.99	0.58	0.28	0.06	0.03	0.02	0.17	0.14	0.14	0.13	0.14	0.11	0.14	0.12
	Bus	g-NMVOC/km	2.16	1.90	1.32	0.04	0.03	0.02	0.07	0.05	0.04	0.04	0.03	0.03	0.06	0.19
	Special-purpose vehicle	g-NMVOC/km	0.97	0.47	0.19	0.05	0.02	0.02	0.16	0.13	0.10	0.10	0.09	0.08	0.24	0.23
	Special-purpose vehicle	g-NMVOC/km	0.97	0.47	0.19	0.05	0.02	0.02	0.16	0.13	0.10	0.10	0.09	0.08	0.24	0.23
Diesel	Passenger vehicle	g-NMVOC/km	0.11	0.10	0.10	0.09	0.08	0.08	0.10	0.10	0.10	0.08	0.07	0.05	0.06	0.05
	Small cargo truck	g-NMVOC/km	0.39	0.34	0.26	0.20	0.12	0.10	0.14	0.13	0.10	0.09	0.08	0.07	0.14	0.11
	Regular cargo truck	g-NMVOC/km	1.62	1.47	1.03	0.75	0.57	0.50	0.35	0.30	0.23	0.21	0.19	0.15	0.14	0.10
	Bus	g-NMVOC/km	1.26	1.24	0.98	0.80	0.63	0.53	0.43	0.39	0.38	0.34	0.32	0.28	0.32	0.26
	Special-purpose vehicle	g-NMVOC/km	1.09	0.96	0.52	0.57	0.38	0.32	0.27	0.23	0.17	0.16	0.13	0.12	0.14	0.10
	Special-purpose vehicle	g-NMVOC/km	1.09	0.96	0.52	0.57	0.38	0.32	0.27	0.23	0.17	0.16	0.13	0.12	0.14	0.10

Table A 3-5 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		
Gasoline and LPG	(Light) passenger vehicle	CO	2.1	<<							0.67					1.15	<<			<<		<<				
		HC	0.25	<<							0.08						0.05	<<			<<		0.1			
		NOx	0.25	<<								0.08					0.05	<<			<<		<<			
		Unit	g/km	<<								<<					<<	<<			<<		<<			
		Mode	10	10-15								<<					10-15+11	10-15+JC08C			JC08H+JC08C		WLTC			
	(Light) cargo truck	CO	13	<<						6.5							4.02	<<			<<		<<		<<	
		HC	2.1	<<						0.25							0.05	<<			<<		<<		0.1	
		NOx	0.5	<<													0.05	<<			<<		<<		<<	
		Unit	g/km	<<						<<		<<					<<	<<			g/km		<<		<<	
		Mode	10	10-15						<<		<<					10-15+11	10-15+JC08C			JC08H+JC08C		WLTC			
	Truck and bus	Light duty	CO	100						76							38									
			HC	13						7							3.5									
		NOx	5.5						4.4							2.2										
		Unit	g/test						<<			<<				<<										
		Mode	11						<<			<<				<<										
	Medium duty	CO	2.1	<<								0.67					1.15	<<			<<		<<		7)	
		HC	0.25	<<								0.08					0.05	<<			<<		<<		0.1	
		NOx	0.25	<<								0.08					0.05	<<			<<		<<		<<	
		Unit	g/km	<<						<<		<<					<<	<<			<<		<<		<<	
		Mode	10	10-15						<<		<<					10-15+11	10-15+JC08C			JC08H+JC08C		WLTC			
Heavy duty	CO	60									19															
	HC	7									2.2															
	NOx	4.4									1.4															
	Unit	g/test									<<					<<										
	Mode	11									<<					<<										
Common name	CO	13	<<		<<				6.5			2.1				2.55	<<			<<		<<		<<		
	HC	2.1	<<		<<				0.25			0.08				0.05	<<			<<		<<		0.15		
	NOx	0.7	<<		0.4				<<		<<	0.13				0.07	<<			<<		<<		<<		
	Unit	g/km	<<		<<				<<		<<	<<				<<	<<			<<		<<		<<		
	Mode	10	10-15		<<				<<		<<	<<				10-15+11	10-15+JC08C			JC08H+JC08C		WLTC				
Truck and bus	Light duty	CO	100						76			24														
		HC	13						7			2.2														
	NOx	6.5						5			1.6															
	Unit	g/test						<<			<<					<<										
	Mode	11						<<			<<					<<										
Heavy duty	CO	1.2		102			<<		51			16				<<				<<		<<		7)		
	HC	410		6.2			<<		1.8			0.58				0.23				<<		<<		8)		
	NOx	650		5.5			4.5		<<		<<	1.4				0.7				<<		<<		<<		
	Unit	ppm		g/kWh			<<		<<		<<	<<				<<	<<			<<		<<		<<		
	Mode	6		G13			<<		<<		<<	<<				JE05										
Common name							Short-term regulation		Long-term regulation		New short-term regulation					New long-term regulation										
Diesel	Passenger vehicle	CO	2.1	<<	<<				<<	<<							0.63			<<	<<			<<		
		HC	0.4	<<	<<				<<	<<							0.12			<<	<<			<<		
		NOx	0.5/0.9	<<	0.5/0.6				0.4/0.6	0.4			0.28/0.3				0.14/0.15	<<		0.08				0.15		
		Unit	g/km	<<	<<			<<	<<	<<		<<	<<				<<	<<			<<		<<		<<	
		Mode	10	10-15	<<			<<	<<	<<		<<					10-15+11	10-15+JC08C			JC08H+JC08C		WLTC			
	Truck and bus	Light duty	CO	2.1	<<		<<										0.63			<<	<<			<<		
			HC	0.4	<<		<<										0.12			<<	<<			<<		
		NOx	0.9	<<		0.6			0.4				0.28				0.14	<<		0.08				0.15		
		Unit	g/km	<<		<<		<<	<<	<<		<<	<<				<<	<<			<<		<<		<<	
		Mode	10	10-15	<<			<<	<<	<<		<<					10-15+11	10-15+JC08C			JC08H+JC08C		WLTC			
	Medium duty	CO	790			2.1			<<								0.63			<<	<<			<<		
		HC	510			0.4			<<								0.12			<<	<<			<<		
		NOx	380/260			1.3			0.7								0.49			<<	<<			0.24		
		Unit	ppm			g/km			<<			<<					<<	<<			<<		<<		<<	
		Mode	6			10-15			<<			<<					10-15+11	10-15+JC08C			JC08H+JC08C		WLTC			
Heavy duty	CO	790			7.4			<<	<<	<<						2.22	<<		<<	<<		<<	<<			
	HC	510			2.9			<<	<<	<<						0.87	<<		0.17	<<		<<	<<			
	NOx	400/260			6/5			4.5	<<	<<						3.38	<<		2	<<		0.7	<<			
	Unit	ppm			g/kWh			(2.5-3.5)	(2.5-3.5)	(>12)						(2.5-12)	<<		(>12)	<<		(3.5-12)	(>7.5)	(trac-tor)		
	Mode	6			D13			3.5)	3.5)	(>12)						JE05			<<		WHDC		(7.5)			
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) << stands for "the same as left side".

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 3-6 Sulfur content (by weight) by fuel type

Fuel	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
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%
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%
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%

Source: 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.

c) **Completeness**

Emissions of NO_x , CO, NMVOCs, and SO_x from natural gas vehicles and motorcycles are reported as “NE”.

A3.1.1.2.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 3-7 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 .

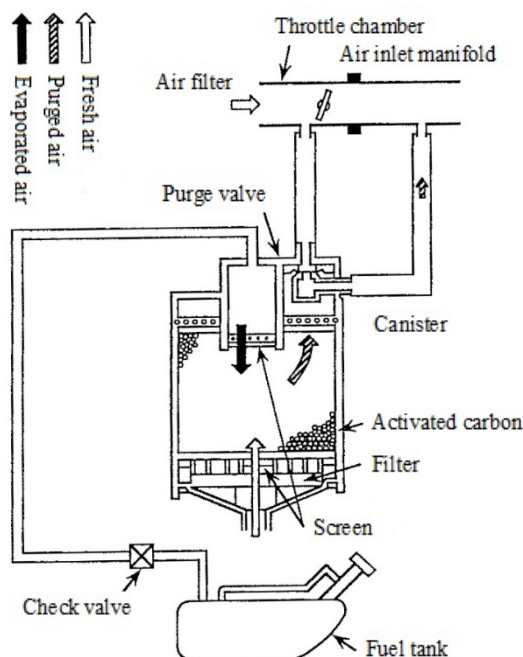
1 “Breakthrough” means going through the absorption process without being absorbed when the amount of gas/gasoline goes beyond the absorption capacity of canister.

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.

Source: *Estimation Methods for Releases from Sources not Required to Report under PRTR (Pollutant Release and Transfer Register)* (Ministry of Economy, Trade and Industry, and Ministry of the Environment, 2012.)



Source: *Technology of engine in vehicle for environment* (Society of Automotive Engineers of Japan, Inc., 2008)

Figure A 3-1 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)*, Ministry of the Environment, FY2003. This methodology is similar to that described in the *Estimation Methods for Releases from Sources not Required to Report under PRTR*, Ministry of Economy, Trade and Industry, and Ministry of the Environment.

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 gas². The outline of estimation method for each emission source and used data is shown in Table A 3-8.

² Regarding concrete volatile element composition, please refer to *Characteristics of Gasoline Evaporation Composition and VOCs Emission Estimates from Gasoline Passenger Cars at Refueling*, Year book of Tokyo Metropolitan Research Institute for Environmental Protection, 2011.

Table A 3-8 Descriptions for estimating emissions from evaporated gas by mobile fuel combustion

Category	Equation	Data for calculation
DBL	$E_n = \sum_p \sum_q \sum_r (E_{2002} \times N_{n,p,q,r} / N_{2002,p,q,r})$ <p>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</p>	<p>E_{2002}: THC emission amount in FY2002 provided in <i>Development Research on New Testing Methodology for Emission Gas from Vehicle (Off-road vehicle)</i> (Ministry of the Environment, FY2003)</p> <p>N: Based on <i>Monthly Report Statistics of Vehicles</i> (Japan Automobile Manufacturers Association, Inc. (JAMA)) and <i>Statistics of AIRIA/ Number of Motor Vehicles</i> (Automobile Inspection & Registration Information Association (AIRIA)).</p>
HSL	$E_n = \sum_p \sum_q (E_{2002} \times N_{n,p,q} / N_{2002,p,q})$ <p>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</p>	<p>E_{2002}: THC emission amount in FY2002 provided in <i>Development Research on New Testing Methodology for Emission Gas from Vehicle (Off-road vehicle)</i> (Ministry of the Environment, FY2003)</p> <p>N: Based on <i>Monthly Report Statistics of Vehicles</i> (JAMA) and <i>Statistics of AIRIA/ Number of Motor Vehicles</i> (AIRIA).</p>
RL	<p>[1990-2002]</p> $E_n = \sum_p \sum_q (E_{2002} \times N_{n,p,q} / N_{2002,p,q} \times M_{n,p} / M_{2002,p})$ <p>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 motorcycle [km] in FY n in a prefecture p</p> <p>[2003-] PRTR emissions were used.</p>	<p>E_{2002}: THC emission amount in FY2002 provided in <i>Development Research on New Testing Methodology for Emission Gas from Vehicle (Off-road Vehicle)</i> (Ministry of the Environment, FY2003)</p> <p>N: Based on <i>Monthly Report Statistics of Vehicles</i> (JAMA) and <i>Statistics of AIRIA/ Number of Motor Vehicles</i> (AIRIA).</p> <p>M: Based on <i>Monthly Report of Motor Vehicle Transport Statistics</i> and <i>Monthly Report Statistics of Vehicles</i> (JAMA).</p>

A3.1.1.2.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)*, Ministry of the Environment, 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*, Ministry of Economy, Trade and Industry, and Ministry of the Environment.

Table A 3-9 Description of estimating emissions from evaporated gas by motorcycle fuel combustion

Category	Equation	Data for calculation
DBL	$E_n = \sum_p \sum_q (E_{2001} \times M_{n,p,q} / M_{2001,p,q})$ <p>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</p>	<p>E_{2001}: THC emission amount in FY2001 estimated based on <i>Development Research on New Testing Methodology for Emission Gas from Vehicle (Motorcycle)</i> (Ministry of the Environment, FY2002).</p> <p>M: Based on <i>Monthly Report Statistics of Vehicles</i> (Japan Automobile Manufacturers Association, Inc. (JAMA)), and <i>Survey of Motorcycle Market Trends</i> (JAMA).</p>
HSL	$E_n = \sum_p \sum_q (E_{2001} \times M_{n,p} / M_{2001,p} \times R_{n,p})$ <p>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: Use factor adjustment ratio in FY n by vehicle type p</p>	<p>E_{2001}: THC emission amount in FY2001 estimated based on <i>Development Research on New Testing Methodology for Emission Gas from Vehicle (Motorcycle)</i> (Ministry of the Environment, FY2002).</p> <p>M: Based on <i>Monthly Report Statistics of Vehicles</i> (JAMA), and <i>Survey of Motorcycle Market Trends</i> (JAMA).</p> <p>R: Estimated by multiplying the sales unit for domestic sales of each vehicle type (Website of JAMA) by survival rate of each elapsed year (Ministry of the Environment), by the usage factor of each elapsed year (<i>Estimation Methods for Releases from Sources not Required to Report under PRTR</i> (Ministry of the Environment)).</p>

A3.1.1.2.e. Railways (1.A.3.c.: NO_x, CO, and NMVOCs)

a) Category Description

This section provides the estimation methods for emissions of precursors (NO_x, 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 3-10 IPCC default emission factors for locomotives

Gas	Emission factor [g/MJ(NCV)]
NO _x	1.8
CO	0.61
NMVOCs	0.13

Source: *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.

A3.1.1.2.f. Domestic Navigation (1.A.3.d.: NO_x, CO, NMVOCs, and SO_x)**a) Category Description**

This section provides the estimation methods for emissions of precursors (NO_x, 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 3-11 IPCC default emission factors for ocean-going ships

Gas	Emission factor [g/MJ(NCV)]
NO _x	1.8
CO	0.18
NMVOCs	0.052

Source: *Revised 1996 IPCC Guidelines*, Vol. 3; Page 1.90, Table 1-48

● **Activity data**

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.

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 dioxide³ 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 SO₂. For major sources, SO₂ emissions are estimated.

Table A 3-12 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
Fuel Oil B	0.91	3.0
Fuel Oil C	0.93	3.5

Source: Sulfur ratio of diesel oil based on *Petroleum Industry in Japan 2015* (Petroleum Association of Japan)

Sulfur ratio of each fuel oil based on *Japanese Industrial Standard K2205*

Specific gravity based on *Regulation of Total NO_x Emission Manual*

● *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.

A3.1.1.3. Fugitive emissions from fuel (Oil and natural gas) (1.B.2: NMVOCs)

A3.1.1.3.a. Oil production (1.B.2.a.ii)

a) *Category Description*

This section provides the estimation methods for NMVOC emissions occurring during production of crude oil in oil fields. As for the NMVOC emissions when lowering measuring instruments into operating wells at servicing, the estimation methods are provided in the section “Fugitive emissions during servicing of operating gas fields” (1.B.2.b.ii).

b) *Methodological Issues*

In order to keep consistency with the methods to estimate CH₄ and CO₂, 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 *2006 IPCC Guidelines*.

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

E : NMVOC fugitive emissions caused by crude oil production [kt-NMVOC]

AD_i : Amount of crude oil production (excluding condensate) from offshore oil fields or onshore oil fields [1000 kl]

EF_i : Emission factor for crude oil production from offshore oil fields or onshore oil fields [kt-NMVOC/1000 kl]

● *Emission factors*

For NMVOC emission factors of fugitive emissions from oil production, the default values for fugitive emissions of conventional oil from onshore and offshore oil fields (onshore: 2.25×10^{-3} , offshore: 7.4×10^{-7} kt-NMVOC/10³ kl), which are indicated in the *2006 IPCC Guidelines*, are

used. As for the emission factor for onshore fields, the median of the default values (1.80×10^{-6} - 4.50×10^{-3}) is used.

- **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 *Production, Supply and Demand of Petroleum, Coal and Coke*, the *Yearbook of Mineral Resources and Petroleum Products* and the *Yearbook of Current Production Statistics*, all by the Ministry of Economy, Trade and Industry. The production amounts of natural gas and crude oil from offshore are obtained from *Natural Gas Data Year Book* compiled by the Japan Natural Gas Association.

A3.1.1.3.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 are established by using 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*”), Ministry of the Environment. 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 evaluated as shown in Table A 3-13, based on evaluated emissions by Japan Natural Gas Association⁴.

Table A 3-13 Emission factors for oil transport

Fiscal Year (FY)	Method of establishing emission factors
FY1990-2004	Established by dividing the estimated total emissions provided by Japan Natural Gas Association by the activity data (amount of crude oil production).
FY2005-	Established by dividing the estimated total emissions in the <i>Study on the VOC Emission Inventory</i> by the activity data (amount of crude oil production).

● *Activity Data*

The amount of crude oil production (including condensate) which is provided in the *Yearbook of Mineral Resources and Petroleum Products Statistics* is used for activity data.

A3.1.1.3.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 confined chemical tankers and is prohibited from being delivered by product tankers which are not enough treated for electrostatic generation so as to avoid the risk of auto-ignition. Therefore, it is considered that naphtha is not emitted into the air during delivering, thus, it is not used for 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).

VOC 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.

VOC emissions from “chemical agent” are also estimated in “A3.1.2.2.n Chemicals Manufacture” in “2.Industrial Process and Product Use”. 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

⁴ Japan Natural Gas Association provided the emissions from the following five sources: “breathing and acceptance”, “shipping (lorry)”, “reboiler vent (GDH)”, “gas release” and “CO₂ 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*.

transported “crude oil”, “oil products (gasoline)”, and “chemical agents” which are reported in the tables entitled “Export cargo volume by type of goods, by destination” and “Delivery cargo volume by type of goods, by destination” in the *Statistical Yearbook of Port*, 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 3-14, based on the *Survey Report on influence of VOC emissions from vessels in FY2005* (Ocean Policy Research Foundation, March 2006).

Table A 3-14 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

Source: *Survey Report on influence of VOC emissions from vessels in FY2005* (Ocean Policy Research Foundation, March 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* (Ministry of Land, Infrastructure, Transport and Tourism), the following methods in Table A 3-15 are used for activity data for this category.

Table A 3-15 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 <i>Yearbook of Mineral Resources and Petroleum Products Statistics</i> .
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 the actual export amount of five chemical agents (benzene, methanol, toluene, dichloroethane, and acetone), probable emission sources of NMVOCs, provided in <i>Report on Estimation of Improvement of Air Environment</i> (Ocean Policy Research Foundation, 2003), is adopted for the percentage of NMVOCs in chemical agents.

*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.

A3.1.1.3.d. Refining and storage of oil (1.B.2.a.iv): Fugitive emissions from oil refinery

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/10⁵BPSD] which is provided in the *Business Report on Grid Database on Atmospheric Pollutants Emissions, 2000* by The Institute of Behavioral Sciences, 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) by the annual operating ratio of the crude oil distillation units at normal pressure, which is provided by *Sekiyu Shiryô* (Sekiyu Tsushin) (=annual processing amount [bbl/year] / annual capacity[bbl/year]).

A3.1.1.3.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 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, emission factors are established for toluene and methyl ethyl ketone.

Table A 3-16 Toluene and methyl ethyl ketone emission factors in lubricant oil production

Gas	Emission factor [g/kl]
Toluene	333.2
Methyl ethyl ketone	415.5

Source: *Basic Study on HC Sources* (Institute of Behavioral Science, 1987)

● **Activity data**

Figures for gross sales amount of lubricants to consumers, provided in the *Yearbook of Mineral Resources and Petroleum Products Statistics* (Ministry of Economy, Trade and Industry), are used for the calculation of activity data.

A3.1.1.3.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 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*, and the following activity data (the received amounts of crude oil, gasoline and naphtha) are applied for establishing emission factors for this category. The emission amount provided in the *Study on the VOC Emission Inventory* are limited to FY2000 and from FY2005 onward, therefore, the emission factor for each FY is established as indicated in Table A 3-17.

No relevant information for FY1990-1999 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 interpolation 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.

Table A 3-17 Emission factors in fuel storage and shipping in crude oil transshipment stations, refineries, and oil tank facilities

Fiscal Year (FY)	Method of establishing emission factors
1990-1999	Emission factor for FY2000 is applied for this period
2000	Established by dividing the emissions provided in the <i>Study on the VOC Emission Inventory</i> , by the activity data (the total of received amounts of crude oil, gasoline and naphtha)
2001-2003	Calculated by interpolating the figures in FY2000 and FY2004.
2004	Established by dividing the emissions reported in Petroleum Association of Japan’s voluntary action plan by the activity data (the total of received amounts of crude oil, gasoline and naphtha).
2005-	Established by dividing the emissions provided in the <i>Study on the VOC Emission Inventory</i> , by the activity data (the total of received amounts of crude oil, gasoline and naphtha)

● *Activity Data*

The processed amount of crude oil, and the received amounts of gasoline and naphtha provided in the *Yearbook of Mineral Resources and Petroleum Products Statistics* by the Ministry of Economy, Trade and Industry are used for activity data. As for the crude oil, the received amount has not yet been identified, therefore the processed amount is used instead.

A3.1.1.3.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.

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

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 the *Study on the total system for prevention of HC-Vapor in petroleum industries* (Agency for Natural Resources and Energy, 1975).

The average monthly temperature in each prefectural capital provided in *Weather Statistics Information* by 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 [degree 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, by following the *Study on the VOC Emission Inventory*, the emission factors for losses from acceptance are established by multiplying the established emission factors by 0.15, taking into consideration of the 85% emission reduction by vapor recovery instrument.

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 [degree C]

$B_{i,j}$: Temperature difference between fuel in car tank and filling fuel in prefecture i in month j [degree C]

C : Gasoline filling speed [l/minute]

D : Reid vapor pressure [kPa]

Table A 3-18 Establishing method of parameters of emission factor for loss from filling gasoline

Parameter	Establishing method
$A_{i,j}$: Fuel temperature in car tank in prefecture i in month j [degree C]	Average temperature in prefecture i in month j ($T_{i,j}$) [degree C] + 5 [degree C]
$B_{i,j}$: Temperature difference between fuel in car tank and filling fuel in prefecture i in month j [degree C]	
Filling fuel temperature (Fuel temperature in underground tank)	Established depending on the average temperature in prefecture i in month j ($T_{i,j}$) [degree C] as follows; $T_{i,j} < 15$: $T_{i,j} + 5$ $15 \leq T_{i,j} < 20$: $T_{i,j} + 2.5$ $20 \leq T_{i,j} < 25$: $T_{i,j}$ $25 \leq T_{i,j} < 30$: $T_{i,j} - 2.5$ $30 \leq T_{i,j}$: $T_{i,j} - 5$
C : Gasoline filling speed [l/minute]	35 [l/minute]
D : Reid vapor pressure [kPa]	June to September: 63.2 [kPa], October to May: 86.0 [kPa]

Source: *Study on the VOC Emission Inventory*, by the Ministry of the Environment.

● Activity Data

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 Mineral Resources and Petroleum Products Statistics* by the Ministry of Economy, Trade and Industry, by annual gasoline sales volume by prefecture, provided in the *Oil Product Sales Summary by Prefecture* by Petroleum Association of Japan, are used for activity data.

A3.1.1.3.h. Production of natural gas (1.B.2.b.ii)

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 “Fugitive emissions during servicing of operating gas fields” (1.B.2.b.ii).

b) Methodological Issues

In order to keep consistency with the methods to estimate CH₄ and CO₂, the emissions from offshore and onshore are estimated separately.

- **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 m³]

EF_i : Emission factor for natural gas production from offshore gas fields or onshore gas fields [kt-NMVOC/million m³]

- **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 m³), which are indicated in the *2006 IPCC Guidelines*, are used.

- **Activity Data**

The production volume of natural gas from offshore in the *Natural Gas Data Year Book* published by the Japan Natural Gas Association is used for the production volume of natural gas from offshore gas fields. 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*, all prepared by the Ministry of Economy, Trade and Industry.

A3.1.1.3.i. Fugitive emissions during servicing of operating gas fields (1.B.2.b.ii)

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

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. Therefore, the number of operation wells is used for the activity data for CO₂, CH₄ and N₂O emission estimation based on IPCC, *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories*, 2000 (hereafter, *GPG (2000)*). However as for NMVOCs, the emission factor based on the number of operating wells is not indicated in the *GPG (2000)*, thus the estimation method of using the crude oil production amount is adopted based on the *2006 IPCC Guidelines*.

- **Estimation Method**

Emission amount of NMVOCs in this category is estimated by multiplying the amount of domestic production of crude oil by the default emission factor for NMVOC.

$$E=AD\times EF$$

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]

- **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. In CO₂, CH₄ and N₂O emission estimation, the emissions from other than flaring and venting are also estimated for well servicing, however the emission factor, which is available for NMVOC emission estimation for well servicing, is only the default value for flaring and venting during well servicing shown in the *2006 IPCC Guidelines*, thus such emission factor is used.

- **Activity Data**

The production amount of crude oil in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* and the *Yearbook of Mineral Resources and Petroleum Products Statistics*, both prepared by the Ministry of Economy, Trade and Industry is used for activity data.

A3.1.1.3.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 m³]

EF : Emission factor per production volume of natural gas [t-NMVOC/million m³]

- **Emission factors**

Emission factors are established using the natural gas emission amount which has been estimated in the *Study on the VOC Emission Inventory* by the Ministry of the Environment (based on the

reported figures of voluntary action plan by Japan Natural Gas Association) and later-indicated activity data (domestic production volume of natural gas). Emission factors in and before FY2004 are established as indicated in Table A 3-19, using the emissions provided by Japan Natural Gas Association, since the indicated 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 (1B.2.a.iii)”).

Table A 3-19 Method of establishing emission factors for processing of natural gas

Fiscal Year (FY)	Method of establishing emission factors
1990-2004	Established by dividing the emissions provided by Japan Natural Gas Association, by the activity data (production amount of natural gas) for FY1990-2004.
2005-	Established by dividing the emissions derived from the <i>Study on the VOC Emission Inventory</i> by the activity data (production amount of natural gas) from FY2005 onward.

- **Activity data**

Domestic production volume of natural gas provided by the *Yearbook of Mineral Resources and Petroleum Products Statistics* (Ministry of Economy, Trade and Industry) is used for activity data.

- **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.Venting.ii)”.

A3.1.1.3.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 based on 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 Ministry of the

Environment and 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 factor for each year is established as indicated in Table A 3-20.

Table A 3-20 Method of establishing emission factors for city gas production

Fiscal Year (FY)	Method of establishing emission factors
FY1990-1999	Emission factor for FY2000 is used for all fiscal years.
FY2000	Established by dividing the emission amount in FY2000 provided in the <i>Study on the VOC Emission Inventory</i> by the activity data (consumption amount of crude gasoline).
FY2001-2003	Established by interpolation, using the emission factors for FY2000 and FY2004.
FY2004	Established by dividing the emission amount in FY2004 provided in the <i>Voluntary Action Plan</i> by the activity data (consumption amount of crude gasoline)..
FY2005-	Established by dividing emission amount provided in the <i>Study on the VOC Emission Inventory</i> in FY2005 onward by the activity data (consumption amount of crude gasoline).

- **Activity data**

The consumption amount of gasoline used as raw material for city gas production provided in the *Current Survey of Production Concerning Gas Industry* of the Agency for Natural Resources and Energy is used for activity data.

A3.1.1.3.1. Venting (Oil) (1.B.2.c.Venting.i)

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 production amount of crude oil in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* and the *Yearbook of Mineral Resources and Petroleum*

Products Statistics, both prepared by the Ministry of Economy, Trade and Industry, is used for activity data.

A3.1.1.3.m. Flaring (Oil) (1.B.2.c.Flaring.i)

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 production amount of crude oil in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* and the *Yearbook of Mineral Resources and Petroleum Products Statistics*, both prepared by the Ministry of Economy, Trade and Industry, is used for activity data.

A3.1.1.3.n. Flaring (Gas) (1.B.2.c.Flaring.ii)

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 m³]

EF : Emission factor per natural gas production [kt-NMVOC/1000 m³]

- **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 production amount of natural gas in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* and the *Yearbook of Mineral Resources and Petroleum Products Statistics*, both prepared by the Ministry of Economy, Trade and Industry, is used for activity data.

A3.1.1.3.o. Flaring (Combined) (1.B.2.c.Flaring.iii)

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.Flaring.i) or in Flaring (Gas) (1.B.2.c.Flaring.ii) respectively. In this category, CO₂, CH₄ and N₂O 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

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, in case of CO₂, CH₄, and N₂O emission estimation, 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, thus the number of drilled and tested wells is used for the activity data based on *GPG (2000)* similar to the emissions from well servicing. Especially, as for the emissions from the exploration of wells, the number of 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. However, as for NMVOCs, the emission factor based on the number of operating wells is not indicated in the *GPG (2000)*, thus the estimation method of using the crude oil production amount is adopted based on the *2006 IPCC Guidelines*. Also, 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.

- **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 and venting in 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]

- **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 production amount of natural gas in Japan given in the *Yearbook of Production, Supply and Demand of Petroleum, Coal and Coke* and the *Yearbook of Mineral Resources and Petroleum Products Statistics*, both prepared by the Ministry of Economy, Trade and Industry, is used for activity data.

A3.1.2 Industrial Processes and Product Use (IPPU)

A3.1.2.1. 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* by the Ministry of the Environment.

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:

Calculation of NO_x emissions from metallurgical coal or coke (for IPPU sector)

NO_x emissions from metallurgical coal or coke [t-NO_x]

= NO_x emission factor by material [t- NO_x /kcal] × energy consumed by material [kcal]
× (1 – Nitrogen removal rate [%])

For raw material falling under either [41: Iron/ironstone] or [46: Other], the following equation is used:

Calculation of NO_x emissions from iron/ironstone or other material (for IPPU sector)

$$\text{NO}_x \text{ emissions from iron/iron ore or other material [t-NO}_x\text{]} \\ = \text{Nitrogen content in each material [t-NO}_x\text{]} \times (1 - \text{Nitrogen removal rate [\%]})$$

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.

Calculation of SO_x emissions (in the IPPU sector)

$$\text{SO}_x \text{ emissions [t-SO}_x\text{]} \\ = \text{Sulfur content in each material [t-SO}_x\text{]} \times (1 - \text{desulfurization rate [\%]})$$

● **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:

Calculation of nitrogen removal rate

$$\text{Nitrogen removal rate [\%]} \\ = \text{Nitrogen removal efficiency [\%]} \times (\text{Hours of operation of nitrogen removal unit [h/yr]} \\ / \text{Hours of operation of furnace [h/yr]}) \times (\text{Processing capacity of nitrogen removal unit [m}^3\text{/yr]} \\ / \text{Maximum exhaust gas emission [m}^3\text{/yr]})$$

The *General Survey of the Emissions of Air Pollutants* data was used for all items.

Nitrogen removal efficiency = (NO_x volume before treatment – NO_x volume after treatment) / volume of smoke and soot

➤ **Desulfurization rate**

The desulfurization rate was calculated by the following equation:

Calculation of desulfurization rate

Desulfurization rate [%]

$$= \text{Desulfurization efficiency [\%]} \times (\text{Hours of operation of desulfurization units [h/yr]} \\ / \text{Hours of operation of furnaces [h/yr]} \times (\text{Processing capacity of desulfurization units [m}^3\text{/yr]} \\ / \text{Maximum exhaust gas emissions [m}^3\text{/yr]})$$

The *General Survey of the Emissions of Air Pollutants* data were used for all items.

Desulfurization efficiency = (SO_x volume before treatment – SO_x volume after treatment) / volume of smoke and soot

● **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.

A3.1.2.2. Non-energy products from fuels and solvent use (2.D.3.) (NMVOCs)

A3.1.2.2.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 buildings⁵.

b) Methodological Issues

● **Estimation Method**

NMVOC emissions from use of paint were estimated by multiplying the sales amount of paint by the NMVOC emission factors per sales amount of paint.

$$E = AD * EF$$

⁵ The emissions in the process of manufacturing were estimated in “A3.1.2.2.n Chemicals Manufacture”

- 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.

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. (Please refer to Table A 3-21)

Table A 3-21 Method of establishing NMVOC emission factors for use of paint

Fiscal Year (FY)	Method of establishing emission factors
1990-1999	Established by extrapolation based on the trend in FY2000-2010
2000-2001	Established by dividing VOC emissions in FY2000 from the use of paints (by Japan Paint Manufacturers Association) by the sales amount of paint.
2002	Established by interpolation based on the emission factor which was calculated by dividing the emissions in FY2001 and FY2003 by the activity data in FY2001 and FY2003.
2003-	Established by dividing VOC emissions from paint in FY2003 and thereafter (Japan Paint Manufacturers Association) by the sales amount of paint.

● *Activity Data*

The sales amount of paint provided in the *Yearbook of current production statistics chemical industry* by the Ministry of Economy, Trade and Industry was used for activity data.

A3.1.2.2.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 (Tetrachloroethylene, Industrial gasoline No.5) [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**

Used weight of dry-cleaning solvent (tetrachloroethylene, Industrial gasoline No.5) was estimated according to Table A 3-22 and Table A 3-23, based on data in the *Study on the VOC Emission Inventory*.

Table A 3-22 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 <i>Demand by end-use</i> by Japan Association for Hygiene of Chlorinated Solvents, since the data for FY1990 and 1991 was not available.
1992	Used weight of tetrachloroethylene provided in <i>Demand by end-use</i> by Japan Association for Hygiene of Chlorinated Solvents was used for activity data.
1993, 1994	Estimated by interpolating the value provided in <i>Demand by end-use</i> by Japan Association for Hygiene of Chlorinated Solvents for FY1992 and FY1995.
1995-	Used weight of tetrachloroethylene provided in <i>Demand by end-use</i> by Japan Association for Hygiene of Chlorinated Solvents was used for activity data.

Table A 3-23 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 <i>The survey on usage of dry-cleaning solvent</i> by the Ministry of Health, Labour and Welfare
1992-1999	Estimated by multiplying the shipping weight of petroleum dry-cleaning solvent in FY2000, provided in <i>Shipping weight of solvents</i> by Japan Cleaning Chemicals Association, by the used weight of industrial gasoline no.5 in FY2000
2000	Used the result of the survey on the shipping weight of dry-cleaning solvent by petroleum solvent manufacturer, indicated in the <i>Study on the VOC Emission Inventory</i> .
2001-2004	Estimated by interpolating the values in FY2000 and FY2005.
2005-	Used the result of the survey on the shipping weight of dry-cleaning solvent by petroleum solvent manufacturer, indicated in VOC emissions inventories.

- 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 3-24, in accordance with the method of the *Study on the VOC Emission Inventory* by the Ministry of the Environment; 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* by the Ministry of Health, Labour and Welfare 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 3-24 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	<p>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.</p> <p>Absorbed weight in cartridge (kg/year) = Absorbed VOC weight (L/time/kg) in each changing of cartridge per 1kg of loading weight by washer × Density (kg/L) × Annual average of operating washer (time/year) / Average washer times per changing cartridge filter (time/time) × Number of laundry units installed (unit)</p>
Transfer weight of residual solvent in distilling sludge	<p>Transferred weight of solvent in distilling was estimated according to the following formula.</p> <p>Contained residual solvent in distilling sludge (kg/year) = Standard load of washer (kg/unit) × Annual average of operating times of washer (time/year) × Factors by type of filter (kg/kg) × Unit of installation of laundry (unit) × Installation rate of distilling (%)</p>

Source : Study on the VOC Emission Inventory (Ministry of the Environment)

A3.1.2.2.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.

$$E = AD * R * EF$$

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 cleaners by the atmospheric emission rate.

⁶ JICC research 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)

$$E = AD * EF$$

- 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* by Ministry of the Environment, as shown in Table A 3-25, were used for chlorine cleaners and non-chlorine cleaners.

Table A 3-25 NMVOC emission factors for use of each type of cleaner

Type of cleaner	Atmospheric emission rate	Source
Chlorine cleaner	75%	Commission report on manual for promoting voluntary approach for emission control of VOCs in FY2005 by Japan Industrial Conference on Cleaning (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 A 3-26 and Table A 3-27, based on the *Study on the VOC Emission Inventory* by the Ministry of the Environment and data provided by Japan Association for Hygiene of Chlorinated Solvents. 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 3-26 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 "Demand by use" by Japan Association for Hygiene of Chlorinated Solvents) since data was not available for FY1990-1994.
1995-	The sales amount of dichloromethane, trichloroethylene, and tetrachloroethylene for metallic cleaning provided in "Demand by use" by Japan Association for Hygiene of Chlorinated Solvents was adopted for activity data.

Table A 3-27 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 for 2000 by the ratio in FY1990-1999 to the activity data in FY2000.
2000	The sales amount provided in the <i>Study on the VOC Emission Inventory</i> was used for activity data. (the results of research by JICC).
2001-2004	Estimated by interpolating the activity data for FY2000 and FY2005
2005-	The sales amount provided in the <i>Study on the VOC Emission Inventory</i> was used for activity data. (the results of research by JICC).

2) Non-chlorine cleaner

Activity data for non-chlorine cleaners was established as shown in Table A 3-28 based on the information provided in the *Study on the VOC Emission Inventory* by the Ministry of the Environment.

Table A 3-28 Activity data for non-chlorine cleaner

Fiscal year (FY)	Activity data
FY1990-1999	Total amount of raw materials by type of cleaner was calculated by multiplying the proportion for each type of manufacturer provided in the <i>Study on the VOC Emission Inventory</i> (Table A 3-29) by the corresponding used weight of raw material; then, the activity data (the used weight) for each year was estimated by multiplying the calculated total weight by the ratio from FY2000.
FY2000	Used weight of each type of cleaner in the <i>Study on the VOC Emission Inventory</i> 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 <i>Study on the VOC Emission Inventory</i> was adopted for activity data. As for values in the <i>Study on the VOC Emission Inventory</i> , 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 3-29 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	Other alcohol cleaner	Isopropyl cleaner	Other alcohol cleaner	HFC cleaner	Other fluorine cleaner	Bromine cleaner	Other cleaner
19 Plastic Products			3%	6%	4%				12%				
23 Iron and Steel			3%	0.1%	5%					1%	2%		
24 Non-Ferrous Metals and Products			16%	0.05%	7%					1%	2%		
25 Fabricated Metal Products		2%	17%	30%	26%	8%						4%	
26 Machinery			11%	8%	15%	11%				1%	2%		
28 Communications		19%						1%					
29 Electric device	70%	49%	17%	15%	7%	13%	25%	28%	28%	38%	30%	100%	
30 Transport		2%	16%	26%	36%	10%		12%	7%	19%	18%		
31 Precision apparatus	30%	18%	17%	15%		18%	74%	46%	61%	37%	48%		
32 Other		10%	0.1%		1%	41%		3%					
Total	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Source: The *Survey Report on VOC emission inventories*, Ministry of the Environment, FY2012

A3.1.2.2.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.

$$E = AD * EF$$

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* by the Ministry of the Environment 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 A 3-30).

Table A 3-30 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	Estimated by dividing the emissions in FY2000 provided in the <i>Study on the VOC Emission Inventory</i> by the activity data.
2001-2004	Estimated by interpolating the activity data for FY2000 and FY2005
2005-	Estimated by dividing the emissions in FY2005 and thereafter provided in the <i>Study on the VOC Emission Inventory</i> by the activity data.

● **Activity data**

The sales volume of thinner in FY1990 and thereafter was estimated by deducting the consumption amount of diluent thinner provided in *Summary of estimation for the current status of VOC emissions from painting* (Japan Paint Manufacturers Association) from the sales volume of thinner provided in the *Yearbook of chemical industry* (Ministry of Economy, Trade and Industry).

Since data on the consumption amount of diluent thinner in and before FY2004 was unidentified, it was estimated (Table A 3-31).

Table A 3-31 Method of estimating activity data for the use of cleaning thinner for manufacturing equipment

Fiscal Year (FY)	Activity data
1990-2004	The consumption amount of diluent thinner in and before FY2004, 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 <i>Summary of estimation for the current status of VOC emissions from painting</i> (Japan Paint Manufacturers Association) from the sales amount of thinner provided in the <i>Yearbook of chemical industry</i> (Ministry of Economy, Trade and Industry)

A3.1.2.2.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 “thinner for cleaning manufacturing equipment”), and emissions at the stage of production of printing ink (estimated as “A3.1.2.2.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.

$$E = AD * EF$$

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 3-32) 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 3-32 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 <i>Study of Establishment of Methodology for Estimation of Hydrocarbon Emissions</i> (Institute of Behavioral Science, 1984) and the 2000 value.
2000	Established based on the <i>Study on the VOC Emission Inventory</i> in FY2000	
2001-2004	Established by interpolating the figures in FY2000 and FY2005	
2005-	Established based on the <i>Study on the VOC Emission Inventory</i> in FY2000	

* 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 3-33.

Table A 3-33 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 <i>Yearbook of Chemical Industry</i> (Ministry of Economy, Trade and Industry), by the activity data of FY2000.
2000	Used amount of VOCs in the process of printing, provided in the <i>Study on the VOC Emission Inventory</i> , was used.
2001-2004	Estimated by interpolating the activity data of FY2000 and 2005.
2005-	Used amount of VOCs in the process of printing, provided in the <i>Study on the VOC Emission Inventory</i> , was used.

A3.1.2.2.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 “A3.1.2.2.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.

$$E = AD * EF$$

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 *VOC emission inventories* by the Ministry of the Environment, by the sales amount of film for laminating. For fiscal years which were not subject to voluntary action plan, emission factor was established as shown in the following Table A 3-34 .

Table A 3-34 Method of establishing emission factor for lamination

Fiscal Year	Method of establishing emission factor
1990-1999	Emission factor in FY2000 was adopted for each fiscal year.
2000	Established by dividing VOC emissions from the use of adhesive agent for laminate (estimated by voluntary action plan) by the sales amount of film for laminating by the Japan Polyethylene Products Industrial Federation).
2001-2004	Established by interpolating the emission factors for FY2000 and FY2005.
2005-	Established by dividing VOC emissions from the use of adhesive agent for laminate (estimated figures by the Japan Polyethylene Products Industrial Federation) by the sales amount of film for laminate.

- **Activity data**

The sales amount of film for laminate provided in the *Yearbook of paper, printing, and plastics products statistics* by the Ministry of Economy, Trade and Industry was used for activity data.

A3.1.2.2.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 for FY2001-2004 was estimated by interpolating the *Study on the VOC Emission Inventory* by the Ministry of the Environment. Activity data for and before FY2000 was estimated by multiplying the used amount of VOCs in FY2000 by the ratio of the shipping weight of each type of adhesive to the 2000 level (Table A 3-35).

Table A 3-35 Method of establishing activity data for the use of adhesive

Fiscal year	Activity data
1990-1999	Estimated by multiplying the used amount of VOCs in FY2000 by the ratio of shipping weight of each type of adhesive in each year to the 2000 level.
2000	Used amount of VOC emissions provided in the <i>Study on the VOC Emission Inventory</i> (estimated by the review meeting on the <i>Study on the VOC Emission Inventory</i>)
2001-2004	Estimated by interpolation, using activity data for FY2000 and FY2005
2005-	Used amount of VOCs provided in the VOC Emission Inventory (estimated by review meeting on the <i>Study on the VOC Emission Inventory</i>)

A3.1.2.2.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 rubber solvents were estimated by multiplying the consumption of volatile oil for solvent use 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* by the Ministry of the Environment.

$$E = AD * EF$$

E : NMVOC emissions [t-NMVOC]

AD : Consumption of volatile oil for solvent use [t]

EF : Emission factor per consumption of volatile oil for solvent use [t-NMVOC/ t]

● Emission Factors

VOC emissions per consumption of rubber solvent use, which was calculated by dividing emissions based on reported figure by Japan Rubber Manufacturers Association, by the consumption of volatile oil for solvent use were adopted for emission factor.

Table A 3-36 Method of establishing NMVOC emission factor from gum solvent use

Fiscal Year	Method of establishing emission factor
1990-1999	Emission factor for FY2000 was applied.
2000	Established by dividing VOC emissions from volatile oil for solvent use (estimated figures based on the report by Japan Rubber Manufacturers Association) by the consumption of volatile oil for solvent use.
2001-2004	Interpolated between FY2000 and FY2005.
2005-	Established by dividing VOC emissions from volatile oil for solvent use (estimated figures based on the report by Japan Rubber Manufacturers Association) by the consumption of volatile oil for solvent use.

● 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.

A3.1.2.2.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 “A3.1.2.2.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.

$$E = AD * EF$$

E : NMVOC emissions from the use of adhesive and detachment solvent [t-NMVOC]

AD : Shipping amount of adhesive tape [Million m²]

EF : Emission factor per shipping amount of adhesive tape [t-NMVOC/million m²]

● Emission factors

Emission factors 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.

Table A 3-37 NMVOC emission factors for the use of adhesive and detachment solvent

Fiscal year	Method of establishing emission factor
1990-1999	Emission factor for FY2000 was applied.
2000	Established by dividing VOC emissions (estimated based on the reported figure by four business associations including Japan Paper Association) by the shipping amount of adhesive tape.
2001-2004	Established by interpolating between the FY2000 and FY2005 EFs
2005-	Established by dividing VOC emissions (estimated based on the reported figure by four business association including Japan Paper Association) by the shipping amount of adhesive tape

● Activity data

The shipping amount provided by Japan Adhesive Tape Manufacturers Association was adopted for activity data.

A3.1.2.2.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; 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* (Ministry of Economy, Trade and Industry and Ministry of the Environment) 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.

Table A 3-38 Method of estimating activity data for repellents and air fresheners

Fiscal year	Activity data
1990-1991	Estimated by extrapolation from the shipping volume in FY1992-2010
1992-2000	Estimated by multiplying the shipping volume in FY2001 by the growth rate of market size of p-dichlorobenzene from FY2001.
2001-	The total amount of p-dichlorobenzene shipped as repellent and air freshener, which was provided by Japan Moth Repellent Association and indicated in <i>Estimation Methods for Releases from Sources not Required to Report under PRTR</i> (Ministry of Economy, Trade and Industry and Ministry of the Environment) was applied for activity data.

A3.1.2.2.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, in March in 2009. 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.

$$E = \sum AD_i * EF_{LPG,DME}$$

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 emissions per aerosols production capacity [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.

$$EF_{LPG,DME} = R_{LPG,DME} * R_P * C_{LPG,DME} * d_{LPG,DME}$$

$EF_{LPG, DME}$: LPG and DME emissions 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 3-39.

Table A 3-39 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	-

Source: *Research report on VOC emissions from public sector* (March, 2009, The Institute of Behavioral Science)

1) Percentage of aerosol products which used LPG and DME as propellant

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 3-40 (established by Tokyo Metropolitan Government research) from 100% for each product. As for paint and pharmaceutical products, 100% was applied since no data was available. (Table A 3-41)

Table A 3-40 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%

Source: *Research report on VOC emissions from public sector*
(March, 2009, The Institute of Behavioral Science)

Table A 3-41 Percentage of aerosol products which used LPG and DME as propellant

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%

Source: Based on *Research report on VOC emissions from public sector*
(March, 2009, The Institute of Behavioral Science)

* As for paint and pharmaceutical products, 100% was applied since no data was available.

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 3-42.

Table A 3-42 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%
Car-related products	Other body care products	50%	50%
	Anti-fog	100%	0%
	Other car-related products	100%	0%
Others	Handy extinguisher	0%	0%
	Others	100%	0%

Source: Research report on VOC emissions from public sector (March 2009, The Institute of Behavioral Science)

4) Specific gravity of LPG and DME

Based on the survey by the Tokyo Metropolitan Government, specific gravity of LPG and DME was established as 0.56 and 0.67, respectively.

● Activity data

Following the survey by the 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.

$$AD_i = \sum N_{i,k} * P_{ave,k}$$

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 3-43, Table A 3-44, and Table A 3-45).

Table A 3-43 Average capacity by capacity class (tinplate container)

Capacity class [cc]	420-	280-	220-	180-	150-	100-
Average capacity[cc]	420	350	250	200	165	125

Table A 3-44 Average capacity by capacity class (aluminum container)

Capacity class [cc]	300-	200-	150-	100-	50-	-49
Average capacity[cc]	300	250	175	125	75	25

Table A 3-45 Average capacity by capacity class (synthetic resin container)

Capacity class [cc]	*
Average capacity[cc]	210

* Same for all capacity classes

Source: *Research Report on VOC Emissions from Public Sector* (March, 2009, The Institute of Behavioral Science)

A3.1.2.2.1. 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.

$$E = \sum_i (AD_i * C_i * EF_i)$$

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 A 3-46)

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 3-46 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*	4.4%	100%
	Other skincare products	7.5%	100%
Makeup	Foundation*	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) *	76.8%	100%
Fragrance	Perfume and cologne	7.5%	100%
Body care	Lip balm	10.0%	100%
	Sunscreen and cosmetics for sun-burn	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* Hairdressing*, Setting lotion*	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)*	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%

* Integrated categories by weighted average

Source: *Research report on VOC emissions from public sector*, March 2009, The Institute of Behavioral Science

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 3-47 and Table A 3-48).

Table A 3-47 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%

Source: *Research report on VOC emissions from public sector* (March, 2009, The Institute of Behavioral Science)

Table A 3-48 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 gloss	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
	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)	-

Source: *Research report on VOC emissions from public sector* (March, 2009, The Institute of Behavioral Science)

● **Activity data**

Sales amount of cosmetic products by types provided in the *Yearbook of chemical industry*

(Ministry of Economy, Trade and Industry) is used for activity data. However, since import goods are not included in the *Yearbook of chemical industry* (Ministry of Economy, Trade and Industry) there might be a wide gap between reported sales amount and actual consumption amount. Therefore, as for “perfume and cologne”, since the percentage of import excess was especially high, correction measures were conducted.

Table A 3-49 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-burn
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)

A3.1.2.2.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.

$$E = \sum_i (AD_i * C_i)$$

E : NMVOC emissions by the use of car washing and repairing products [t-NMVOC]

AD_i : The production amount of i [t]

C_i : VOC content rate 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 3-50)

Table A 3-50 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%

Source: *Research report on VOC emissions from public sector* (March, 2009, The Institute of Behavioral Science)

● 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. 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 by the number of registered vehicles in FY2005. The consumption of wax and coating material for cars has been showing a downward trend since FY1990. According to Auto-parts & Accessories Retail Association, recently, consumption per vehicle has been decreasing due to a decline in the rate of utilization of car, miniaturization of cars, and the prevalence of car washing machine. Therefore, in consideration of the trend of travel distance per vehicle, the consumption weight of wax and coating material for cars per vehicle in and after FY2006 was estimated by multiplying the average consumption

weight of wax and coating material for car per vehicle for three years (FY2003-2005)⁷ by the growth rate of travel distance per vehicle.

The consumption of other products for cars was also estimated based on the growth rate of travel distance per vehicle.

Table A 3-51 Method of establishing activity data for car washing and repairing products

Fiscal Year	Activity data
1990	The value for FY1991 was used.
1991-1996	Production weight of chemical products for car by type provided in <i>Research report on the current status of auto chemical manufacturing</i> (Japan Auto Chemical Industry Association) was used.
1997, 1998	Estimated by interpolation, using activity data in FY1996 and FY1999.
1999-2005	Production weight of products for cars by type provided in <i>Research report on the current status of auto chemical manufacturing</i> (Japan Auto Chemical Industry Association) was used.
2006-	Estimated by multiplying the consumption of car washing and repairing products per vehicle by the number of registered vehicles (<i>Statistical Yearbook of Motor Vehicle Transport</i>). Consumption of car washing and repairing products per vehicle was estimated by dividing the production weight of products for cars by type by the number of registered vehicles in FY2005, provided in <i>Statistical Yearbook of Motor Vehicle Transport</i> (Ministry of Land, Infrastructure, Transport and Tourism). Consumption of car washing and repairing products in and from FY2006 onward was estimated by multiplying the average of consumption of the products per vehicle for three years (FY2003-2005) by the travel distance per vehicle.

A3.1.2.2.n. Chemicals Manufacture

a) Category Description

This source category provides the methods for estimating NMVOC fugitive 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 each 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 (per activity data) defined by dividing VOC emissions in the *Study on the VOC Emission Inventory* (Ministry of the Environment) by activity data.

$$E = AD * EF$$

E : NMVOC emissions by chemical manufacture [t-NMVOC]

AD : Activity data by source

EF : Emission factor per sales amount of laminating film [t-NMVOC/ t]

The emissions estimated by the equation above include the emissions from chemical tankers

⁷ Three-year average was used since the FY2005 value drastically increased from the previous year.

estimated in A3.1.1.3.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* (Ministry of the Environment) by each activity data shown in Table A 3-58. From FY1990 to FY1999 and FY2001 to FY2004, the emission factor was established as shown in Table A 3-52 - Table A 3-57.

Table A 3-52 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	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	Median value of FY2000 and 2005 was used.
2005-	Established by dividing VOC emissions (estimated figure based on voluntary action plan by Japan Paint Manufacturers Association) by the production amount of paint.

Table A 3-53 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	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	Median value of FY2000 and 2005 was used.
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.

Table A 3-54 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	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	Median value of FY2000 and 2005 was used.
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.

Table A 3-55 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	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	Median value of FY2000 and 2005 was used.
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.

Table A 3-56 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. (*)
2000	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.
2005-	Established by dividing VOC emissions from chemical industry (estimated figure based on voluntary action plan by Japan Chemical Industry Association) by the shipping value of chemical industry-related products.

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 3-57 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	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	Median value of FY2000 and 2005 was used.
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.

● Activity data

The following data indicated in Table A 3-58 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.

$$S_{FYi} = S_{CYi} * 0.75 + S_{CY(i+1)} * 0.25$$

S : Shipping value

FY_i : Fiscal year i

CY_i : Calendar year i

Table A 3-58 Activity data for chemical manufacture

Emission source	Activity data	Source
Paint manufacturing	The production amount of paint	<i>Yearbook of chemical industry</i> , Ministry of Economy, Trade and Industry
Print ink manufacturing	The production amount of print ink	<i>Yearbook of chemical industry</i> , Ministry of Economy, Trade and Industry
Solvent-type adhesive manufacturing	The shipping amount of solvent-type adhesive	<i>Current Survey Report on Adhesive</i> , Japan Adhesive Industry Association
Manufacturing of surface finishing equipment	Used amount of VOCs by manufacturing surface finishing equipment *For FY1990-1999, the value for FY2000 was applied. For FY2001-2004, the average of the values for FY2000 and 2005 was used.	<i>VOC voluntary action plan and achievement report</i> , Ministry of Economy, Trade and Industry
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)”))	<i>Census of manufactures</i> , Ministry of Economy, Trade and Industry
Cellophane manufacturing	The production amount of film-soft chemical products for wrapping.	<i>Yearbook of Paper, Printing, Plastics Products and Rubber Products Statistics</i> , Ministry of Economy, Trade and Industry

A3.1.2.2.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 Japan Association for Hygiene of Chlorinated Solvents data as follows:

Table A 3-59 The method of establishing activity data for the use of removers

Fiscal year	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 <i>Consumption by End-Use</i> by the Japan Association for Hygiene of Chlorinated Solvents

A3.1.2.2.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 VOC emission inventory, the amount of reagents used by substance is multiplied by the emission rate by substance, to estimate emissions.

$$E = AD * EF$$

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 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. The EFs up to 1999 and 2001- 2004 are established as described in the following Table.

Table A 3-60 The method of establishing emission factors for reagent use

Fiscal Year (FY)	The method of establishing emission factor
1990-1999	Emission factor for FY2000 was applied.
2000	EF for reagent use as described in the <i>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)</i>
2001-2004	Estimated by interpolating between 2000 and 2005 EFs.
2005-	EF for reagent use as described in the <i>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)</i>

● Activity Data

The Dichloroethane/Trichloroethylene used for reagents was established based on the VOC inventory by the Ministry of the Environment and the data provided by the Japan Association for Hygiene of Chlorinated Solvents data as follows:

Table A 3-61 The method of establishing activity data for the use of reagents

Fiscal year	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 <i>Consumption by End-Use</i> by the Japan Association for Hygiene of Chlorinated Solvents)
1995-	The Dichloroethane/Trichloroethylene used for reagents in <i>Consumption by End-Use</i> by the Japan Association for Hygiene of Chlorinated Solvents

For other reagents, Dichloroethane used for reagents in *Consumption by End-Use* by the Japan Association for Hygiene of Chlorinated Solvents is multiplied by the ratio of reported substances in the VOC inventory (from the environmental ordinance of Tokyo) that are used as reagents to the amount of Dichloroethane used as reagents, to estimate emissions.

A3.1.2.2.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 was established based on the data provided by the Japan Association for Hygiene of Chlorinated Solvents data as follows:

Table A 3-62 The method of establishing activity data for the use of blowing agents

Fiscal year	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 <i>Consumption by End-Use</i> by the Japan Association for Hygiene of Chlorinated Solvents

A3.1.2.2.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 3-63 The method of establishing activity data for the use of Fishing Net Antifouling Agents

Fiscal year	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 Sources not Required to Report under PRTR, was used.

A3.1.2.2.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 VOC emission inventory, by product quantity totals in the dyeing and finishing processes (excluding wool fabrics).

Table A 3-64 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	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.
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).

- **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.

A3.1.2.2.t. Use of coating solvents

a) Category Description

Emissions occur from solvents used when coating plastic films for special functions (such as antistatic agents, abrasion and scratch resistants, anti-fogging agents, electromagnetic shielding, conductivity imparting agents, UV absorbers)

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 VOC emission inventory by film sales amounts.

Table A 3-65 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 Current Production Statistics: Paper, Printing, Plastics Products and Rubber Products Statistics* (METI) are used.

A3.1.2.2.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 atmospheric emissions of N, N-dimethylformamide from the plastic product manufacturing industry, reported under the PRTR is used as emissions.

- **Emission factors**

No emission factors were established since the activity data is directly the emissions.

- **Activity Data**

The atmospheric emissions of N, N-dimethylformamide from the plastic product manufacturing industry, reported under the PRTR is used as emissions.

Table A 3-66 The method of establishing activity data for the use of synthetic leather solvents

Fiscal year	Method of establishing activity data
1990-2000	Estimated by multiplying FY2001 atmospheric emissions by the ratio to the FY2001 data for consumption of other resin for synthetic leather in the <i>Yearbook of Current Production Statistics: Paper, Printing, Plastic Products and Rubber Products</i> (METI)
2001-	The atmospheric emissions of N, N-dimethylformamide from the plastic product manufacturing industry, reported under the PRTR is used as emissions.

A3.1.2.2.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.

- **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 3-67 The method of establishing activity data for the use of fumigants

Fiscal year	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	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.
2005-	Amount of methyl bromide used for fumigants provided in the domestic shipment amounts by use from the Methyl Bromide Association

A3.1.2.3. Others – Food and beverage industry (2.H.2.) (NMVOCs)**A3.1.2.3.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**

$$E = AD * EF$$

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**

$$E = AD * ABV * EF$$

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 of shochu, whiskey, spirits and liquor, provided in European Environment Agency's *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2009* was basically used. (Table A 3-68 and Table A 3-69)

However, under the alcohol tax in Japan, liquor includes low-alcohol content beverages including shochu-based beverages, chuhai, or newly-marketed alcohol beverages. Therefore, the alcohol content rate of liqueur in Japan was established as 7%⁸.

⁸ According to the *National Health Nutrition Survey* by the Ministry of Health Labour and Welfare, the alcohol content of shochu-based beverages is 7%.

Table A 3-68 Ethyl alcohol content for alcoholic drinks

Alcoholic drinks	Ethyl alcohol content
Shochu (Japanese distilled spirit)	25%
Whiskey	40%
Spirits	40%
Liqueur	7%

Note: Based on *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2009*

Table A 3-69 Emission factors for brewing alcoholic drinks

Alcoholic drinks	Emission factor	Unit
Refined sake	0.08	kg/100L- volume of brewed alcoholic drinks
Synthetic refined sake	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
Liqueur	0.4	kg/100L- volume of brewed ethyl alcohol
Other liquors (including low-malt beer)	0.035	kg/100L-volume of brewed alcoholic drinks

Source: *EMEP/EEA Air Pollutant Emission Inventory Guidebook 2009*, established by using the *Study on the VOC Emission Inventory* by the Ministry of the Environment

● Activity data

For bread, the production amount of various kinds of bread, provided in *Yearbook of rice and wheat processed food production statistics* (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.

A3.1.3 Agriculture

A3.1.3.1. Field burning of agricultural residues (3.F: CO, NO_x)

a) Methodological Issues

● Estimation Method

CO and NO_x emissions were calculated by using the method indicated in the *2006 IPCC Guidelines*, which is the same method as that for CH₄ and N₂O estimation.

$$E = A \times M_B \times C_f \times G_{ef} \times 10^{-3}$$

E : CO and NO_x 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*)

NO_x: 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 CH₄ and N₂O estimation described in “5.7. Field Burning of Agricultural Residues (3.F)”.

A3.1.4 Land Use, Land-Use Change and Forestry

a) Methodological Issues

1) Biomass burning in Forest land (4(V))

- **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 [tC/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 6.16 in Chapter 6.

2) From burning of pruned branches from orchard trees (4(V))

- **Estimation Method**

For CO and NO_x 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:

$$L_{fire} = M_B \times C_f \times G_{ef} \times 10^{-6}$$

L_{fire} : CO and NO_x 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 3-70 Emission factors [t/kt-d.m.]

Category	CO	NO _x
Agricultural residue	92	2.5

Source: *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 6.16 in Chapter 6.

3) Biomass burning in grassland (4(V))

- **Estimation Method**

For CO and NO_x 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 NO_x 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 (Agricultural residue value) described in the *2006 IPCC Guidelines* are used.

Table A 3-71 Emission factors [t/kt-d.m.]

Category	CO	NO _x
Agricultural residue	65	3.9

Source: *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 6.16 in Chapter 6.

A3.1.5 Waste

A3.1.5.1. Incineration and Open Burning of Waste (5.C.)

A3.1.5.1.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 3-72 NO_x and SO_x emission factors for municipal waste incineration by facility type

	Furnace type	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
NO _x	Continuous incinerator	kg-NO _x /t	1.238	1.213	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127
	Semi-continuous incinerator	kg-NO _x /t	1.055	1.226	1.226	1.226	1.226	1.226	1.226	1.226	1.226	1.226	1.226	1.226	1.226	1.226
	Batch type incinerator	kg-NO _x /t	1.137	1.918	1.850	1.850	1.850	1.850	1.850	1.850	1.850	1.850	1.850	1.850	1.850	1.850
	Gasification melting furnace	kg-NO _x /t	1.238	1.213	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127	1.127
SO _x	Continuous incinerator	kg-SO _x /t	0.555	0.539	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361
	Semi-continuous incinerator	kg-SO _x /t	0.627	1.141	0.712	0.712	0.712	0.712	0.712	0.712	0.712	0.712	0.712	0.712	0.712	0.712
	Batch type incinerator	kg-SO _x /t	1.073	1.625	1.714	1.714	1.714	1.714	1.714	1.714	1.714	1.714	1.714	1.714	1.714	1.714
	Gasification melting furnace	kg-SO _x /t	0.555	0.539	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361	0.361

The data for 2000 were used for 2001 and subsequent years.

Source: *General Survey of the Emissions of Air Pollutants* (Ministry of the Environment)

➤ *CO*

For incinerators, the emission factors were established for each incinerator class based on the emission factors for individual facilities summarized in the *Report on Emission Factor Results for Combustion Facilities* (Japan Society for Atmospheric Environment, 1997) 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 3-73 CO emission factors for municipal waste incineration by facility type

	Furnace type	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
CO	Continuous incinerator	g-CO/t	557	557	555	554	554	554	554	553	553	553	553	553	553	553
	Semi-continuous incinerator	g-CO/t	548	548	567	591	613	605	611	609	613	609	614	607	600	600
	Batch type incinerator	g-CO/t	8,237	8,237	8,298	8,341	8,343	8,351	8,270	8,272	8,270	8,274	8,274	8,279	8,281	8,281
	Gasification melting furnace	g-CO/t	567	567	567	567	567	567	567	567	567	567	567	567	567	567

Source: *Report on Emission Factor Results for Combustion Facilities* (Japan Society for Atmospheric Environment, 1997), and others.

➤ NMVOCs

For both incinerators and gasification melting furnaces, NMVOC emission factors were established by multiplying the CH₄ emission factors for each furnace type of each fuel type by “NMVOC/CH₄”, the emission ratio for fuel type. The ratio was determined by using the reference material by Japan Environmental Sanitation Center and Institute of Behavioral Science, which estimated CH₄ and NMVOC emissions per unit calorific value.

Table A 3-74 NMVOC emission factors for municipal waste incineration by facility type

	Furnace type	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
NMVOC	Continuous incinerator	g-NMVOC/t	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
	Semi-continuous incinerator	g-NMVOC/t	7.8	7.8	8.5	2.2	2.4	2.3	2.4	2.3	2.4	2.3	2.4	2.3	2.3	2.3
	Batch type incinerator	g-NMVOC/t	9.1	9.1	9.5	1.5	1.5	1.5	1.3	1.3	1.3	1.3	1.3	1.3	1.3	1.3
	Gasification melting furnace	g-NMVOC/t	-	-	0.6	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8

Source: *Report on Screening Survey Regarding Measures to Counter Global Warming (Atmospheric Management)* (Japan Environmental Sanitation Center, 1989), *Study of Establishment of Methodology for Estimation of Hydrocarbon Emissions* (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) by the Ministry of the Environment. The incineration rate was calculated in the *Waste Treatment in Japan* published by the Ministry of the Environment.

For gasification melting furnaces, the activity data used was the amount incinerated in gasification melting furnaces, calculated from data in the Ministry of the Environment’s “*Waste Treatment in Japan*.”

A3.1.5.1.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 “Waste paper or waste wood”, “Sludge”, “Waste oil”, “Waste plastics”, “Waste textiles”, and “Animal/plant residue, livestock carcasses”. Category [23: Sawn Timber] was used for “Waste paper or waste wood”, “Waste textiles”, and “Animal/plant residues, livestock 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 3-75 NO_x and SO_x emission factors for industrial waste by facility type

	Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
NO _x	Fuel Wood 23*	kg-NO _x /t	1.545	1.312	5.828	5.828	5.828	5.828	5.828	5.828	5.828	5.828	5.828	5.828	5.828	5.828
	Industrial Waste 54*	kg-NO _x /t	0.999	1.158	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415	1.415
SO _x	Fuel Wood 23*	kg-SO _x /t	1.528	1.274	2.118	2.118	2.118	2.118	2.118	2.118	2.118	2.118	2.118	2.118	2.118	2.118
	Industrial Waste 54*	kg-SO _x /t	1.179	1.882	1.352	1.352	1.352	1.352	1.352	1.352	1.352	1.352	1.352	1.352	1.352	1.352

The data for 2000 were used for 2001 and subsequent years.

Source: *General Survey of the Emissions of Air Pollutants* (Ministry of the Environment)

➤ CO

Based on the emission factors for individual facilities summarized in the *Report on Emission Factor Results for Combustion Facilities* (Japan Society for Atmospheric Environment, 1997) as well as other reports, an emission factor was established for each type of industrial solid waste. The six types of industrial waste were “Waste paper or waste wood”, “Sludge”, “Waste oil”, “Waste plastics”, “Waste textiles”, and “Animal/plant residues, livestock carcasses”. The emission factor for “wood waste” was used for “Waste textiles” and “Animal/plant residues, livestock carcasses”, for which there are no measurements. No emission factor was set for the mixed burning of multiple waste types.

Table A 3-76 CO emission factors for industrial waste incinerators by operation type

	Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
CO	Paper/cardboard, wood	g-CO/t	1.334	1.334	1.334	1.334	1.334	1.334	1.334	1.334	1.334	1.334	1.334	1.334	1.334	1.334
	Waste oil	g-CO/t	127	127	127	127	127	127	127	127	127	127	127	127	127	127
	Plastics	g-CO/t	1,790	1,790	1,790	1,790	1,790	1,790	1,790	1,790	1,790	1,790	1,790	1,790	1,790	1,790
	Sludge	g-CO/t	2,285	2,285	2,285	2,285	2,285	2,285	2,285	2,285	2,285	2,285	2,285	2,285	2,285	2,285
	Textile	g-CO/t	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334
	Animal and vegetable residues/ animal carcasses	g-CO/t	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334	1,334

Source: *Report on Emission Factor Results for Combustion Facilities* (Japan Society for Atmospheric Environment, 1997) and others

➤ NMVOCs

NMVOC emission factors were established by multiplying the CH₄ emission factors for each furnace type of each fuel type by “NMVOC/CH₄”, the emission ratio for fuel type. The ratio was determined by using the reference materials by Japan Environmental Sanitation Center and Institute of Behavioral Science, which estimated CH₄ and NMVOC emissions per unit calorific value.

Table A 3-77 NMVOC emission factors for industrial waste incineration by facility type

	Item	Unit	1990	1995	2000	2005	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
NMVOC	Paper/cardboard, wood	g-NMVOC/t	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48
	Waste oil	g-NMVOC/t	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
	Plastics	g-NMVOC/t	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40	3.40
	Sludge	g-NMVOC/t	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61	1.61
	Textile	g-NMVOC/t	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48
	Animal and vegetable residues/ animal carcasses	g-NMVOC/t	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48	2.48

Source: *Report on Screening Survey Regarding Measures to Counter Global Warming (Atmospheric Management)* (Japan Environmental Sanitation Center, 1989), *Study of Establishment of Methodology for Estimation of Hydrocarbon Emissions* (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) and the *Waste Treatment in Japan* published by the Ministry of the Environment.

A3.1.5.1.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 "A3.1.5.1.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*, Ministry of the Environment" 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.

A3.1.5.1.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 1A Stationary Sources, to weight-based emission factors by multiplying the calorific values in the *General Energy Statistics*.

Table A 3-78 CO emission factors from incineration in conjunction with use of waste as fuel and raw material

Application	Units	Waste oil	RDF	RPF	Waste tires (FY2004 and before)	Waste tires (FY2005 and after)	Plastics	Plastics (Liquefaction)	Wood
Simple incineration	kg-CO/t	0.13	1.79	1.79	1.79	1.79	-	-	-
Boilers	kg-CO/t	0.052	0.24	0.39	0.28	0.44	0.39	0.034	3.64
Cement kilns	kg-CO/t	-	19.8	32.2	23.0	36.5	32.2	-	-
Other furnaces	kg-CO/t	0.052	0.24	0.39	0.28	0.44	-	-	-
Pyrolysis furnaces	kg-CO/t	-	-	-	0.021	0.033	-	-	-
Gasification	kg-CO/t	-	-	-	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 CH₄ and NMVOCs per unit calorific values.

Table A 3-79 NMVOC emissions factors from incineration in conjunction with use of waste as fuel and raw material

Application	Units	Waste oil	RDF	RPF	Waste tires (FY2004 and before)	Waste tires (FY2005 and after)	Plastics	Plastics (Liquefaction)	Wood
Boilers	kg-NMVOC/t	0.015	0.00027	0.00043	0.00031	0.00049	0.00043	0.010	0.12
Cement kilns	kg-NMVOC/t	-	-	0.043	0.031	0.049	0.043	-	-
Pyrolysis furnaces	kg-NMVOC/t	-	-	-	0.0051	0.0080	-	-	-
Gasification	kg-NMVOC/t	-	-	-	0.0187	0.0297	-	-	-

● Activity data

Same activity data that were used when estimating CH₄ emissions for the use of waste as fuel and raw material were used.

A3.1.6 Other sectors

A3.1.6.1. Smoking (6.-: CO)

● Estimation Method

CO emissions were calculated by multiplying the amount of cigarette sales by Japan's country-specific emission factor.

● Emission factors

The emission factor (0.055 [g-CO/cigarette]) was provided by Japan Tobacco Inc.

● Activity data

The amount of cigarette sales published on Tobacco Institute of Japan website (<http://www.tioj.or.jp/>) was used for activity data.

References

1. IPCC, *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories*, 1997.
2. IPCC, *Good Practice Guidance and Uncertainty Management in national Greenhouse Gas Inventories*, 2000.
3. IPCC, *Good Practice Guidance for Land Use, Land Use Change and Forestry*, 2003.
4. IPCC, *2006 IPCC Guidelines for National Greenhouse Gas Inventories*, 2006.
5. European Environment Agency, *EMEP/EEA Air Pollutant Emission Inventory Guidebook*.
6. Agency for Natural Resources and Energy, *General Energy Statistics*.
7. Agency for Natural Resources and Energy, *Study on the total system for prevention of HC-Vapor in petroleum industries*, 1975.
8. Agency for Natural Resources and Energy, *Current Survey of Production Concerning Gas Industry*.
9. Ministry of Economy, Trade and Industry, *Statistics of Rubber Products*.
10. Ministry of Economy, Trade and Industry, *Yearbook of Chemical Industries Statistics*.
11. Ministry of Economy, Trade and Industry, *Production, Supply and Demand of Petroleum, Coal and Coke*.
12. Ministry of Economy, Trade and Industry, *Yearbook of Mineral Resources and Petroleum Products Statistics*.
13. Ministry of Economy, Trade and Industry, *Yearbook of Current Production Statistics*.
14. Ministry of Economy, Trade and Industry, *Yearbook of Current Production Statistics: Paper, Printing, Plastics Products and Rubber Products Statistics*.
15. Ministry of Economy, Trade and Industry, *Yearbook of Current Production Statistics: Textiles and Consumer Goods Statistics*.
16. Ministry of Economy, Trade and Industry, *VOC Voluntary Action Plan and Achievement Report*
17. Ministry of Economy, Trade and Industry, *Census of Manufactures*.
18. Ministry of Economy, Trade and Industry and Ministry of the Environment, *Compilation Results of Emissions and Transfers Reported under PRTR by Chemical Substance*.
19. Ministry of Economy, Trade and Industry and Ministry of the Environment, *Estimation Methods for Releases from Sources not Required to Report under PRTR (Pollutant Release and Transfer Register)*, 2012.
20. Ministry of Land, Infrastructure, Transport and Tourism, *Statistical Yearbook of Air Transport*.
21. Ministry of Land, Infrastructure, Transport and Tourism, *Statistical Yearbook of Motor Vehicle Transport*.
22. Ministry of Land, Infrastructure, Transport and Tourism, *Statistical Yearbook of Port*.
23. Ministry of Agriculture, Forestry and Fisheries, *Yearbook of Current Production Statistics of Processed Rice and Wheat Foods*.
24. National Tax Agency, *Liquor Production and Stocks*.
25. Ministry of the Environment, *The National Emission Inventory for Volatile Organic Compounds (VOC)*.
26. Ministry of the Environment, *Report of the Research on the State of Wide-range Movement and*

- Cyclical Use of Wastes (the Volume on Cyclical Use).*
27. Ministry of the Environment, *Report on Survey of Organizations in Industrial Waste Administration.*
 28. Ministry of the Environment, *General Survey of the Emissions of Air Pollutants.*
 29. Ministry of the Environment, *Survey for Consideration Estimation of Emission Factors and Total Emissions of Exhaust Gas from Automobiles.*
 30. Ministry of the Environment, *Development Research of New Testing Methodology for Emission Gas from Vehicle (Off-road vehicle), FY2003.*
 31. Ministry of the Environment, *Development Research of New Testing Methodology for Emission Gas from Vehicle (Motorcycle), FY2002.*
 32. Ministry of the Environment, *Waste Treatment in Japan.*
 33. Environmental Agency, Air Quality Management Bureau, *Report of Research on Measures for Emission Sources of Small Facilities, 1996.*
 34. Japan Meteorological Agency, *Weather Statistics Information.*
 35. Ministry of Health, Labour and Welfare, *The Survey on Usage of Dry-cleaning Solvent.*
 36. National Institute for Environmental Studies, *Survey of Actual Use of Methyl Bromide, 1998.*
 37. Energy Data and Modeling Center, *Handbook of Energy & Economic Statistics in Japan*
 38. Institute of Behavioral Science, *Study of Establishment of Methodology for Estimation of Hydrocarbon Emissions, 1984.*
 39. Institute of Behavioral Science, *Basic Study on HC Sources, 1987.*
 40. Institute of Behavioral Science, *Report of the Research on the Indirect Greenhouse Gas Emission Inventory in FY1996, 1997.*
 41. Institute of Behavioral Sciences *Business Report on Grid Database on Atmospheric Pollutants Emissions, 2000.*
 42. Institute of Behavioral Science, *Research Report on VOC emissions from private sector, March 2010.*
 43. Japan Adhesive Industry Association, *Current Survey Report on Adhesive.*
 44. Japan Environmental Sanitation Center, *Report on Screening Survey Regarding Measures to Counter Global Warming (Atmospheric Management), 1989.*
 45. Japan Society for Atmospheric Environment, *Report on Emission Factor Results for Combustion Facilities, 1997.*
 46. Tobacco Institute of Japan website. (<http://www.tioj.or.jp/>)
 47. Environmental Research and Control Center, *Regulation of Total NO_x Emission Manual (New Edition), 2000.*
 48. Automobile Inspection and Registration Information Association, *Statistics of AIRIA/ Number of Motor Vehicle*
 49. Ocean Policy Research Foundation, *Survey Report on influence of VOC emissions from vessels in FY2005, March 2006.*
 50. Ocean Policy Research Foundation, *Report on Estimation of Improvement of Air Environment, 2003.*

51. Sekiyu Tsushinsha, *Sekiyu shiryō*
52. Japan Industrial Conference on Cleaning (JICC), *Commission report on manual for promoting voluntary approach for emission control of VOC in FY2005*
53. Voluntary action plan of Petroleum Association of Japan
54. Voluntary action plan of The Japan Gas Association
55. Japan Natural Gas Association, *Natural Gas Data Year Book*
56. Voluntary action plan of Japan Natural Gas Association
57. Japan Paint Manufacturers Association, *Summary of estimation for the current status of VOC emissions from painting*
58. Fuji Keizai CO., Ltd, *Cosmetic Products Marketing Directory*
59. Japan Auto Chemical Industry Association, *Research report on the current status of auto chemical manufacturing*
60. Yokota, Ueno, Ishii, Utida, and Akiyama, *Volatile organic compound losses during refueling of passenger cars*, Journal of Japan Society for Atmospheric Environment, Vol.47, No.5, pp.231-239, 2012.
61. Petroleum Association of Japan, *Petroleum Industry in Japan 2015*, 2015.
62. Petroleum Association of Japan, *Oil Product Sales Summary by Prefecture*.
63. Japan Cleaning Chemicals Association, *Shipping Weight of Solvents*.
64. Aerosols Industry Association of Japan, *Survey of Production Amounts of Aerosols*.
65. Ministry of Economy, Trade and Industry, *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)*.
66. Automobile Inspection and Registration Information Association (AIRIA), *Statistics of AIRIA/ Number of Motor Vehicles*
67. Japan Automobile Manufacturers Association, *Monthly Report Statistics of Vehicles*
68. Japan Automobile Manufacturers Association, *Survey of Motorcycle Market Trends*
69. United States Environmental Protection Agency, *Compilation of Air Pollutant Emission Factors (AP-42)*, Volume 1, 4th Edition, 1985.

Annex 4. The National Energy Balance for the Most Recent Inventory Year

A4.1. 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 and the IEA statistics is hereby updated with the FY2016 actual data. The IEA statistical data used in the explanation were extracted from the *World Energy Statistics*, 2018 Edition, OECD/IEA (CD-ROM version).

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 residual 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 mm²/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 mm²/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 mm²/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 revised 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 4-1 Exports of jet kerosene in FY2016 (reference)

CRF Table 1.A(b)	IEA statistics
Exports: $10,946.89 \times 10^3$ kl	Exports: $2,697.40 \times 10^3$ t [$3,442.46 \times 10^3$ kl (exports excluding bonded exports) $\times 0.7834$ t/kl (density) = $2,697 \times 10^3$ t]
<Breakdown> Exports excluding bonded exports: $3,442.46 \times 10^3$ kl	<Remarks 1> International aviation: $6,314 \times 10^3$ t [$7,504.43 \times 10^3$ kl (bonded exports) + 555.61×10^3 kl (bonded imports) = $8,060.04 \times 10^3$ kl; $8,060.04 \times 10^3$ kl $\times 0.7834$ t/kl (density) = $6,314 \times 10^3$ t]
Bonded exports: $7,504.43 \times 10^3$ kl	

<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 4-2 Exports of residual fuel oil in FY2016 (reference)

CRF Table 1.A(b)	IEA statistics
Exports: $9,007.05 \times 10^3$ kl [$1,041.55 \times 10^3$ kl (fuel oil A) + $7,965.50 \times 10^3$ kl (fuel oils B and C) = $9,007.05 \times 10^3$ kl] <Breakdown> Exports of fuel oil A: $1,041.55 \times 10^3$ kl Exports excluding bonded exports: 848.89×10^3 kl Bonded exports: 192.66×10^3 kl Exports of fuel oils B and C: $7,965.50 \times 10^3$ kl Exports excluding bonded exports: $3,405.36 \times 10^3$ kl Bonded exports: $4,560.14 \times 10^3$ kl	Exports: $3,065 \times 10^3$ t [$3,406 \times 10^3$ kl (exports of fuel oils B and C excluding bonded exports) $\times 0.9$ t/kl (density) = $3,065 \times 10^3$ t] <Remarks> International marine bunkers: $4,150 \times 10^3$ t [$4,560.14 \times 10^3$ kl (bonded exports of fuel oils B and C) + 51.26×10^3 kl (bonded imports of fuel oils B and C) = $4,611.41 \times 10^3$ kl; $4,611.41 \times 10^3$ kl $\times 0.9$ t/kl (density) = $4,150 \times 10^3$ 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.) The bonded imports and exports of FY2016 in the CRF tables were corrected in this submission, as the figures of FY2015 have been reported as the figures of FY2016 in the previous submission. Although the bonded imports in FY2016 was 555.61×10^3 kl at the time of reporting to IEA, it was revised to 605.68×10^3 kl due to the update of the primary statistics. The revised value was reported to IEA.

Table A 4-3 Imports of jet kerosene in FY2016 (reference)

CRF Table 1.A(b)	IEA statistics
Imports (original): $7,984.01 \times 10^3$ kl Imports (corrected): $8,337.95 \times 10^3$ kl <Breakdown> Imports excluding bonded imports: 227.84×10^3 kl Bonded imports (original): 471.35×10^3 kl Bonded exports (original): $7,284.83 \times 10^3$ kl Bonded imports (corrected): 605.68×10^3 kl Bonded exports (corrected): $7,504.43 \times 10^3$ kl	Imports: 614×10^3 t [227.84×10^3 kl (imports excluding bonded imports) + 555.61×10^3 kl (bonded imports) = 783.44×10^3 kl. 783.44×10^3 kl (imports including bonded imports) $\times 0.7834$ t/kl (density) = 614×10^3 t] <Remarks> Although this value appears in <i>World Energy Statistics</i> 2018 Edition, the latest value of the imports of jet kerosene in FY2016 is 652×10^3 t, because the bonded imports of the primary statistics was revised to 605.68×10^3 kl. It will be reflected in 2019 Edition.

<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. The bonded imports and exports of FY2016 in the CRF tables were corrected in this submission, as the figures of FY2015 have been reported as the figures of FY2016 in the previous submission.

Table A 4-4 Imports of gas/diesel oil in FY2016 (reference)

CRF Table 1.A(b)	IEA statistics
Imports (original): 458.30×10^3 kl Imports (corrected): 461.36×10^3 kl	Imports: 398×10^3 t [431.49×10^3 kl (imports of gas/diesel oil excluding bonded imports) + 12.07×10^3 kl (bonded imports of gas/diesel oil) + 30.00×10^3 kl (imports of fuel oil A excluding bonded imports) + 0 kl (bonded imports of fuel oil A) = 473.00×10^3 kl; 473.00×10^3 kl \times 0.843 t/kl (density) = 398×10^3 t]
<Imports of gas/diesel oil> Imports excluding bonded imports: 431.49×10^3 kl Bonded imports (original): 0.00×10^3 kl Bonded exports (original): 26.82×10^3 kl Bonded imports (corrected): 12.07×10^3 kl Bonded exports (corrected): 17.80×10^3 kl	<Remarks> The figure (399×10^3 t) for imports of gas/diesel oil reported to the IEA as data for <i>World Energy Statistics</i> (2018 edition) has contained biodiesel erroneously. However, the correct value (the above-mentioned value) has already been reported to the IEA.

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 4-5 Imports of coking coal in FY2016 (reference)

CRF Table 1.A(b)	IEA statistics
Imports: $48,293.40 \times 10^3$ t	Imports: $48,294 \times 10^3$ t
<Remarks> The simple sum of coking coal and pulverized coal injection (PCI) coal is reported in the CRF. Coking coal: $48,293.40 \times 10^3$ t PCI coal: 0×10^3 t	<Remarks> The figure in the IEA statistics is also the simple sum of coking coal and PCI coal. The decimals are rounded up in the IEA statistics.

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 4-6 Changes in crude oil stock in FY2016 (reference)

CRF Table 1.A(b)	IEA statistics
Stock changes: $-1,149.01 \times 10^3$ kl	Stock changes: $1,546 \times 10^3$ t

<Explanation 2: Changes in NGL stock>

Stock changes concerning NGL in FY2016 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 figures for “stock changes” required by the CRF tables are not included in the MOS. On the other hand, 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 FY2016.

<Explanation 3: Changes in gasoline stock>

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.

Table A 4-7 Changes in gasoline stock in FY2016 (reference)

CRF Table 1.A(b)	IEA statistics
Stock changes: 22.88×10^3 kl	Stock changes in motor gasoline: -19×10^3 t <Remarks 1> The values relating to the stock of motor gasoline in the IEA statistics are changes of gasoline stock plus national stockpile minus other gasoline stock. <Remarks 2> The difference is calculated from the amount which is rounded off to whole after multiplying the stock volume at the end of fiscal year by density. Therefore, it sometimes slightly differs from the result which is obtained by multiplying the total changes by density.

<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 4-8 Changes in jet kerosene stock in FY2016 (reference)

CRF Table 1.A(b)	IEA statistics
Stock changes: -4.18×10^3 kl (final figure)	Stock changes: 3×10^3 t [4.18×10^3 kl \times 0.7834 t/kl (density) = 3×10^3 t] <Remarks> The difference is calculated from the amount which is rounded off to whole after multiplying the stock volume at the end of fiscal year by density. Therefore, it sometimes slightly differs from the result which is obtained by multiplying the total changes by density.

<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 4-9 Changes in kerosene stock in FY2016 (reference)

CRF Table 1.A(b)	IEA statistics
Stock changes: -128.94×10^3 kl	Stock changes: 105×10^3 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 4-10 Changes in gas/diesel oil stock in FY2016 (reference)

CRF Table 1.A(b)	IEA statistics
Stock changes: 135.44×10^3 kl	Stock changes: -197×10^3 t <Remarks 1> The figures for changes of gas/diesel oil stock reported to the IEA were the difference between the stock at the beginning of the current fiscal year and the stock at the beginning of the next fiscal year. The figures for changes of gas/diesel oil stock reported in the CRF tables were the difference between the stock at the end of the previous fiscal year and the stock at the end of the current fiscal year. Therefore, the figures in the IEA statistics sometimes slightly differ from the figures in the CRF tables even for the stock changes of gas/diesel oil only. <Remarks 2> The difference is calculated from the amount which is rounded off to whole after multiplying the stock volume at the end of fiscal year by density. Therefore, it sometimes slightly differs from the result which is obtained by multiplying the total changes by density.

<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 4-11 Changes in residual fuel oil stock in FY2016 (reference)

CRF Table 1.A(b)	IEA statistics
Stock changes: 13.50×10^3 kl <Breakdown> Stock changes in fuel oil A: 48.53×10^3 kl Stock changes in fuel oil C: -35.04×10^3 kl	Stock changes: 31×10^3 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 4-12 Changes in LPG stock in FY2016 (reference)

CRF Table 1.A(b)	IEA statistics
Stock changes: -253.2×10^3 t	Stock changes: 56×10^3 t

<Explanation 9: Changes in naphtha stock>

The figures for changes in naphtha stock reported in the CRF tables are basically the same as the figures in the IEA statistics.

Table A 4-13 Changes in naphtha stock in FY2016 (reference)

CRF Table 1.A(b)	IEA statistics
Stock changes: -323.43×10^3 kl (final figure)	Stock changes: 238×10^3 t (preliminary figures) [323.00×10^3 kl \times 0.737 t/kl (density) = 238×10^3 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 4-14 Changes in bitumen stock in FY2016 (reference)

CRF Table 1.A(b)	IEA statistics
Stock changes: -29.07×10^3 t <Breakdown> Asphalt: -30.49×10^3 t Stock at the end of March 2016: 223.60×10^3 t (final figure) Stock at the end of March 2017: 193.11×10^3 t Grease: 0.46×10^3 t Paraffin: 0.96×10^3 t	Stock changes in bitumen: 31×10^3 t <Breakdown> Asphalt: 31×10^3 t Stock at the end of March 2016: 223.60×10^3 t (preliminary figures) Stock at the end of March 2017: 193.11×10^3 t <Remarks 1> The figures for grease and paraffin were reported under bitumen in the CRF tables, while they were reported under paraffin waxes in the IEA statistics.

<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 4-15 Changes in lubricants stock in FY2016 (reference)

CRF Table 1.A(b)	IEA statistics
Stock changes: 7.12×10^3 kl (final figure)	Stock changes: -7×10^3 t (preliminary figures) [-7.00×10^3 kl \times 0.891 t/kl (density) = -6×10^3 t] <Remarks> The decimals are rounded up in the IEA statistics.

<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 4-16 Changes in petroleum coke stock in FY2016 (reference)

CRF Table 1.A(b)	IEA statistics
Stock changes: 1.05×10^3 t	Stock changes: -1×10^3 t <Remarks> In the IEA statistics, the stock changes (or the differences) are calculated after the stock amount is rounded off.

<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 the 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 4-17 Changes in refinery feedstock stock in FY2016 (reference)

CRF Table 1.A(b)	IEA statistics
Stock changes: 57.41×10^3 kl	Stock changes: -71×10^3 t
<Breakdown>	<Breakdown>
Slack gasoline: -150.33×10^3 kl	Slack gasoline: -150×10^3 kl
Slack kerosene: 26.63×10^3 kl	Slack kerosene: 27×10^3 kl
Slack diesel oil or gas oil: 57.12×10^3 kl	Slack diesel oil or gas oil: 57×10^3 kl
Slack fuel oil: 113.61×10^3 kl	Slack fuel oil: 114×10^3 kl
Slack lubricant: 10.39×10^3 kl	Slack lubricant: 10×10^3 kl
	Slack wax: -2×10^3 kl
	Slack coke: 1×10^3 kl
	Each of the above figures is multiplied by its density for conversion to weight for reporting purposes.

<Explanation 14: Changes in natural gas stock>

The figures for changes in natural gas stock (imported LNG and domestic natural gas) reported in the CRF tables were different from those in the IEA statistics mainly 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 source figures for imported LNG were the statistical data in the CRF tables and the estimated data in the IEA statistics. The figures for stock changes reported to the IEA were the difference between the stock of imported LNG at the end of the previous year and the stock at the end of the current 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 current year. One reason for reporting the estimated data to IEA is that the Japanese statistics may not catch whole stocks. Another reason is continuity and consistency, as the data have been estimated in this way for over twenty years.

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 4-18 Changes in natural gas stock in FY2016 (reference)

CRF Table 1.A(b)	IEA statistics
Stock changes: 90 TJ (GCV)	Stock changes: 1,395 TJ (GCV)

A4.2. General Energy Statistics

A4.2.1. 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.

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 [\$0100¹], 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:

http://www.enecho.meti.go.jp/statistics/total_energy/results.html#headline2

The following is the energy balance simplified table (Table A 4-19 –Table A 4-22).

¹ Code number of the *General Energy Statistics* (Energy Balance Table)

Table A 4-19 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	2,026,426	2,056,326	0	265,253	8,185,19	0	317,978	1,883,500	0	0	19,667,485	18,065,096	1,602,388
#02	Indigenously Produced	193,762	0	24,484	0	89,203	0	264,134	8,185,19	0	317,978	1,883,500	0	0	3,591,581	0	0
#03	Import	3,161,715	15,352	9,139,187	2,341,168	1,967,475	0	1,119	0	0	0	0	0	0	16,626,016	0	0
#04	Total Primary Energy Supply	3,355,476	15,352	9,163,671	2,341,168	2,056,678	0	265,254	8,185,19	0	317,978	1,883,500	0	0	20,217,596	18,615,208	1,602,388
#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) (Demand)	3,357,112	-39,341	8,981,710	2,026,426	2,056,326	0	265,253	8,185,19	0	317,978	1,883,500	0	0	19,667,485	18,065,096	1,602,388
#08	Energy Transformation & Own Use	-3,151,561	1,278,447	-8,961,984	5,499,143	-1,980,245	510,901	-210,804	-8,185,19	0	-317,978	-1,883,500	2,785,371	1,017,851	-6,232,880	-6,170,658	-62,222
#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	8,125,199	5,121	0	0	0	0	0	0	0	-94,149	-36,882	0	-36,882
#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	-432,338	-4,367	-27,139	-87,643	-65,995	0	-170,247	-997	407,088	0	-676,431	-676,431	0
#14	Auto Steam Generation	-147,046	-135,509	0	-640,435	-4,241	-61,907	-109,183	0	0	-145,775	0	0	1,106,351	-137,745	-137,745	0
#15	District Heat Supply	-824	0	0	-2,592	0	-6,169	-37	0	0	-1,511	0	-1,229	8,445	-3,916	-3,916	0
#16	Own Use and Loss	-3,015	-161,697	-1,017	-319,060	-238	-20,889	0	0	0	0	-299,854	-2,796	-808,566	-808,566	0	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	610,760	18,443	967	7,398	0	0	0	0	32,051	-3,906	502,201	428,368	73,832
#19	Final Energy Consumption	401,151	1,226,745	0	7,525,569	57,638	510,901	54,449	0	0	0	2,753,319	1,021,756	13,551,529	12,011,363	1,540,166	0
#20	Industry	401,119	1,223,865	0	3,918,348	57,638	167,823	7,398	0	0	0	2,036,799	1,020,472	8,833,463	7,334,048	1,499,414	0
#21	Agriculture, Fishery, Mining and Construction	133	5,090	0	676,135	1,753	2,182	0	0	0	0	82,174	2,276	769,744	538,526	231,218	0
#22	Manufacturing	400,852	1,218,775	0	2,186,936	55,885	100,469	0	0	0	0	0	1,453,695	935,052	6,351,664	5,157,299	1,194,364
#23	Food, Beverages, Tobacco and Feed	48	0	0	52,839	0	8,102	0	0	0	0	0	55,667	49,454	166,110	166,110	0
#24	Textile Mill Products	544	0	0	50,419	0	4,699	0	0	0	0	0	70,615	92,180	218,458	218,458	0
#25	Pulp, Paper and Paper Products	126	0	0	31,978	2	4,731	0	0	0	0	0	130,637	274,119	441,594	441,594	0
#26	Chemical and Allied Products, Oil and Coal Products	6,633	46,779	0	1,458,711	25,021	9,582	0	0	0	0	0	209,979	234,151	1,990,956	809,905	1,180,951
#27	Ceramic, Stone and Clay Products	236,521	37,016	0	202,373	854	13,546	0	0	0	0	0	110,399	42,437	643,147	630,418	12,728
#28	Iron and Steel	140,959	1,109,711	0	126,609	24,987	11,084	0	0	0	0	271,771	110,581	1,795,703	1,795,703	0	685
#29	Non-Ferrous Metals	15,811	11,378	0	56,323	322	9,162	0	0	0	0	0	61,575	17,411	171,982	171,982	0
#30	Machinery	15	13,891	0	170,765	4,698	33,072	0	0	0	0	0	395,851	76,719	695,011	695,011	0
#31	Miscellaneous	194	0	0	36,918	0	6,489	0	0	0	0	0	147,202	38,000	228,803	228,803	0
#32	Commercial Industry	133	0	0	1,055,278	0	65,172	7,398	0	0	0	0	500,931	83,144	1,712,055	1,638,223	73,832
#33	Residential	0	2,880	0	606,330	0	343,074	47,051	0	0	0	0	656,006	1,284	1,656,625	1,656,625	0
#34	Transportation	33	0	0	3,000,891	0	3	0	0	0	0	0	60,514	0	3,061,441	3,020,689	40,752
#35	Passenger	33	0	0	1,513,029	0	1	0	0	0	0	0	56,610	0	1,569,672	1,537,748	31,923
#36	Freight	0	0	0	1,487,862	0	3	0	0	0	0	0	3,905	0	1,491,770	1,482,941	8,829
#37	Non-energy and Feedstock Use	6,063	26,437	0	1,493,632	13,997	38	0	0	0	0	0	0	0	1,540,166	0	1,540,166

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	1,642,489	2,477,257	0	270,876	728,509	0	380,411	2,693,458	0	0	21,993,285	20,191,531	1,801,754
#02	Indigenously Produced	153,374	0	32,455	0	95,250	0	268,391	728,509	0	380,411	2,693,458	0	0	4,351,848	0	0
#03	Import	3,575,648	18,016	10,171,504	2,226,378	2,382,172	0	2,491	0	0	0	0	0	0	18,376,210	0	0
#04	Total Primary Energy Supply	3,729,022	18,016	10,203,959	2,226,378	2,477,422	0	270,882	728,509	0	380,411	2,693,458	0	0	22,728,057	20,926,303	1,801,754
#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) (Demand)	3,725,382	-91,908	10,166,812	1,642,489	2,477,257	0	270,876	728,509	0	380,411	2,693,458	0	0	21,993,285	20,191,531	1,801,754
#08	Energy Transformation & Own Use	-3,316,691	1,148,397	-10,063,320	6,946,884	-2,418,050	685,997	-224,089	-728,509	0	-380,411	-2,693,458	3,146,437	1,055,422	-6,841,391	-6,776,339	-65,052
#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	9,417,456	5,773	0	0	0	0	0	0	0	-103,260	-55,781	0	-55,781
#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	-439,103	-5,482	-45,424	-97,713	-61,110	0	-202,462	-1,523	440,632	0	-733,124	-733,124	0
#14	Auto Steam Generation	-160,158	-127,828	-669	-672,325	-4,887	-98,261	-99,257	0	0	-174,443	0	0	1,145,849	-191,980	-191,980	0
#15	District Heat Supply	-638	0	0	-1,601	0	-11,101	-99	0	0	-3,505	0	-2,548	15,985	-3,507	-3,507	0
#16	Own Use and Loss	-2,978	-139,799	-1,058	-322,242	-86	-19,128	0	0	0	0	0	-345,686	-3,152	-834,129	-834,129	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	597,548	991	1,724	6,146	0	0	0	0	8,298	-32,390	640,318	561,034	79,283
#19	Final Energy Consumption	454,606	1,056,064	0	8,589,373	58,216	685,997	46,786	0	0	0	0	3,138,139	1,087,812	15,116,994	13,380,291	1,736,703
#20	Industry	454,575	1,054,427	0	4,287,233	58,216	286,618	6,182	0	0	0	0	2,252,156	1,086,444	9,485,851	7,781,649	1,704,203
#21	Agriculture, Fishery, Mining and Construction	82	1,590	0	632,231	1,571	2,963	0	0	0	0	0	80,014	1,944	720,394	511,426	208,969
#22	Manufacturing	454,325	1,052,837	0	2,523,618	56,645	160,422	36	0	0	0	0	1,407,034	969,692	6,624,609	5,208,658	1,415,951
#23	Food, Beverages, Tobacco and Feed	82	0	0	63,040	0	14,756	0	0	0	0	0	65,040	70,106	213,026	213,026	0
#24	Textile Mill Products	823	0	0	46,240	14	6,320	0	0	0	0	0	64,732	92,448	210,577	210,577	0
#25	Pulp, Paper and Paper Products	0	0	0	35,616	5	10,330	36	0	0	0	0	132,158	274,405	452,551	452,551	0
#26	Chemical and Allied Products, Oil and Coal Products	6,103	31,971	0	1,779,418	21,427	16,674	0	0	0	0	0	210,028	248,201	2,313,821	913,726	1,400,096
#27	Ceramic, Stone and Clay Products	236,215	34,354	0	216,059	1,758	15,743	0	0	0	0	0	104,388</				

Table A 4-20 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	4,202,973	-3,821	9,634,832	1,528,928	3,058,878	0	273,741	745,903	0	409,621	2,858,092	0	0	22,709,148	20,834,599	1,874,549
#02	Indigenously Produced	66,683	0	28,034	0	106,340	0	269,008	745,903	0	409,621	2,858,092	0	0	4,483,681	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	4,206,057	76,219	9,761,337	2,252,207	3,058,742	0	273,741	745,903	0	409,621	2,858,092	0	0	23,641,932	21,767,383	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) (Demand)	4,202,973	-3,821	9,634,832	1,528,928	3,058,878	0	273,741	745,903	0	409,621	2,858,092	0	0	22,709,148	20,834,599	1,874,549
#08	Energy Transformation & Own Use	-3,705,208	1,114,629	-9,622,842	7,212,868	-3,022,830	806,834	-223,793	-745,903	0	-403,364	-2,858,092	3,414,136	1,158,623	-6,874,942	-6,769,391	-105,551
#09	Manufacture of Coal Products (+/- output/-)	-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	9,412,940	6,972	0	0	0	0	0	0	0	-137,327	-48,474	0	-48,474
#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	-27,668	-679,439	0	-2,851,772	3,320,803	0	-4,948,477	-4,948,477	0	0
#13	Auto Power Generation	-222,305	-114,011	-83	-431,572	-9,034	-71,592	-99,374	-66,464	0	-178,038	-6,320	457,666	0	-741,126	-741,126	0
#14	Auto Steam Generation	-198,902	-69,828	-135	-673,602	-7,845	-120,034	-96,581	0	0	-220,572	0	1,276,604	0	-118,895	-118,895	0
#15	District Heat Supply	-708	0	0	-1,692	0	-1,455	-116	0	0	-4,755	0	-3,940	22,910	-2,817	-2,817	0
#16	Own Use and Loss	-4,240	-132,502	-518	-335,337	-519	-13,139	0	0	0	0	0	-360,392	-3,564	-850,210	-850,210	0
#17	Transformation and Consumption Stockpile Change (+/- withdrawal/- build-up)	-27,422	-4,989	10,199	3,549	-5,414	0	-22	0	1	0	0	0	0	-24,098	0	-24,098
#18	Statistical Discrepancy (+/- excess/- shortage)	75,778	60,164	11,990	579,916	-14,343	1,900	4,904	0	0	0	0	-87,507	-65,597	567,206	492,144	75,062
#19	Final Energy Consumption	421,987	1,050,644	0	8,741,796	50,391	806,834	49,948	0	0	6,256	0	3,501,643	1,224,220	15,853,720	14,084,722	1,768,998
#20	Industry	421,941	1,050,644	0	4,217,503	50,391	386,796	17,046	0	0	6,256	0	2,534,187	1,222,914	9,907,679	8,172,843	1,734,835
#21	Agriculture, Fishery, Mining and Construction	47	1,744	0	553,302	1,930	2,959	0	0	0	0	0	75,110	1,530	636,622	470,277	166,345
#22	Manufacturing	421,754	1,048,900	0	2,490,337	48,461	178,337	12,142	0	0	6,256	0	1,442,530	1,076,657	6,725,374	5,231,946	1,493,428
#23	Food, Beverages, Tobacco and Feed	34	0	0	66,924	0	21,171	0	0	0	0	0	76,030	79,504	243,663	243,663	0
#24	Textile Mill Products	257	0	0	34,638	1	5,888	0	0	0	0	0	56,856	79,810	177,420	177,420	0
#25	Pulp, Paper and Paper Products	0	0	0	26,149	71	8,250	12,142	0	0	0	0	140,751	287,154	474,517	474,517	0
#26	Chemical and Allied Products, Oil and Coal Products	556	36,239	0	1,872,199	23,397	22,408	0	0	0	0	0	212,850	352,672	2,520,320	1,028,207	1,492,113
#27	Ceramic, Stone and Clay Products	185,818	24,256	0	171,471	1,681	19,036	0	0	0	6,235	0	96,439	33,996	538,932	537,768	1,164
#28	Iron and Steel	230,744	973,938	0	109,345	22,154	36,208	0	0	0	0	0	261,843	109,404	1,743,636	1,743,484	152
#29	Non-Ferrous Metals	4,209	10,185	0	49,559	238	14,836	0	0	0	19	0	57,029	23,072	159,147	159,147	0
#30	Machinery	0	4,282	0	123,449	919	37,437	0	0	0	2	0	389,555	65,343	620,985	620,985	0
#31	Miscellaneous	137	0	0	36,602	0	13,133	0	0	0	0	0	151,177	45,703	246,753	246,753	0
#32	Commercial Industry	140	0	0	1,173,863	0	205,500	4,904	0	0	0	0	1,016,548	144,727	2,545,682	2,470,621	75,062
#33	Residential	0	0	0	768,778	0	418,897	32,902	0	0	0	0	900,592	1,306	2,122,475	2,122,475	0
#34	Transportation	46	0	0	3,755,515	0	1,141	0	0	0	0	0	66,864	0	3,823,565	3,789,403	34,162
#35	Passenger	46	0	0	2,188,610	0	172	0	0	0	0	0	63,385	0	2,252,212	2,226,404	25,808
#36	Freight	0	0	0	1,566,905	0	969	0	0	0	0	0	3,479	0	1,571,353	1,562,999	8,354
#37	Non-energy and Feedstock Use	19	19,641	0	1,740,814	8,523	0	0	0	0	0	0	0	0	1,768,998	0	1,768,998

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	15,795	9,517,554	1,173,834	3,291,376	0	381,401	671,487	0	428,091	2,660,242	0	0	22,905,552	20,957,622	1,947,930
#02	Indigenously Produced	28,110	0	33,051	0	134,612	0	375,991	671,487	0	428,091	2,660,242	0	0	4,331,584	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	381,452	671,487	0	428,091	2,660,242	0	0	23,913,601	21,965,671	1,947,930
#05	Export	-85	-49,279	-4	-880,259	0	0	-51	0	0	0	0	0	0	-929,678	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) (Demand)	4,765,771	15,795	9,517,554	1,173,834	3,291,376	0	381,401	671,487	0	428,091	2,660,242	0	0	22,905,552	20,957,622	1,947,930
#08	Energy Transformation & Own Use	-4,310,565	1,121,057	-9,510,672	7,253,280	-3,227,280	966,321	-354,038	-671,487	0	-421,786	-2,660,242	3,561,818	1,200,062	-22,954,739	-21,006,810	1,947,930
#09	Manufacture of Coal Products (+/- output/-)	-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	9,278,313	8,203	0	0	0	0	0	0	0	-139,784	-62,992	0	-62,992
#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	-2,660,242	3,440,790	0	-5,039,177	-5,039,177	0	0
#13	Auto Power Generation	-250,929	-106,559	-20	-400,673	-16,206	-115,803	-132,042	-57,360	0	-178,129	0	0	0	-755,149	-755,149	0
#14	Auto Steam Generation	-215,125	-66,543	-37	-573,353	-12,856	-183,042	-168,956	0	0	-238,466	0	1,317,977	-140,401	-140,401	0	0
#15	District Heat Supply	-633	0	0	-1,023	0	-18,102	-146	0	0	-5,124	0	-4,129	25,433	-3,724	-3,724	0
#16	Own Use and Loss	-6,994	-129,554	-91	-331,117	-16,279	-9,176	0	0	0	0	0	-377,413	-3,563	-874,188	-874,188	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	93,718	6,882	689,356	-566	2,003	4,315	0	0	0	0	-127,635	-55,234	646,487	579,348	67,138
#19	Final Energy Consumption	421,558	1,043,135	0	8,427,113	64,662	966,321	27,363	0	0	6,305	0	3,689,453	1,255,296	15,901,205	14,076,076	1,825,130
#20	Industry	421,521	1,043,135	0	4,159,284	64,662	526,270	4,340	0	0	6,305	0	2,624,656	1,253,971	10,104,143	8,314,686	1,789,456
#21	Agriculture, Fishery, Mining and Construction	34	524	0	478,484	2,758	3,115	0	0	0	0	0	61,043	1,350	547,307	430,354	116,954
#22	Manufacturing	421,249	1,042,611	0	2,438,710												

Table A 4-21 Energy balance simplified table (General Energy Statistics, FY2010, 2015)

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	Renewabl e (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	3,994,127	1,105	436,721	715,871	0	529,798	2,462,243	0	0	21,995,185	20,126,923	1,868,262
#02	Indigenously Produced	25,764	0	30,637	0	149,324	0	421,916	715,871	0	529,798	2,462,243	0	0	4,335,554	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	436,723	715,871	0	529,798	2,462,243	0	0	23,270,050	21,401,788	1,868,262
#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	-194	1,105	0	0	0	0	0	0	0	-67,255	0	0
#07	Domestic Primary Energy Supply (Supply) (Demand)	4,983,144	14,115	8,127,286	730,774	3,994,127	1,105	436,721	715,871	0	529,798	2,462,243	0	0	21,995,185	20,126,923	1,868,262
#08	Energy Transformation & Own Use	-4,523,260	1,090,966	-8,133,969	6,531,651	-3,960,650	1,087,983	-415,373	-715,871	0	-522,602	-2,462,243	3,799,612	1,004,032	21,931,268	20,063,006	1,868,262
#09	Manufacture of Coal Products (+: output/-:)	-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	8,038,382	5,579	0	-8,588	0	0	0	0	0	-146,978	-60,732	0	-60,732
#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	-49,589	-574,862	0	-5,678	-2,462,243	3,474,987	0	-4,878,205	-4,878,205	0
#13	Auto Power Generation	-440,814	-104,816	-46	-309,431	-149,028	-133,885	-172,142	-141,010	0	-282,311	0	704,858	0	-1,028,624	-1,028,624	0
#14	Auto Steam Generation	-240,628	-76,411	-90	-379,511	-27,268	-168,223	-184,754	0	-229,472	0	0	1,131,316	0	-175,042	-175,042	0
#15	District Heat Supply	0	0	0	-822	0	-17,003	-331	0	0	0	0	-4,126	24,925	-1,425	-1,425	0
#16	Own Use and Loss	-20,471	-134,613	-62	-293,998	-4,773	-50,390	0	0	0	0	0	-376,108	-5,231	-885,645	-885,645	0
#17	Transformation and Consumption Stockpile Change (+: withdrawal/-: build-up)	-29,368	2,555	4,654	-9,526	1,573	0	278	0	0	-987	0	0	0	-30,821	0	-30,821
#18	Statistical Discrepancy (+: excess/-: shortage)	68,210	49,980	-6,683	305,495	-34,148	108,373	4,483	0	0	0	0	72,105	-85,415	482,400	424,308	58,092
#19	Final Energy Consumption	391,674	1,055,101	0	7,262,558	67,624	1,089,087	21,349	0	0	7,196	0	3,727,507	1,089,447	14,711,544	12,980,516	1,731,028
#20	Industry	391,630	1,055,101	0	3,299,700	67,624	657,370	4,832	0	0	7,196	0	2,584,207	1,088,165	9,155,827	7,460,274	1,695,552
#21	Agriculture, Fishery, Mining and Construction	87	140	0	395,747	5,064	2,672	0	0	0	0	0	45,685	1,392	450,859	371,050	79,738
#22	Manufacturing	391,306	1,052,992	0	2,193,545	62,560	281,280	350	0	0	7,196	0	1,328,271	976,583	6,294,085	4,736,363	1,557,722
#23	Food, Beverages, Tobacco and Feed	28	91	0	50,351	0	39,753	0	0	0	0	0	91,017	99,108	280,349	280,349	0
#24	Textile Mill Products	153	0	0	13,555	0	7,678	0	0	0	0	0	35,646	49,765	106,797	106,797	0
#25	Pulp, Paper and Paper Products	322	0	0	20,024	333	5,171	344	0	0	89	0	123,781	228,675	378,740	378,740	0
#26	Chemical and Allied Products, Oil and Coal Products	1,051	49,884	0	1,838,713	34,826	27,260	0	0	0	0	0	204,731	365,869	2,522,335	964,981	1,557,354
#27	Ceramic, Stone and Clay Products	128,254	17,780	0	97,328	4,255	28,179	6	0	0	6,582	0	72,081	19,889	374,355	374,174	181
#28	Iron and Steel	258,193	972,911	0	77,484	20,273	76,514	0	0	387	0	258,467	118,085	1,782,315	1,782,128	186	
#29	Non-Ferrous Metals	2,314	8,661	0	24,276	1,024	16,292	0	0	137	0	52,474	10,665	115,843	115,843	0	
#30	Machinery	76	3,587	0	52,817	1,849	65,643	0	0	0	0	372,900	58,690	555,562	555,562	0	
#31	Miscellaneous	915	78	0	18,996	0	14,790	0	0	0	0	117,174	25,837	177,789	177,789	0	
#32	Commercial Industry	237	1,970	0	710,408	0	373,417	4,483	0	0	0	1,210,250	110,189	2,410,953	2,352,861	58,092	
#33	Residential	0	0	0	646,431	0	427,050	16,516	0	0	0	0	1,077,621	1,282	2,168,901	2,168,901	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	62,658	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	1,696,536	16,575	0	0	0	0	0	0	0	0	1,731,028	0	1,731,028

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	Renewabl e (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	731,232	4,658,056	-833	728,467	725,929	0	537,319	78,638	0	0	20,019,431	18,221,362	1,798,070
#02	Indigenously Produced	31,982	0	20,896	0	110,598	0	696,394	725,929	0	537,319	78,638	0	0	2,201,755	0	0
#03	Import	5,064,950	80,375	7,414,496	1,952,079	4,551,428	0	32,118	0	0	0	0	0	0	19,095,445	0	0
#04	Total Primary Energy Supply	5,096,932	80,375	7,435,391	1,952,079	4,662,026	0	728,512	725,929	0	537,319	78,638	0	0	21,297,200	19,499,131	1,798,070
#05	Export	-62	-22,999	0	-1,265,962	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	-3,970	-833	0	0	0	0	0	0	0	11,299	0	0
#07	Domestic Primary Energy Supply (Supply) (Demand)	5,096,871	57,471	7,406,284	731,232	4,658,056	-833	728,467	725,929	0	537,319	78,638	0	0	20,019,431	18,221,362	1,798,070
#08	Energy Transformation & Own Use	-4,717,988	932,945	-7,406,973	5,867,079	-4,603,419	1,060,013	-712,914	-725,929	0	-512,058	-78,638	3,464,857	896,669	-6,536,356	-6,420,487	-115,869
#09	Manufacture of Coal Products (+: output/-:)	-1,523,216	1,436,363	0	-19,673	0	0	0	0	0	-4,893	0	0	0	-1,111,419	-1,111,419	0
#10	Oil Products (+: output/-: input)	0	0	-7,191,157	7,208,184	4,204	0	-14,525	0	0	0	0	0	-119,254	-112,548	0	-112,548
#11	Gas Conversion and Production (+: output/-: input)	0	0	0	-68,501	-1,669,358	1,738,070	-116	0	0	0	0	0	0	95	95	0
#12	Power Generation	-2,375,953	-214,775	-226,562	-382,133	-2,924,275	-121,051	-53,911	-588,693	0	-5,484	-78,638	2,945,950	0	-4,025,526	-4,025,526	0
#13	Auto Power Generation	-502,927	-101,086	-39	-280,709	-154,755	-142,191	-472,130	-137,235	0	-297,982	0	844,188	0	-1,244,867	-1,244,867	0
#14	Auto Steam Generation	-243,912	-70,119	-74	-332,121	-24,529	-193,980	-171,077	0	-200,818	0	0	999,345	-237,284	-237,284	0	
#15	District Heat Supply	0	0	0	-225	0	-14,094	-578	0	0	0	0	-3,609	21,750	612	612	0
#16	Own Use and Loss	-20,270	-120,507	-83	-274,458	-13,393	-46,544	0	0	0	0	0	-321,672	-5,171	-802,098	-802,098	0
#17	Transformation and Consumption Stockpile Change (+: withdrawal/-: build-up)	-51,710	3,069	10,941	11,383	18,491	0	-128	0	0	-250	0	0	0	-8,204	0	-8,204
#18	Statistical Discrepancy (+: excess/-: shortage)	-52,944	34,367	-690	196,212	-7,177	19,407	4,842	0	0	0	0	46,688	-47,628	193,078	149,530	43,548
#19	Final Energy Consumption	431,827	956,049	0	6,598,751	61,813	1,059,179	15,553	0	0	25,260	0	3,418,170	944,297	13,510,899	11,828,698	1,682,201
#20	Industry	431,788	956,049	0	2,985,816	61,813	655,522	5,233	0	0	25,260	0	2,391,174	943,194	8,455,849	6,810,081	1,645,768
#21	Agriculture, Fishery, Mining and Construction	28	291	0	361,031	4,695	3,364	0	0	0	0	0	37,634	1,095	408,139	34	

Table A 4-22 Energy balance simplified table (General Energy Statistics, FY2016, 2017)

2016FY	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	Renewabl e (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	5,013,671	27,456	7,358,473	519,809	4,730,154	-755	812,894	676,129	0	572,669	153,626	0	0	19,864,126	18,143,239	1,720,886
#02	Indigenously Produced	32,565	0	19,860	0	113,938	0	771,332	676,129	0	572,669	153,626	0	0	2,340,118	0	0
#03	Import	4,981,163	59,763	7,295,582	1,782,011	4,615,551	0	41,562	0	0	0	0	0	0	18,775,665	0	0
#04	Total Primary Energy Supply	5,013,728	59,763	7,315,442	1,782,011	4,729,490	0	812,926	676,129	0	572,669	153,626	0	0	21,115,783	19,394,897	1,720,886
#05	Export	-57	-30,072	0	-1,282,183	0	0	-32	0	0	0	0	0	0	-1,312,343	0	0
#06	Stockpile Change / Supply (+: withdrawal/-: build-up)	0	-2,236	43,031	19,981	665	-755	0	0	0	0	0	0	0	60,686	0	0
#07	Domestic Primary Energy Supply (Supply) (Demand)	5,013,671	27,456	7,358,473	519,809	4,730,154	-755	812,894	676,129	0	572,669	153,626	0	0	19,864,126	18,143,239	1,720,886
#08	Energy Transformation & Own Use	-4,655,653	971,432	-7,371,835	5,926,735	-4,681,943	1,052,321	-798,438	-676,129	0	-545,404	-153,626	3,437,081	885,197	-6,610,261	-6,505,639	-104,622
#09	Manufacture of Coal Products (+: output/-: -)	-1,553,070	1,465,007	0	-20,987	0	0	0	0	0	-4,967	0	0	0	-1,140,18	-1,140,18	0
#10	Oil Products (+: output/-: input)	0	0	-7,274,032	7,228,844	3,405	0	-17,352	0	0	0	0	0	-117,544	-1,766,679	0	-176,679
#11	Gas Conversion and Production (+: output/-: input)	0	0	0	-69,927	-1,741,947	1,812,037	-130	0	0	0	0	0	0	33	33	0
#12	Power Generation	-2,626,226	-229,184	-124,252	-438,729	-3,106,450	-172,324	-168,173	-644,254	0	-119,611	-153,626	3,289,538	0	-4,493,291	-4,493,291	0
#13	Auto Power Generation	-218,035	-65,252	-48	-209,532	-29,155	-112,948	-432,056	-31,874	0	-225,650	0	533,199	0	-791,352	-791,352	0
#14	Auto Steam Generation	-236,756	-70,827	-89	-328,065	-23,665	-199,879	-171,730	0	0	-190,085	0	986,106	0	-234,990	-234,990	0
#15	District Heat Supply	0	0	0	-206	0	-14,984	-585	0	0	-2,449	0	-3,635	22,696	837	837	0
#16	Own Use and Loss	-12,652	-123,098	-2,592	-267,143	-14,418	-60,333	-4,540	0	0	-1	0	-382,020	-6,060	-872,857	-872,857	0
#17	Transformation and Consumption Stockpile Change (+: withdrawal/-: build-up)	-8,914	-5,214	29,179	8,370	31,055	-16	-3,504	0	0	-2,640	0	0	0	48,315	0	48,315
#18	Statistical Discrepancy (+: excess/-: shortage)	-60,882	47,333	-13,362	185,378	-14,394	871	4,601	0	0	0	0	17,860	-56,820	110,585	66,346	44,239
#19	Final Energy Consumption	418,901	951,555	0	6,444,943	62,605	1,051,566	14,456	0	0	27,266	0	3,419,221	942,016	13,344,528	11,718,264	1,616,264
#20	Industry	418,859	951,555	0	2,861,299	62,605	640,357	4,916	0	0	27,266	0	2,394,351	940,898	8,302,106	6,722,942	1,579,163
#21	Agriculture, Fishery, Mining and Construction	11	16	0	350,551	4,606	3,249	0	0	0	0	0	36,049	820	395,693	362,957	32,736
#22	Manufacturing	418,470	947,787	0	1,974,671	57,609	264,564	314	0	0	27,266	0	1,208,348	875,344	5,774,373	4,272,185	1,502,188
#23	Food, Beverages, Tobacco and Feed	43	62	0	29,900	0	33,723	0	0	0	0	0	92,186	81,525	257,439	257,439	0
#24	Textile Mill Products	0	0	0	6,242	58	5,788	0	0	0	0	0	30,734	49,486	92,307	92,307	0
#25	Pulp, Paper and Paper Products	0	0	0	15,728	504	4,495	260	0	0	0	0	111,963	205,641	339,366	339,366	0
#26	Chemical and Allied Products, Oil and Coal Products	1,088	51,057	0	1,704,503	27,501	22,886	0	0	0	0	0	187,837	329,375	2,326,169	824,251	1,501,918
#27	Ceramic, Stone and Clay Products	129,117	12,511	0	89,122	5,302	25,493	55	0	0	21,655	0	65,065	20,339	368,660	368,499	160
#28	Iron and Steel	285,907	874,838	0	59,431	21,158	82,244	0	0	0	1,456	0	251,380	98,307	1,674,721	1,674,611	110
#29	Non-Ferrous Metals	2,119	6,825	0	17,871	1,365	17,620	0	0	0	1,457	0	45,177	13,180	105,615	105,615	0
#30	Machinery	196	2,449	0	39,721	1,721	60,298	0	0	0	0	0	316,886	41,052	462,323	462,323	0
#31	Miscellaneous	0	45	0	12,153	0	12,017	0	0	0	0	0	107,120	36,439	167,774	167,774	0
#32	Commercial Industry	378	3,751	0	536,077	0	372,544	4,601	0	0	0	0	1,149,954	64,734	2,132,040	2,087,801	44,239
#33	Residential	0	0	0	528,632	0	408,393	9,540	0	0	0	0	962,016	1,119	1,909,700	1,909,700	0
#34	Transportation	41	0	0	3,057,011	0	2,816	0	0	0	0	0	62,855	0	3,122,723	3,085,622	37,101
#35	Passenger	41	0	0	1,788,754	0	248	0	0	0	0	0	60,605	0	1,849,108	1,820,781	28,327
#36	Freight	0	0	0	1,268,257	0	2,568	0	0	0	0	0	2,790	0	1,273,615	1,264,841	8,774
#37	Non-energy and Feedstock Use	23	18,641	0	1,586,299	11,301	0	0	0	0	0	0	0	0	1,616,264	0	1,616,264

2017FY	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	Renewabl e (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	5,039,817	3,936	7,108,909	722,579	4,693,649	2,529	938,025	710,387	0	595,577	279,158	0	0	20,094,566	18,259,739	1,834,827
#02	Indigenously Produced	33,574	0	19,645	0	119,167	0	884,798	710,387	0	595,577	279,158	0	0	2,642,305	0	0
#03	Import	5,006,323	37,635	7,076,730	1,940,739	4,568,897	0	53,259	0	0	0	0	0	0	18,683,582	0	0
#04	Total Primary Energy Supply	5,039,897	37,635	7,096,374	1,940,739	4,688,064	0	938,057	710,387	0	595,577	279,158	0	0	21,325,887	19,491,060	1,834,827
#05	Export	-80	-36,027	0	-1,228,882	0	0	-32	0	0	0	0	0	0	-1,265,020	0	0
#06	Stockpile Change / Supply (+: withdrawal/-: build-up)	0	2,328	12,535	10,721	5,586	2,529	0	0	0	0	0	0	0	33,699	0	0
#07	Domestic Primary Energy Supply (Supply) (Demand)	5,039,817	3,936	7,108,909	722,579	4,693,649	2,529	938,025	710,387	0	595,577	279,158	0	0	20,094,566	18,259,739	1,834,827
#08	Energy Transformation & Own Use	-4,624,992	975,393	-7,089,723	5,734,366	-4,625,098	1,101,594	-924,332	-710,387	0	-567,405	-279,158	3,478,246	901,556	-6,629,940	-6,453,160	-176,780
#09	Manufacture of Coal Products (+: output/-: -)	-1,535,648	1,446,972	0	-18,762	0	0	0	0	0	-4,869	0	0	0	-112,306	-112,306	0
#10	Oil Products (+: output/-: input)	0	0	-7,026,818	6,982,813	2,496	0	-19,101	0	0	0	0	0	-122,642	-183,252	0	-183,252
#11	Gas Conversion and Production (+: output/-: input)	0	0	0	-76,871	-1,761,650	1,838,536	-143	0	0	0	0	0	0	-128	-128	0
#12	Power Generation	-2,681,237	-218,872	-78,550	-366,685	-2,962,128	-156,681	-226,768	-683,639	0	-141,437	-279,158	3,306,578	0	-4,488,576	-4,488,576	0
#13	Auto Power Generation	-175,415	-64,040	-46	-211,755	-28,179	-112,611	-493,895	-26,748	0	-219,689	0	542,619	0	-789,758	-789,758	0
#14	Auto Steam Generation	-242,255	-72,157	-85	-322,716	-23,550	-204,796	-179,019	0	0	-197,753	0	1,007,648	0	-234,683	-234,683	0
#15	District Heat Supply	0	0	0	-208	0	-15,057	-530	0	0	-2,569	0	-3,598	23,065	1,103	1,103	0
#16	Own Use and Loss	-11,456	-121,048	-3,094	-257,279	-16,326	-42,248	-3,491	0	0	-4	0	-367,353	-6,514	-828,812	-828,812	0
#17	Transformation and Consumption Stockpile Change (+: withdrawal/-: build-up)	21,018	4,557	18,870	362	-41,313	0	-1,023	0	0	-1,084	0	0	0	1,368	0	1,368
#18	Statistical Discrepancy (+: excess/-: shortage)	-14,535	43,120	19,186	195,756	5,730	34,052	4,567	0	0	0	0	8,194	-50,078	245,992	203,606	42,387
#19	Final Energy Consumption	429,360	936,209	0	6,457,400	62,821	1,104,122	13,693	0	0	28,172	0	3,470,052	951,634	13,453,463	11,795,416	1,658,046
#20	Industry	429,318	936,209	0	2,856,792	62,821	673,297	4,839	0	0	28,172	0	2,423,396	950,495	8,365,340	6,745,199	1,620,141
#21	Agriculture, Fishery, Mining and Construction	0	3	0	348,296	5,135	2,996	0	0	0	0	0	38,407				

A4.2.2. General Energy Statistics and CRF

In order to report CO₂ emissions in CRF, emissions reported under the sectors in *General Energy Statistics* (Energy Balance Table) were reported under each sector in CRF. The correspondence of categories between *General Energy Statistics* and CRF table 1.A(a) ‘sectoral approach’ is indicated in Table A 4-23.

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 CO₂, 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], ‘district 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 energy consumptions recorded under ‘manufacture of coal products’ correspond to the difference between the coke-making carbon input and carbon output. This is considered to be energy consumption of 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 CO₂ emissions, and it was calculated as carbon emissions from this sector.

Energy consumptions recorded under ‘oil products’ correspond to the difference between the carbon input and carbon output for oil products. This is considered to be energy consumption of the portion that is burned carbon precipitated on catalysts in fluid catalytic cracking of oil refining processes for the purpose of recovery of the catalytic activities lowered by the cracking reaction of slack fuel oil, as well as heat recovery at boilers of the off-gas generated in the fluid catalytic cracking mainly consisting of CO, and CO₂ as by-product of hydrogen generating facilities. It was considered appropriate to count this as CO₂ emissions, and it was calculated as carbon emissions from this sector.

Table A 4-23 Correspondence between sectors of General Energy Statistics (Detailed Sector) and of the CRF table 1.A(a)

CRF		General Energy Statistics	
1A1	Energy industries		
		Power generation	#240000
		Own use; Power generation	#301400
1A1a	Public electricity and heat production	District heat supply	#270000
		Own use; District heat supply	#301500
		Auto power generation; Production, transmission and distribution of electricity (until 2015)	#255330
		Oil products	#220000
		Own use; Oil products	#301200
1A1b	Petroleum refining	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
		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
1A1c	Manufacture of solid fuels and other energy industries		
1A2	Manufacturing industries and construction		
		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
1A2a	Iron and steel		
		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
1A2b	Non-ferrous metals		
		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
1A2c	Chemicals		
		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
1A2d	Pulp, paper and print		
		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
1A2e	Food processing, beverages and tobacco		
		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
1A2f	Non-metallic minerals		
		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 1A1b, 1A1c, 1A2a through 1A2f)	#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 1A1b, 1A1c, 1A2a through 1A2f)	#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 1A1b, 1A1c, 1A2a through 1A2f)	#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 1A1b, 1A1c, 1A2a through 1A2f)	#951500
1A2g	Other		
		Non-energy and feedstock use; Manufacturing industry, small and medium scale	#951700

Table A 4-23 Correspondence between sectors of General Energy Statistics (Detailed Sector) and of the CRF table 1.A(a) (cont.)

CRF		General Energy Statistics	
1A3	Transport		
1A3a	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
1A3b	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 (1A3biii)	-
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 (1A3biii)	-
1A3c	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
1A3d	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
1A3e	Other transportation	NO	-
1A4	Other sectors		
1A4a	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])	#255000
		Auto steam generation (except for Agriculture, fishery, mining and construction [#261000] and Manufacturing [#262000])	#265000
		Final energy consumption; Commercial industry	#650000
		Non-energy and feedstock use; Commercial	#951800
1A4b	Residential	Final energy consumption; Residential	#700000
		Non-energy and feedstock use; Household	#952000
1A4c	Agriculture/forestry/fishing		
i	Stationary	Auto power generation; Agriculture, fishery, mining and construction (agriculture, forestry and fishery)	#251000
		Auto steam generation; Agriculture, fishery, mining and construction (agriculture, forestry and fishery)	#261000
		Final energy consumption; Agriculture, forestry and fishery [#610000]; stationary sources (estimates)	
		Non-energy and feedstock use; Agriculture, fishery, mining and construction (agriculture, forestry and fishery)	#951100
ii	Off-road vehicles and other machinery	Final energy consumption; Agriculture [#611100]; mobile sources (estimates)	
		Final energy consumption; Forestry [#611200]; mobile sources (estimates)	
iii	Fishing	Final energy consumption; Fishery, except aquaculture [#611300]; mobile sources (estimates)	
		Final energy consumption; Aquaculture [#611400]; mobile sources (estimates)	
1A5	Other	NO	-

- #9xxxxx items are subtracted as a Non-energy use activity.

The correspondence of fuels among *General Energy Statistics*, CRF table 1.A(b) 'reference approach' and CRF table 1.A(d) 'non-energy use of fuels' is indicated in Table A 4-24.

Table A 4-24 Correspondence of fuels among *General Energy Statistics*, CRF table 1.A(b) and (d)

		Fuel in CRF table 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 gas	Liquefied petroleum gas (LPG)	\$0458
		Naphtha	Pure naphtha	\$0420
			Reformed feedstock Oil	\$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
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	

A4.3. 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 4-25 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 4-25 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 mm²/s or less.

2) Cetane number is also available for cetane index.

Source: Japanese Industrial Standards K 2204, revised in 2007

References

1. Environmental Agency, *The Report on Estimation of CO₂ Emissions in Japan*, 1992.
2. Research Institute of Economy, Trade & Industry, Kazunari Kainou, *Interpretation of General Energy Statistics*, 2012.
3. Japanese Industrial Standards K 2204, revised in 2007.
4. OECD/IEA, *World Energy Statistics*
5. Agency for Natural Resources and Energy, *General Energy Statistics*

Annex 5. Assessment of Completeness, Definition of Notation Keys, and Sources and Sinks Reported as “NE”

A5.1. Assessment of Completeness

Current inventory is submitted in accordance with the common reporting format (CRF), which requires entering emission data or a notation key such as “NO”, “NE”, or “NA” for all sources. This chapter presents the definition of notation keys and decision trees for the application of them (including applicability criteria of “NE” when the emissions are considered insignificant), both of which are based on the UNFCCC reporting guidelines (Decision 24/CP.19) and the results of Committee for Greenhouse Gases Emissions Estimation Methods in 2002, 2012, and 2014.

This chapter also indicates classification of emission source categories reported as “NE” into one which are considered insignificant and the other which are not estimated.

A5.2. Definition of Notation Keys

In Japan, notation keys are used in accordance with UNFCCC reporting guidelines (Decision 24/CP.19). The following table A5-1 indicates definitions of notation keys provided in the UNFCCC reporting guidelines.

Table A 5-1 Definitions of notation keys indicated in UNFCCC reporting guidelines

Notation Key	Explanation
NO (Not Occurring)	(a) “NO” (not occurring) for categories or processes, including recovery, under a particular source or sink category that do not occur within an Annex I Party;
NE (Not Estimated)	(b) “NE” (not estimated) for emissions by sources and removals by sinks of GHGs and AD which have not been estimated but for which a corresponding activity may occur. When “NE” is used, the reason should be indicated in both the NIR and the CRF. Also, when emissions from a specific category are considered to be insignificant, “NE” can be used. In such case, justifications for exclusion in terms of the likely level of emissions should be provided in NIR. An emission should only be considered insignificant if the likely level of emissions is below 0.05 per cent of the national total GHG emissions and does not exceed 500kt CO ₂ eq. The total national aggregate of estimated emissions for all gases and categories considered insignificant shall remain below 0.1 per cent of the national total GHG emissions. Parties should use approximated AD and default IPCC EFs to derive a likely level of emissions for the respective category. Once emissions from a specific category have been reported in a previous submission, emissions from this specific category shall be reported in subsequent GHG inventory 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. If the cells for categories in the CRF tables for which “NA” is applicable are shaded, they do not need to be filled in;
IE (Included Elsewhere)	“IE” (included elsewhere) for emissions by sources and removals by sinks of GHGs estimated but included elsewhere instead of under the expected source/sink category. Where “IE” is used, the Annex I Party should indicate where the emissions or removals have been included and explain why they have been reported in that category in the CRF completeness table, especially if it is due to confidentiality;
C (Confidential)	“C” (confidential) for emissions by sources and removals by sinks of GHGs of which the reporting could lead to the disclosure of confidential information, in accordance with paragraph 36. (Paragraph 36: Emissions and removals should be reported at the most disaggregated level of each source/sink category, taking into account that a minimum level of aggregation may be required to protect confidential business and military information.)

Source : UNFCCC reporting guidelines on annual greenhouse gas inventories (Decision 24/CP.19)

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, as shown

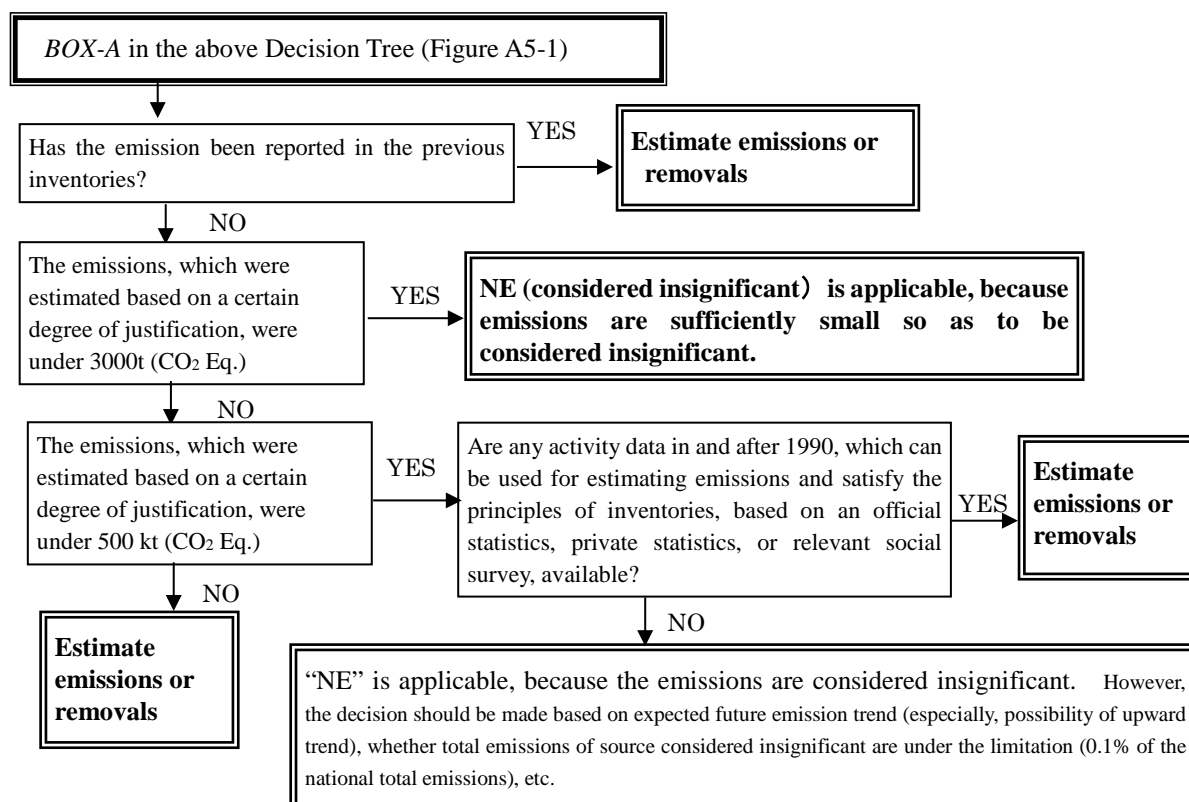


Figure A 5-2 Decision tree for determining applicability of “NE” when the emissions are considered insignificant

When emissions by sources and removals by sinks of GHGs could be confidential information, they are reported as “C”.

A5.4. Emission sources reported as “NE” (considered insignificant) in Japan

The notation key NE (considered insignificant) was used for the emission source categories indicated in the following Table A5-2, because the emissions are sufficiently small so as to be considered insignificant. Since the approximate total amount of emissions from these emission sources (excluding removal) is 103 kt (in CO₂ eq.) at maximum, it is not expected to exceed 0.1% of the national total emissions (approximately 1.3Mt. in CO₂ eq. for Japan), which is stipulated in paragraph 37(b) in the UNFCCC reporting guidelines (Decision 24/CP.19) as the upper limit of applicability of “NE” for being considered insignificant.

Table A 5-2 Emission sources reported as “NE” (considered insignificant)

Code	Category No.	Sector and Category		Gas	Likely Level Emissions [kt-CO ₂ eq]	
1	1.C.	Energy	CO ₂ transport and storage	CO ₂	< 0.007	
2	2.D.3.	IPPU	NMVOIC incineration	CH ₄	<0.2	
3	2.D.3.	IPPU	NMVOIC incineration	N ₂ O	<1.0	
4	2.F.1.	IPPU	Refrigeration and Air Conditioning Equipment	Fugitive emissions from refrigerant containers	HFCs	<44
5	2.F.4.	IPPU	Product uses as substitutes for ODS	Aerosols	HFCs	<1.8
6	2.G.2.	IPPU	Other product manufacture and use	Soundproof windows	SF ₆	<0.3
7	3.A.4.-	Agriculture	Enteric Fermentation	Deer	CH ₄	< 2.3
8	3.A.4.-	Agriculture	Enteric Fermentation	Alpaca	CH ₄	< 0.07
9	3.B.4.-	Agriculture	Manure Management	Deer	CH ₄	<0.03
10	3.B.4.-	Agriculture	Manure Management	Reindeer	CH ₄	<0.01
11	3.B.4.-	Agriculture	Manure Management	Silver Fox	CH ₄	<0.04
12	3.B.4.-	Agriculture	Manure Management	Other Poultry (Duck, Turkey, Quail, Goose, Guinea Fowl, Pheasant)	CH ₄	<0.8
13	3.B.4.-	Agriculture	Manure Management	Deer	N ₂ O	<0.6
14	3.B.4.-	Agriculture	Manure Management	Reindeer	N ₂ O	<0.02
15	3.B.4.-	Agriculture	Manure Management	Silver Fox	N ₂ O	<0.01
16	3.B.4.-	Agriculture	Manure Management	Other Poultry (Duck, Turkey, Quail, Goose, Guinea Fowl, Pheasant)	N ₂ O	<0.3
17	4.D.	LULUCF	Wetlands	Peat Production	CO ₂	<50
18	4.D.	LULUCF	Wetlands	Biomass Burning	CH ₄	<0.14
19	4.D.	LULUCF	Wetlands	Biomass Burning	N ₂ O	<0.16
20	5.B.2	Waste	Anaerobic digestion at biogas facilities		CH ₄	<1.4
Total						<103

* 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

A5.5. Source and sink categories not estimated in Japan’s inventory

The following table A5-3 indicates source and sink categories which were not estimated, excluding “NE” applicable categories for being “considered insignificant” as described above.

Table A 5-3 Source and sink categories which were not estimated in Japan’s inventory

Code	Sector	Source and sink category			GHG	
1	Energy	Fuel Combustion, Transportaion	Liquid Fuels	Domestic Aviation	Cruise	CH ₄
2	Energy	Fuel Combustion	Liquid Fuels	Lubricants		CH ₄
3	Energy	Fuel Combustion	Liquid Fuels	Lubricants		N ₂ O
4	Energy	Fugitive Emissions from Fuels	Solid Fuels	Coal Mining and Handling	Recovery/Flaring	CH ₄
5	Energy	Fugitive Emissions from Fuels	Solid Fuels	Others (Uncontrollable Combustion)		CO ₂
6	Energy	Fugitive Emissions from Fuels	Oil and Natural Gas	Oil	Refining/Storage	CO ₂
7	Energy	Fugitive Emissions from Fuels	Oil and Natural Gas	Oil	Distribution of Oil Products	CO ₂
8	Energy	Fugitive Emissions from Fuels	Oil and Natural Gas	Oil	Distribution of Oil Products	CH ₄
9	IPPU	Chemical Industry	Ammonia Production			CH ₄
10	LULUCF	Wetlands	Wetlands remaining Wetlands	Flooded land	Living Biomass	Carbon Stock Change
11	LULUCF	Wetlands	Wetlands remaining Wetlands	Flooded land	Dead Organic Matter	Carbon Stock Change
12	LULUCF	Wetlands	Wetlands remaining Wetlands	Flooded land	Soil	Carbon Stock Change
13	LULUCF	Wetlands	Land converted to Wetlands	Cropland converted to Wetlands	Soil	Carbon Stock Change
14	LULUCF	Wetlands	Land converted to Wetlands	Grassland converted to Wetlands	Soil	Carbon Stock Change
15	LULUCF	Wetlands	Land converted to Wetlands	Settlements converted to Wetlands	Soil	Carbon Stock Change
16	LULUCF	Wetlands	Land converted to Wetlands	Other Land converted to Wetlands	Soil	Carbon Stock Change
17	LULUCF	Settlements	Settlements remaining Settlements	Other than Urban Green Areas	Living Biomass	Carbon Stock Change
18	LULUCF	Settlements	Settlements remaining Settlements	Other than Urban Green Areas	Dead Organic Matter	Carbon Stock Change
19	LULUCF	Settlements	Settlements remaining Settlements	Other than Urban Green Areas	Soil	Carbon Stock Change
20	LULUCF	Settlements	Settlements remaining Settlements	Urban Green Areas not subject to RV	Dead Organic Matter	Carbon Stock Change
21	LULUCF	Settlements	Settlements remaining Settlements	Urban Green Areas not subject to RV	Soil	Carbon Stock Change

Annex 6. Hierarchical Structure of Japan's National GHG Inventory File System

Multiple MS Excel files have been used when estimating Japanese inventory. The explanation of each MS Excel file and the hierarchical structure of Japanese National GHGs Inventory (JNGI) file system are shown below.

Table A6-1 Explanation of each MS Excel file

category	file name	contents
	JPN_2019_1990.xlsx - JPN_2019_2017.xlsx	Common reporting format generated by CRF reporter
1. Energy	1A-L3-CO2-1990-2019.xlsx - 1A-L3-CO2-2017-2019.xlsx	CO ₂ emissions from fuel combustions
	1A-L3-CRF-2019.xlsx	CRF format data of GHG emissions from fuel combustion (including emissions by energy use of waste)
	1A-L3-timeseries-2019.xlsx	Time-series data of GHG emissions from fuel combustion
	1A-L2-MAP_EB-1990-2019.xlsx - 1A-L2-MAP_EB-2017-2019.xlsx	Activity Data for furnaces
	1A-L3-Biomass-2019.xlsx	GHG emissions from biomass combustion
	1A-L3-CO-2019.xlsx	CO emissions from furnace and off-road vehicle
	1A-L3-HC-2019.xlsx	CH ₄ , NMVOC emissions from furnace and off-road vehicle
	1A-L3-N2O-2019.xlsx	N ₂ O emissions from furnace and off-road vehicle
	1A-L3-NOxSO2-2019.xlsx	NOx, SO ₂ emissions from fuel combustion (except transport sector)
	1A-L2-nonCO2-ADEF-2019.xlsx	Activity Data and Emission Factors of Non-CO ₂ from fuel combustion (except transport sector)
	1A-L2-NOxSO2-ADEF-2019.xlsx	Activity Data and Emission Factors of NOx, SO ₂ from fuel combustion (except transport sector)
	1A-L3-Lub-2019.xlsx	CO ₂ emissions from lubricant
	1A-L2-EBEF-2019.xlsx	Emission Factors for CO ₂ from fuel combustion
	1A-L1-EB-2019.xlsx	Data of the General Energy Statistics using in categories other than stationary combustion
	1A3-L3-CH4N2O-2019.xlsx	GHG emissions from Mobile Combustion (transport sector) (except CO ₂)
	1A3-L2-ADEF-2019.xlsx	Activity Data and Emission Factors for Mobile Combustion (transport sector)
	1A3-L2-2wADEF-2019.xlsx	Activity Data and Emission Factors for Motorcycles
	1B-L3-2019.xlsx	Fugitive GHG emissions from fuels
	1B-L2-ADEF-2019.xlsx	Activity Data and Emission Factors for Fugitive Emissions from Fuels
	2. Industrial Processes and Other Product Use (IPPU)	2-L2-ADEF-2019.xlsx
2-L3-2019.xlsx		GHG emissions from Sector 2 (IPPU)
2-L3-Fgas-2019.xlsx		F-gas (HFCs, PFCs, SF ₆ , NF ₃) emissions
2-L3-NMVOC-2019.xlsx		NMVOC emissions in Industrial Processes
2-L2-NMVOC-2019.xlsx		AD and EF for NMVOC emissions in Industrial Processes
3. Agriculture	3A-L3-CH4-2019.xlsx	CH ₄ emissions from enteric fermentation
	3B-L3-CH4N2O-2019.xlsx	GHG emissions from manure management
	3C-L3-CH4-2019.xlsx	CH ₄ emissions from rice cultivation
	3D-L3-N2O-2019.xlsx	N ₂ O emissions from agricultural soils
	3F-L3-CH4N2OCO-2019.xlsx	GHG emissions from field burning of agricultural residues
	3GH-L3-CO2-2019.xlsx	CO ₂ emissions from lime application and urine application to agricultural soil
	3-L2-ADEF-2019.xlsx	Activity Data and Emission Factors of Sector 3
4. LULUCF	4-L3-nonCSC-2019.xlsx	GHG emissions excluding carbon stock change
	4-L3-4A-CO2-2019.xlsx	CO ₂ emissions and removals from forest land
	4-L3-4B-CO2-2019.xlsx	CO ₂ emissions and removals from cropland
	4-L3-4C-CO2-2019.xlsx	CO ₂ emissions and removals from grassland
	4-L3-4D-CO2-2019.xlsx	CO ₂ emissions and removals from wetlands
	4-L3-4E-CO2-2019.xlsx	CO ₂ emissions and removals from settlements
	4-L3-4F-CO2-2019.xlsx	CO ₂ emissions and removals from other land
	4-L3-4G-CO2-2019.xlsx	CO ₂ emissions and removals from HWP
	4-L2-Area(Pref)-2019.xlsx	Mineral and Organic Soil Area
	4-L2-LandArea-2019.xlsx	Land area for each land use category
	4-L2-LandArea-Matrix-2019.xlsx	Land-use matrix
	4-L2-Orchard-2019.xlsx	Carbon stock changes in orchard
	4-L2-Parameter-2019.xlsx	Parameters for each land use category
	4-L2-Soil-2019.xlsx	Land area and carbon stock changes in cropland and grassland
	5. Waste	5A3-L2-AD-2019.xlsx
5A-L3-2019.xlsx		GHG emissions from solid waste disposal
5A-L2-AD-2019.xlsx		Activity data of solid waste disposal (managed disposal site)
5B-L3-2019.xlsx		GHG emissions from biological treatment of solid waste
5B-L2-AD-2019.xlsx		Activity data of biological treatment of solid waste
5C-L2-AD-2019.xlsx		Activity data of incineration and open burning of waste
5C-L3-2019.xlsx		GHG emissions from incineration and open burning of waste
5C-L3-Energy-2019.xlsx		GHG emissions from waste incineration and energy use (reported in the energy sector)
5D-L3-2019.xlsx		GHG emissions from waste water treatment and discharge
5D-L2-AD-2019.xlsx		Activity data of waste water treatment and discharge
5E-L3-2019.xlsx		GHG emissions from other
5E-L2-AD-2019.xlsx		Activity data of other
5-L2-EF-2019.xlsx		Emission factors of Sector 5 (Waste)
6. Other		6-L3-2019.xlsx
7. Indirect CO ₂ and Nitrous	7-L3-Indirect CO2-2019.xlsx	Indirect CO ₂ emissions
Memo Item	1D-L3-bunker-2019.xlsx	GHGs emissions from bunker fuels
KP-LULUCF	4KP-3-Summary-2019.xlsx	GHG emissions and removals from KP3.3 and 3.4 activities
	4KP-2-AR-2019.xlsx	GHG emissions and removals from Afforestation/Reforestation
	4KP-2-CM-2019.xlsx	GHG emissions and removals from Cropland Management
	4KP-2-D-2019.xlsx	GHG emissions and removals from Deforestation
	4KP-2-FM-2019.xlsx	GHG emissions and removals from Forest Management
	4KP-2-GM-2019.xlsx	GHG emissions and removals from Grazing Land Management
	4KP-2-RV-2019.xlsx	GHG emissions and removals from Revegetation

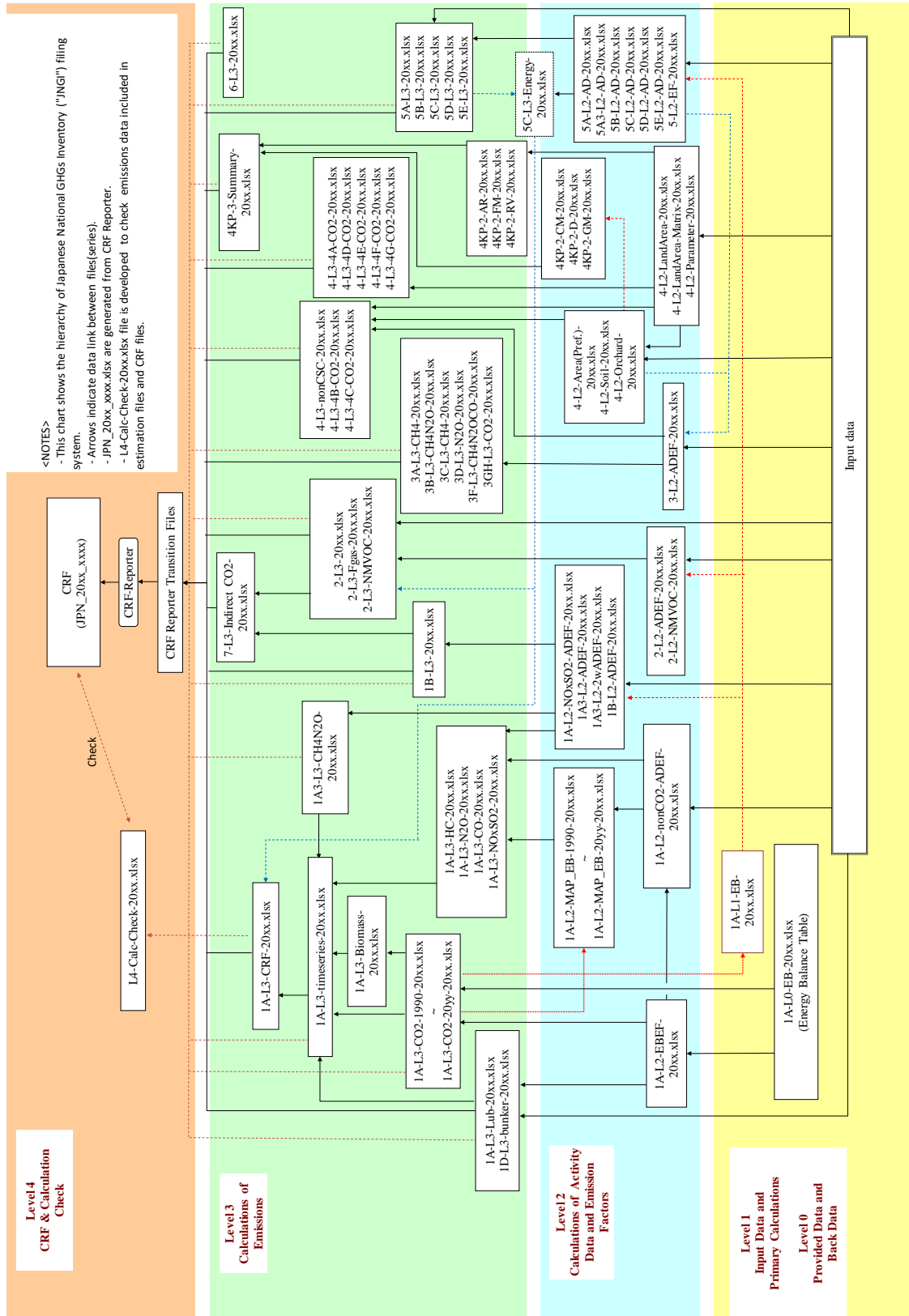


Figure A 6-1 Hierarchical structure of Japan's National GHG Inventory File System

Abbreviations

1. Greenhouse Gases

Table AB-1 Greenhouse Gases

Term	Gas
CO ₂	Carbon dioxide
CH ₄	Methane
N ₂ O	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	Sum of nitrogen oxide and nitrogen dioxide
CO	Carbon monoxide
NMVOG	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
l	litter
a	are
ha	hectare
g	gram
t	tonne
J	joule
°C	degree Celsius
yr	year
cap	capita
d.m.	dry matter

3. Notation Keys

Table AB-5 Notation keys (See Annex 5 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	AAU	Assigned Amount Units
	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
	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
	MOFA	Ministry of Foreign Affairs of Japan
	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
	NFRDB	National Forest Resource DataBase
	NGL	Natural Gas Liquids
	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
S	SEF	Standard Electronic Format
T	THC	Total Hydrocarbon
	TOE	Tonnes of Oil Equivalent
U	UNFCCC	United Nations Framework Convention on Climate Change