

GREENHOUSE GAS EMISSIONS IN FINLAND  
1990-2012

*National Inventory Report under the UNFCCC and  
the Kyoto Protocol*

*15 April 2014*

# PREFACE

Finland's National Inventory Report (NIR) under the UNFCCC (United Nations Framework Convention on Climate Change) and the Kyoto Protocol contains the following parts:

- Part 1 Finland's national greenhouse gas emission inventory report (NIR) prepared using the reporting guidelines (UNFCCC 2006) and the guidelines for the preparation of the information required under Article 7, paragraph 1 in Decision 15/CMP.1 of the Kyoto Protocol.
- Part 2 CRF (Common Reporting Format) data tables showing Finland's greenhouse gas emissions for the years 1990-2012 including KP-LULUCF data tables. The CFR tables were compiled using UNFCCC CRF Reporter software (version 3.7.3).
- Part 3 SEF (Standard Electronic Tables) for the reporting of Kyoto units of the first commitment period (AAU, ERU, CER, t-CER, l-CER, RMU) in the registry, 31.12.2013, and transfers of the units during 2013.

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The Finnish inventory report as well as the CRF tables can be downloaded from the following address: <http://stat.fi/greenhousegases>.

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<b>PREFACE .....</b>	<b>2</b>
<b>EXECUTIVE SUMMARY.....</b>	<b>7</b>
ES.1 Background information on greenhouse gas inventories and climate change .....	7
ES.2 Summary of trends in national emissions and removals.....	8
ES.3 Overview of source and sink category emission estimates and trends.....	10
ES.4 Background information and summary of emissions and removals from KP-LULUCF activities .....	13
<b>1 INTRODUCTION .....</b>	<b>14</b>
1.1 Background information on greenhouse gas inventories and climate change .....	14
1.2 A description of the institutional arrangements for inventory preparation .....	17
1.3 Brief description of the process of inventory preparation .....	21
1.4 Brief general description of the methodologies and data sources used .....	22
1.5 Brief description of the key categories.....	24
1.6 Information about the QA/QC plan including verification and treatment of confidentiality issues .....	27
1.7 Summary of the uncertainty analysis .....	37
1.8 General assessment of completeness .....	40
<b>2 TRENDS IN GREENHOUSE GAS EMISSIONS .....</b>	<b>41</b>
2.1 Description and interpretation of emission trends for aggregated greenhouse gas emissions .....	41
2.2 Description and interpretation of emission trends by gas .....	43
2.3 Description and interpretation of emission trends by category .....	45
2.4 Description and interpretation of emission trends of indirect greenhouse gases and sulphur oxides .....	52
2.5 Emissions and removals from KP-LULUCF activities .....	54
<b>3 ENERGY (CRF 1).....</b>	<b>55</b>
3.1 Overview of the sector (CRF 1) .....	55
3.2 Energy industries and Manufacturing industries and Construction (CRF 1.A 1, CRF 1.A 2) ....	67
3.3 Transport (CRF 1.A 3).....	87
3.4 Other sectors and Other (CRF 1.A 4, CRF 1.A 5).....	117
3.5 Fugitive emissions from solid fuels (CRF 1.B 1) .....	123
3.6 Fugitive emissions from oil and natural gas (CRF 1.B 2) .....	124
3.7 Reference approach.....	128
3.8 International bunkers .....	130
Appendix_3a .....	132
Appendix_3b .....	136
Appendix_3c.....	141
Appendix_3d .....	142
<b>4 INDUSTRIAL PROCESSES (CRF 2).....</b>	<b>144</b>
4.1 Overview of the sector .....	144

4.2 Mineral Products (CRF 2.A) .....	148
4.3 Chemical Industry (CRF 2.B).....	162
4.4 Metal Production (CRF 2.C) .....	173
4.5 Other Production (CRF 2.D) .....	184
4.6 Consumption of Halocarbons and SF <sub>6</sub> (CRF 2.F) .....	185
Appendix_4 .....	203
<b>5 SOLVENT AND OTHER PRODUCT USE (CRF 3).....</b>	<b>207</b>
5.1 Overview of the sector .....	207
5.2 Paint application (CRF 3.A), Degreasing and dry cleaning (CRF 3.B) and Chemical products, manufacture and processing (CRF 3.C) .....	210
5.3 Other (CRF 3.D) .....	212
<b>6 AGRICULTURE (CRF 4).....</b>	<b>215</b>
6.1 Overview of the sector .....	215
6.2 Enteric Fermentation (CRF 4.A) .....	220
6.3 Manure Management (CRF 4.B) .....	229
6.4 Agricultural Soils (CRF 4.D) .....	245
6.5 Field Burning of Agricultural Residues (CRF 4.F) .....	255
Appendix_6a .....	258
Appendix_6b .....	264
<b>7 LAND USE, LAND-USE CHANGE AND FORESTRY (CRF 5) .....</b>	<b>265</b>
7.1 Overview of the sector .....	265
7.2 Forest land (CRF 5.A) .....	275
7.3 Cropland (CRF 5.B) .....	295
7.4 Grassland (CRF 5.C).....	304
7.5 Wetlands (CRF 5.D) .....	309
7.6 Settlements (CRF 5.E).....	317
7.7 Other land (CRF 5.F) .....	320
7.8 Non-CO <sub>2</sub> emissions .....	321
7.9 Harvested Wood Products (CRF 5.G) .....	331
Appendix_7a .....	338
Appendix_7b .....	341
Appendix_7c.....	344
Appendix_7d .....	348
Appendix_7e.....	350
Appendix_7f.....	356
Appendix_7g .....	359
Appendix_7h .....	361
Appendix_7i .....	362
Appendix_7j .....	365

Appendix_7k .....	366
<b>8 WASTE (CRF 6) .....</b>	<b>374</b>
8.1 Overview of the sector .....	374
8.2 Solid Waste Disposal on Land (CRF 6.A) .....	378
8.3 Wastewater Handling (CRF 6.B) .....	389
8.4 Waste Incineration (CRF 6.C).....	396
8.5 Composting (CRF 6.D).....	397
Appendix_8a .....	401
Appendix_8b .....	403
Appendix_8c.....	404
<b>9 OTHER (CRF 7) .....</b>	<b>407</b>
<b>10 RECALCULATIONS AND IMPROVEMENTS .....</b>	<b>408</b>
10.1 Explanations and justification for recalculations, implications on emission levels and trends including time series' consistency .....	408
10.2 Implications for emission levels.....	413
10.3 Implications for emission trends, including time series' consistency.....	413
10.4 Recalculations, including in response to the review process, and planned improvements to the inventory.....	414
<b>11 KP-LULUCF .....</b>	<b>421</b>
11.1 General information .....	421
11.2 Land related information.....	427
11.3 Activity-specific information .....	429
11.4 Article 3.3 .....	435
11.5 Article 3.4 .....	440
11.6 Other information .....	443
11.7 Information relating Article 6 .....	443
Appendix_11a .....	444
<b>12 INFORMATION ON ACCOUNTING OF KYOTO UNITS.....</b>	<b>447</b>
12.1 Background information.....	447
12.2 Summary of information reported in the SEF tables.....	447
12.3 Discrepancies and notifications .....	447
12.4 Publicly accessible information .....	447
12.5 Calculation of the commitment period reserve (CPR) .....	448
12.6 KP-LULUCF accounting .....	448
<b>13 INFORMATION ON CHANGES IN NATIONAL SYSTEM.....</b>	<b>449</b>
<b>14 INFORMATION ON CHANGES IN NATIONAL REGISTRY.....</b>	<b>450</b>
<b>15 INFORMATION ON MINIMISATION OF ADVERSE IMPACTS IN ACCORDANCE WITH ARTICLE 3, PARAGRAPH 14 .....</b>	<b>452</b>
<b>REFERENCES .....</b>	<b>456</b>

<b><i>ANNEXES TO THE NATIONAL INVENTORY REPORT .....</i></b>	<b><i>472</i></b>
<b>ANNEX 1. Key categories .....</b>	<b>472</b>
<b>ANNEX 2. Description of the Compliance Monitoring Data System VAHTI .....</b>	<b>479</b>
<b>ANNEX 3. Discussion of the default CO<sub>2</sub> emission factor for coal and its applicability to the Finnish inventory.....</b>	<b>482</b>
<b>ANNEX 4. Tier 1 Reference calculation based on National Energy Balances of 2012.....</b>	<b>486</b>
<b>ANNEX 5. Assessment of completeness and (potential) sources and sinks of greenhouse gas emissions and removals excluded.....</b>	<b>494</b>
<b>ANNEX 6. Uncertainty analysis.....</b>	<b>507</b>
<b>ANNEX 7. Additional information to be considered as part of the annual inventory submission and the supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol or other useful reference information .....</b>	<b>523</b>

# EXECUTIVE SUMMARY

## *ES.1 Background information on greenhouse gas inventories and climate change*

Finland is a Party to the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. Under these international agreements, Finland is committed to provide annually information on its national anthropogenic greenhouse gas emissions by sources and removals by sinks for all greenhouse gases not controlled by the Montreal Protocol. As a member of the European Union, Finland has reporting obligations also under the Regulation (EU) No 525/2013 on the European Parliament and of the Council on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change and repealing Decision No 280/2004/EC. This regulation encompasses also reporting to fulfil the EU Effort Sharing Decision (406/2009/EC) and the EU LULUCF Decision (529/2013/EU). The implementing and delegated acts under Regulation 525/2013 are under preparation with a view for adoption in the first half of 2014. This report aims at fulfilling the reporting commitments under all above-mentioned agreements.

The annual greenhouse gas inventory provides information on the trends in national greenhouse gas emissions and removals since 1990. This information is essential for the planning and monitoring of climate policies.

In accordance with the Government resolution of 30 January 2003 on the organisation of climate policy activities of Government authorities in Finland, Statistics Finland assumed the responsibilities of the National Entity for Finland's greenhouse gas inventory from the beginning of 2005. Statistics Finland as the general authority of the official statistics of Finland is independently responsible for greenhouse gas inventory submissions under the UNFCCC, the Kyoto Protocol and the EU monitoring mechanism. Besides Statistics Finland, the Finnish Environment Institute, MTT Agrifood Research Finland and the Finnish Forest Research Institute take part in the inventory preparation. Statistics Finland acquires also parts of the inventory calculations as purchased services from VTT (Technical Research Centre of Finland). In Finland the national system, as intended in the Kyoto Protocol (Article 5.1), is based, besides regulations concerning Statistics Finland, on agreements on the production of emission/removal estimations and reports between the inventory unit at Statistics Finland and the expert organisations mentioned above. Statistics Finland has also agreements with the responsible ministries defining the responsibilities and collaboration in relation to the reporting requirements under the UNFCCC and Kyoto Protocol, as well as the EU monitoring mechanism. A short description on the National Greenhouse Gas Inventory System in Finland is provided in Section 1.2. A more detailed, although partly outdated description can be found from the report "National Greenhouse Gas Inventory System in Finland" which is available on the web: <http://stat.fi/greenhousegases>. Updated information on the institutional arrangements is provided in Chapter 1 Introduction of this report. Changes in Finland's national system have been reported annually in Chapter 13 of the national inventory reports.

This report also includes supplementary information in accordance with Article 7, paragraph 1, of the Kyoto Protocol. The required information is specified in the Annex of Decision 15/CMP.1 and includes information on changes in the national system and nations registry (see Chapters 13 and 14), information related to Article 3, paragraphs 3 and 4 (see Chapter 11), and Article 3, paragraph 14 (Chapter 15). A summary of information on the accounting of Kyoto units is provided in Chapter 12, and more detailed information in the Standard Electronic Tables (SEF) that are part of Finland's inventory submission.

## *ES.2 Summary of trends in national emissions and removals*

In 2012, Finland's greenhouse gas emissions totalled 61.0 Tg CO<sub>2</sub> eq. (million tonnes of CO<sub>2</sub> equivalent). The total emissions in 2012 were approximately 14% (10.0 Tg) below the level of the base year (1990 for CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O, and 1995 for HFCs, PFCs and SF<sub>6</sub>) – the level to which Finland should limit its emissions during the Kyoto Protocol's first commitment period between 2008 and 2012. Compared to 2011, the emissions decreased with 9%.

A summary of the Finnish national emissions and removals for 1990-2012 is presented in Table ES.2-1.

Energy related CO<sub>2</sub> emissions vary much in Finland, mainly according to the economic trend, the energy supply structure and climate conditions. Total consumption of energy in Finland amounted to 1.37 million terajoules (TJ) in 2012, which was one per cent less than in 2011. The industrial output decreased slightly as well as total energy consumption in industry. The share of renewable energy of total energy consumption increased in 2012 and stood at 32 per cent. The biggest growth was seen in the use of wood fuels that for the first time became the most used source of energy. The use of forest chippings rose to a new record level in 2012 and 11 per cent more was used than in 2011. The use of fossil fuels went down by eight per cent from the year before. Of fossil fuels, the consumption of coal (including hard coal, coke, and blast furnace and coke oven gas) decreased by 16 per cent. The use of coal diminished significantly in condensing power production. The use of natural gas fell by 12 per cent and the use of peat by 23 per cent from 2011. The availability of hydro power improved in the Nordic countries in 2012. The production of hydro power increased by 36 per cent in Finland. (Energy supply and consumption, Statistics Finland).

Imports of electricity increased by eight per cent. The largest amount of electricity was imported from Sweden, from where imports amounted to 14.2 TWh. Finland was a net buyer on the Nordic electricity market. Imports from Russia decreased by 59 per cent from 2011. Altogether, 57 per cent less electricity was exported than in the year before, which was the result of hydro power being readily available in the Nordic countries. Net imports of electricity covered 20.5 per cent of total electricity consumption. (Energy supply and consumption, Statistics Finland).

Emissions in the Industrial Processes sector increased between 1993 and 2008 to a level almost 40 per cent higher than the base year emissions, but decreased almost equally due to the economic downturn and technical abatement measures implemented to reduce N<sub>2</sub>O emissions in nitric production in 2009. The emissions took an upward trend again in 2010 being at a level almost 30 per cent lower than the peak value in 2008. Since 2010 emissions have had a decreasing trend, emissions in 2012 are 8% lower than 2010. In the beginning of the time series, several plants were closed down due to an earlier economic recession. The technical abatement of N<sub>2</sub>O emissions from nitric acid production has contributed much to the lowering of the emissions since 2009 in the Industrial Processes sector. The growth in HFC emissions has contributed with an almost equal amount to the increase of the emissions in this sector. Indirect CO<sub>2</sub> emissions have decreased over 75% since 1990, main reason is that industry has reduced use of solvent chemicals.

Emissions in the Agriculture and Waste sectors have decreased since 1990. The decrease can largely be attributed to changes in waste legislation, implementation of the Landfill Directive (1999/31/EC), and changes in agricultural policy and farming subsidies.

The LULUCF sector in Finland has been a net sink during the whole reporting period 1990-2012 as the removals in the sector exceeded the emissions. Most of the removals in the LULUCF sector came from tree biomass growth; that is to say the tree volume increment has exceeded the annual total drain. The increment of the growing stock has increased in Finland since 1990. Annual variations in the total drain (roundwood removals, logging residues and natural losses) have been considerable. In addition, the aggregated dead organic matter and soil organic matter pool in mineral soils has been a significant sink during the reporting period. The largest emissions in the LULUCF sector came from changes in soil organic carbon in organic forest and agricultural soils.



**Table ES.2-1** Finnish greenhouse gas emissions and removals. The base year of the Kyoto Protocol is 1990 except for F-gases 1995

<b>Sector</b>	<b>Base year</b>	<b>1990</b>	<b>1991</b>	<b>1992</b>	<b>1993</b>	<b>1994</b>	<b>1995</b>	<b>1996</b>	<b>1997</b>	<b>1998</b>	<b>1999</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>	<b>2011</b>	<b>2012</b>
Energy	54.7	54.5	53.1	52.3	54.3	59.5	56.0	61.7	60.2	56.8	56.3	54.4	59.7	62.3	70.0	65.8	54.0	65.3	63.2	54.7	52.7	60.5	53.3	47.8
Industrial processes <sup>1</sup>	5.0	5.0	4.7	4.4	4.5	4.6	4.6	4.8	5.0	4.9	5.0	5.0	5.0	5.0	5.3	5.5	5.4	5.5	5.9	6.1	4.4	4.6	4.5	4.3
F- gases	0.10	0.12	0.08	0.05	0.03	0.04	0.10	0.15	0.24	0.30	0.40	0.57	0.72	0.53	0.73	0.76	0.94	0.83	0.96	1.06	0.95	1.21	1.07	0.96
Solvent and other product use	0.18	0.18	0.17	0.16	0.15	0.15	0.14	0.14	0.14	0.14	0.13	0.12	0.12	0.11	0.10	0.10	0.10	0.10	0.10	0.09	0.07	0.07	0.07	0.07
Agriculture	7.1	6.5	6.2	5.8	5.8	5.9	6.0	5.9	5.9	5.8	5.7	5.8	5.7	5.8	5.8	5.7	5.7	5.7	5.8	5.8	5.7	5.9	5.8	5.7
Waste	4.0	4.0	4.0	4.0	4.0	4.0	3.9	3.8	3.7	3.6	3.5	3.3	3.1	2.9	2.7	2.6	2.4	2.5	2.4	2.3	2.2	2.2	2.1	2.1
<b>TOTAL</b>	<b>71.0</b>	<b>70.3</b>	<b>68.1</b>	<b>66.7</b>	<b>68.8</b>	<b>74.2</b>	<b>70.8</b>	<b>76.5</b>	<b>75.1</b>	<b>71.5</b>	<b>71.0</b>	<b>69.2</b>	<b>74.4</b>	<b>76.6</b>	<b>84.6</b>	<b>80.6</b>	<b>68.6</b>	<b>79.9</b>	<b>78.2</b>	<b>70.1</b>	<b>66.0</b>	<b>74.4</b>	<b>66.9</b>	<b>61.0</b>
<b>(exl. LULUCF<sup>2</sup>)</b>																								
LULUCF <sup>2</sup>	NA	-13.7	-27.4	-22.0	-19.9	-13.0	-12.8	-22.2	-17.4	-15.3	-18.5	-19.2	-22.4	-22.9	-23.4	-24.3	-28.6	-32.5	-24.3	-29.0	-38.8	-24.1	-24.1	-25.9

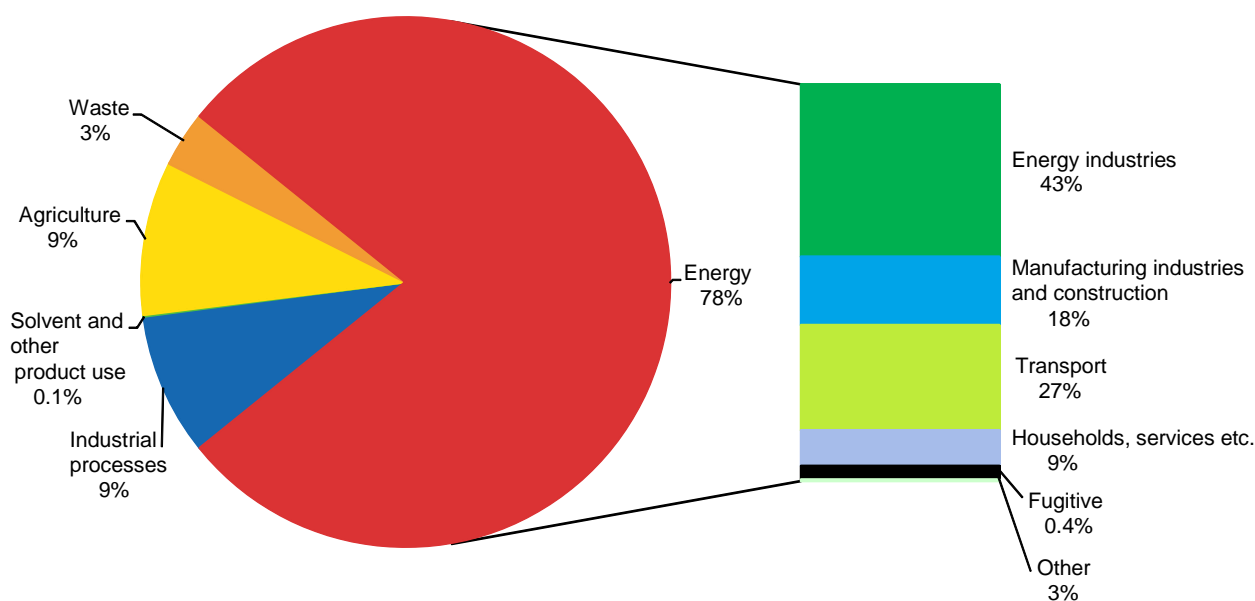
<sup>1</sup>excluding F-gases<sup>2</sup>Land use, land-use change and forestry

(Note: Due to rounding, the sum of subtotals does not necessarily equal to total figures.)

## ES.3 Overview of source and sink category emission estimates and trends

The greenhouse gas emissions and removals are divided into the following reporting categories according to the Updated UNFCCC reporting guidelines on annual inventories following incorporation of the provisions of decision 14/CP.11 (UNFCCC 2006): Energy (CRF 1), Industrial Processes (CRF 2), Solvent and product use (CRF 3), Agriculture (CRF 4), Land Use, Land Use Change and Forestry (LULUCF) (CRF 5), and Waste (CRF 6).

The composition of Finnish greenhouse gas emissions in 2012 is presented in Figure ES.3-1.



**Figure ES.3-1** The composition of Finnish greenhouse gas emissions in 2012 (LULUCF sector excluded). Due to independent rounding the sums do not add up

The energy sector is the most significant source of greenhouse gas emissions in Finland with an 78% share of the total emissions in 2012, being 47.8 Tg CO<sub>2</sub> eq. This reflects the high energy intensity of the Finnish industry, extensive consumption for a long heating period, as well as energy consumption for transport in a large and sparsely inhabited country. Energy-related CO<sub>2</sub> emissions vary mainly according to the economic trend, the energy supply structure and climate conditions. The total primary energy supply decreased in 2012 by 1% compared with the previous year.

Agriculture is the second most significant source of greenhouse gas emissions in Finland. In 2012, agricultural emissions accounted for almost 9% (5.7 Tg CO<sub>2</sub> eq.) of total emissions. Emissions from agriculture include CH<sub>4</sub> and N<sub>2</sub>O emissions. The total emissions from agriculture have a decreasing trend. The annual emissions have reduced by 13% since 1990 due to decreases in the number of livestock and in nitrogen fertilisation. Changes in the agricultural policy and farming subsidies have had a significant influence on the agricultural activities and hence the emissions from this sector.

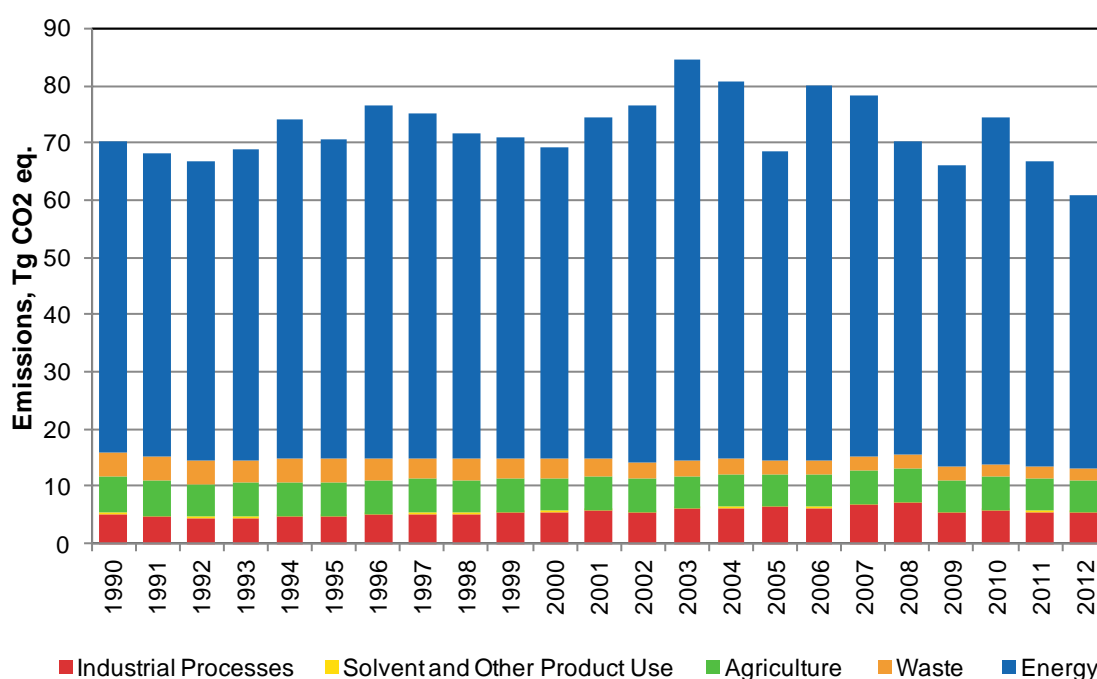
The emissions from industrial processes (referred to as non-energy related ones), including CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O and F-gases, were also 9% (5.3 Tg CO<sub>2</sub> eq.) of total greenhouse gas emissions in Finland in 2012, being the third largest source of greenhouse gas emissions. Emissions from the process industry have increased by about 3% (~0.2 Tg CO<sub>2</sub> eq.) since 1990. Their share from the total greenhouse gas emissions has varied from 6 to 10 per cent of total emissions during the reporting period. The fluctuation in the emissions from industrial processes is largely consistent with the economic trend, even if the factors influencing the emissions are more diverse.

The waste sector accounted for 3% (2.1 Tg CO<sub>2</sub> eq.) of total Finnish greenhouse gas emissions in 2012. Emissions from the waste sector consist of CH<sub>4</sub> and N<sub>2</sub>O emissions and they have had a decreasing trend since 1990. Overall, the annual emissions in the waste sector have decreased by 48% since 1990. The decrease has been mainly due to the implementation of the Waste Act introduced in 1994, which requires increased recycling and recovery of waste as material or energy as well as recovery of landfill gas.

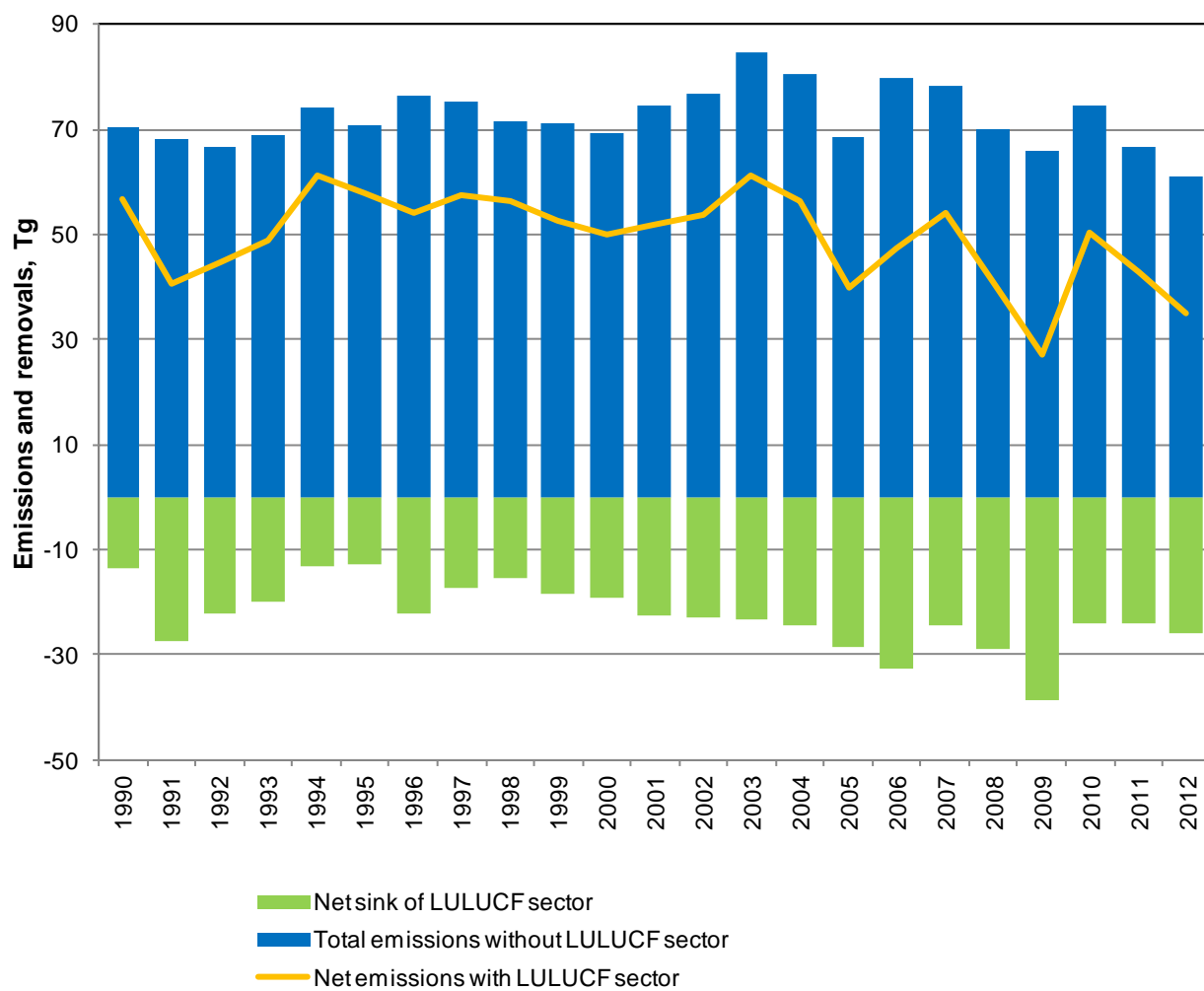
The contribution of emissions from solvents and other product use to the Finnish greenhouse gas emissions is small, about 0.1% of the total greenhouse gas emissions in Finland.

Indirect N<sub>2</sub>O emissions caused from N deposition of NO<sub>x</sub> emissions are reported in the category Energy in the Finnish inventory. These contribute about 0.3% to the total emissions.

The LULUCF sector is a net sink in Finland. The net sink in the LULUCF sector has varied from approximately 20% to over 60% of the annual emissions from the other sectors during 1990-2012 (Figure ES.3-3). Most of the removals in the LULUCF sector come from tree biomass growth. The annual volume increment has increased steadily for which reason the CO<sub>2</sub> uptake has also grown. The total drain is very much affected by commercial roundwood fellings and the global market situation. Due to the falling domestic roundwood markets the commercial roundwood 2009 were 41 million m<sup>3</sup> being 20% smaller than in previous year. In 2010, production of forest industry recovered. The wood products industry's production rebounded closer to its normal level when demand increased both domestically and in the export markets. In 2010, commercial fellings totalled 52 million m<sup>3</sup>, which is almost one fourth more than in previous year. Increased fellings resulted in a decrease in biomass C stock sinks compared the previous year. In 2012, the growth of the Finnish national economy was at a modest rate. The total drain was 70 million m<sup>3</sup> of which the commercial roundwood removals were 52 million m<sup>3</sup> that is about at the same level as in previous year. (Finnish Statistical Yearbook of Forestry 2013).



**Figure ES.3-2** Greenhouse gas emissions in Finland by reporting sector (Tg CO<sub>2</sub> eq.)



**Figure ES.3-3** Net CO<sub>2</sub> equivalent emissions of greenhouse gases (emissions plus removals). Emissions are positive and removals negative quantities

## ES.4 Background information and summary of emissions and removals from KP-LULUCF activities

Finland's emission limitation target for the Kyoto Protocol's first commitment period (CP, 2008-2012) is to limit its greenhouse gas emissions to the same average level as the emissions in the base year. Finland's base year is 1990, except for F-gas emissions for which the year 1995 was selected. The assigned amount for the first CP is 355,017,545 tonnes CO<sub>2</sub> equivalents, which is approximately 71 million tonnes CO<sub>2</sub> eq. annually on average.

For the LULUCF activities under Article 3 paragraphs 3 and 4, of Kyoto Protocol Finland has chosen commitment period accounting. Article 3.3 covers direct, human induced afforestation (A), reforestation (R) and deforestation (D) activities, and accounting of these activities is mandatory. Under Article 3.4 Finland has elected the activity Forest Management (FM) for optional accounting of the first CP. Net removals from FM activity can be used to compensate net emissions from activities under Article 3.3, and through the issuance of removal units (RMUs) up to a cap value. Finland's cap value for the CP is 2,933,333 tonnes CO<sub>2</sub> equivalents.

Net emissions from ARD activities in 2012 were 2.4 million tonnes CO<sub>2</sub> eq., and net removals from FM activity were 35.6 million tonnes CO<sub>2</sub> eq. (Table ES.4-1). Based on the estimates for the fifth year of the CP Finland would be able to issue RMUs 0.58 million tonnes CO<sub>2</sub> eq. (cap value divided by 5) for this year at the end of the CP.

**Table ES.4-1** Emissions and removals in 2012 resulting from activities under Article 3.3 and 3.4 of Kyoto Protocol

GREENHOUSE GAS SOURCE AND SINK ACTIVITIES <sup>1,2</sup>	Net CO <sub>2</sub> emissions/ removals	CH <sub>4</sub>	N <sub>2</sub> O	Net CO <sub>2</sub> eq. emissions/ removals
			(Gg)	
A. Article 3.3 activities				2 351
A.1. Afforestation and Reforestation	- 181	NA,NO	0.15	- 135
A.1.1. Units of land not harvested since the beginning of the commitment period	- 181	NO	0.15	- 135
A.1.2. Units of land harvested since the beginning of the commitment period	NA	NA	NA	NA
A.2. Deforestation	2 482	IE,NE,NO	0.02	2 486
B. Article 3.4 activities				-35 596
B.1. Forest Management	-36 788	0.02	3.84	-35 596
B.2. Cropland Management	NA	NA	NA	NA
B.3. Grazing Land Management	NA	NA	NA	NA
B.4. Revegetation	NA	NA	NA	NA

<sup>1</sup> IE (included elsewhere), NA (not applicable), NO (not occurring)

<sup>2</sup> The signs for removals are negative (-) and for emissions positive (+)

# 1 INTRODUCTION

## 1.1 Background information on greenhouse gas inventories and climate change

### 1.1.1 Greenhouse gas inventories

The annual inventory and reporting of greenhouse gas emissions and removals provide an information base for the planning and monitoring of climate policy. The Kyoto Protocol obliges its parties to establish a national greenhouse gas inventory system by the end of 2006. Finland's National Greenhouse Gas Inventory System was set up at the beginning of 2005.

The national system produces data and background information on emissions and removals for the UNFCCC, the Kyoto Protocol and the EU Commission. In addition, the scope of the system covers the archiving of the data used in emission estimations, the publishing of the results, participation in inventory reviews and the quality management of the inventory.

The decisions of the European Parliament and of the Council concerning a mechanism for monitoring Community greenhouse gas emissions and for implementing the Kyoto Protocol obliges the Member States (MS) of the European Union (EU) to participate in the compilation of the EU's common greenhouse gas inventory. This procedure causes a two-phased submission of MS inventory reporting to the Commission with annual deadlines for submission 15 January and 15 March.

This National Inventory Report (NIR) of Finland for the submission to the EU, the UNFCCC and the Kyoto Protocol includes data of the anthropogenic emissions by sources and removals by sinks of all greenhouse gases (GHGs) not controlled by the Montreal Protocol, i.e. carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF<sub>6</sub>).

Indirect CO<sub>2</sub> emissions resulting from atmospheric oxidation of CH<sub>4</sub> and NMVOC emissions from non-biogenic sources are also included in the inventory. These have been separately estimated for fugitive emissions in the Energy sector and sources in the Industrial Process and Solvent and Other Product Use sectors using the methodology given in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006, Vol. 1, see Section 7.2.1.5). For fossil fuel combustion, indirect emissions are included in the methodology to estimate CO<sub>2</sub> emissions. The estimation and reporting of indirect CO<sub>2</sub> emissions are also addressed in the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 1997) and the UNFCCC reporting guidelines on annual inventories (UNFCCC 2006).

The NIR includes also estimates of so-called indirect greenhouse gases (carbon monoxide (CO), nitrogen oxides (NO<sub>x</sub>) and non-methane volatile organic compounds (NMVOCs) and sulphur dioxide (SO<sub>2</sub> meaning sulphur oxides and other sulphur emissions calculated as SO<sub>2</sub>). Indirect greenhouse gases and sulphur dioxide do not have a direct warming effect, but influence on the formation or destruction of direct greenhouse gases, such as tropospheric ozone. These gases are not included in Annex A of the Kyoto Protocol.

The emission estimates and removals are presented by gas and by source category and refer to the latest inventory year unless otherwise specified. Full time series of the emissions and removals from 1990 to latest inventory year are included in the submission.

The structure of this NIR follows the UNFCCC reporting guidelines on annual inventories (UNFCCC 2006). The annotated outline of the NIR, and the guidance contained therein, developed by the UNFCCC secretariat in 2009, has also been followed for most parts. Chapter 1 introduces the background of greenhouse gas inventories and the inventory preparation process and Chapter 2 presents the overall emission trend in Finland from 1990 to 2009. In Chapters 3–9 more detailed information of GHG emission estimates are given for the seven sectors: (i) energy, (ii) industrial processes, (iii) solvent and other product use, (iv) agriculture, (v) land use, land-use change and forestry, (vi) waste, and (vii) other. In Chapter 10 improvements and recalculations since the previous submission are summarised. Chapter 11 provides description of KP-LULUCF, Chapter 12 information

on accounting of Kyoto units, Chapter 13 information on changes in national system and Chapter 14 information on changes in national registry. Chapter 15 gives information on minimisation of adverse impacts in accordance with Article 3, paragraph 14. Annex 1 contains the mandatory key category reporting tables, the information which is also provided in summary form in Section 1.5 and CRF table 7. In Annex 2 the VAHTI emission database of Finland's environmental administration is described. Annex 3 discusses the applicability of the IPCC default CO<sub>2</sub> emission factor for coal to Finnish circumstances. A national reference calculation for CO<sub>2</sub> emissions from energy combustion is included in Annex 4 (Comparison of CO<sub>2</sub> emissions calculated from the Energy balance with fuel combustion emissions as reported in the CRF tables). Assessment of completeness and (potential) sources and sinks of greenhouse gas emissions and removals excluded is included in Annex 5. Annex 6 contains the mandatory uncertainty reporting table (table 6.1 of Good Practice Guidance 2000), and additional information on Tier 2 uncertainty analysis. Annex 7 includes additional information to be considered as part of the annual inventory submission and the supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol or other useful reference information.

### 1.1.2 Climate change

Over the past century, atmospheric concentrations of carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O) and halogenated hydrocarbons, i.e. greenhouse gases, have increased as a consequence of human activity. Greenhouse gases prevent the radiation of heat back to space and cause warming of the climate. According to the Fifth Assessment Report of the International Panel of Climate Change (IPCC 2013), the atmospheric concentrations of CO<sub>2</sub> have increased by 40%, CH<sub>4</sub> concentrations have more than doubled and N<sub>2</sub>O concentration has risen by 20%, compared with the pre-industrial era.

Changing climate has effects on both human and natural systems (e.g. human settlements, human health, water and food resources, ecosystems and biodiversity). Some of the effects on environmental and socio-economic systems will be beneficial, some damaging. The larger the changes and the rate of changes in climate, the more the adverse effects will predominate. In Finland the adverse impacts are related, for example, to the resilience of the northern ecosystems, winter tourism, increased flooding and the prevalence of pests and diseases. Positive impacts could be possible growth of productivity in agriculture and forestry and decreased need for heating energy.

### 1.1.3 International agreements

Finland is committed to follow the United Nations Framework Convention on Climate Change that entered into force on 21 March 1994. The Kyoto Protocol negotiated in 1997 under the UN Framework Convention on Climate Change was ratified by the EU and Finland in May 2002. The Kyoto Protocol took effect on 16 February 2005 and became legally binding. *Under the first commitment period 2008 – 2012 of Kyoto Protocol Finland's commitment, as part of the EC's common emission reduction target and burden sharing agreement, is to limit its emissions of greenhouse gases in the first commitment period, i.e. from 2008 to 2012, to the same average level as the emissions in 1990<sup>1</sup>.*

The Kyoto Protocol (Article 5.1) requires that the parties have in place a National System by the end of 2006 at the latest for estimating anthropogenic greenhouse gas emissions by sources and removals by sinks not controlled by the Montreal Protocol. The guidelines for national systems under Article 5, paragraph 1, of the Kyoto Protocol (Decision 19/CMP.1) provide the requirements for the general and specific functions of the national systems. Finland's inventory system was established on 1 January 2005, and reviewed successfully as part of the review of the Finland's initial report under Protocol in 2007.

Under the UNFCCC and the Kyoto Protocol, Finland is required to submit annually to secretariat of the Convention a national greenhouse gas inventory covering emissions and removals of direct greenhouse gases from the six sectors (Energy, Industrial Processes, Solvent and Other Product Use, Agriculture, Land use, Land-use change and Forestry and Waste) and for all years from the base year or period to the most recent year. The preparation and reporting of the inventories are guided by the UNFCCC guidelines (UNFCCC 2006) and are

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<sup>1</sup> Finland's base year under the Kyoto Protocol is 1990. However, in accordance with Article 3, paragraph 8 of Kyoto Protocol Finland has elected 1995 as the base year for emissions of hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride.

based on the following IPCC methodologies to ensure the comparability, accuracy and completeness of the inventories;

- *Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories referred hereafter as 1996 IPCC GL (IPCC 1997 in References)*
- *IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories 2000 referred hereafter as GPG 2000 (IPCC 2000 in References)*
- *IPCC Good Practice Guidance for Land Use, Land Use Change and Forestry 2003 referred hereafter as GPG LULUCF 2003 (IPCC 2003 in References)*

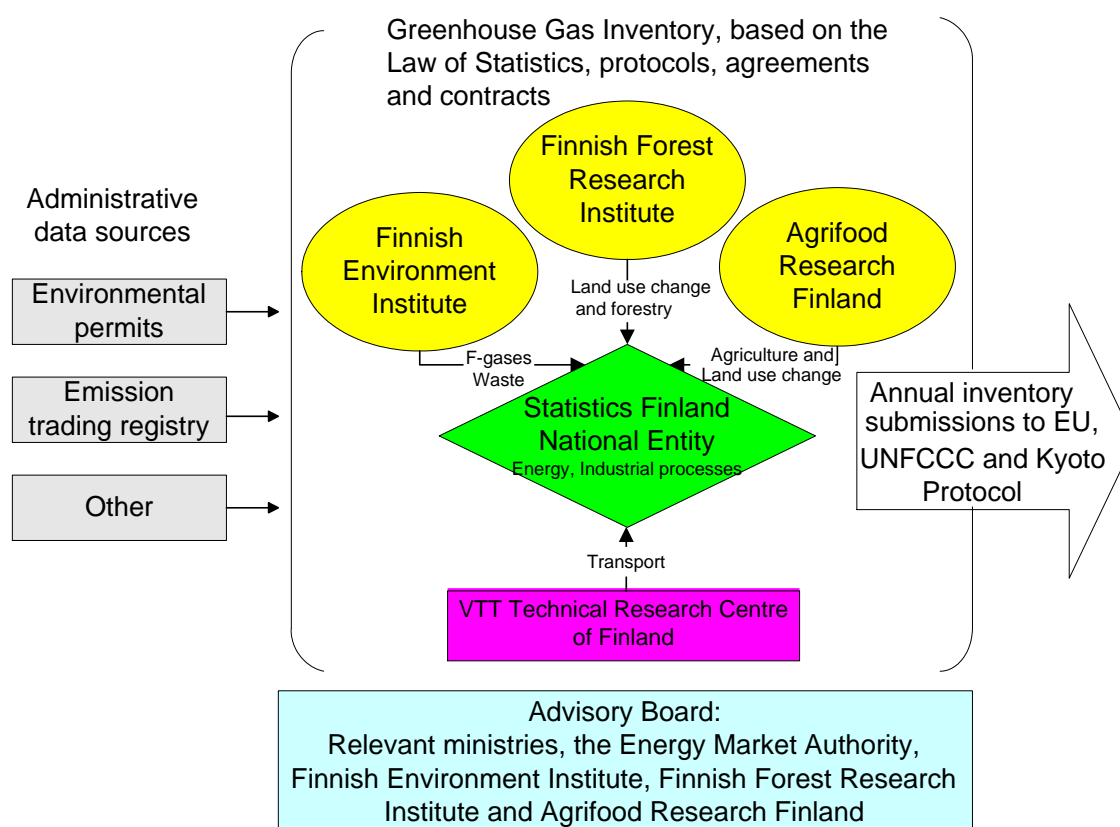
The EU's greenhouse gas monitoring mechanism (EU/525/2013) combines information on annual emission inventories, among other the evaluation of the effects of the policy measures and planning of new measures as well as monitoring related to legislation under the EU Climate and Energy package, namely the EU Effort Sharing Decision (406/2009/EC), which sets legally binding targets for the sectors not included in the EU Emissions Trading, and the EU LULUCF Decision (529/2013/EU), which provides requirement for accounting of emissions/removals from LULUCF activities but does not include any targets for these in the period 2013 to 2020. The EU rules and modalities for reporting of greenhouse gas inventory data are based on those applied in the reporting under the UNFCCC and Kyoto Protocol, supplemented with provisions for reporting to enable the assessment of actual and projected progress of the EU and its Member States to meet their commitments under the UNFCCC and the Kyoto Protocol, and for Member States under the EU ESD and EU LULUCF decision starting with the 2015 submission.



## 1.2 A description of the institutional arrangements for inventory preparation

### 1.2.1 National Greenhouse Gas Inventory System in Finland

According to the Government resolution of 30 January 2003 on the organisation of climate policy activities of Government authorities, Statistics Finland assumes the responsibilities of the National Authority for Finland's greenhouse gas inventory from the beginning of 2005. In Finland, the National System is established on a permanent footing and it guides the development of emission calculation in the manner required by the Kyoto Protocol. The national system is based on regulations concerning Statistics Finland, on agreements between the inventory unit and expert organisations on the production of emission estimates and reports as well as on co-operation between the responsible ministries. The National System is designed and operated to ensure the transparency, consistency, comparability, completeness, accuracy and timeliness of greenhouse gas emission inventories. The quality requirements are fulfilled by implementing consistently the inventory quality management procedures. The National System for the Greenhouse Gas Inventory in Finland is presented in Figure 1.2-1 below<sup>2</sup>. Changes in national system since the previous submission are addressed in Chapter 13.



**Figure 1.2-1** The National System for the Greenhouse Gas Inventory in Finland

#### *Statistics Finland as the National Authority for the inventory*

Statistics Finland is the general authority of the official statistics of Finland and is independently responsible for greenhouse gas emission inventory preparation, reporting and submission under the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol. In its activity as the National Authority for the greenhouse gas inventory, the Statistics Finland Act and the Statistics Act are applied.

Statistics Finland defines the placement of the inventory functions in its working order. The advisory board of the greenhouse gas inventory set up by the Statistics Finland ensures collaboration and information exchange in

<sup>2</sup> The detailed description of the National Greenhouse Gas Inventory System can be download at: <http://stat.fi/greenhousegases>

issues related to the reporting of greenhouse gas emissions under the UNFCCC and the Kyoto Protocol. The advisory board reviews planned and implemented changes in inventory and the achieved quality. It approves changes to the division of tasks between the expert organisations preparing the inventory as specified in the reporting protocol (see below). In addition, the advisory board promotes research and review projects related to the development of the inventory and reporting, as well as gives recommendations on participation in international co-operation in this area (UNFCCC, IPCC and EU). The advisory board is composed of representatives from the expert organisations and the responsible Government ministries.

Statistics Finland is in charge of the compilation of the national emission inventory and its quality management in the manner intended in the Kyoto Protocol. As the National Entity Statistics Finland also bears the responsibility for the general administration of the inventory and communication with the UNFCCC, co-ordinates participation in the review of the inventory, and publishes and archives the inventory results.

### *Responsibilities of expert organisations*

Finland's inventory system includes in addition to Statistics Finland the expert organisations the Finnish Environment Institute, MTT Agrifood Research Finland and the Finnish Forest Research Institute. Statistics Finland also acquires parts of the inventory as purchased services from VTT (Technical Research Centre of Finland).

Up to 2009, Finavia (former Civil Aviation Administration) provided emission data on aviation to the inventory. In 2010, Finavia's status in Finland's inventory system changed. Finavia is not performing the calculations and is not responsible for the related calculations anymore. Statistics Finland has overtaken this task and been responsible for the calculations since 2010. Statistics Finland makes the CO<sub>2</sub> emissions calculations based on data on aviation fuel use. Finavia is supporting Statistics Finland in the task by providing Statistics Finland with additional data and expert advice. Finland's has also used aviation emission data provided by Eurocontrol for the inventory. Eurocontrol has been developing together with European Environmental Agency (EEA) and DG CLIMA a web based portal from which EU Member States could download data on fuel use and emissions in aviation. Finland has taken part in the development project to define the data and parameters to be included in the portal. However, the development of the portal has not progressed as anticipated. However, in 2011, 2012 and 2013, Eurocontrol has provided the EEA data sets with information on aviation fuel use and emissions by EU Member State based on model runs using flight data from the Eurocontrol database for representative months. According to evaluations made by EEA, the data can be used to calibrate estimates made by the countries. Finland has used the data provided for this purpose in the latest submission as one source of information (the calculations are described in Section 3.3.1).

The agreements confirm the division of responsibilities recorded in the so-called reporting protocols and they specify the procedures and tasks for the annual inventory process co-ordinated by Statistics Finland. The reporting protocols are based on the areas of responsibility of the different expert organisations and on Finland's established practice for the preparation and compilation of the greenhouse gas emission inventory. The reporting sectors for which Statistics Finland is responsible are also defined in the protocols. The list of the reporting protocols and corresponding responsible organisations is presented in Table 1.2-1.

**Table 1.2-1** Reporting protocols and their responsible organisations

Reporting protocols	Responsible organisations
A. Stationary sources - fuel combustion in point sources, such as power plants, heating boilers, industrial combustion plants and processes	Statistics Finland
B. Mobile sources (transport and off-road machinery)	Statistics Finland, VTT Technical Research Centre of Finland (as a purchased service)
C. Other fuel combustion (agriculture, households, services, public sector, etc.)	Statistics Finland
D. Fugitive emissions from energy production and distribution	Statistics Finland
E. Emissions from industrial processes	Statistics Finland

Reporting protocols	Responsible organisations
F. Emissions of F-gases	Finnish Environment Institute
G. Non-methane volatile organic compounds, NMVOC	Finnish Environment Institute
H. Emissions from agriculture	MTT Agrifood Research Finland
I. Emissions from land use, land-use change and forestry	Finnish Forest Research Institute, MTT Agrifood Research Finland
J. Emissions from waste treatment	Finnish Environment Institute
L. Activities under Article 3, paragraphs 3 and 4 of the Kyoto Protocol (ARD and FM)	Finnish Forest Research Institute, MTT Agrifood Research Finland

Most of the reporting protocols are annexed to the description of the National Greenhouse Gas Inventory System in Finland, which is available on the web: <http://stat.fi/greenhousegases>. The protocols describe the estimation process for the CRF sector or category(ies) in question using the following format:

- Scope and definitions
- CRF reporting categories
- Organisation and responsibilities
- Estimation methods
- Data sources and responsible organisations
- QA/QC
- Uncertainty estimation
- Reviews
- Annual schedule.

The reporting protocols H and I were updated in 2008. Protocol L, addressing the reporting of emissions and removals under Article 3, paragraphs 3 and 4, was added to the list of protocols, also in 2008. The updates reflect the current estimation and reporting practices as well as planned improvements.

### *The role of responsible ministries and Energy Authority in the national system*

The resources of the National System for the participating expert organisations are channelled through the relevant ministries' performance guidance (Ministry of the Environment and Ministry of Agriculture and Forestry). In addition, other ministries participating in the preparation of the climate policy advance in their administrative branch that the data collected in the management of public administration duties can be used in the emission inventory.

In accordance with the Government resolution, the ministries produce the data needed for international reporting on the content, enforcement and effects of the climate strategy. Statistics Finland assists in the technical preparation of the policy reporting. Statistics Finland also compiles technically the National Communications under the UNFCCC and the Kyoto Protocol. Separate agreements have been made on the division of responsibilities and co-operation between Statistics Finland and the ministries. The agreement between Statistics Finland and the Ministry of the Environment was updated in 2008.

The Energy Authority is the National Emissions Trading Authority in Finland, and supervises the monitoring and reporting of the emissions data under the European Emission Trading Scheme (EU ETS) and the Kyoto Protocol. Statistics Finland and the Energy Authority concluded an agreement in 2006 on collaboration between the national inventory system and registry, including a division of the responsibilities relating to reporting. The agreement between the Energy Authority and Statistics Finland was updated in 2010.

## **1.2.2 National Registry**

Finland's registry and changes to it since the previous inventory submission are described in Chapter 14. The registry was connected to the international transaction log (ITL) of the UNFCCC secretariat in October 2008.

Finland switched from separate national registry to the Union Registry on 20 June 2012. The Energy Authority continues to be the National Administrator of the Finnish Registry whereas the European Commission is now responsible for hosting the registry.

The Energy Authority provides the necessary information on emission reduction units, certified emission reductions, temporary certified emission reductions, long-term certified emission reductions and assigned amount units and removals units for annual inventory submissions in accordance with the guidelines for preparation of information under Article 7 of the Kyoto Protocol. This reporting is done using so-called standard electronic tables (SEF), which are addressed in Chapter 12.

Chapter 14 has been updated for this submission to incorporate the changes in the registry since the 2013 submission. A common description on the changes to registry applicable to all EU Member States' registries has been obtained from the Commission and the Energy Authority has attached to this description information relevant to Finland.

### *1.3 Brief description of the process of inventory preparation*

The UNFCCC, the Kyoto Protocol and the EU's greenhouse gas monitoring mechanism require Finland to submit annually a National Inventory Report (NIR) and Common Reporting Format (CRF) tables. The annual submission contains emission estimates for the second but last year, so that the 2014 submission contains estimates for the calendar year 2012.

The organisation of the preparation and reporting of Finland's greenhouse gas inventory and the duties of its different parties are detailed in the previous Section (1.2). The expert organisations acting as the parties to the inventory system are in charge of the inventory data of the different reporting sectors. The expert organisations produce emission estimates following the division of labour defined in the reporting protocols (Table 1.2-1) and according to the UNFCCC guidelines. Statistics Finland compiles from the data produced by expert organisations national reporting and submits them to the UNFCCC Secretariat and to the European Commission.

The preparation of the annual inventory follows the schedule of the reporting. In the EU monitoring mechanism the annual inventory is submitted to the Commission by 15 January. The Member States may complement and update their submission by 15 March. The greenhouse gas inventory is submitted to the UNFCCC Secretariat by 15 April. The joint EU inventory is compiled from the Member States' submissions and it is also supplied to the UNFCCC Secretariat by 15 April. The Commission uses the inventory data submitted annually by Member States also when evaluating the progress of the Community and its Member States towards the set greenhouse gas emission objectives.

## 1.4 Brief general description of the methodologies and data sources used

The methodologies used for the Finnish greenhouse gas inventory are consistent with 1996 IPCC GL and GPG 2000 and GPG LULUCF 2003. Detailed descriptions of the methodologies used can be found as sector specific from Chapters 3 to 9 and 11.

A specific feature of the Finnish system is its extensive use of bottom-up data. This is especially true in the case of the energy (excluding transport) and industrial processes sectors, where emissions originate from point sources. For these sources, simple equations that combine activity data with emission factors are used. Also in the waste sector, bottom-up data from solid waste disposal sites and other treatment facilities form the basic activity data. Different sources in the transport, agriculture and LULUCF sectors necessitate the use of more complicated equations and models. Table 1.4-1 summarises the most important data sources used in the inventory.

**Table 1.4-1** Main data sources used in the Finnish greenhouse gas inventory

Sector	Main data sources
1.A Energy: Fuel Combustion	VAHTI system Energy Statistics, Yearbook (Statistics Finland) Surveys: electricity production, district heating plants, energy consumption of the manufacturing industry LIPASTO and TYKO models of VTT, Finavia Energy Authority (ETS emission data)
1.B Fugitive Emissions	VAHTI system Energy Statistics, Yearbook (Statistics Finland) Individual companies
2. (I) Industrial Processes	Energy Authority (ETS emission data) Industrial statistics database VAHTI system Individual production plants
2. (II) Industrial Processes (F-gases)	Surveys of the Finnish Environment Institute
3. Solvents and Other Product Use	VAHTI system ULTIKA/ULJAS, import statistics of Finland Association of Finnish Paint Industry Individual companies Published literature
4. Agriculture	Matilda database of the Ministry of Agriculture and Forestry Yearbook of Farm Statistics Finnish Trotting and Breeding Association MTT Agrifood Research Finland Finnish Environment Institute (SYKE) Published literature
5. LULUCF	NFI (National Forest Inventory) Finnish Statistical Yearbook of Forestry Yearbook of Farm Statistics Published literature National Land Survey of Finland
6. Waste	VAHTI system The Finnish Biogas Plant Register Water and Sewage Works Register Register for Industrial Water Pollution Control

The VAHTI system of Finland's environmental administration is one of the main data sources used in the inventory (especially in the Energy and Waste sectors). The VAHTI system functions as a tool for the 15

Centres for Economic Development, Transport and the Environment in their work on processing and monitoring environmental permits. The data system contains information on the clients (more than 31,000) required by the environmental permits, such as:

- identification
- contact persons
- respective authorities
- licence conditions
- environmental insurance
- loading points, such as stacks and sewers
- emissions control equipment
- treatment plans
- boilers and fuels used
- landfills
- emissions to air, discharges to water and waste
- energy production
- raw materials.

The range of facilities that have requirements to report information of their releases to the environment to supervising authorities (e.g. according to their environmental permit/emission monitoring programme) is in Finland much wider than the IPCC activities, and includes also fish farms regarding wastewater issues. The installations report annually emission data to the supervising authority. Monitoring of releases is carried out according to the requirements in the monitoring programme (e.g., measurement methods are determined there).

The authorities check the quality of this data before accepting it to the VAHTI system. The checks include an overview if the requirements in the permit/programme have been met and of the submitted data. In case the authorities find inconsistencies, the facilities are required to correct the data and resubmit it. The authorities carry out regular visits to supervise the activities at a plant and check issues related to emission monitoring during these visits. Data reported by the plants are also checked (level of emissions, completeness of emissions and activity data reported etc.) by the inventory preparers (Statistics Finland, SYKE). If inconsistencies are found, questions are sent to the facilities, which check their data and resubmit the corrected data to the authorities. A more detailed description of VAHTI is included in Annex 2.

The EU ETS data obtained from the Energy Authority has become an increasingly important source of activity and emission data for the inventory. It has been used as prime source of activity data (especially for emissions in the industrial process sector) and for comparison of fuel consumption and CO<sub>2</sub> emissions of specific installations (mainly energy emissions). During 2005–2007, Finland implemented the Directive 2003/87/EC of the European Parliament and of the Council establishing a scheme for greenhouse gas emission allowance trading within the Community with the Emissions Trading Act. The Emissions Trading Act was applied to CO<sub>2</sub> emissions from combustion installations with a rated thermal input of more than 20 MW, smaller combustion installations connected to the same district heating network, mineral oil refineries and coke ovens, as well as of certain installations and processes of the steel, mineral and forest industries. An installation belonging to emissions trading scheme needs an emissions permit, pursuant to which it has the right to emit CO<sub>2</sub> into the atmosphere. The issuance of permits lies with the Energy Authority. In Finland, the number of installations needing a permit has been around 530 during the first period of the EU ETS.

During the period 2008–2012, the EU ETS was extended to cover international emissions trading under the Kyoto Protocol. Also the scope of installations included in the emissions trading was expanded to involve petrochemical cracking installations and mineral wool production as well as carbon black production. Carbon black is not produced in Finland. At the moment there are about 600 installations, which need a permit.

## *1.5 Brief description of the key categories*

### *1.5.1 GHG inventory*

Statistics Finland has identified the national key categories for the base year and the latest reported inventory year, as described in GPG 2000, using tier 2 level and trend assessment, and considering also qualitative criteria. This section provides a summary of the key categories identified (Table 1.5-1 below which corresponds to the information reported in CRF table 7). Annex 1 provides more information on the key category analysis.

Results of the key category analysis are important because they guide decisions on methodological choice (together with uncertainty analysis, see Section 1.7). The goal is to screen the long list of category-gas combinations (about 160 categories), and find those that are the most important in terms of the emissions level and the trend. This short list (Table 1.5-1) forms the basis of discussions with the sectoral experts on the quality of the estimates and possible need for improvement. The key categories are also subject to more detailed documentation and quality control.

The uncertainty analysis was re-evaluated and updated for 2013 submission to follow the suggested subcategorization of source categories (GPG 2000), especially the division of the energy subcategories were rearranged. Previously the CO<sub>2</sub> emissions in Fuel Combustion category were aggregated in uncertainty analysis to the 2nd subcategory level (1.A), now they are divided to the 3rd category level (see Section 1.7).

### *1.5.2 KP-LULUCF inventory*

Key category analysis for KP-LULUCF was performed according to Section 5.4.4 of GPG LULUCF 2003. Uncertainties used in key category analysis are estimated with the IPCC Tier 2 method, and the key categories reported are results of the Tier 2 key category analysis. The results of the key category analysis are reported here in Table 1.5-2 below and in Section 11.6.1 and in CRF table NIR.3.



**Table 1.5-1** Key categories identified using Tier 2 level and trend assessment

Category		Gas	Level		Trend
			Base year	Year 2012	
1.A.1. Energy Industries	1 Liquid	CO2	Yes	Yes	
1.A.1. Energy Industries	2 Solid	CO2	Yes	Yes	
1.A.1. Energy Industries	3 Gaseous	CO2			Yes
1.A.1. Energy Industries	4 Biomass	N2O		Yes	Yes
1.A.1. Energy Industries	5 Other	CO2	Yes	Yes	Yes
1.A.1. Energy Industries	5 Other	N2O			Yes
1.A.2 Manufacturing Industries and Construction	1 Liquid	CO2	Yes	Yes	Yes
1.A.2 Manufacturing Industries and Construction	2 Solid	CO2	Yes	Yes	Yes
1.A.2 Manufacturing Industries and Construction	5 Other	CO2	Yes		
1.A.3.a. Civil Aviation	1 Liquid	CO2			Yes
1.A.3.b. Road Transportation	1 Liquid - diesel oil	CO2		Yes	Yes
1.A.3.b. Road Transportation	1 Liquid - diesel oil	N2O		Yes	Yes
1.A.3.b. Road Transportation	1 Liquid - gasoline	CO2	Yes	Yes	Yes
1.A.3.b. Road Transportation	1 Liquid - gasoline	CH4			Yes
1.A.3.b. Road Transportation	1 Liquid - gasoline	N2O	Yes	Yes	Yes
1.A.3.e. Other Transportation	1 Liquid	CO2	Yes	Yes	
1.A.4. Other Sectors	1 Liquid	CO2	Yes	Yes	Yes
1.A.4. Other Sectors	4 Biomass	CH4	Yes	Yes	Yes
1.A.4. Other Sectors	4 Biomass	N2O			Yes
1.A.5.a.1. Indirect N2O emissions from NOx		N2O	Yes	Yes	Yes
1.A.5.a.2. Non-specified emissions of Fuels from non-energy use	1 Liquid	CO2			Yes
1.A.5.a.3. Other non-specified	1 Liquid	CO2	Yes	Yes	
1.A.5.a.3. Other non-specified	3 Gaseous	CO2		Yes	Yes
1.A.5.b. Mobile	1 Liquid	CO2			Yes
1.B.2.d. Other (CO2 from NMVOC)		CO2			Yes
2.B.2. Nitric Acid Production		N2O	Yes		Yes
2.B.5.g. Hydrogen		CO2			Yes
2.C.1. Iron and Steel Production		CO2	Yes	Yes	Yes
2.F.1. Refrigeration and Air Conditioning Equipment		HFC		Yes	Yes
2.F.8. Electrical Equipment		SF6			Yes
3. Solvent and Other Product Use		CO2			Yes
4.A. Enteric Fermentation		CH4	Yes	Yes	Yes
4.B. Manure Management		N2O	Yes	Yes	Yes
4.D.1. Direct Soil Emissions		N2O	Yes	Yes	Yes
4.D.2. Pasture, Range and Paddock Manure		N2O	Yes	Yes	Yes
4.D.3. Indirect Emissions		N2O	Yes	Yes	Yes
5.A.1. Forest Land remaining Forest Land		CO2	Yes	Yes	Yes
5.A.2. Land converted to Forest Land		CO2	Yes	Yes	Yes
5.B.1. Cropland remaining Cropland		CO2	Yes	Yes	Yes
5.B.2. Land converted to Cropland		CO2	Yes	Yes	Yes
5.C.1. Grassland remaining Grassland		CO2	Yes	Yes	Yes
5.C.2. Land converted to Grassland		CO2	Yes	Yes	Yes
5.D.2. Land converted to Wetlands		CO2	Yes	Yes	Yes
5.E.2. Land converted to Settlements		CO2	Yes	Yes	Yes
5.G. Other (Harvested Wood Products)		CO2		Yes	Yes
5.II Non-CO2 emissions from drainage of soils and wetlands		N2O	Yes	Yes	Yes
6.A. Solid Waste Disposal on Land		CH4	Yes	Yes	Yes
6.B.2. Domestic and Commercial Wastewater		N2O	Yes	Yes	Yes
6.B.3.a. Other (N input from fish farming)		N2O			Yes
6.B.3.b. Other (N input from industrial wastewater)		N2O	Yes	Yes	Yes
6.D. Other (compost production)		CH4			Yes
6.D. Other (compost production)		N2O			Yes

**Table 1.5-2** Key categories for KP-LULUCF inventory

<b>Key category</b>	<b>Associated category in UNFCCC inventory is key</b>	<b>Category contribution is greater than the smallest category considered key in the UNFCCC inventory</b>
Article 3.3 Afforestation / Reforestation	5.A.2. Land converted to Forest Land	Yes
Article 3.3 Deforestation	5.B.2. Land converted to Cropland	Yes
	5.C.2. Land converted to Grassland	
	5.D.2. Land converted to Wetlands	
	5.E.2. Land converted to Settlements	
Article 3.4 Forest Management	5.A.1. Forest Land remaining Forest Land	Yes

## *1.6 Information about the QA/QC plan including verification and treatment of confidentiality issues*

This section presents the quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level. Source-specific QA/QC details are discussed in the relevant sections of this NIR.

### *1.6.1 Quality management is implemented in a structured way*

The objective of Finland's GHG inventory system is to produce high-quality GHG inventories. As a national statistical office Statistics Finland and its Greenhouse Gas Inventory Unit are committed to quality. The quality framework based on the European Statistics Code of Practice and Statistics Finland's Guidelines on Professional Ethics supports the GHG inventory quality management ([http://www.tilastokeskus.fi/org/periaatteet/laadunhallinta\\_en.html](http://www.tilastokeskus.fi/org/periaatteet/laadunhallinta_en.html)).

Statistics Finland has the overall responsibility for the GHG inventory in Finland, including the responsibility for co-ordinating the quality management measures at the national level. The quality co-ordinator steers and facilitates the quality assurance and quality control (QA/QC) process. The expert organisations contributing to the production of emission or removal estimates are responsible for the quality of their own inventory calculations. Experts on each inventory sector implement and document the QA/QC procedures.

All the participating organisations are represented in the inventory working group set up to support the process of producing annual inventories and the fulfilment of reporting requirements. The working group advances collaboration and communication between the inventory unit and the experts producing the estimates for the different reporting sectors and ensures the implementation of the QA/QC process of the inventory. Statistics Finland has also set up an advisory board that functions as a higher level forum for collaboration and communication with the parties involved in the national system.

Issues related to QA/QC are discussed at the meetings of the inventory working group (3-5 meetings per year) and at the bilateral quality meetings between the inventory unit and the expert organisations (once a year). The main findings and conclusions concerning the inventory's quality and improvement needs are communicated to the advisory board.

An electronic quality manual including e.g. guidelines, plans, templates and checklists is in place and available to all parties of the national inventory system via the Internet.

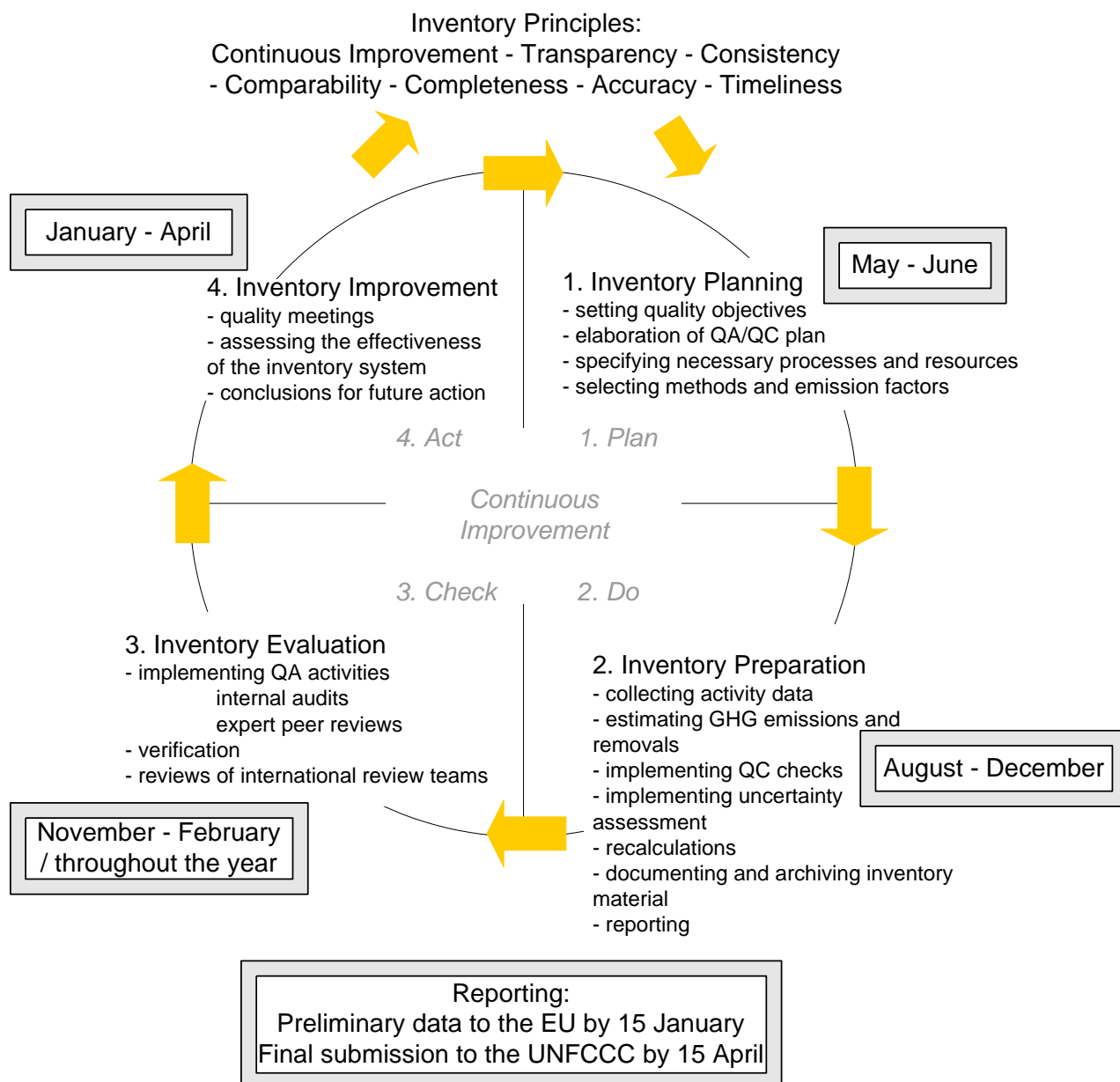
Statistics Finland bears the responsibility for archiving the quality manual and for submissions of annual inventories (CRF tables and NIR). Expert organisations contributing to the sectoral calculations archive the primary data used, internal documentation of calculations (including the sector-specific QC checklists) and sectoral CRF tables (See Section 1.6.4).

Statistics Finland co-ordinates the participation of the partners of the national system in the reviews, as well as responses to issues raised by the reviews of the UNFCCC Secretariat.

### *1.6.2 Inventory process*

The annual inventory process set out in Figure 1.6-1 illustrates at a general level how the inventory is produced within the national system. The quality of the output is ensured by inventory experts during inventory preparation, compilation and reporting, which consists of four main stages: planning, preparation, evaluation and improvement. The quality control and quality assurance elements are integrated into the inventory production system, which means that each stage of the inventory process includes relevant procedures for quality management.

A clear set of documents is produced on the different work phases of the inventory. The documentation ensures the transparency of the inventory: it enables external evaluation of the inventory and, where necessary, its replication.

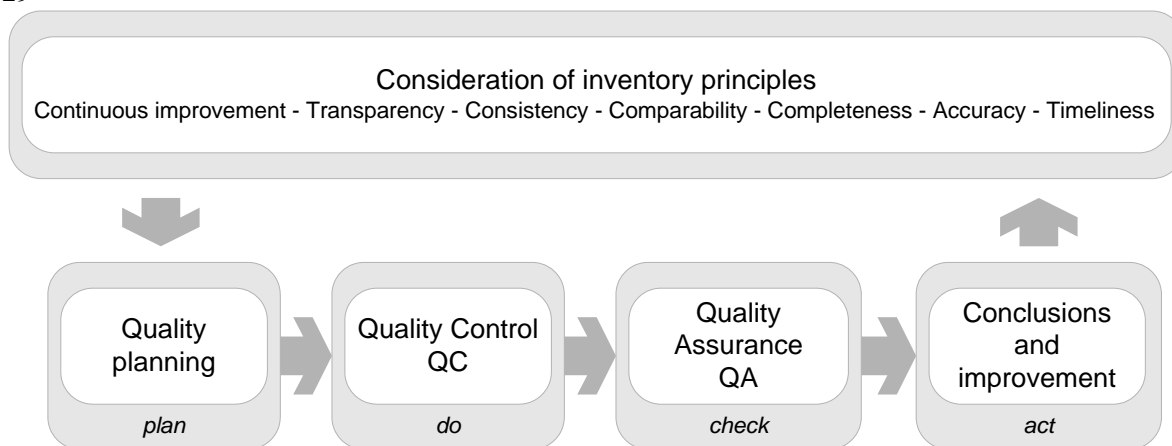


**Figure 1.6-1** Inventory process

### 1.6.3 QA/QC process

In the context of greenhouse gas inventories, high quality means that the structure of the national system (i.e. all institutional, legal and procedural arrangements) for estimating greenhouse gas emissions and removals and the content of the inventory submissions (i.e. outputs, products) comply with the requirements and principles.

The starting point for accomplishing a high-quality GHG inventory is consideration of the expectations and requirements directed at the inventory. The quality requirements set for the annual inventories - transparency, consistency, comparability, completeness, accuracy, timeliness and continuous improvement - are fulfilled by implementing the QA/QC process consistently (Figure 1.6-2).



**Figure 1.6-2** QA/QC process of the inventory

*Quality planning includes setting of quality objectives and planning the QC and QA procedures*

The inventory planning stage includes the setting of quality objectives and elaboration of the QA/QC plan for the coming inventory preparation, compilation and reporting work. In addition, a schedule of the coming inventory round is prepared and presented to the expert organisations. The timetable includes deadlines for example for QC checks of the inventory compilation and draft meeting schedules of the inventory working group and advisory board.

The setting of quality objectives is based on the inventory principles. Quality objectives are specified statements about the quality level that is aimed at in the inventory preparation with regard to the inventory principles. The objectives aim to be appropriate and realistic while taking into account the available resources and other conditions in the operating environment. Where possible, quality objectives should be measurable.

The quality objectives regarding all calculation sectors for the 2012 inventory were the following:

1. Continuous improvement
  - 1.1. Treatment of review feedback is systematic
  - 1.2. Improvements promised in the National Inventory Report (NIR) are carried out
  - 1.3. Improvement of the inventory is systematic
  - 1.4. Inventory quality control (QC) procedures meet the requirements
  - 1.5. Inventory quality assurance (QA) is appropriate and sufficient.
2. Transparency
  - 2.1. Archiving of the inventory is systematic and complete
  - 2.2. Internal documentation of calculations supports emission and removal estimates
  - 2.3. CRF tables and the National Inventory Report (NIR) include transparent and appropriate descriptions of emission and removal estimates and of their preparation.
3. Consistency
  - 3.1. The time series are consistent
  - 3.2. Data have been used in a consistent manner in the inventory.
4. Comparability
  - 4.1. The methodologies and formats used in the inventory meet comparability requirements.
5. Completeness
  - 5.1. The inventory covers all the emission sources, sinks, gases and geographic areas.
6. Accuracy
  - 6.1. Estimates are systematically neither higher nor lower than the true emissions or removals
  - 6.2. Calculation is correct
  - 6.3. Inventory uncertainties are estimated.
7. Timeliness
  - 7.1. High-quality inventory reports reach their receivers (EU / UNFCCC) within the set time.

The quality objectives and the planned general QC and QA procedures regarding all sectors are set in the QA/QC plan. This is a checklist that specifies the actions, schedules and responsibilities in order to attain the quality objectives and to provide confidence in the Finnish national system's capability to deliver high-

quality inventories. The QA/QC plan is written in Finnish, updated yearly and consists of instructions and a QA/QC form. Instructions include descriptions of, e.g., quality objectives, general inventory QC checks and schedules. The QA/QC form addresses the actions to be taken and is filled in annually by the sectoral experts. The QA/QC plan is part of the electronic quality manual of the inventory and archived according to the inventory unit's archive formation plan.

In addition to the general QA/QC plan, the expert organisations may use source-specific QC checklists and perform source-specific QA and verification. These lists are included in the internal documentation of the calculation.

### *Quality control procedures aim at attainment of the quality objectives*

The QC procedures are performed by the experts during inventory calculation and compilation according to the QA/QC plan.

The QC procedures used in Finland's GHG inventory comply with the IPCC Good Practice Guidance. General inventory QC checks (GPG 2000, Table 8.1 and GPG LULUCF 2003, Table 5.5.1) include routine checks of the integrity, correctness and completeness of the data, identification of errors and deficiencies and documentation and archiving of the inventory data and quality control actions. Category-specific QC checks including technical reviews of the source categories, activity data, emission factors and methods are applied on a case-by-case basis focusing on key categories and on categories where significant methodological changes or data revisions have taken place.

Once the experts have implemented the QC procedures, they complete the QA/QC form for each source/sink category, which provides a record of the procedures performed. Results of the completed QC checks are recorded in the internal documents of the calculation and archived in the expert organisations. Key findings are summarised in the sector-specific chapters of this NIR.

Several QC checks are implemented at Statistics Finland during the compilation of the CRF Tables and the NIR. A specific excel workbook is established to improve the assessment of results, emission trends and to ease the detection of errors and inconsistencies. Also, the NIR tables and figures are produced based on CRF data to ensure consistency between CRF Tables and NIR. This is continuously improved in order to avoid any discrepancies.

In addition, the QA/QC of member states' submissions conducted under the European Community GHG Monitoring Mechanism (e.g. completeness checks, consistency checks and comparisons across Member States) produces valuable information on errors and deficiencies, and the information is taken into account before Finland submits its final annual inventory to the UNFCCC.

### *Quality assurance comprises a planned system of review procedures*

The QA reviews are performed after the implementation of QC procedures concerning the finalised inventory. The QA system comprises reviews and audits to assess the quality of the inventory and the inventory preparation and reporting process, to determine the conformity of the procedures taken and to identify areas where improvements could be made.

Specific QA actions differ in their viewpoints and timing. The actions include basic reviews of the draft report, quality meetings, internal audits, peer reviews, UNFCCC and EU inventory reviews and data verifications.

A basic review of the draft GHG emission and removal estimates and the draft report (i.e. a basic expert review of an inventory, Tier 1 QA according to GPG 2000, Chapter 8.8) takes place before the initial submission to the EU (in November to December) and again before the final submissions to the EU and UNFCCC (January to March) by the inventory working group, the inventory unit and the advisory board. Final official consideration, which includes review and approval of the submission, is done by Statistics Finland after the annual quality meetings and after the EU initial check.

The in-depth-review of the inventory is done mainly in conjunction with the bilateral quality meetings, which function as Tier 1 QA reviews (as defined in GPG 2000, Chapter 8.8). The bilateral quality meetings are held annually between the inventory unit (the compiler) and the expert organisations (producing the inventory estimates and descriptions) in January to February. The main objective of the quality meetings is to ensure that the experts have implemented the QC checks and procedures according to the QC plan and to evaluate the results and documentation of the procedures. Quality meetings follow a fixed agenda that include the following items: Implementation of the QC plan, sector-specific QC including Tier 2 QC if relevant, sector-specific QA and verification, review feedback, structure and transparency of the reporting (NIR and CRF tables), improvement needs and projects, and functioning of the national inventory system (e.g. resources for inventory preparation). As a result of the quality meetings held in 2014, for example, some quality assurance or verification possibilities were identified for specific sectors and the NIR descriptions were improved based on documentations on the QA/QC forms and feedback from the UNFCCC review.

Internal audits are sector-specific Tier 2 QA audits that have a specific viewpoint and timing in the QA system. They are extensive QA assessments that are focused on topical or otherwise important factors in one specific sector (not a submission) at a time, e.g. implementation of general and source-specific QC checks, QA and verification procedures, internal documentation or recalculations. In internal audits representatives of the inventory unit visit the expert organisation to evaluate how effectively the actual activity and the results attained in the specific calculation sectors comply with the requirements. Internal audits provide an in-depth analysis of the respective procedures taken to develop the inventory, and of the documentation available. Above all, the basic task of internal audits is to contribute to the improvement of an inventory in a longer term. Internal audits also contribute to learning and sharing of knowledge and good practices among the actors in the national system. The timing of internal audits is not dependent on the annual submissions: they are carried out throughout the year within the available resources. The need and focus of internal audits are identified annually in the bilateral quality meetings. The audit findings and conclusions are documented in audit reports (in Finnish).

The first internal audit took place in the agriculture sector in November 2009. The audit covered issues related to the management of review feedback, recalculations and institutional arrangements for inventory preparation. In general, the audit findings and conclusions indicated conformance with the requirements. Some minor improvement needs were identified as well, e.g. the need for establishment of an in-house steering group to support the agriculture sector inventory. The steering group was set up in 2010.

The second internal audit was conducted in the LULUCF sector in October 2010. The audit focused on institutional arrangements for inventory preparation and documentation of the general and sector-specific QA/QC procedures. Non-conformities with the requirements were not found. The audit concluded that the inventory QA/QC system in the sector is effectively implemented and continually improved. In addition, it was noticed that the resources for the inventory preparation have been increasing.

In 2011 two audits were carried out, one in mobile sources and another in waste sector. The aim of the audits was to ensure the adequacy of the working instructions and other internal documentation for the calculation. In addition, the archiving procedures were reviewed. The audit findings indicated that the internal documents and archiving procedures were in line with the requirements.

In 2013 the working instructions of the industrial processes sector were audited in order to assess the transparency of the instructions. The audit confirmed that the instructions were adequate for the inventory preparation but a few improvement suggestions were made in order to ease the work of new or substitute experts in the future.

Statistics Finland has its own internal quality audit system (statistical auditing). The objectives of this quality audit are, for example, to evaluate and question ways of working, methods and techniques, and to identify and search for good practices (Piela, 2011). A tentative plan is to undergo this procedure within the greenhouse gas inventory unit in order to improve processes and documentation of the inventory. Also, a need for an external audit of the Energy sector is under consideration (see Section 3.2.6). However, due to the implementation of the IPCC 2006 Guidelines, including renewal the data handling and calculation processes for the energy sector in 2014 – 2015, the earliest timing for the audits is estimated to be in 2016. The resources for these audits need to be confirmed.

Peer reviews are sector or category-specific projects that are performed by external experts or expert groups. The reviewers should preferably be external experts who are independent of the inventory preparation. The reviewers may also be experts in other calculation sectors of the GHG inventory system. The objective of the peer review is to ensure that the inventory's results, assumptions and methods are reasonable, as judged by those knowledgeable in the specific field. Peer review activities that have been undertaken are described in the sector-specific chapters.

Peer reviews may also be bilateral collaboration. For example, the Finnish and Swedish GHG inventory teams have met periodically to exchange information, experiences and views relating to the preparation on the national GHG inventories. This collaboration also provides opportunities for bilateral peer reviews. The first step in this collaboration relating to quality assurance was an independent comparison and review of the emission factors in the energy sector in Swedish and Finnish inventories that was carried out from September to October 2006. The objectives of the review were to check whether the reporting and choice of emission factors were in accordance with the UNFCCC and IPCC guidelines and, in addition, to compare the emission factors used in Finland and Sweden, and to assess whether the differences (if any) were explainable and reasonable taking the national circumstances into account. In the 2011, the meeting between the Finnish and Swedish inventory teams discussed the use of EU ETS data in inventories, exchanged information on methods for provision of regional emissions, e.g. at municipal level and decided to launch a joint project to verify reported carbon stock changes in dead organic matter and soils carbon. The project is ongoing and expected to be finalised in late 2014. In 2012, the collaboration meeting focused on the LULUCF sector and the LULUCF reporting under the Kyoto Protocol. Special focus was given on methods on land area identification and reporting.

A voluntary bilateral cross-country review (complemented with testing of adjustment procedure under Article 5.2 of the Kyoto Protocol) was conducted between Finland and Germany in August to November 2004. The cross-country review covered emission categories 1.A 1 and 1.A 2 in the Energy sector, and categories 4.A, 4.B and 4.D in the Agriculture sector.

The UNFCCC inventory review teams co-ordinated by the UNFCCC Secretariat carry out international reviews of the inventory according to the annual schedule after the submission of the annual inventory report. The expert review teams produce yearly an independent review report on Finland's GHG inventory. In 2012, the EU implemented an internal technical review of its Member States' greenhouse gas inventory as part of the implementation of the EU Effort Sharing Decision (ESD). This technical review of the 2012 greenhouse gas inventory submission had focus on the estimates for the years 2005, 2008, 2009 and 2010 and was performed by a Technical Expert Review Team (TERT). The European Commission determined the annual emission allocations of Finland for the period from 2013 to 2020 using this reviewed and verified emission data.

Emission and activity data are verified by comparing them with other available data compiled independently of the GHG inventory system. These include measurement and research projects and programmes initiated to support the inventory system, or for other purposes but producing information relevant to the inventory preparation. Verification activities that have been undertaken are described in the sector-specific chapters.

In addition to consideration of the special requirements in the guidelines for greenhouse gas inventories, the development of the inventory quality management system has followed the principles and requirements of the ISO 9001 standard. ISO 9001 certification has been under consideration. However, the advantages (e.g. the perspective of a third party assessment) and costs (e.g. the amount of resources required for registration) of certification have been evaluated, and Statistics Finland has decided not to apply for the ISO 9001 compliance certification. Even without certification Finland continues to utilize the ISO 9001 as a benchmark for the general quality management system of the inventory.

### *QA/QC process contributes to the improvement of the inventory*

The ultimate aim of the QA/QC process is to ensure the quality of the inventory and to contribute to the improvement of the inventory. At the improvement stage of the QA/QC process, conclusions are made based on the realised QA/QC measures taken and their results. The main findings and conclusions concerning the inventory's quality and improvement needs are considered by the advisory board and communicated to the parties to Finland's GHG inventory system for decision-making concerning the next inventory round.



### 1.6.4 Documentation and archiving

Inventory documentation consists of inventory data and metadata (data explaining the calculated estimates). Documentation has a key role in the inventory quality management. Meeting the requirement of transparency requires systematic documentation. Careful documentation also facilitates external evaluation of the inventory. The goal is to make replication of the inventory possible for the expert reviewers, should it be necessary. Documentation also stands as evidence of the compliance and functionality of the National System. In addition, continuous, fact-based improvement of the inventory is steered by an analysis of the materials accumulated during the inventory process.

The inventory documentation system consists of the following document types:

1. The basic documents of the National System that are produced, updated and archived by Statistics Finland according to its archiving system (the system is described below):
  - description of Finland’s Greenhouse Gas Inventory System
  - reporting protocols
  - agreements related to the calculation
  - quality manual.
2. The annual inventory process documents by reporting sector, which are produced, updated and archived in the expert organisations responsible for the sectors according to the reporting protocols, such as:
  - primary material for the calculation
  - internal documents for the calculation.
3. The whole inventory level documents of the annual inventory process, which are produced, updated and archived in the inventory unit according to Statistics Finland’s archiving system:
  - the general plan for compiling the inventory
  - internal documents for compiling the inventory
  - the CRF Reporter databases, the set of CRF tables and the National Inventory Report (NIR)
  - the inventory improvement plan.

The main archives of the greenhouse gas inventory unit are at Statistics Finland. The main archive’s purpose is to fill the specific function mandated in the guidelines for national systems (UNFCCC Decision 20/CP.7, paragraphs 16 and 17): it holds all the important data, models and documentation needed in inventory development. It aims to facilitate efficient review of the inventory and provide fast responses to questions posed by expert review teams during reviews. The greenhouse gas inventory unit has prepared a plan for archive creation that describes the records being archived and the manner they are preserved. The plan for archive formation is stored in a database application, where it can be viewed, changed and searched for information needed in archives management. According to the plan, the archiving takes place in between January to May each year, after submission of the inventory to the EU or UNFCCC. The main archive of the inventory is located on a server of the Statistics Finland’s local area network. This archive has restricted writing privileges and daily back-up copies are created. In addition, Statistics Finland has a system called KOONTI for archiving data and metadata electronically. The CRF data and SAS data sets of the Energy sector are also archived at the KOONTI system annually. Finally, electrical files created during the inventory process are back-up copied annually on CD-ROMs and kept in the archive of the inventory unit. In addition to the guidelines for national systems, Statistics Finland needs to comply with the general record management duties laid down in Finnish legislation (for instance, the Archives Act 831/1994).

In addition to the main archive, the expert organisations have archives located in their own facilities. Typically, these organisations keep records of their work on the hard disks of individual experts’ desktop workstations, with copies on backed-up network servers. Electronic copies on CD-ROMs are also produced. The expert organisations have implemented their archival procedures according to their own plans of archive creation, with systems for electronic storage and retrieval of records.

The Energy (except transportation) and Industrial Processes sector (except F-gases and NMVOCs) documentation and annual inventory records are archived according to a plan for archive formation (See above). The archiving of inventory records for these categories takes place as follows:

1. The archives are located physically in the premises of Statistics Finland.
2. All data, models used at Statistics Finland and documentation needed in inventory preparation are preserved in an archive located on a server of the Statistics Finland's local area network which is daily back-up copied. This archive have restricted writing privileges.
3. The CRF data and SAS data sets of the Energy sector are also archived at the KOONTI system annually (see above).
4. All data, models and documentation are copied and stored on CD-ROMs.

The archiving of inventory records for the category transport takes place as follows:

1. All calculation results are filed as a paper copy to the official archive of VTT Technical Research Centre of Finland
2. All calculation models (LIISA, RAILI, MEERI, and TYKO) including the calculation results and time series are yearly filed on a CD-ROM. One copy to the official archive of VTT Technical Research Centre of Finland and one copy to the responsible person (presently Kari Mäkelä)
3. All information produced during the calculation process is included in VTT's official back-up tapes and are stored for one year.

The archiving of inventory records for the category civil aviation has been as follows (Finavia will keep the records in their archives for 10 years):

1. Calculation results and ILMI model documents are filed as a paper copy to the archive of Finavia's Environmental unit
2. The ILMI model, including the calculation results and time series and all information produced during the calculation process are yearly stored in the specific folder in the server maintained by the Information and Communication Technology unit of Finavia.

The archiving of inventory records for the category F-gases takes place as follows:

1. Original survey responses of the sectoral inventory are archived in the office of the sectoral expert at the Finnish Environment Institute.
2. The survey responses received from the web-based data collection system are archived in the official electronic database (AHJO) of Finland's environmental administration.
3. In addition to the original survey responses, the material archived in the sectoral expert's office consists of hand written notes, printed copies of survey questionnaires and mailing lists. Incoming survey responses are entered into an electric database in chronological order and the original paper copies are filed in dated folders (see point 1). The sectoral expert's archives also include printouts of data analysing spreadsheets, final CRF tables, quality assurance plans for each year and the references used in the inventory.
4. All material, except hand written notes, is also archived in electric files. Electrical files are saved on Finnish Environment Institute's servers, which are back-up copied regularly, and on CD-ROMs, which are kept in the archive among the registry of paper copies. The archived electronic files contain the following information:
  - Survey data in a matrix database
    - All activity data is entered in electric database
    - Chronological listing and recording of responses enables easy access to original copies of survey responses
  - Spreadsheet applications used for data analysing and calculation
    - Used methods, emission factors and parameters used are displayed on worksheets
    - Estimates are presented for different gases in subcategory level as well as in aggregated category level
  - Simulation reports of data uncertainty analysis
    - Initial data and assumptions are provided in reports
  - Backup copy of CRF Reporter database and submitted CRF data
  - Final version of inventory report (NIR)
  - Annual QA/QC plans

The archiving of inventory records for the category NMVOCs takes place as follows:

1. Calculation model of NMVOC emissions is stored in electrical form and saved on Finnish Environment Institute's servers. Back-up tapes are created automatically every day.
2. Calculation model includes calculation results and time series.
3. Activity data, including questionnaires to industry, and information on emission factors are stored at least in paper form in the office of sectoral expert and in electrical form if available.
4. All electrical files created during the calculation process are safe copied regularly on CD-ROMs and kept in the archive of sectoral expert

### *Agriculture*

During the inventory compilation, the calculation sheets and data related to inventory are archived in personal folders in the server maintained by the information services of MTT Agrifood Research Finland. The folder structure is similar for each inventory year which makes data management easier. Back-up copies from the server are stored six months by the information services. After the compilation, the results and relevant data are archived in the project network folders of the inventory group and on CR-ROM. The location of the data and responsible persons are described in a database called Datainfo maintained by MTT. Datainfo is updated annually.

### *LULUCF*

The archiving of LULUCF sector (land areas, Forest land, Wetlands, Settlements, biomass burning, N fertilisation, harvested wood products, KP-LULUCF):

1. Original National Forest Inventory data (NFI) are archived in the Finnish Forest Research Institute (Metla). Database comprise of ASCII-files stored in LINUX operating system.
2. The statistics on forestry are published annually in the Finnish Statistical Yearbook of Forestry. Documentation and original data are archived in Metla.
3. All activity data, calculation procedures, results and reports are stored at Metla. The files are recorded in the network drives from which back-up copies are taken on a daily basis. A limited group of persons have access rights to these files.
4. The reported results are also stored in CRF Reporter database files and MS Excel files in the network drives and in an external disc drive. Paper copies of referred articles and literature are archived in the same place at Metla.

The archiving of the data for Croplands and Grasslands reporting is done in MTT Agrifood Research Finland. The activity data, relevant articles, calculation files and database files are stored in network drives from which backup copies are made regularly.

### *Waste*

All electronic data (mainly Excel, Word or Access files) on the yearly waste inventory including databases, models and documentation are collected in four different places: the folder of the hard disk of the computer used in the inventory, the outer hard disk of the computer, the network disk (under back-up copies) of the Finnish Environment Institute and CD-ROM. The most important files are collected in the last two places. Yearly information on paper is collected in one place.

## *1.6.5 Treatment of confidentiality issues*

The treatment of confidential information in GHG inventory is based on national<sup>3</sup> and international<sup>4</sup> legislation on statistical confidentiality as well as internal guidelines and regulations. Statistics Finland does not by rule disclose data related to single statistical units. The main principle in publishing aggregated data is that that data from a single unit cannot be identified based on the published information. In practise this

<sup>3</sup> Statistics Act 280/2004

<sup>4</sup> Regulation (EC) No 223/2009 of the European Parliament and of the Council of 11 March 2009 on European statistics and repealing Regulation (EC, Euratom) No 1101/2008 of the European Parliament and of the Council on the transmission of data subject to statistical confidentiality to the Statistical Office of the European Communities, Council Regulation (EC) No 322/97 on Community Statistics, and Council Decision 89/382/EEC, Euratom establishing a Committee on the Statistical Programmes of the European Communities

means that data from at least three units are needed for disclosing the aggregate value. If one unit is very dominant in a specific category, this can also lead to treating the whole category as confidential. In case Statistics Finland has an agreement with the data producer, the information can be made public.

## 1.7 Summary of the uncertainty analysis

This section provides an overview of the uncertainty analysis for the Finnish inventory. For the 2013 submission, the Tier 1 and Tier 2 uncertainty analyses were updated for all sectors and also for the Kyoto Protocol LULUCF activities. The mandatory, detailed reporting table of the analysis is in Annex 6.

Finland carries out Tier 1 uncertainty analysis annually, and Tier 2 analysis periodically. For this submission, both Tier 1 and Tier 2 analyses were carried out. The Tier 2 analysis was based on Monte Carlo simulation, and it was prepared in accordance with IPCC methodology (IPCC 2000, 2003). The uncertainty analysis includes all categories of emissions and removals reported in the 2013 submission.

The results of the uncertainty analysis are used to prioritize inventory improvement by using them in the key category analysis (KCA). The highest percentage of Tier 2 uncertainty (usually the upper bound) of emissions in 2012 is used for KCA.

The main methodologies used by sector and changes are summarized below. More information on the uncertainty assessment by category is given in sector-specific chapters.

The uncertainty analysis in the energy sector was carried out in a detailed level, covering more than 30 fuel type mainly at the 4<sup>th</sup> CRF category level (e.g. 1.A 1a). The disaggregation level was such that uncertainties of AD and EFs (within the same year) could be considered independent. For the calculation of different GHG emissions from the same fuel and category combination, the same AD distribution was used. EF uncertainties were assumed fully correlated between 1990 and 2012 except CO<sub>2</sub> EF for coal and refinery gases for which the EF uncertainties are independent due to difference in data sources used.

In the industrial processes sector, most uncertainties were determined at 3<sup>rd</sup> CRF category level (e.g. 2.A 1) and by GHG. Uncertainties in indirect CO<sub>2</sub> emissions were estimated separately from direct CO<sub>2</sub>. The EF uncertainties were assumed fully correlated across years for other emission sources of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O than lime, nitric acid, phosphoric acid and hydrogen production, for which methodologies and/or data sources had changed between 1990 and 2012, and therefore partial or zero correlations were applied. For the first time in this submission, the uncertainties in process emissions from iron and steel (CO<sub>2</sub> from 2.C 1) were estimated based on uncertainty in total CO<sub>2</sub> emissions from iron and steel production (2.C 1+1.A 2a) and uncertainties in emissions in the energy sector (1.A 2a). The uncertainties in emissions from F-gases were calculated in the Finnish Environment Research Institute. Uncertainty distributions were fitted to results and included in the overall inventory tier 2 uncertainty model. The uncertainties in emission estimates between 1990 and 2012 were assumed independent due to different methods used for f-gases.

The uncertainties in Solvent and other product use were estimated at the level of 3.A etc. for indirect CO<sub>2</sub> from NMVOC and separately for N<sub>2</sub>O use as in the previous submission. The EFs were assumed fully correlated across years.

In the agriculture sector, Monte Carlo simulation was applied directly to the calculation parameters of emission calculation models (MTT calculation model and Nitrogen Mass Flow model). The calculated uncertainties by category and GHG were included in the overall uncertainty model of the inventory. The correlations between 1990 and 2012 were also simulated for emissions calculated using the MTT calculation model, whereas correlations in emissions calculated with the Nitrogen Mass Flow model were estimated based on expert judgement.

In the LULUCF sector, the uncertainties for some categories were based on uncertainty analyses carried out by Metla (for example for Forest land remaining forest land, separately for biomass, mineral and organic soils), whereas for other categories uncertainties were estimated based on AD and EF/IEF uncertainties in the Tier 2 uncertainty model. In most cases, in which the uncertainty range was applied directly to the emission/removal estimate, sufficient information on correlations between years was not available. In such cases, the correlations were assumed zero, which is likely overestimating the trend uncertainty.

In the waste sector, the uncertainties in CH<sub>4</sub> emissions from landfills were estimated by applying Monte Carlo simulation to the SWDS model. Other categories uncertainties were estimated based on AD and EF/IEF uncertainties in the Tier 2 uncertainty model.

Uncertainties in KP-LULUCF activities were also included in the Tier 2 uncertainty estimate. Most of the uncertainty estimates were based on those of respective categories in the LULUCF sector (see also 11.3).

The uncertainties estimated at a detailed level were aggregated (with Monte Carlo simulation) to the level presented in Tier 2 uncertainty reporting table in Annex 6. In addition to uncertainties in emissions, also uncertainties in aggregated AD and IEFs (in some cases the same as EFs) were estimated by Monte Carlo simulation. The higher uncertainty values (usually the upper bound of uncertainty range) of simulated AD and IEFs were used as AD and EF uncertainties in Tier 1 method (also in Annex 6). In the cases in which uncertainty estimates could not be divided between AD and IEF/EF, only emission uncertainty was presented in the Tier 2 table in Annex 6. Similarly, the emission uncertainty was used in those cases in Tier 1 calculation following IPCC GPG.

Table 1.7-1 shows the uncertainties (for CO<sub>2</sub>-eq emissions/removals) for the 2012 level and trend (percentage change from 1990) estimated with Tier 1 and Tier 2 methods for this submission. Both uncertainties for UNFCCC sectors and for KP activities are shown. For UNFCCC sectors Tier 1 and Tier 2 gave similar results for 2012, owing to the use of the same input data. Differences were caused by the fact that asymmetry of uncertainties cannot be taken into account in Tier 1; however, as the majority of emission is from sources with symmetrical distributions, the results of Tier 1 and 2 are quite close to each other. The similarity of results of Tier 1 and Tier 2 confirm that both methods to combine uncertainties were applied correctly. The differences of Tier 1 and Tier 2 estimates of trend uncertainty were larger. This is due to the fact that in Tier 1 method, when uncertainties are available only for emissions (not for AD and EF separately) the estimates of 1990 and 2012 have to be expressed either as “correlated” or “not correlated”. In particular in agriculture sector, partial correlation occurs, and the trend uncertainty is highly sensitive to whether partial correlation is treated as “correlated” or “not correlated”. In the current approach, uncertainties in most agriculture categories were treated as “not correlated”, and therefore the trend uncertainty estimated with Tier 1 is somewhat overestimated.

**Table 1.7-1** Inventory uncertainties and comparison to previous submission

Uncertainty estimate	Level uncertainty 2012		Trend uncertainty 2012		Level uncertainty 2011		Trend uncertainty 2011	
	Tier 2		Tier 1		Tier 2		Tier 1	
	%	%	%	%	%	%	%	%
<b>Total UNFCCC, without LULUCF</b>	-5 .. +7	±6	-5 .. +5	±8	-4 .. +7	±6	-5 .. +5	±8
<b>Total UNFCCC, with LULUCF</b>	-33 .. +33	±33	-22 .. +28	±29	-25 .. +34	±32	-25 .. +32	±33
1. Energy	-1 .. +1	±1	-2 .. +2	±1	-1 .. +1	±1	-2 .. +2	±1
2. Industrial processes	-4 .. +4	±4	-27 .. +54	±7	-3 .. +3	±3	-27 .. +54	±7
3. Solvents and other product use	-37 .. +38	±37	-17 .. +33	±19	-38 .. +40	±39	-18 .. +35	±21
4. Agriculture	-43 .. +66	±65	-32 .. +41	±80	-42 .. +67	±64	-32 .. 40	±79
5. LULUCF	-42 .. +42	±42	-445 .. +982	±112	-40 .. +54	±53	-507 .. +609	±116
6. Waste	-29 .. +30	±29	-7 .. 6	±3	-29 .. +30	±29	-7 .. 6	±3
<b>KP-LULUCF</b>								
KP 3.3. ARD	-69 .. +69				-70 .. +69			
AR	-248 .. +250				-225 .. +224			
D	-65 .. +64				-72 .. +72			
KP 3.4. FM	-33 .. +33				-32 .. +32			

The uncertainty analysis was re-evaluated for 2013 submission and the uncertainty parameters were then thoroughly checked. Thus, for this submission only minor changes were done in parameterization of f-gases uncertainty estimation and the results were not much changed when compared with previous submission (see Table 1.7-2).

Quantitative estimates of uncertainty for the Finnish greenhouse gas inventory were published for the first time in 2001, starting from inventory year 1999. This was immediately after the publishing of IPCC good practice guidance with its methodologies for uncertainty analysis. Table 1.7-3 summarises the estimates over time. The changes in the uncertainty estimates over time are due to improvements in the inventory methodologies, the share of different categories in the annual inventories and improvements in the uncertainty analysis.

Both the level and trend uncertainty estimates of the total emissions without LULUCF sector have remained quite stable during the last ten years. The emissions in LULUCF sector can fluctuate significantly between years depending mostly on the changes in the amount of domestic commercial roundwood fellings. This fluctuation produces variation over time to the uncertainty results of the total inventory including LULUCF sector.

**Table 1.7-2** Uncertainties analysed since inventory year 1999

Uncertainty estimates			Method and documentation		
year 1990	year t	trend	method	source	notes
-	7 %	10 %	tier 1	Pipatti 2001	Preliminary analysis for 1999, based entirely on expert judgement
-	-5 ... +6%	(6 ± 5)%	tier 2	Monni & Syri 2003	Analysis for year 2001 LULUCF not included.
-6 ... +7%	-5 ... +6%	(8 ± 5)%	tier 2	Monni 2004	Analysis for years 1990 and 2002. LULUCF not included
-	-4 ... +8% -14 ... +15%	-6 ... +4% -18 ... +23%	tier 2	NIR 2005	Without LULUCF With LULUCF
-6 ... +13% ±50%	-5 ... +6% ±30%	-2 ... +25% -20 ... +130%	tier 2	NIR 2006	Without LULUCF With LULUCF
-7 ... +13% ±50%	-4 ... +7% ±50%	-14 ... +6% -65 ... +45%	tier 2	NIR 2007	Without LULUCF With LULUCF
-	±5% ±29%	±6% ±36%	tier 1	NIR 2008	Without LULUCF With LULUCF
-	±5% ±22%	±6% ±31%	tier 1	NIR 2009	Without LULUCF With LULUCF
-	±5% ±40%	±6% ±36%	tier 1	NIR 2010	Without LULUCF With LULUCF
-	±5% ±60%	±6% ±39%	tier 1	NIR 2011	Without LULUCF With LULUCF
-	±5% ±24%	±6% ±32%	tier 1	NIR 2012	Without LULUCF With LULUCF
-	-4 ... +7% -25 ... +34%	-5 ... +5% -25 ... +32%	tier 2	NIR 2013	Without LULUCF With LULUCF
-	-5 ... +7% -33 ... +33%	-5 ... +5% -22 ... +28%	tier 2	NIR 2014	Without LULUCF With LULUCF

## *1.8 General assessment of completeness*

### *1.8.1 Completeness by source and sink categories and gases*

Finland has provided estimates for all significant IPCC source and sink categories according to the detailed CRF classification. Estimates are provided for the following gases: CO<sub>2</sub>, N<sub>2</sub>O, CH<sub>4</sub>, F-gases (HFC, PFC and SF<sub>6</sub>), NMVOC, NO<sub>x</sub>, CO and SO<sub>2</sub>.

In accordance with the IPCC Guidelines, international aviation and marine bunker fuel emissions are not included in national totals.

Assessment of completeness is included in Annex 5.

### *1.8.2 Completeness by geographical coverage*

The geographical coverage of the inventory is complete. It includes emissions from the autonomic territory of Åland (Ahvenanmaa). The emissions for the territory of Åland are not reported separately.

### *1.8.3 Completeness by timely coverage*

A complete set of CRF tables are provided for all years and the estimates are calculated in a consistent manner.

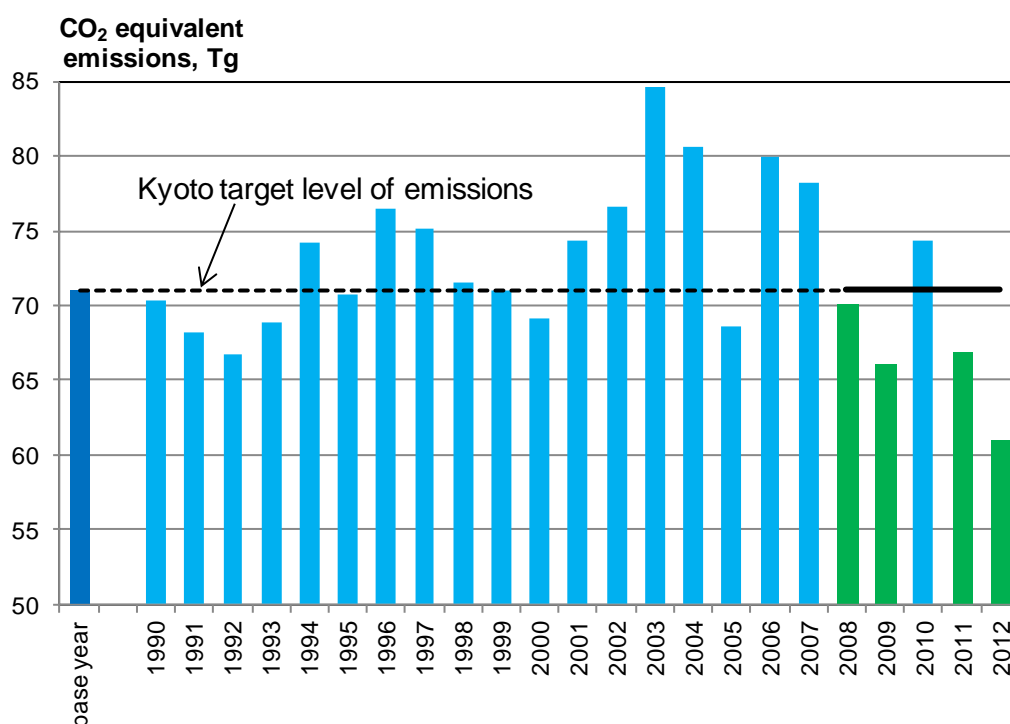


## 2 TRENDS IN GREENHOUSE GAS EMISSIONS

### 2.1 Description and interpretation of emission trends for aggregated greenhouse gas emissions

In 2012, Finland's greenhouse gas emissions totalled 61.0 Tg CO<sub>2</sub> eq. (million tonnes of CO<sub>2</sub> equivalent). The total emissions in 2012 were approximately 14% (10.0 Tg) below the level of the base year (1990 for CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O, and 1995 for HFCs, PFCs and SF<sub>6</sub>) – the level to which Finland should limit its emissions during the Kyoto Protocol's first commitment period between 2008 and 2012. Compared to 2011, the emissions decreased with 9%.

Figure 2.1-1 shows a time series of CO<sub>2</sub> equivalent emissions in Finland during 1990–2012 and the emission target of the Kyoto Protocol. The total greenhouse gas emissions as CO<sub>2</sub> equivalence and indexed emissions in relation to year 1990 level are presented in Table 2.1-1.



**Figure 2.1-1** CO<sub>2</sub> equivalent emissions and the emission target of the Kyoto Protocol (Tg CO<sub>2</sub> eq.)

**Table 2.1-1** Total greenhouse gas emissions in Tg CO<sub>2</sub> eq. and indexed the years 1990-2012 (index 1990=100)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
CO <sub>2</sub> with LULUCF	41.7	26.4	30.9	35.0	47.1	43.8	40.2	43.6	42.4	38.8	36.3	38.3	40.3	47.6	42.8	26.6	34.1	40.6	27.6	14.9	38.0	30.9	23.5
CO <sub>2</sub> without LULUCF	56.6	55.1	54.2	56.1	61.4	57.9	63.7	62.4	59.1	58.7	56.8	62.1	64.6	72.4	68.5	56.5	67.9	66.2	58.0	55.1	63.5	56.4	50.7
CH <sub>4</sub> with LULUCF	6.22	6.20	6.17	6.20	6.17	6.03	5.95	5.87	5.67	5.55	5.34	5.23	5.04	4.86	4.70	4.49	4.56	4.43	4.33	4.26	4.32	4.18	4.14
CH <sub>4</sub> without LULUCF	6.17	6.16	6.13	6.16	6.12	5.98	5.90	5.82	5.63	5.50	5.29	5.17	4.99	4.81	4.65	4.44	4.50	4.38	4.28	4.21	4.27	4.12	4.08
N <sub>2</sub> O with LULUCF	8.65	8.08	7.57	7.74	7.88	8.05	8.01	7.97	7.81	7.71	7.78	7.72	7.82	7.97	7.98	8.01	7.93	7.97	8.13	7.10	6.76	6.59	6.51
N <sub>2</sub> O without LULUCF	7.40	6.84	6.33	6.50	6.62	6.79	6.74	6.69	6.53	6.43	6.50	6.44	6.53	6.68	6.68	6.72	6.62	6.66	6.80	5.78	5.44	5.27	5.18
HFCs	0.000	0.000	0.000	0.000	0.007	0.029	0.077	0.168	0.245	0.318	0.492	0.646	0.463	0.651	0.694	0.863	0.747	0.903	0.993	0.889	1.170	1.032	0.926
PFCs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.028	0.022	0.020	0.013	0.015	0.012	0.010	0.015	0.008	0.011	0.009	0.001	0.001	0.002
SF <sub>6</sub>	0.115	0.083	0.046	0.030	0.031	0.071	0.072	0.071	0.056	0.050	0.054	0.054	0.058	0.062	0.059	0.066	0.071	0.053	0.051	0.050	0.035	0.036	0.037
<b>Total emissions with LULUCF</b>	<b>56.7</b>	<b>40.7</b>	<b>44.7</b>	<b>49.0</b>	<b>61.2</b>	<b>58.0</b>	<b>54.3</b>	<b>57.7</b>	<b>56.2</b>	<b>52.5</b>	<b>50.0</b>	<b>52.0</b>	<b>53.7</b>	<b>61.1</b>	<b>56.3</b>	<b>40.1</b>	<b>47.4</b>	<b>54.0</b>	<b>41.2</b>	<b>27.2</b>	<b>50.3</b>	<b>42.7</b>	<b>35.1</b>
<b>Total emissions</b>	<b>70.3</b>	<b>68.1</b>	<b>66.7</b>	<b>68.8</b>	<b>74.2</b>	<b>70.8</b>	<b>76.5</b>	<b>75.1</b>	<b>71.5</b>	<b>71.0</b>	<b>69.2</b>	<b>74.4</b>	<b>76.6</b>	<b>84.6</b>	<b>80.6</b>	<b>68.6</b>	<b>79.9</b>	<b>78.2</b>	<b>70.1</b>	<b>66.0</b>	<b>74.4</b>	<b>66.9</b>	<b>61.0</b>
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>Index (1990=100)</b>																							
CO <sub>2</sub> without LULUCF	100.0	97.2	95.7	99.1	108.4	102.2	112.5	110.1	104.3	103.6	100.3	109.6	114.0	127.8	120.9	99.8	119.9	116.9	102.4	97.2	112.1	99.6	89.6
CH <sub>4</sub> without LULUCF	100.0	99.8	99.3	99.8	99.3	96.9	95.6	94.4	91.2	89.1	85.7	83.8	80.8	77.9	75.4	71.9	73.0	71.0	69.3	68.2	69.1	66.8	66.2
N <sub>2</sub> O without LULUCF	100.0	92.4	85.6	87.8	89.5	91.8	91.1	90.5	88.2	86.9	87.9	87.0	88.2	90.2	90.3	90.8	89.5	90.0	91.9	78.1	73.5	71.2	70.1
Total (group of three)	100.0	96.9	95.0	98.0	105.6	100.6	108.7	106.6	101.4	100.5	97.7	104.9	108.4	119.4	113.7	96.4	112.6	110.1	98.4	92.7	104.2	93.7	85.5
F-gases	100.0	71.9	40.0	26.3	33.1	87.6	130.3	207.4	262.3	344.2	494.0	626.1	464.7	632.7	664.7	816.5	724.6	838.6	917.7	824.2	1048.0	929.4	838.3
<b>Total (without LULUCF)</b>	<b>100.0</b>	<b>96.9</b>	<b>94.9</b>	<b>97.8</b>	<b>105.5</b>	<b>100.6</b>	<b>108.8</b>	<b>106.8</b>	<b>101.7</b>	<b>100.9</b>	<b>98.4</b>	<b>105.8</b>	<b>109.0</b>	<b>120.3</b>	<b>114.6</b>	<b>97.6</b>	<b>113.6</b>	<b>111.3</b>	<b>99.7</b>	<b>93.8</b>	<b>105.8</b>	<b>95.1</b>	<b>86.7</b>

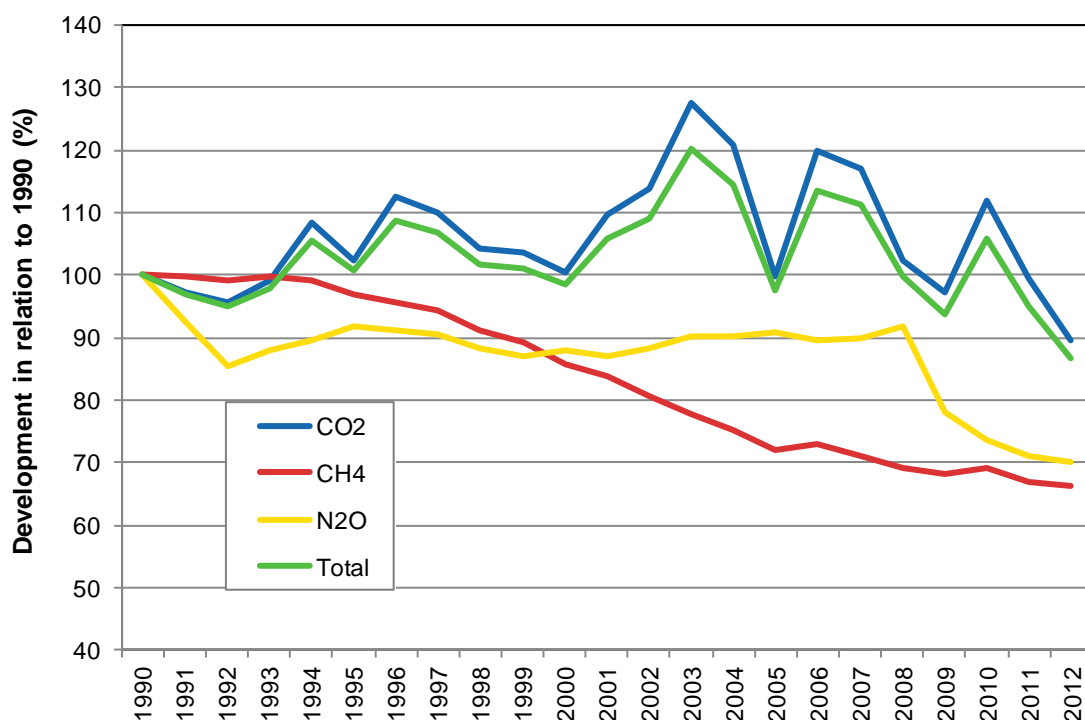
## 2.2 Description and interpretation of emission trends by gas

The most important greenhouse gas in Finland is carbon dioxide. The share of CO<sub>2</sub> emissions from the total greenhouse gas emissions has varied from 81% to 86%. In absolute terms, CO<sub>2</sub> emissions have decreased 5.9 Tg (i.e. 10%) since 1990. Around 91% of all CO<sub>2</sub> emissions originate from the Energy sector in 2012. The amount of energy-related CO<sub>2</sub> emissions has fluctuated much according to the economic trend, the energy supply structure (including electricity imports and exports) and climate conditions.

Methane emissions (CH<sub>4</sub>) have decreased by 34% from the 1990 level. This is mainly due to the improvements in waste treatment and a contraction in animal husbandry in the Agriculture sector.

Correspondingly, emissions of nitrous oxide (N<sub>2</sub>O) have also decreased by 30%; the biggest decline occurred 2009 when the implementation a N<sub>2</sub>O abatement technology in nitric acid production reduced emissions significantly. Another reason for the decrease of the emission is the reduced nitrogen fertilisation of agricultural fields.

The development of emissions of the three main greenhouse gases (CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O) relative to the 1990 level is presented in Figure 2.2-1.



**Figure 2.2-1** Relative development of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O without the LULUCF sector in time series relative to the 1990 level (%)

The emissions of F-gases have increased tenfold during 1990-2012. A key driver behind the trend has been the substitution of ozone depleting substances (ODS) by F-gases in many applications. In Table 2.2-1 the development of emissions of F-gases during 1990-2012 is presented by gas category.

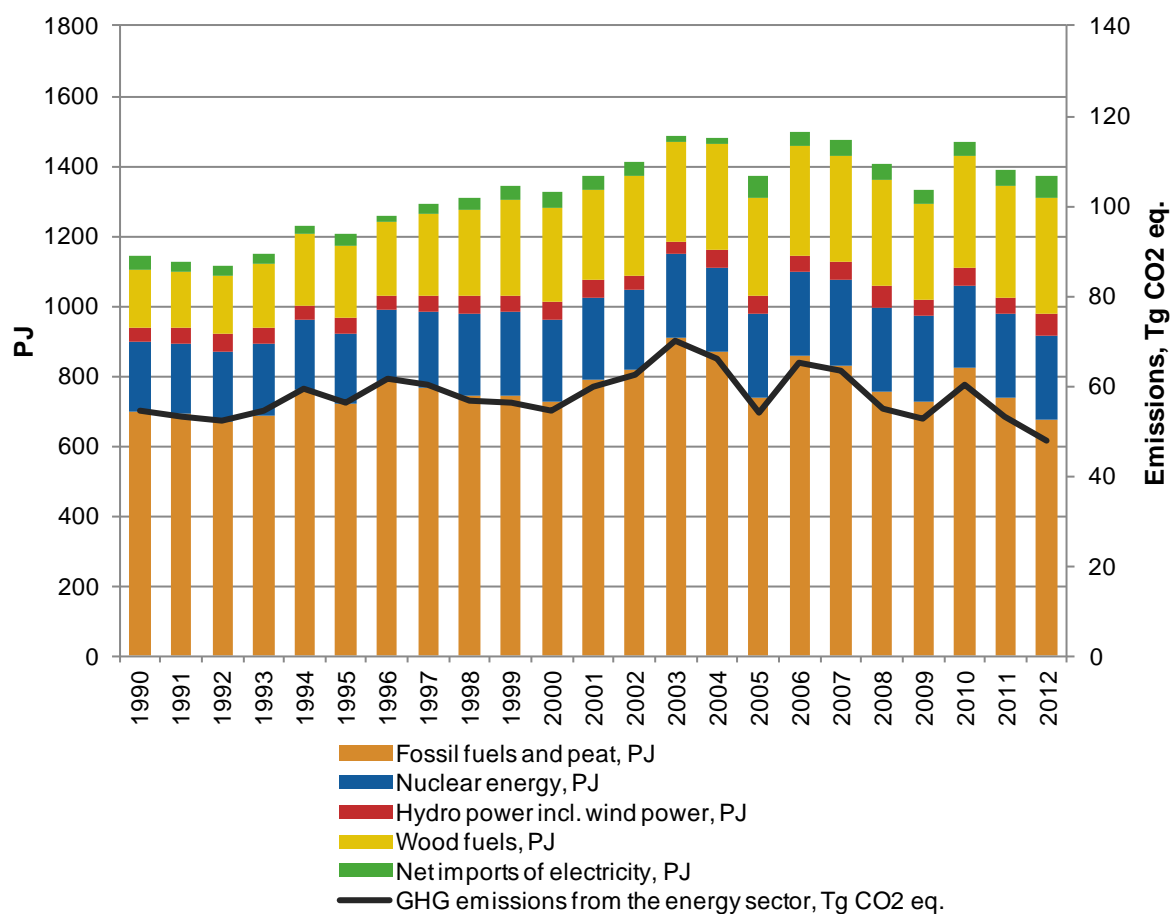
**Table 2.2-1** Actual emissions of HFCs, PFCs and SF<sub>6</sub> (CO<sub>2</sub> equivalent Gg)

	<b>HFCs</b>	<b>PFCs</b>	<b>SF<sub>6</sub></b>	<b>Total F- gases</b>
1990	0.02	0.07	115	<b>115</b>
1991	0.05	0.08	83	<b>83</b>
1992	0.10	0.09	46	<b>46</b>
1993	0.10	0.10	30	<b>30</b>
1994	6.5	0.12	31	<b>38</b>
1995	29	0.14	71	<b>101</b>
1996	77	0.16	72	<b>150</b>
1997	168	0.18	71	<b>239</b>
1998	245	0.21	56	<b>302</b>
1999	318	28.0	50	<b>396</b>
2000	492	22.5	54	<b>568</b>
2001	646	20.1	54	<b>720</b>
2002	463	13.4	58	<b>535</b>
2003	651	14.9	62	<b>728</b>
2004	694	11.9	59	<b>765</b>
2005	863	9.9	66	<b>939</b>
2006	747	15.4	71	<b>833</b>
2007	903	8.4	53	<b>965</b>
2008	993	11.2	51	<b>1 056</b>
2009	889	9.3	50	<b>948</b>
2010	1 170	0.7	35	<b>1 205</b>
2011	1 032	1.4	36	<b>1 069</b>
2012	926	1.9	37	<b>964</b>

## 2.3 Description and interpretation of emission trends by category

The development of the greenhouse gas emissions by sector is presented in Table 2.3-1. The energy sector is the most significant source of greenhouse gas emissions in Finland. This reflects the high energy intensity of the Finnish industry, extensive consumption during the long heating period, as well as energy consumption for transport in a large and sparsely inhabited country (Figure 2.3-1). In the middle of time series total energy consumption increased even if emissions decreased, reasons for that were in increased use of wood fuels, nuclear energy and net imports of electricity. In 2012, the energy sector's emissions were about 12% below the 1990 level. The total energy consumption decreased in 2012 approximately 1% compared with the previous year, totalling 32.8 Mtoe. The final energy consumption has decreased in most consumption sectors in 2012. The biggest reasons for decreasing emissions are the increased shares of wood fuels and net imports of electricity, which lowers the condensing power production.

Energy industries (mainly electricity and district heating production) caused approximately 43 of the total emissions in the energy sector in 2012. Emissions from the energy industries were 8% higher in 2012 than in 1990.



**Figure 2.3-1** Development of total energy consumption by energy source (PJ) and the energy sector's greenhouse gas emissions (Tg CO<sub>2</sub> eq.) in Finland (GHG Inventory and Energy Statistics, Yearbook)

**Table 2.3-1** Summary of emission trend by source category and gas (unit Tg CO<sub>2</sub> eq.)

IPCC sector	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>1. Energy</b>	<b>54.5</b>	<b>53.1</b>	<b>52.3</b>	<b>54.3</b>	<b>59.5</b>	<b>56.0</b>	<b>61.7</b>	<b>60.2</b>	<b>56.8</b>	<b>56.3</b>	<b>54.4</b>	<b>59.7</b>	<b>62.3</b>	<b>70.0</b>	<b>65.8</b>	<b>54.0</b>	<b>65.3</b>	<b>63.2</b>	<b>54.7</b>	<b>52.7</b>	<b>60.5</b>	<b>53.3</b>	<b>47.8</b>
A Fuel combustion total	54.3	52.8	52.1	54.0	59.3	55.8	61.5	59.9	56.6	56.1	54.2	59.5	62.1	69.8	65.7	53.8	65.1	63.0	54.6	52.5	60.3	53.1	47.6
<b>CO<sub>2</sub></b>	53.0	51.5	50.8	52.7	58.0	54.5	60.2	58.5	55.3	54.8	53.0	58.2	60.8	68.3	64.3	52.5	63.7	61.7	53.3	51.3	58.9	51.9	46.4
1. Energy industries	19.1	18.8	18.6	21.3	26.2	23.9	29.6	27.2	23.9	23.4	21.9	27.2	30.0	37.0	32.9	21.7	32.5	30.5	23.9	24.9	30.2	24.4	20.4
2. Manufacturing industries and construction	13.2	12.7	12.2	12.2	12.5	12.0	11.8	12.1	11.7	11.7	11.7	11.3	11.0	11.4	11.4	11.2	11.4	11.2	10.6	8.2	9.7	9.5	8.2
3. Transport	12.5	12.1	12.1	11.6	11.9	11.7	11.7	12.3	12.4	12.7	12.6	12.7	12.9	13.1	13.5	13.5	13.7	14.0	13.4	12.7	13.2	13.0	12.5
4. Other sectors	6.91	6.72	6.83	6.44	5.95	5.46	5.56	5.55	5.62	5.52	5.17	5.40	5.35	5.27	5.16	4.83	4.71	4.54	4.04	4.05	4.33	3.69	3.96
5. Other	1.33	1.20	1.20	1.11	1.37	1.47	1.50	1.44	1.57	1.47	1.62	1.57	1.56	1.62	1.36	1.42	1.42	1.38	1.41	1.38	1.46	1.30	1.36
<b>CH<sub>4</sub></b>	0.31	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.29	0.31	0.32	0.32	0.31	0.30	0.31	0.31	0.31	0.32	0.36	0.31	0.33
<b>N<sub>2</sub>O</b>	1.00	0.97	0.95	0.99	1.02	0.98	1.03	1.03	1.01	1.00	0.98	1.03	1.05	1.11	1.07	0.95	1.05	1.02	0.96	0.90	1.02	0.96	0.92
B Fugitive fuel emissions	0.23	0.25	0.28	0.34	0.25	0.25	0.24	0.27	0.22	0.19	0.18	0.19	0.18	0.18	0.17	0.19	0.17	0.18	0.19	0.16	0.18	0.16	0.17
<b>CO<sub>2</sub></b>	0.22	0.21	0.22	0.27	0.17	0.17	0.15	0.20	0.14	0.13	0.13	0.12	0.12	0.12	0.11	0.13	0.11	0.13	0.14	0.11	0.14	0.12	0.13
<b>CH<sub>4</sub></b>	0.011	0.042	0.057	0.072	0.081	0.080	0.082	0.071	0.073	0.059	0.055	0.068	0.057	0.062	0.056	0.064	0.055	0.051	0.049	0.047	0.041	0.037	0.038
<b>N<sub>2</sub>O</b>	0.0007	0.0007	0.0006	0.0008	0.0004	0.0004	0.0005	0.0008	0.0004	0.0003	0.0004	0.0004	0.0005	0.0004	0.0005	0.0005	0.0005	0.0007	0.0007	0.0005	0.0006	0.0007	0.0010
<b>2. Industrial processes</b>	<b>5.1</b>	<b>4.7</b>	<b>4.4</b>	<b>4.5</b>	<b>4.7</b>	<b>4.7</b>	<b>4.9</b>	<b>5.2</b>	<b>5.2</b>	<b>5.4</b>	<b>5.6</b>	<b>5.7</b>	<b>5.5</b>	<b>6.0</b>	<b>6.3</b>	<b>6.4</b>	<b>6.3</b>	<b>6.8</b>	<b>7.2</b>	<b>5.4</b>	<b>5.8</b>	<b>5.6</b>	<b>5.3</b>
<b>CO<sub>2</sub></b>	3.4	3.2	3.1	3.1	3.2	3.1	3.3	3.5	3.5	3.6	3.6	3.7	3.6	3.8	4.0	3.8	4.0	4.4	4.5	3.6	4.4	4.4	4.2
<b>CH<sub>4</sub></b>	0.005	0.005	0.005	0.009	0.010	0.010	0.010	0.009	0.010	0.009	0.010	0.010	0.010	0.009	0.009	0.009	0.009	0.009	0.009	0.008	0.009	0.009	0.009
<b>N<sub>2</sub>O</b>	1.66	1.44	1.30	1.36	1.43	1.46	1.46	1.44	1.38	1.35	1.36	1.29	1.33	1.41	1.50	1.63	1.44	1.48	1.58	0.79	0.17	0.13	0.17
<b>HFCs</b>	0.00	0.00	0.00	0.00	0.01	0.03	0.08	0.17	0.25	0.32	0.49	0.65	0.46	0.65	0.69	0.86	0.75	0.90	0.99	0.89	1.17	1.03	0.93
<b>PFCs</b>	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.00	0.00	0.00
<b>SF<sub>6</sub></b>	0.11	0.08	0.05	0.03	0.03	0.07	0.07	0.07	0.06	0.05	0.05	0.05	0.06	0.06	0.06	0.07	0.07	0.05	0.05	0.05	0.04	0.04	0.04
<b>3. Solvent and other product use</b>	<b>0.178</b>	<b>0.170</b>	<b>0.157</b>	<b>0.150</b>	<b>0.146</b>	<b>0.142</b>	<b>0.138</b>	<b>0.135</b>	<b>0.136</b>	<b>0.135</b>	<b>0.123</b>	<b>0.121</b>	<b>0.111</b>	<b>0.104</b>	<b>0.104</b>	<b>0.104</b>	<b>0.100</b>	<b>0.097</b>	<b>0.086</b>	<b>0.072</b>	<b>0.073</b>	<b>0.070</b>	<b>0.066</b>
<b>CO<sub>2</sub></b>	0.116	0.108	0.095	0.088	0.084	0.080	0.076	0.073	0.074	0.073	0.072	0.072	0.067	0.064	0.065	0.060	0.060	0.060	0.052	0.047	0.045	0.043	0.040
<b>N<sub>2</sub>O</b>	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.062	0.0517	0.0486	0.0437	0.0401	0.0391	0.0448	0.0394	0.0364	0.0341	0.0248	0.0279	0.0266	0.0262

IPCC sector	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>4. Agriculture</b>	<b>6.5</b>	<b>6.2</b>	<b>5.8</b>	<b>5.8</b>	<b>5.9</b>	<b>6.0</b>	<b>5.9</b>	<b>5.9</b>	<b>5.8</b>	<b>5.7</b>	<b>5.8</b>	<b>5.7</b>	<b>5.8</b>	<b>5.8</b>	<b>5.7</b>	<b>5.7</b>	<b>5.7</b>	<b>5.8</b>	<b>5.8</b>	<b>5.7</b>	<b>5.9</b>	<b>5.8</b>	<b>5.7</b>
<b>CH<sub>4</sub></b>	2.04	1.96	1.90	1.92	1.93	1.84	1.85	1.88	1.84	1.82	1.83	1.81	1.84	1.83	1.82	1.82	1.82	1.80	1.79	1.80	1.84	1.81	1.80
A. Enteric fermentation	1.832	1.759	1.698	1.711	1.712	1.620	1.623	1.646	1.612	1.588	1.598	1.580	1.598	1.582	1.569	1.558	1.558	1.541	1.528	1.543	1.576	1.558	1.544
B. Manure management	0.203	0.199	0.199	0.205	0.214	0.222	0.225	0.238	0.232	0.228	0.227	0.228	0.239	0.248	0.252	0.260	0.261	0.263	0.262	0.259	0.259	0.255	0.251
E. Field burning of agricultural residues	0.0019	0.0002	0.0001	0.0004	0.0001	0.0003	0.0006	0.0003	0.0002	0.0001	0.0008	0.0004	0.0005	0.0005	0.0004	0.0002	0.0003	0.0006	0.0005	0.0005	0.0003	0.0004	0.0004
<b>N<sub>2</sub>O</b>	4.51	4.20	3.86	3.93	3.95	4.12	4.02	3.99	3.92	3.87	3.95	3.91	3.94	3.96	3.92	3.93	3.93	3.95	4.06	3.90	4.07	3.98	3.91
B. Manure management	0.49	0.45	0.44	0.45	0.45	0.44	0.45	0.46	0.45	0.44	0.44	0.41	0.42	0.43	0.42	0.42	0.42	0.41	0.40	0.42	0.43	0.42	0.42
D. Agricultural soils	4.03	3.75	3.41	3.49	3.50	3.68	3.58	3.53	3.47	3.43	3.52	3.50	3.51	3.53	3.50	3.51	3.51	3.54	3.65	3.48	3.64	3.57	3.50
E. Field burning of agricultural residues	0.0006	0.0000	0.0000	0.0001	0.0000	0.0001	0.0002	0.0001	0.0001	0.0000	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001
<b>5. Land-use, land-use change and forestry</b>	<b>-13.7</b>	<b>-27.4</b>	<b>-22.0</b>	<b>-19.9</b>	<b>-13.0</b>	<b>-12.8</b>	<b>-22.2</b>	<b>-17.4</b>	<b>-15.3</b>	<b>-18.5</b>	<b>-19.2</b>	<b>-22.4</b>	<b>-22.9</b>	<b>-23.4</b>	<b>-24.3</b>	<b>-28.6</b>	<b>-32.5</b>	<b>-24.3</b>	<b>-29.0</b>	<b>-38.8</b>	<b>-24.1</b>	<b>-24.1</b>	<b>-25.9</b>
<b>CO<sub>2</sub></b>	-14.97	-28.7	-23.27	-21.14	-14.3	-14.07	-23.5	-18.77	-16.64	-19.84	-20.5	-23.76	-24.28	-24.79	-25.67	-29.91	-33.86	-25.64	-30.35	-40.17	-25.48	-25.5	-27.23
<b>CH<sub>4</sub></b>	0.046	0.044	0.046	0.044	0.046	0.047	0.047	0.049	0.049	0.051	0.050	0.053	0.053	0.052	0.051	0.052	0.053	0.053	0.055	0.056	0.056	0.057	0.057
<b>N<sub>2</sub>O</b>	1.249	1.247	1.242	1.242	1.255	1.256	1.263	1.273	1.279	1.279	1.281	1.285	1.289	1.291	1.293	1.296	1.306	1.309	1.332	1.325	1.327	1.329	1.325
<b>6. Waste</b>	<b>4.0</b>	<b>4.0</b>	<b>4.0</b>	<b>4.0</b>	<b>4.0</b>	<b>3.9</b>	<b>3.8</b>	<b>3.7</b>	<b>3.6</b>	<b>3.5</b>	<b>3.3</b>	<b>3.1</b>	<b>2.9</b>	<b>2.7</b>	<b>2.6</b>	<b>2.4</b>	<b>2.5</b>	<b>2.4</b>	<b>2.3</b>	<b>2.2</b>	<b>2.2</b>	<b>2.1</b>	<b>2.1</b>
<b>CH<sub>4</sub></b>	3.81	3.85	3.87	3.87	3.81	3.75	3.66	3.56	3.40	3.32	3.11	2.98	2.77	2.59	2.45	2.24	2.31	2.21	2.11	2.03	2.03	1.95	1.91
<b>N<sub>2</sub>O</b>	0.164	0.160	0.159	0.156	0.157	0.162	0.163	0.162	0.158	0.156	0.158	0.160	0.157	0.161	0.161	0.164	0.167	0.167	0.169	0.155	0.160	0.161	0.158
<b>7. Other</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>	<b>NA</b>
<b>National total emissions with LULUCF</b>	56.7	40.7	44.7	49.0	61.2	58.0	54.3	57.7	56.2	52.5	50.0	52.0	53.7	61.1	56.3	40.1	47.4	54.0	41.2	27.2	50.3	42.7	35.1
<b>NATIONAL TOTAL EMISSIONS</b>	<b>70.3</b>	<b>68.1</b>	<b>66.7</b>	<b>68.8</b>	<b>74.2</b>	<b>70.8</b>	<b>76.5</b>	<b>75.1</b>	<b>71.5</b>	<b>71.0</b>	<b>69.2</b>	<b>74.4</b>	<b>76.6</b>	<b>84.6</b>	<b>80.6</b>	<b>68.6</b>	<b>79.9</b>	<b>78.2</b>	<b>70.1</b>	<b>66.0</b>	<b>74.4</b>	<b>66.9</b>	<b>61.0</b>

The most important drivers in the trend of the energy sector's greenhouse emissions have been the changes in the level of annually imported electricity and fossil fuel based condensing power in annual energy production (Figure 2.3-2). Total consumption of energy in Finland amounted to 1.37 million terajoules (TJ) in 2012, which was one per cent less than in 2011. The industrial output decreased slightly as well as total energy consumption in industry. The share of renewable energy of total energy consumption increased in 2012 and stood at 32 per cent. The biggest growth was seen in the use of wood fuels that for the first time became the most used source of energy. The use of forest chippings rose to a new record level in 2012 and 11 per cent more was used than in 2011. The use of fossil fuels went down by eight per cent from the year before. Of fossil fuels, the consumption of coal (including hard coal, coke, and blast furnace and coke oven gas) decreased by 16 per cent. The use of coal diminished significantly in separate production of condensing power. The use of natural gas fell by 12 per cent and the use of peat by 23 per cent from 2011. The availability of hydro power improved in the Nordic countries in 2012. The production of hydro power increased by 36 per cent in Finland. (Energy supply and consumption, Statistics Finland).

The share of renewable energy of total energy consumption increased in 2012 and stood at 32 per cent. Wood fuels rose to the most used source of energy, surpassing oil for the first time. The biggest growth was seen in the use of wood fuels that for the first time became the most used source of energy. The use of forest chippings rose to a new record level in 2012 and 11 per cent more was used than in 2011. EU targets for renewable energy are calculated relative to final energy consumption and in Finland this share has been four to five percentage points higher than the share calculated from total energy consumption. Finland's target for the share of renewable energy is 38 per cent of final energy consumption in 2020. (Energy supply and consumption, Statistics Finland).

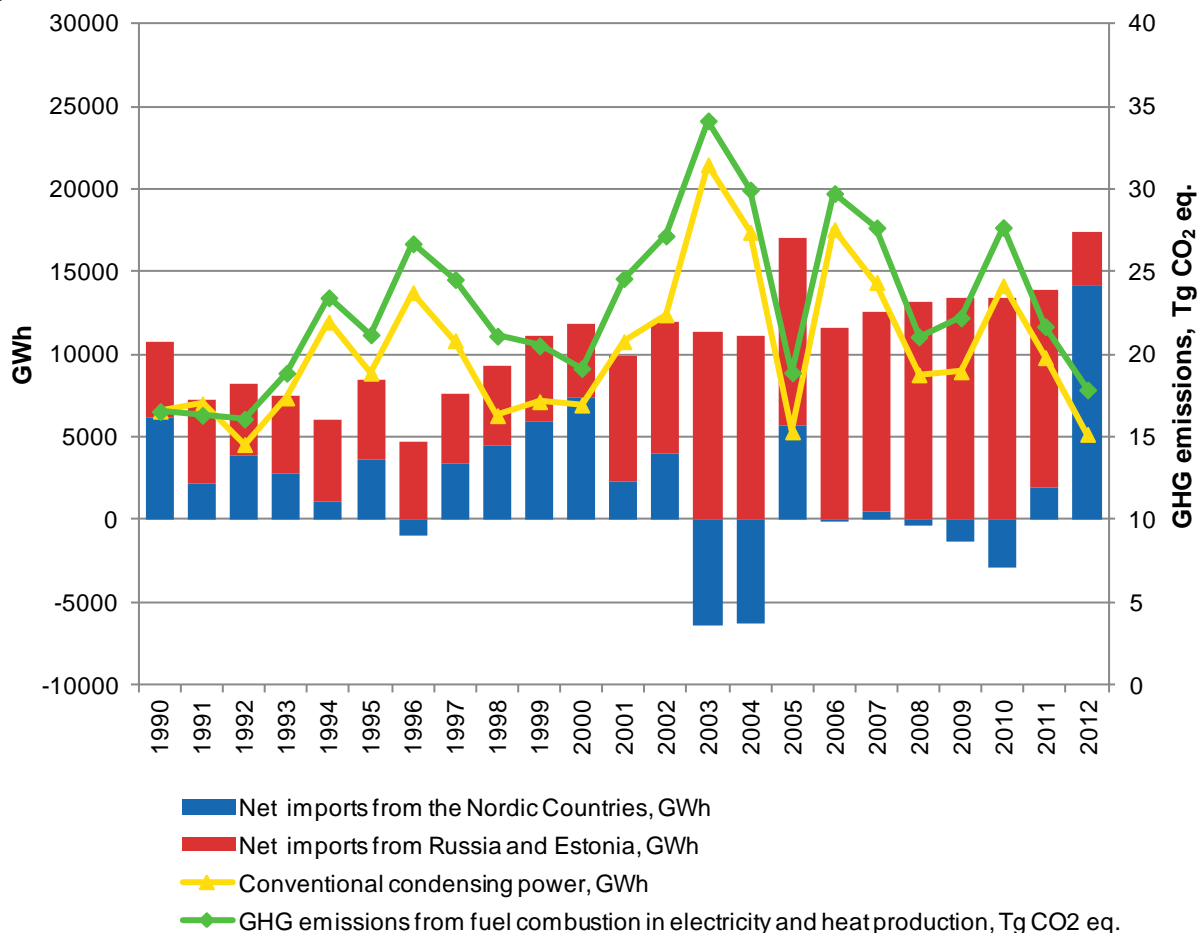
Total electricity consumption went up by one per cent and amounted to 85.1 TWh. Of total electricity consumption, 80 per cent was covered by domestic production and 20 per cent by net imports of electricity from the Nordic countries, Russia and Estonia. Net imports of electricity increased by 26 per cent from the year before due to the good water situation in the Nordic countries. The consumption of electricity rose, although electricity consumption in manufacturing fell, because the early and latter part of the year were slightly colder than usual and the use of electricity to heat buildings grew from the year before.

The production of electricity in Finland amounted to 67.7 TWh in 2012. The production went down by four per cent from the previous year. Altogether 41 per cent of the electricity produced in Finland was produced with renewable energy sources. Over one-half of this was produced with hydro power and almost all of the remainder with wood. Thirty-three per cent of the production of electricity was covered with nuclear power, 21 per cent with fossil fuels and five per cent with peat. The amounts of electricity produced with fossil fuels and peat decreased by nearly one-third from the previous year.

The production of district heat amounted to 36.7 TWh in 2012. The production grew by eight per cent from the previous year. The consumption of district heat rose compared with the previous year, because autumn 2012 was cooler than the previous one. According to the Finnish Meteorological Institute, after the exceptionally mild autumn 2011, autumn 2012 was typical.

The production of industrial heat was 52.6 TWh in 2012. The production went down slightly from the year before. As in the previous years, the use of industrial heat remained at a low level. Over 60 per cent of the heat used by industry was produced with renewable fuels. The individual fuel that was used most was black liquor from the forest industry and other wood fuels. (Production of electricity and heat, Statistics Finland)





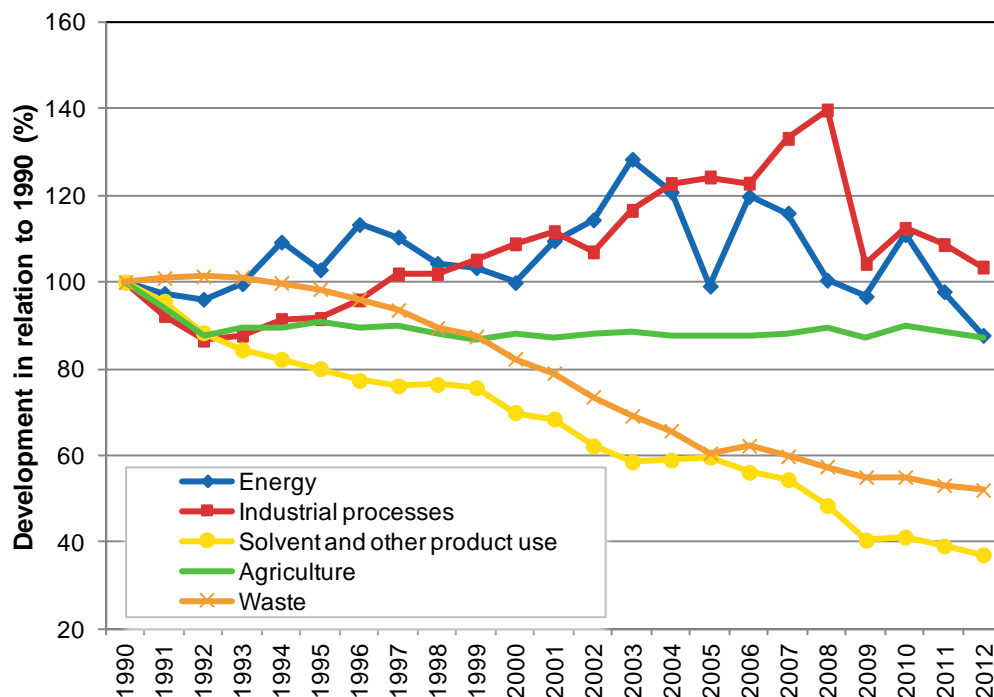
**Figure 2.3-2** Greenhouse gas emissions from fuel combustion in electricity and heat production, net imports of electricity from the Nordic Countries and Estonia and Russia and production of conventional condensing power (Energy Statistics, Yearbook)

Manufacturing industries and construction produce much energy themselves. Their share of the energy-related emissions was around 17% in 2012. Emissions from manufacturing industries and construction have declined by 37% since 1990. The main reasons behind this trend are increased use of biofuels in the forest industry and outsourcing of power plants from industry to the energy sector.

Emissions in the transport sector have decreased by around 1% compared with the 1990 level. The magnitude of the growth is smaller in Finland than in many other Annex I countries, mainly due to the effect that the economic recession in the early 1990's had on transport (see Section 3.3.2). The share of transportation of energy-related emissions was one fourth in 2012. The worldwide economic downturn that began 2008 decreased the kilometrage of all transport modes. The upward trend in emissions in 2010 compared to the year 2009 is due to the recovery from the economic downturn in road traffic. The increase in emissions comes especially from heavy-duty transport. The trend in emissions in 2012 compared to 2011 has continued downwards because of the prolonged economic downturn.

Emissions from the residential sector have decreased by 48% and from commercial sectors by 47% compared with the 1990 levels. The decrease is mainly due to substitution of direct oil heating with district heating and electricity.

Figure 2.3-3 provides an overview of the development of the CO<sub>2</sub> equivalent emissions by IPCC source sector.



**Figure 2.3-3** Relative development of greenhouse gas emissions by main source category relative to the 1990 level (1990=100%)

Emissions of industrial processes have increased by 3% (0.2 Tg CO<sub>2</sub> eq.) from 1990 to 2012. At the beginning of the time series, some production plants were closed down and that caused a fast decrease in emissions. After this, the production outputs and emissions increased and reached the level of the year 1990 in 1996. Since these years the overall trend in the emissions has been increasing, however emissions decreased rapidly in 2009 due to the global recession as the demand for industrial products diminished. Emissions however started to grow along with production after the recession and in 2010 CO<sub>2</sub> emissions were almost at the same level than in 2008. CO<sub>2</sub> emissions have increased 24% from 1990 to 2012, reasons are increased production of steel, hydrogen and use of limestone and dolomite. Methane emissions have increased by 80%, but the total emissions were only 0.009 Tg CO<sub>2</sub> eq. in 2012. Nitrous oxide emissions have fluctuated during the period 1990 to 2012; the first fast decrease due to the closing of a nitric acid production plant and after that a slow increase of emissions, the second fast decrease started in 2009 originated from implementation new N<sub>2</sub>O abatement technology in nitric acid production and decreased demand of fertilisers. Since 1990 nitrous oxide emissions have decreased 1.5 Tg CO<sub>2</sub> eq. (90%). The F-gas emissions are about tenfold compared with the 1990 as well as the 1995 emissions. 1995 is the base year for these emissions under the Kyoto Protocol. Emissions of F-gases have increased 0.8 Tg CO<sub>2</sub> eq. A key driver behind the increasing trend in emissions of F-gases has been the substitution of ozone depleting substances (ODS) by F-gases in many applications.

Agricultural emissions have decreased by 13% (0.8 Tg CO<sub>2</sub> eq.) over the period 1990-2012. The main driver behind the decreasing trend has been the overall change in the economy of agriculture, which has resulted in a decrease in the number of animals and an average increase in farm size. Cattle produce the major part of the emissions from enteric fermentation in Finland, thus the 33% decrease in the number of cattle since has influenced both emissions from enteric fermentation and nitrous oxide emissions from manure management. Methane emissions from manure management have, on the contrary, increased somewhat, despite the decrease in the number of animals. This is mostly due to an increase in the number of cattle and swine kept in slurry-based manure management systems, which have tenfold methane emissions compared with solid storage or pasture. Nitrous oxide emissions from manure management are smaller in slurry than in solid storage systems, which have had an impact on the decreasing trend in N<sub>2</sub>O emissions.

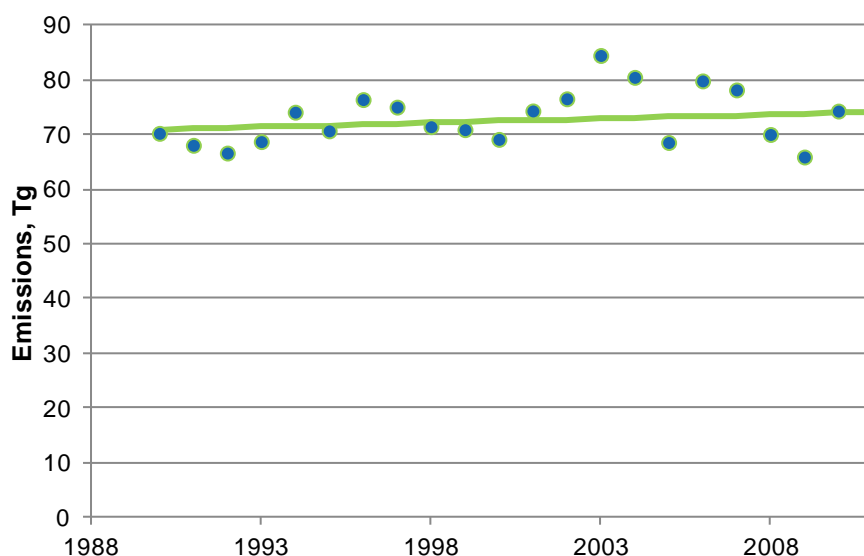
The most important sources of N<sub>2</sub>O emissions in the agricultural sector are agricultural soils. Nitrous oxide emissions from agricultural soils have decreased by over 13% compared with the 1990 level. The main reasons for the decreasing trend are the reduction in animal numbers, which affects the amount of nitrogen

excreted annually to soils and the fall in the amount of synthetic fertilisers used annually. The emissions from cultivated organic soils have increased as a result of the increased area of these soils.

Emissions from the waste sector have declined quite constantly since 1990. The decrease of 1.9 Tg CO<sub>2</sub> eq. has mainly been due to the implementation of the new Waste Act in Finland in 1994. At the beginning of the 1990's, around 80% of the generated municipal waste was taken to solid waste disposal sites (landfills). After the implementation of the new Waste Act, minimisation of waste generation, recycling and reuse of waste material and alternative treatment methods to landfills have been endorsed. Similar developments have occurred in the treatment of industrial waste and municipal and industrial sludges. While the emissions from solid waste disposal on land have decreased, the emissions from composting have increased during the last years. In addition, the increase of waste incineration has decreased the emissions from landfills from 2008 onwards. Implementation of landfill gas recovery has significant impact on emissions. The waste tax and adoption of the National Waste Plan have also had an impact on the decreasing trend in emissions of the waste sector. In the early 1990's the economic recession reduced the amount of waste.

The LULUCF as a whole sector is a net sink in Finland. The sink has varied from approximately 20% to 60% of the annual emissions from other sectors during 1990-2012. Most of the removals in the LULUCF sector come from tree biomass growth. The annual volume increment has increased almost steadily for which reason the CO<sub>2</sub> uptake has also grown. The total drain is very much affected by commercial roundwood fellings and the global market situation. The global economic downturn had a considerable negative effect on demand for forest-based industry products in 2009. In 2010, production of forest industry recovered. The wood products industry's production rebounded closer to its normal level when demand increased both domestically and in the export markets. In addition, pulp and paper demand recovered (Finnish Forest Industries Federation). Thus roundwood fellings in Finland increased in 2010 almost to the normal level. In 2010 commercial fellings totalled 52 million m<sup>3</sup>, which is almost one fourth more than in previous year. (Finnish Statistical Yearbook of Forestry 2011). Increased fellings caused most of the decrease in biomass C stock sinks compared the previous year. In 2012, the growth of the Finnish national economy was at a modest rate. The total drain was 70 million m<sup>3</sup> of which the commercial roundwood removals were 52 million m<sup>3</sup> that is about at the same level as in previous year. (Finnish Statistical Yearbook of Forestry 2013).

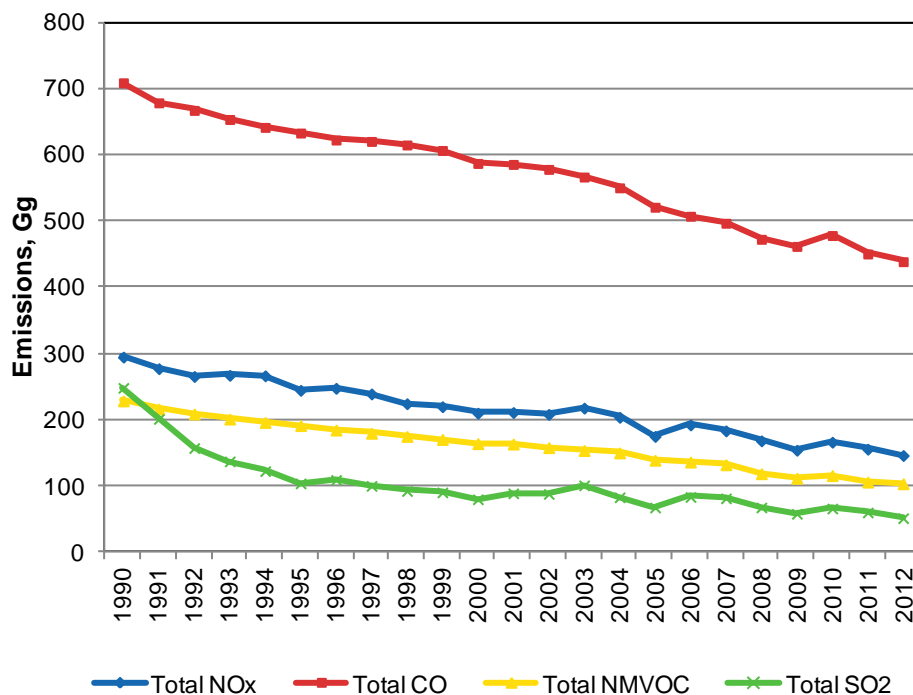
Figure 2.3-4 shows a plot of inventory estimates (in teragrams CO<sub>2</sub> eq.). The graph shows year-to-year variability, increasing somewhat over the years. In addition, the level of emissions seems to increase: the graph shows an eye-fitted line to make the point. If such a partial description were to describe a possible trend behind the data, it would correspond to an addition of 0.15 Tg CO<sub>2</sub> eq. to the level each year, starting from 71 Tg in 1990.



**Figure 2.3-4** One possible description of a trend behind the data. The fitted line corresponds to an addition of 0.15 Tg CO<sub>2</sub> eq. to the level each year, starting from 1990

## 2.4 Description and interpretation of emission trends of indirect greenhouse gases and sulphur oxides

The emissions trends of indirect greenhouse gases; nitrogen oxides, carbon monoxide and non-methane volatile organic compounds and sulphur oxide and other sulphur emissions calculated as sulphur dioxide, are presented in Figure 2.4-1 and Table 2.4-1.



**Figure 2.4-1** Indirect greenhouse gas and sulphur dioxide emissions in the years 1990-2012, Gg

**Nitrogen oxides (NO<sub>x</sub>)** were generated in the energy, industrial, agriculture and LULUCF sectors. The energy sector is the most significant source, over 99% of emissions are energy related. Emissions have decreased by 50% and they were 147 Gg in 2012. The biggest decrease, 65%, has happened in the transport category due to the implementation of catalytic converters to cars and these emissions were 37% of the total emissions in 2012. Energy industries as well as manufacturing industries and construction generated 25% and 23% of the emissions, respectively.

**Carbon monoxide (CO)** emissions, total 439 Gg, originated almost exclusively in the energy sector, where transport generated 55% and other sectors (including small-scale combustion in the residential energy sector as well as off-road machinery in forestry, agriculture and fishery) 33% of the total emissions. Total carbon monoxide emissions have decreased by 38% during this period and the biggest part of this reduction is resulted from increased amount of cars with catalytic converters.

The **non-methane volatile organic compounds (NMVOC)** totalled 104 Gg in 2012. In all, 75% of the total emissions were generated in the energy sector, 17% originated from solvent and other product use and 7% from industrial processes. Total NMVOC emissions have decreased by 55% from 1990 to 2012, the greatest decline has taken place in industrial sector, where emissions decreased by 67%.

The **sulphur dioxide (SO<sub>2</sub>)** emissions totalled 52 Gg out of which 75% originated in the energy sector, where energy industries generated 48% of the total emissions and manufacturing industries and construction 14%. Sulphur dioxide emissions have totally decreased 79% from 1990, reasons for that are increased use of less sulphur containing fuels and sulphur abatement technology in energy production.

**Table 2.4-1** Trends of NO<sub>x</sub>, CO, NMVOC and SO<sub>2</sub> emissions in different sources

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>Total nitrogen oxides</b>	<b>295</b>	<b>278</b>	<b>266</b>	<b>268</b>	<b>267</b>	<b>245</b>	<b>248</b>	<b>240</b>	<b>225</b>	<b>220</b>	<b>211</b>	<b>212</b>	<b>209</b>	<b>218</b>	<b>204</b>	<b>176</b>	<b>193</b>	<b>184</b>	<b>169</b>	<b>155</b>	<b>167</b>	<b>156</b>	<b>147</b>
- energy	294	277	265	267	266	244	247	239	224	219	210	211	208	217	203	174	191	182	166	152	165	154	145
- industry	1.0	1.0	1.0	0.8	0.9	1.2	1.0	1.0	1.1	1.1	1.1	1.0	1.0	1.5	1.5	1.5	1.7	1.6	2.4	2.7	2.2	2.1	2.1
- agriculture and LULUCF	0.11	0.03	0.04	0.03	0.03	0.03	0.04	0.03	0.02	0.03	0.04	0.04	0.05	0.04	0.02	0.02	0.04	0.03	0.03	0.03	0.02	0.03	0.02
<b>Total carbon monoxides</b>	<b>709</b>	<b>679</b>	<b>668</b>	<b>654</b>	<b>642</b>	<b>634</b>	<b>623</b>	<b>621</b>	<b>616</b>	<b>607</b>	<b>588</b>	<b>586</b>	<b>579</b>	<b>567</b>	<b>551</b>	<b>522</b>	<b>508</b>	<b>497</b>	<b>473</b>	<b>462</b>	<b>479</b>	<b>451</b>	<b>439</b>
- energy	706	678	666	653	641	632	622	620	615	606	587	585	577	566	550	521	507	496	472	462	478	450	439
- agriculture	1.9	0.2	0.1	0.4	0.1	0.3	0.6	0.3	0.2	0.1	0.8	0.4	0.5	0.5	0.4	0.2	0.3	0.6	0.5	0.5	0.3	0.4	0.4
- LULUCF	1.7	0.7	1.2	0.5	1.0	0.8	0.6	0.9	0.3	0.8	0.4	1.1	1.1	0.8	0.2	0.6	0.9	0.4	0.5	0.5	0.3	0.4	0.1
<b>Total NMVOCs</b>	<b>229</b>	<b>217</b>	<b>209</b>	<b>202</b>	<b>197</b>	<b>192</b>	<b>185</b>	<b>180</b>	<b>176</b>	<b>171</b>	<b>165</b>	<b>164</b>	<b>159</b>	<b>154</b>	<b>151</b>	<b>140</b>	<b>137</b>	<b>133</b>	<b>119</b>	<b>112</b>	<b>116</b>	<b>107</b>	<b>104</b>
- energy	153	146	146	142	139	137	134	131	129	125	119	119	116	114	109	102	99	94	85	82	87	78	78
- industry	22.7	20.6	19.8	19.0	18.3	17.2	16.3	15.0	12.6	12.0	12.0	11.8	11.1	10.9	11.4	9.6	10.0	10.6	9.8	8.1	8.6	8.6	7.5
- solvent and other product use	52.9	49.3	43.4	40.2	38.4	36.7	34.5	33.5	33.8	33.2	32.7	32.9	30.8	29.2	29.5	27.2	27.6	27.6	23.9	21.6	20.8	19.6	18.2
- waste	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.5	0.4	0.4
<b>Total sulphur oxides</b>	<b>249</b>	<b>202</b>	<b>158</b>	<b>138</b>	<b>123</b>	<b>105</b>	<b>110</b>	<b>101</b>	<b>93</b>	<b>91</b>	<b>81</b>	<b>90</b>	<b>89</b>	<b>102</b>	<b>84</b>	<b>68</b>	<b>84</b>	<b>82</b>	<b>68</b>	<b>59</b>	<b>67</b>	<b>61</b>	<b>52</b>
- energy	187	155	125	111	99	83	90	82	74	72	65	75	74	87	71	54	67	65	50	46	53	47	39
- industry	61.9	47.3	32.8	27.1	24.2	21.1	20.1	18.5	18.7	18.8	15.9	14.7	15.0	14.3	12.4	13.8	17.1	17.4	18.1	13.2	13.8	13.5	12.8

## 2.5 Emissions and removals from KP-LULUCF activities

The coverage of carbon pools and emission sources reported under afforestation (A), reforestation (R) and deforestation (D) (under Article 3.3), and forest management (FM) (under Article 3.4) are presented in Table 2.5-1. Litter and dead wood pools are included to soil carbon pool.

**Table 2.5-1** Activity coverage and other information relating to activities under Article 3.3 and elected activities under Article 3.4

Change in carbon pool reported							Greenhouse gas sources reported						
Activity <sup>1</sup>	Above-ground biomass	Below-ground biomass	Litter	Dead wood	Soil	Fertilisation	Drainage of soils under forest management	Disturbance associated with land-use conversion to croplands	Liming	Biomass burning			
										CO <sub>2</sub>	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
							N <sub>2</sub> O	N <sub>2</sub> O	N <sub>2</sub> O	CO <sub>2</sub>	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O
Article 3.3 activities	A/R D	R	R	IE	IE	R	NO		NO	R, NO	R, NO	R, NO	R, NO
		R	R	IE	R, IE	R				R	NO, IE	NO, IE	
Article 3.4 activities	FM	R	R	IE	IE	R	R	R	NO	R	R	R	R
	CM	NA	NA	NA	NA	NA				NA	NA	NA	
	GM	NA	NA	NA	NA	NA				NA	NA	NA	
	RV	NA	NA	NA	NA	NA				NA	NA	NA	

<sup>1</sup> R (reported), NR (not reported), NE (not estimated), NO (not occurring), IE (included elsewhere), NA (not applicable)

Net emissions from ARD in 2012 were 2.4 million tonnes CO<sub>2</sub> eq. Since 1990 afforested and reforested areas of cropland, grassland, settlements and wetlands were 48,000 ha, 75,400 ha, 19,100 ha and 23,800 ha, respectively. Land areas deforested to cropland, grassland, settlements and wetlands were 87,900 ha, 15,200 ha, 190,600 ha and 30,400 ha, respectively. Net removals from FM activity were 35.6 million tonnes CO<sub>2</sub> eq., in 2012 (Table 2.5-2).

**Table 2.5-2** Emissions and removals resulting from activities under Article 3.3 and 3.4 of Kyoto Protocol in 2012

GREENHOUSE GAS SOURCE AND SINK ACTIVITIES <sup>1,2</sup>	Net CO <sub>2</sub> emissions/removals	CH <sub>4</sub>	N <sub>2</sub> O	Net CO <sub>2</sub> eq. emissions/removals
			(Gg)	
<b>A. Article 3.3 activities</b>				<b>2 351</b>
A.1. Afforestation and Reforestation	- 181	NA,NO	0.15	- 135
A.1.1. Units of land not harvested since the beginning of the commitment period	- 181	NO	0.15	- 135
A.1.2. Units of land harvested since the beginning of the commitment period	NA	NA	NA	NA
A.2. Deforestation	2 482	IE,NE,NO	0.02	2 486
<b>B. Article 3.4 activities</b>				<b>-35 596</b>
B.1. Forest Management	-36 788	0.02	3.84	-35 596
B.2. Cropland Management	NA	NA	NA	NA
B.3. Grazing Land Management	NA	NA	NA	NA
B.4. Revegetation	NA	NA	NA	NA

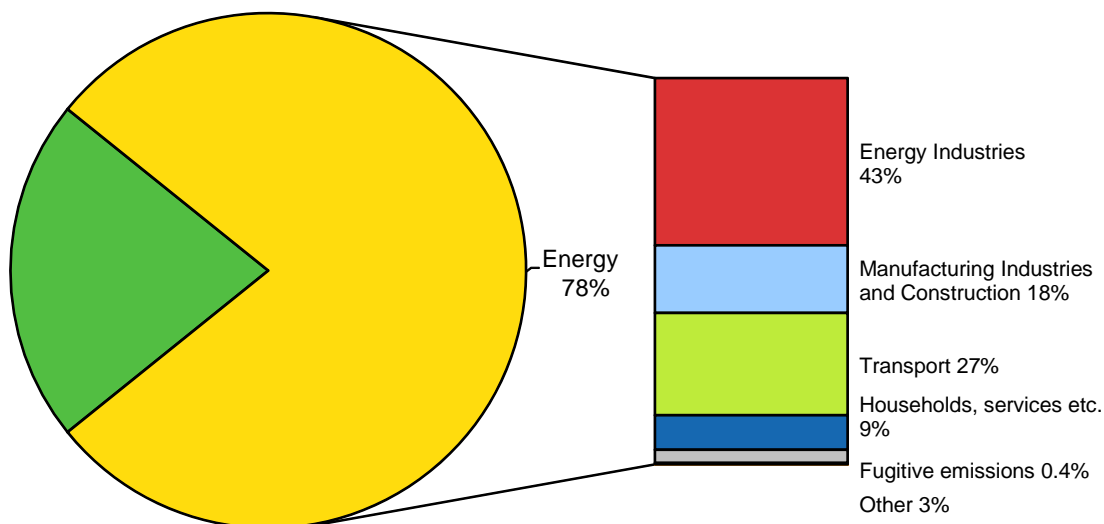
<sup>1</sup> IE (included elsewhere), NA (not applicable), NO (not occurring)

<sup>2</sup> The signs for removals are negative (-) and for emissions positive (+)

## 3 ENERGY (CRF 1)

### 3.1 Overview of the sector (CRF 1)

The energy sector is the main source of greenhouse gas emissions in Finland. In 2012, the sector contributed 78% to total national emissions, totalling 47.8 Tg CO<sub>2</sub> eq. (Figure 3.1-1). Most of the emissions originate from fuel combustion. The substantial amount of energy-related emissions reflect the high energy intensity of the Finnish industry, the extensive consumption of fuels during the long heating period, as well as the energy consumed for transport in this relatively large and sparsely inhabited country.



**Figure 3.1-1** Emissions from the energy sector compared with the total emissions in 2012. Due to independent rounding, the sums do not add up

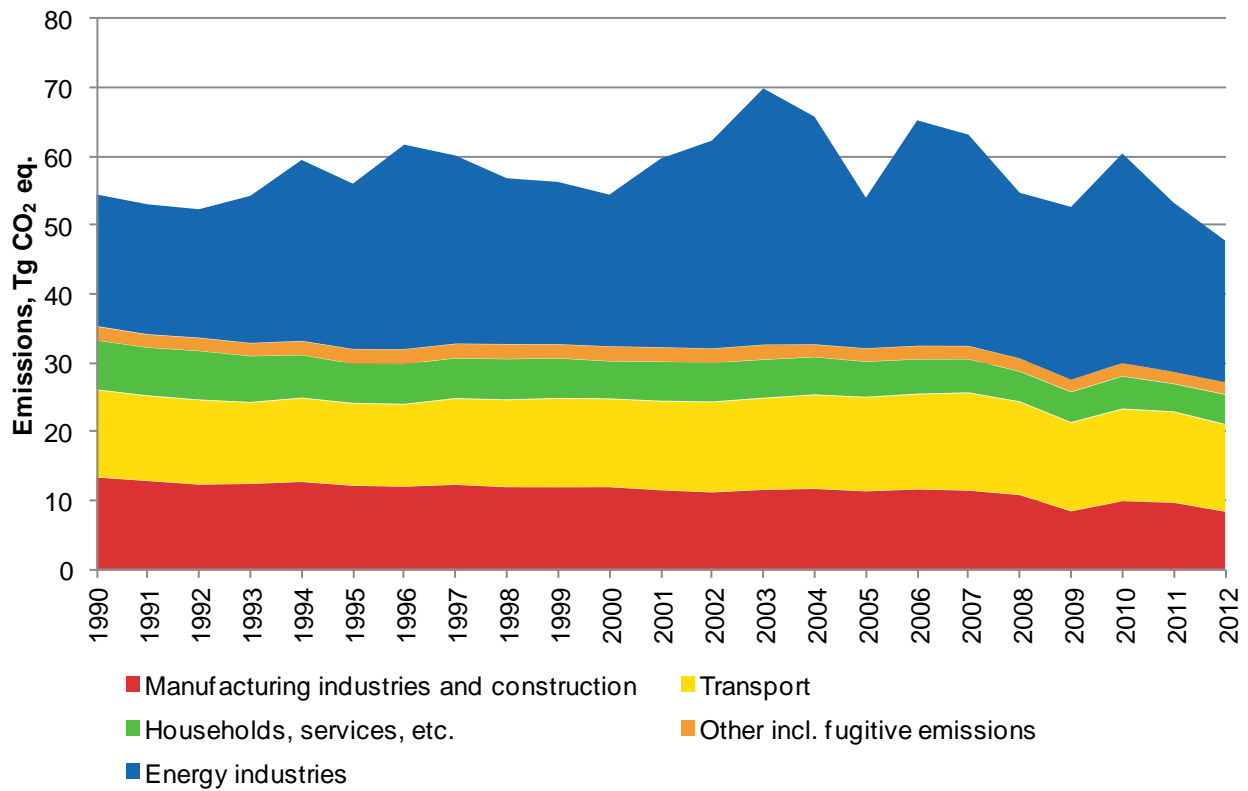
Emissions from the energy sector are divided into two main categories: emissions from fossil fuel combustion (CRF 1.A) and fugitive emissions from fuels (CRF 1.B). In the Finnish inventory, emissions from fuel combustion include direct (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O) and indirect (NO<sub>x</sub>, CO, NMVOCs) greenhouse gas emissions, as well as emissions of SO<sub>2</sub> from fuel combustion. Point sources, transport and other fuel combustion are included. Fugitive emissions from fuels in Finland consist of CH<sub>4</sub> and NMVOCs emissions from oil refining and storage. CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions from venting and flaring at oil refineries and the petrochemical industry are included as well, as are CH<sub>4</sub> emissions from natural gas transmission and distribution (Table 3.1-1). In addition, indirect CO<sub>2</sub> emissions due to atmospheric oxidation of fugitive CH<sub>4</sub> and NMVOCs have been taken into account (Section 3.6.2.1), as well as indirect N<sub>2</sub>O emissions from nitrogen deposition caused by NO<sub>x</sub> emissions. These indirect N<sub>2</sub>O emissions are reported in category 1.A 5a Stationary. General assessment of completeness can be found in Section 1.8 and a more detailed assessment is included in Annex 5.

Energy-related CO<sub>2</sub> emissions vary much from year to year (Figure 3.1-2), mainly following the economic trend, the structure of the energy supply and climatic conditions. Compared with 1990, the emissions in the energy sector in 2012 were about 12% lower. The main contributors to the descent are the manufacturing industries and construction with approximately 37% reduction and household, services etc. with around 44% reduction in emissions relative to 1990. Emissions from energy industry have 8% compared to 1990. Emissions from transport were 2012 under the level of 1990. During the most recent years, the emissions from these source categories have been fluctuating considerably. The trends are discussed in more detail in Chapter 2 and the source-specific sections in this chapter.

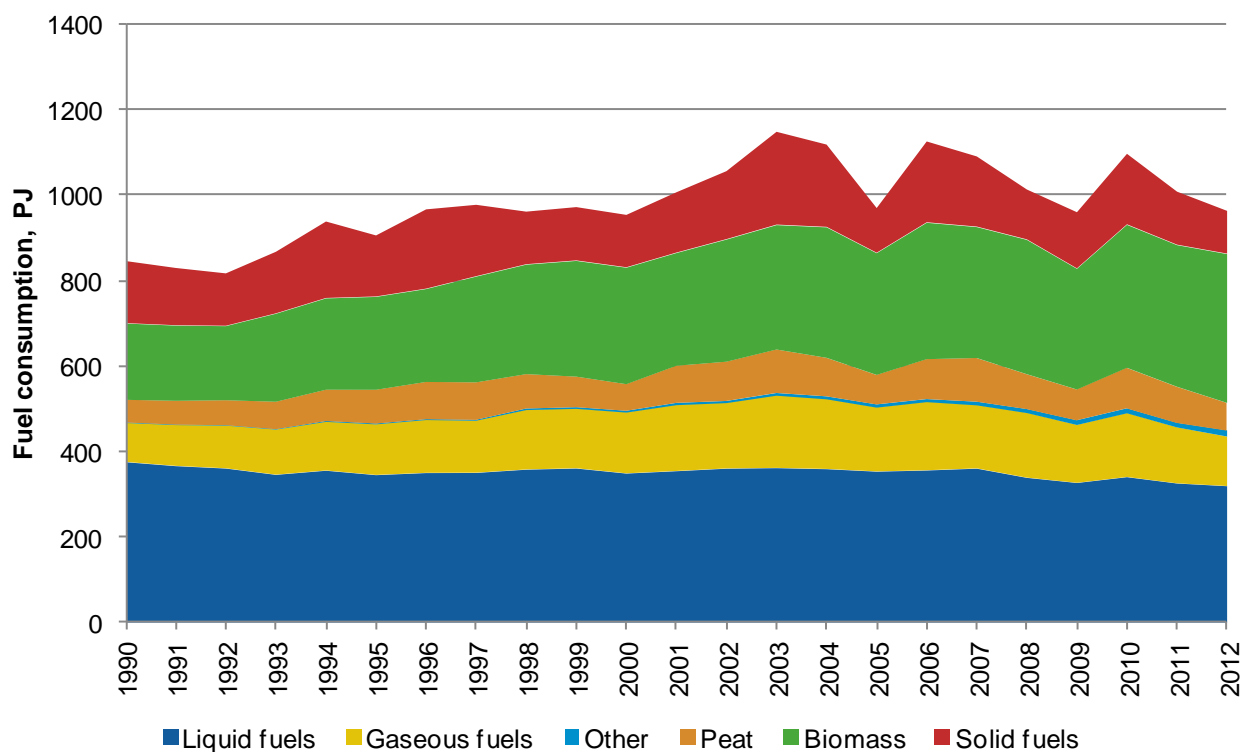
**Table 3.1-1** Emissions from the energy sector by subcategory and gas (Tg CO<sub>2</sub> eq.)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>Total energy</b>	<b>54.5</b>	<b>53.1</b>	<b>52.3</b>	<b>54.3</b>	<b>59.5</b>	<b>56.0</b>	<b>61.7</b>	<b>60.2</b>	<b>56.8</b>	<b>56.3</b>	<b>54.4</b>	<b>59.7</b>	<b>62.3</b>	<b>70.0</b>	<b>65.8</b>	<b>54.0</b>	<b>65.3</b>	<b>63.2</b>	<b>54.7</b>	<b>52.7</b>	<b>60.5</b>	<b>53.3</b>	<b>47.8</b>
Fuel combustion	54.3	52.8	52.1	54.0	59.3	55.8	61.5	59.9	56.6	56.1	54.2	59.5	62.1	69.8	65.7	53.8	65.1	63.0	54.6	52.5	60.3	53.1	47.6
CO <sub>2</sub>	53.0	51.5	50.8	52.7	58.0	54.5	60.2	58.5	55.3	54.8	53.0	58.2	60.8	68.3	64.3	52.5	63.7	61.7	53.3	51.3	58.9	51.9	46.4
CH <sub>4</sub>	0.307	0.301	0.299	0.297	0.299	0.298	0.305	0.303	0.303	0.296	0.286	0.308	0.316	0.319	0.314	0.304	0.312	0.308	0.312	0.321	0.355	0.314	0.332
N <sub>2</sub> O	1.00	0.97	0.95	0.99	1.02	0.98	1.03	1.03	1.01	1.00	0.98	1.03	1.05	1.11	1.07	0.95	1.05	1.02	0.96	0.90	1.02	0.96	0.92
Fugitive fuel emissions	0.23	0.25	0.28	0.34	0.25	0.25	0.24	0.27	0.22	0.19	0.18	0.19	0.18	0.18	0.17	0.19	0.17	0.18	0.19	0.16	0.18	0.16	0.17
CO <sub>2</sub>	0.22	0.21	0.22	0.27	0.17	0.17	0.15	0.20	0.14	0.13	0.13	0.12	0.12	0.12	0.11	0.13	0.11	0.13	0.14	0.11	0.14	0.12	0.13
CH <sub>4</sub>	0.011	0.042	0.057	0.072	0.081	0.080	0.082	0.071	0.073	0.059	0.055	0.068	0.057	0.062	0.056	0.064	0.055	0.051	0.049	0.047	0.041	0.037	0.038
N <sub>2</sub> O	0.0007	0.0007	0.0006	0.0008	0.0004	0.0004	0.0005	0.0008	0.0004	0.0003	0.0004	0.0004	0.0005	0.0004	0.0005	0.0005	0.0005	0.0007	0.0007	0.0005	0.0006	0.0007	0.0010





**Figure 3.1-2** Emissions from the energy sector by subcategory (Tg CO<sub>2</sub> eq.)



**Figure 3.1-3** Consumption of fuel types (PJ)

### 3.1.1 Emissions from fuel combustion (CRF 1.A)

#### 3.1.1.1 Description

Emissions from fuel combustion comprise all fuel combustion, including point sources, transport and other fuel combustion. Direct and indirect greenhouse gases (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, CO, NMVOC, and NO<sub>x</sub>) as well as SO<sub>2</sub> are reported. As suggested in the UNFCCC guidelines, emissions from fuel combustion in the energy sector are divided into five subcategories as follows:

CRF 1.A 1 - Energy Industries

CRF 1.A 2 - Manufacturing industries and construction

CRF 1.A 3 - Transport

CRF 1.A 4 - Other sectors

CRF 1.A 5 - Other

Reported greenhouse gas emissions, used methods and type of emission factors are listed in Table 3.1-2.

**Table 3.1-2** Reported emissions, calculation methods and type of emission factors for the subcategory fuel combustion in the Finnish inventory (M= model, CS = country specific, D= default, PS= plant specific)

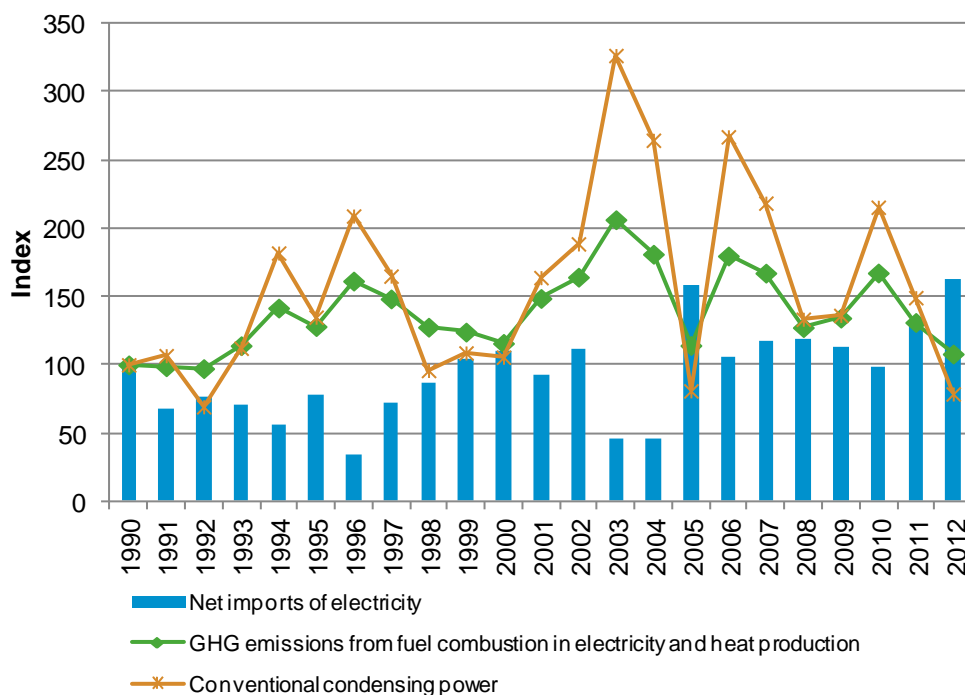
CRF	Source	Emissions reported	Method	Emission factor
1.A 1	Energy Industries	CO <sub>2</sub>	Tier 3	CS, D, PS
		CH <sub>4</sub>	Tier 3	CS
		N <sub>2</sub> O	Tier 3	CS
1.A 2	Manufacturing industries and construction	CO <sub>2</sub>	Tier 3, CS, M	CS, PS
		CH <sub>4</sub>	Tier 3, CS, M	CS
		N <sub>2</sub> O	Tier 3, CS, M	CS, D
1.A 3	Transport	CO <sub>2</sub>	Tier 1, Tier 3, M	CS, D
		CH <sub>4</sub>	Tier 1, Tier 3, CS, M	CS, D
		N <sub>2</sub> O	Tier 1, Tier 3, CS, M	CS, D
1.A 4	Other Sectors	CO <sub>2</sub>	Tier 1, Tier 3, M	CS, D
		CH <sub>4</sub>	Tier 1, Tier 3, M	CS, D
		N <sub>2</sub> O	Tier 1, Tier 3, M	CS, D
1.A 5	Other	CO <sub>2</sub>	Tier 1, CS	CS
		CH <sub>4</sub>	Tier 1, CS	CS
		N <sub>2</sub> O	Tier 1, CS, D	CS, D

#### 3.1.1.2 Quantitative overview

CO<sub>2</sub> emissions from fossil fuel combustion (46.4 Tg) accounted for 97% of the energy sector's total emissions and 76% of total greenhouse gas emissions in 2012.

The portion of N<sub>2</sub>O emissions from fuel combustion in 2012 was less than 2%. N<sub>2</sub>O emissions come mainly from fluidised bed combustion and transport. CH<sub>4</sub> emissions from fuel combustion are about 0.7% and are mainly due to the incomplete combustion of wood fuels (small-scale combustion) (Table 3.1-3).

The availability of hydropower in the Nordic electricity market influences significantly the electricity supply structure and hence the emissions. Especially in 2003-2004 and again in 2006-2007, the shortage of hydropower in the Nordic market increased coal fuelled condensing power generation in Finland. Due to the fluctuations in the Nordic hydropower, the coal-fired power production has varied between 6.1 TWh (2005) and 17.9 TWh (2003), and connected CO<sub>2</sub> emissions between 3.5 and 14 Tg. The trends of emissions are mostly overwhelmed by the annual fluctuations. However, total emissions from fuel combustion decreased by 10% from 2011, but these emissions are still 32% lower than the 2003 record level and were 12% under the 1990 level (Table 3.1-3).



**Figure 3.1-4** Greenhouse gas emissions from fuel combustion in electricity and heat production, net imports of electricity and conventional condensing power indexed (index 1990=100) (Energy Statistics, Yearbook)

### 3.1.1.3 Methods

Emissions from fuel combustion (CRF 1.A 1 - 1.A 5) are calculated by multiplying fuel consumption with either a fuel type-specific emission factor or a technology-specific emission factor. When calculating CO<sub>2</sub> emissions, adjustment with the fraction of carbon (un)oxidised is included.

Calculations of all emissions from fuel combustion are made with the ILMARI calculation system developed at Statistics Finland. The ILMARI system has been specifically designed for the calculation of energy-based emissions. ILMARI uses mostly a bottom-up methodology consistent with the IPCC Tier 3 approach. ILMARI is closely connected to the energy statistics production and has links to economic statistics. The use of bottom-up data for emission calculation (fuel and emission data from environmental permits through the VAHTI data, see Section 1.4 and Annex 2) makes it possible to take into account changes in the technology of combustion processes.

ILMARI combines three main types of activity source data:

1. Detailed bottom-up data for point sources (covering > 2/3 of the total annual fuel combustion)
2. Aggregate transport and off-road vehicle data (covering ~1/6 of the total annual fuel combustion)
3. Aggregate sectoral/subsectoral data for other sources (covering ~1/6 of the total annual fuel combustion)

The ILMARI calculation system has been used for national emission estimations of CO<sub>2</sub>, SO<sub>2</sub>, NO<sub>2</sub>, CO, CH<sub>4</sub>, N<sub>2</sub>O, NMVOC and PM (particulate matter) emissions of fuel combustion from 1990, except for 1991. The CRF tables for the year 1991 are produced by top-down estimates based on data for 1990 and 1992. All emissions from fuel combustion are calculated using as detailed fuel consumption data as possible. ILMARI also includes technical data of the combustion processes, such as type of power plant, capacity, combustion technique, emission reduction technology, etc.

**Table 3.1-3** Emissions from fuel combustion in Finland (Tg CO<sub>2</sub> eq.)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>Total energy</b>	<b>54.5</b>	<b>53.1</b>	<b>52.3</b>	<b>54.3</b>	<b>59.5</b>	<b>56.0</b>	<b>61.7</b>	<b>60.2</b>	<b>56.8</b>	<b>56.3</b>	<b>54.4</b>	<b>59.7</b>	<b>62.3</b>	<b>70.0</b>	<b>65.8</b>	<b>54.0</b>	<b>65.3</b>	<b>63.2</b>	<b>54.7</b>	<b>52.7</b>	<b>60.5</b>	<b>53.3</b>	<b>47.8</b>
Fuel combustion	54.3	52.8	52.1	54.0	59.3	55.8	61.5	59.9	56.6	56.1	54.2	59.5	62.1	69.8	65.7	53.8	65.1	63.0	54.6	52.5	60.3	53.1	47.6
Energy industries	19.2	19.0	18.7	21.5	26.4	24.1	29.8	27.4	24.2	23.7	22.1	27.5	30.3	37.4	33.2	21.9	32.9	30.8	24.2	25.2	30.6	24.7	20.7
Manufacturing industries and construction	13.4	12.8	12.3	12.4	12.7	12.1	12.0	12.3	11.9	11.9	11.9	11.5	11.2	11.5	11.6	11.3	11.6	11.4	10.7	8.4	9.9	9.6	8.4
Transport	12.8	12.4	12.3	11.9	12.2	12.0	12.0	12.6	12.7	12.9	12.8	13.0	13.2	13.3	13.7	13.7	13.9	14.2	13.6	12.9	13.4	13.2	12.7
Other sectors	7.18	6.98	7.10	6.71	6.21	5.72	5.82	5.82	5.89	5.79	5.43	5.68	5.64	5.56	5.45	5.12	5.01	4.84	4.34	4.37	4.69	3.99	4.29
Other	1.78	1.63	1.61	1.52	1.78	1.85	1.88	1.81	1.92	1.82	1.95	1.90	1.88	1.96	1.68	1.69	1.72	1.67	1.68	1.62	1.72	1.55	1.59

Fuel combustion by fuel (PJ) and related CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions for 1990-2012 are given in Appendix\_3b at the end of the Energy Chapter.

The input data for ILMARI come from various databases, models and other information sources. The data sources of the ILMARI calculation system are presented in Figure 3.1-5.

The production process of ILMARI and CRF 1.A data tables is described in Table 3.1-5.

In the production process, the data of point sources are firstly taken to ILMARI for checking and corrections. Thereafter the data from the transport models and heating energy model are imported and the total fuel consumption figures are compared with the total figures taken from the Energy statistics yearbook. If there are significant differences, the reasons will be studied and possible corrections made to either the Energy statistics data or the GHG inventory data, depending on the case.

Calculation systems of mobile sources (LIPASTO and TYKO) are described in detail in Section 3.3 Transport. These models are originally designed for the calculation of transport emissions in the Finnish Economic Region, and the definitions of system boundaries are slightly different from the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 1997). Therefore only selected parts of the results are taken to ILMARI. All data needed for domestic transport sources in the GHG inventory can be taken from LIPASTO and TYKO. Bunker fuels and natural gas in road transport are the only exceptions.

Statistics Finland has decided the level of aggregation of data to be used in ILMARI, consistent with the 1966 IPCC GL and UNFCCC reporting guidelines, see Table 3.1-4. The breakdown (and coverage, as mentioned above) of data published in the VTT LIPASTO website ([lipasto.vtt.fi/](http://lipasto.vtt.fi/)) are different from CRF categories, which must be noticed, when comparing the figures (see for example Table 3.3-13).

**Table 3.1-4** The differences between LIPASTO reporting and greenhouse gas inventory

LIPASTO submodel	GHG inventory
ILMI (aviation) - includes domestic and international aviation (definition of international is different from IPCC)	1.A 3a Civil aviation - domestic aviation taken from ILMI - bunkers are calculated separately
LIISA (road transport) - data reported by vehicle types - natural gas not included	1.A 3b Road transport - data taken from LIISA reported by fuel categories - natural gas included (separate calculation)
RAILI (railways) - includes emissions from fuels and electricity used in railway transport	1.A 3c Railways - only emissions from fuels taken from RAILI
MEERI (navigation) - includes domestic and international navigation (definition of international is different) - breakdown by type of fleet/activity - includes fishing	1.A 3d Navigation - domestic navigation taken from MEERI - bunkers are calculated separately - breakdown by fuel type - fishing reported in 1.A 4c
TYKO (non-road working machinery) - breakdown by machine type and fuel type (over 50 combinations)	Breakdown by following categories (and fuel types) aggregated from TYKO: 1.A 2f Other, construction 1.A 3e Off-road vehicles and other machinery 1.A 4c Agriculture/forestry/ fisheries

A new version of the ILMARI calculation system was developed in 2002. Emissions from 2001 onwards have been calculated using this system. The calculation methods and formulas are the same as in the previous ILMARI, but the database system has been reconstructed. The activity data and time series consistency have been checked during 2005-2008. All results from the previous version of ILMARI have been converted to the present structure and stored in a specific time series database. Time series data by CRF category are produced using SAS Database queries and taken to the CRF Reporter via MS Excel sheets using the manual cut and paste operation. The functionality of the time series database is still being developed. For example, a more automatic export of results to the CRF Reporter has been studied, but not yet resolved.

#### 3.1.1.4 Sector-specific QA/QC

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6. The QC procedures are performed according to the QA/QC plan in the Energy sector in order to attain these quality objectives. The bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert.

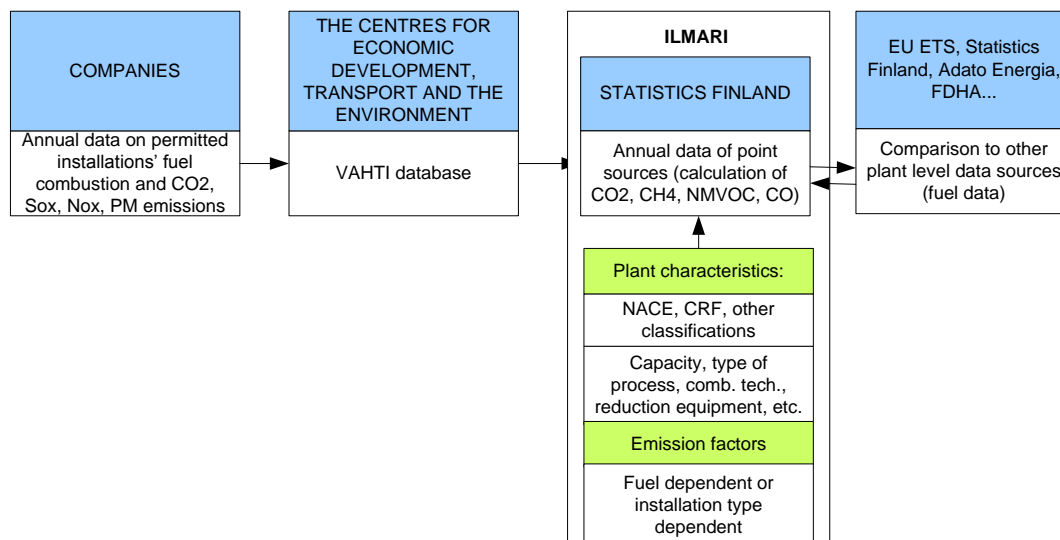
The production of CRF 1.A data tables in the Finnish inventory is summarized in Table 3.1-5. Each year the latest inventory calculations (activity data and CO<sub>2</sub> emissions) are verified by crosschecking the results against the national energy balance (Annex 4). The more detailed QA/QC procedures of the subsectors of Energy sector are described in the corresponding chapters.

**Table 3.1-5** Production process of ILMARI and CRF 1.A data tables

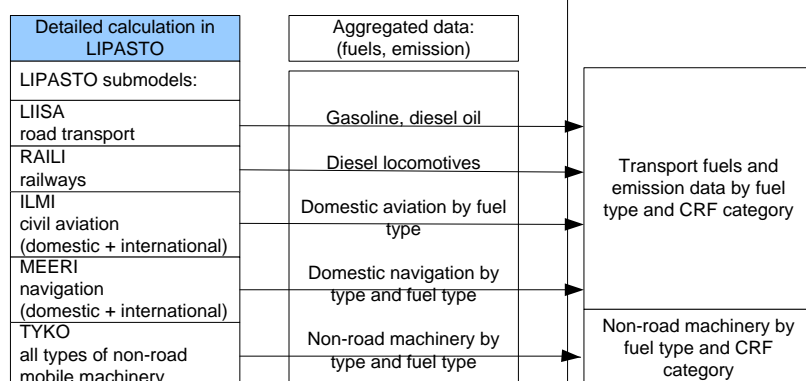
<b>Production of CRF data tables for sector 1.A Fuel combustion</b>	
<b>1. VAHTI data input to ILMARI</b>	Point source data input from database
Checks, corrections	Missing data (plants, fuels, emissions) Erroneous data Order of magnitude errors Quantity units Fuel codes
New data for plants	Technical data Classifications New emission factors
Comparison	Totals by plants Previous years' data Other plant level data Companies environmental reports "Top 20" lists
<b>2. EU ETS data input to ILMARI</b>	Point source data input for comparison and supplementation of VAHTI data
<b>3. Lipasto data input to ILMARI</b>	Manual input of transport and non-road machinery data
<b>4. Energy Statistics data input to ILMARI</b>	Manual input of heating fuels data and other fuel consumption data
<b>5. Comparison to Energy Statistics</b>	Totals by fuel
<b>6. Final annual data sheet</b> (output to ILMARI, stored in SAS time series database)	2 000 plants + 50 sectoral sources identification data, classifications, technical data, fuels, emission factors etc.
<b>7. CRF query from SAS database</b> (output to excel sheets)	SAS database functions
<b>8. CRF time series in excel sheets</b>	Manual cut and paste to CRF Reporter

**Main data inputs of ILMARI**

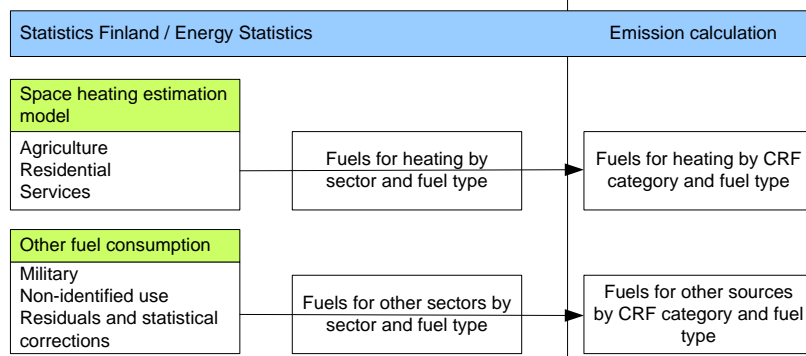
## Point Sources



## Transport and non-road machinery



## Other emission sources

**Figure 3.1-5** Data sources of the ILMARI calculation system.

### 3.1.1.5 Key Categories

Several emission sources in the energy combustion sector are key categories.

**Table 3.1-6** Key categories in Energy combustion (CRF 1.A) in 2012 (quantitative method used: Tier 2)

IPCC source category	Gas	Identification criteria
1.A.1. Energy Industries - Liquid Fuels	CO <sub>2</sub>	L
1.A.1. Energy Industries - Solid Fuels	CO <sub>2</sub>	L
1.A.1. Energy Industries - Gaseous Fuels	CO <sub>2</sub>	T
1.A.1. Energy Industries - Biomass	N <sub>2</sub> O	L, T
1.A.1. Energy Industries - Other	CO <sub>2</sub>	L, T
1.A.1. Energy Industries - Other	N <sub>2</sub> O	T
1.A.2. Manufacturing Industries and Construction - Liquid Fuels	CO <sub>2</sub>	L, T
1.A.2. Manufacturing Industries and Construction - Solid Fuels	CO <sub>2</sub>	L, T
1.A.2. Manufacturing Industries and Construction - Other	CO <sub>2</sub>	L
1.A.3.a. Civil Aviation - Liquid Fuels	CO <sub>2</sub>	T
1.A.3.b. Road Transportation - Diesel Oil	CO <sub>2</sub> , N <sub>2</sub> O	L, T
1.A.3.b. Road Transportation - Gasoline	CO <sub>2</sub> , N <sub>2</sub> O	L, T
1.A.3.b. Road Transportation - Gasoline	CH <sub>4</sub>	T
1.A.3.e. Other Transportation - Liquid Fuels	CO <sub>2</sub>	L
1.A.4. Other Sectors - Liquid Fuels	CO <sub>2</sub>	L, T
1.A.4. Other Sectors - Biomass	CH <sub>4</sub>	L, T
1.A.4. Other Sectors - Biomass	N <sub>2</sub> O	T
1.A.5.a.1. Indirect N <sub>2</sub> O emissions from NO <sub>x</sub>	N <sub>2</sub> O	L, T
1.A.5.a.2. Non-specified emissions of Fuels from non-energy use	CO <sub>2</sub>	T
1.A.5.a.3. Other non-specified - Liquid Fuels	CO <sub>2</sub>	L
1.A.5.a.3. Other non-specified - Gaseous Fuels	CO <sub>2</sub>	L, T
1.A.5.b. Mobile - Liquid Fuels	CO <sub>2</sub>	T

## 3.1.2 Fugitive emissions from fuels (CRF 1.B)

### 3.1.2.1 Description

Under fugitive emissions from fuels, Finland reports CH<sub>4</sub> emissions from oil refining and from natural gas transmission and distribution, and CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions from flaring at oil refineries and in the petrochemical industry. Indirect CO<sub>2</sub> emissions from fugitive emissions from fuels have also been calculated from NMVOCs and CH<sub>4</sub> emissions for the whole time series. NMVOC emissions originate from oil refineries as well as storage of chemicals at the refineries, road traffic evaporative emissions from cars, the gasoline distribution network and refuelling of cars, ships and aircraft. Methane emissions result from evaporation during the refining and storage of oil. There are no coal mines in Finland. Reported emissions are listed in Table 3.1-7. More information on fugitive emissions from fuels are described in Section 3.6.

**Table 3.1-7** Reported emissions, used methods and type of emission factors under the subcategory fugitive emissions from fuels in the Finnish inventory (CS= country specific, PS= plant specific, D= default)

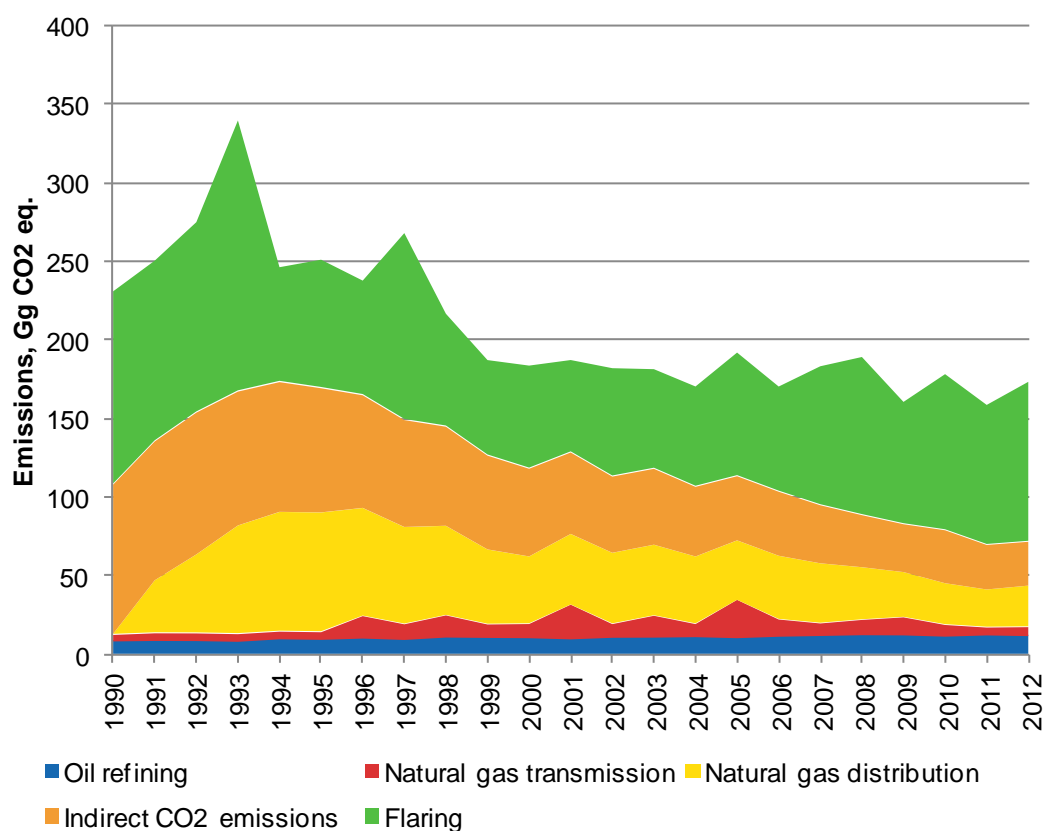
CRF	Source	Emissions reported	Methods	Emission factors
1.B 1	Solid fuels	NO	NA	NA
1.B 2	Oil and Natural Gas	CO <sub>2</sub>	CS	CS, D
		CH <sub>4</sub>	Tier 2, Tier 1, CS	CS, PS, D
		N <sub>2</sub> O	CS	CS



### 3.1.2.2 Quantitative overview

Fugitive emissions from fuels comprise only about 0.3% of total greenhouse gas emissions in Finland. Emissions were totally 0.17 Tg in 2012 and 0.23 Tg in 1990. These emissions have decreased by 25% since the 1990 level (Table 3.1-8 and Figure 3.1-6) due to decreased emissions in oil refining, especially in flaring. Also indirect CO<sub>2</sub> emissions from NMVOC emissions have decreased strongly in the time series due to capture of gasoline fumes in petrol distribution network and in refuelling of cars, gradual renewal of the passenger car fleet and better storage of chemicals at the refineries. There were some disturbances in oil refineries and petrochemical industry in 1993 and 1997, which caused higher flaring emissions.

Emissions from natural gas transmission have remained almost at the same level for the whole period; only more extensive maintenance breaks with emptying of pipelines have caused some peaks in the emissions. Natural gas distribution in town gas network started during 1991. The previously distributed town gas did not include CH<sub>4</sub>, thus the fugitive CH<sub>4</sub> emissions were zero until 1990. Emissions of natural gas distribution were at its highest in 1994 and have halved since.



**Figure 3.1-6** Fugitive emissions from fuels by subcategory (Gg CO<sub>2</sub> eq.)

### 3.1.2.3 Key Categories

Based on the trend analyses, the indirect CO<sub>2</sub> emissions from NMVOCs from fugitive emissions from oil and natural gas (1.B 2d) is a key category.

**Table 3.1-8** Fugitive emissions from oil and gas (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>CO<sub>2</sub></b>																							
1.B 2c Flaring	122	114	120	171	72	81	72	118	71	60	65	58	68	62	63	78	66	87	100	77	98	88	100
<b>CH<sub>4</sub></b>																							
1.B 2a Oil refining	0.36	0.38	0.37	0.35	0.42	0.40	0.44	0.40	0.47	0.46	0.45	0.42	0.46	0.46	0.48	0.45	0.49	0.51	0.53	0.52	0.49	0.52	0.50
1.B 2b Natural gas	0.17	1.63232	2.34848	3.06464	3.42272	3.42	3.47	2.97	3.02	2.35	2.19	2.82	2.24	2.47	2.18	2.58	2.15	1.90	1.81	1.71	1.45	1.22	1.29
1.B 2c Flaring	0.0011	0.0011	0.0010	0.0013	0.0006	0.0006	0.0008	0.0014	0.0007	0.0005	0.0007	0.0006	0.0008	0.0007	0.0008	0.0008	0.0008	0.0011	0.0011	0.0008	0.0010	0.0012	0.0015
<b>N<sub>2</sub>O</b>																							
1.B 2c Flaring	0.00226	0.00226	0.00193	0.00258	0.00116	0.00128	0.00153	0.00274	0.00143	0.00108	0.00137	0.00116	0.0015	0.00143	0.00166	0.00156	0.00162	0.00217	0.00221	0.0016	0.00205	0.00233	0.0031
<b>Indirect CO<sub>2</sub></b>	97	94	98	95	94	90	83	78	73	68	63	61	56	57	52	49	48	44	40	37	39	33	33
<b>Total CO<sub>2</sub> eq.</b>	<b>231</b>	<b>251</b>	<b>276</b>	<b>339</b>	<b>247</b>	<b>252</b>	<b>237</b>	<b>267</b>	<b>218</b>	<b>187</b>	<b>184</b>	<b>187</b>	<b>181</b>	<b>181</b>	<b>171</b>	<b>191</b>	<b>170</b>	<b>182</b>	<b>189</b>	<b>161</b>	<b>179</b>	<b>159</b>	<b>172</b>

## 3.2 Energy industries and Manufacturing industries and Construction (CRF 1.A 1, CRF 1.A 2)

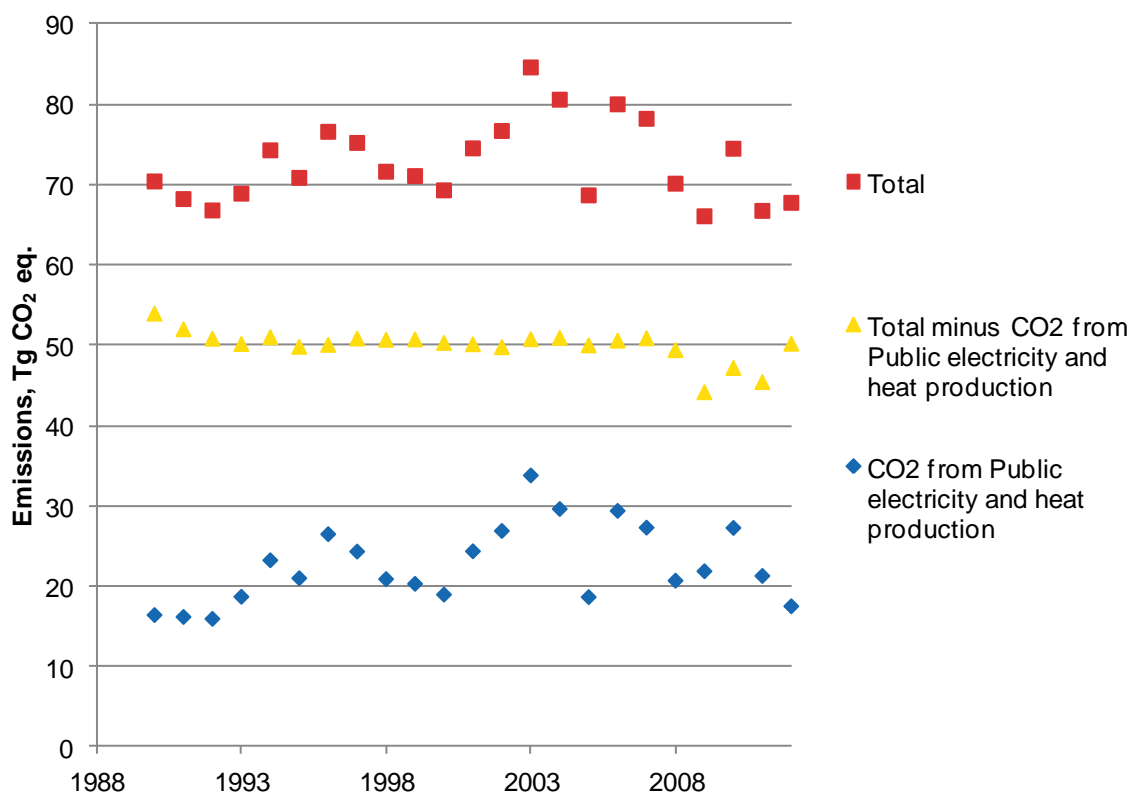
### 3.2.1 Source category description

Energy industries (CRF 1.A 1) and Manufacturing industries and construction (CRF 1.A 2) include emissions from fuel combustion in point sources in energy production and industrial sectors (power plants, boilers  $P_{\text{fuel}} > 5\text{MW}$  and industrial plants with boilers and/or other combustion). The emissions from Energy industries by relevant subcategory and gas in 1990–2012 are presented in Table 3.2-1.

The emissions from Manufacturing industries and construction by relevant subcategory and gas in 1990–2012 are presented in Table 3.2-2.

In 2012, the greenhouse gas emissions from Energy industries amounted to 20.7 Tg and Manufacturing industries and construction amounted to 8.4 Tg CO<sub>2</sub> eq. The share of energy industries was 43% of energy sector's total emissions. The corresponding share was 17% for manufacturing industries and construction. These two subsectors accounted together for 48% of the total greenhouse gas emissions of Finland.

Regarding the annual variations of total greenhouse gas emissions in the Finnish GHG inventory, CO<sub>2</sub> emissions from Public power and heat production are dominant, as shown in Figure 3.2-1. (see also Section 2.3 and Figure 3.1-2).



**Figure 3.2-1** The effect of the CO<sub>2</sub> emissions of 1.A 1a Public Electricity and Heat Production to the total CO<sub>2</sub> equivalent emission trend

**Table 3.2-1** The emissions from Energy industries by relevant subcategory and gas (CO<sub>2</sub> eq. Tg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>Energy industries</b>	<b>19.2</b>	<b>19.0</b>	<b>18.7</b>	<b>21.5</b>	<b>26.4</b>	<b>24.1</b>	<b>29.8</b>	<b>27.4</b>	<b>24.2</b>	<b>23.7</b>	<b>22.1</b>	<b>27.5</b>	<b>30.3</b>	<b>37.4</b>	<b>33.2</b>	<b>21.9</b>	<b>32.9</b>	<b>30.8</b>	<b>24.2</b>	<b>25.2</b>	<b>30.6</b>	<b>24.7</b>	<b>20.7</b>
<b>CO<sub>2</sub></b>	<b>19.1</b>	<b>18.8</b>	<b>18.6</b>	<b>21.3</b>	<b>26.2</b>	<b>23.9</b>	<b>29.6</b>	<b>27.2</b>	<b>23.9</b>	<b>23.4</b>	<b>21.9</b>	<b>27.2</b>	<b>30.0</b>	<b>37.0</b>	<b>32.9</b>	<b>21.7</b>	<b>32.5</b>	<b>30.5</b>	<b>23.9</b>	<b>24.9</b>	<b>30.2</b>	<b>24.4</b>	<b>20.4</b>
Public electricity and heat production	16.4	16.2	16.0	18.7	23.3	21.0	26.5	24.3	20.9	20.3	19.0	24.4	26.9	33.8	29.7	18.7	29.4	27.4	20.8	21.9	27.3	21.4	17.6
Petroleum refining	2.26	2.25	2.25	2.20	2.59	2.56	2.77	2.51	2.64	2.68	2.55	2.53	2.73	2.80	2.79	2.62	2.72	2.78	2.77	2.81	2.65	2.75	2.56
Manufacture of solid fuels and other energy industries	0.35	0.35	0.36	0.37	0.33	0.32	0.30	0.34	0.38	0.42	0.35	0.32	0.36	0.39	0.42	0.39	0.40	0.35	0.33	0.19	0.24	0.27	0.26
<b>CH<sub>4</sub></b>																							
<b>Total</b>	<b>0.008</b>	<b>0.009</b>	<b>0.009</b>	<b>0.010</b>	<b>0.012</b>	<b>0.013</b>	<b>0.015</b>	<b>0.016</b>	<b>0.016</b>	<b>0.016</b>	<b>0.015</b>	<b>0.019</b>	<b>0.024</b>	<b>0.028</b>	<b>0.025</b>	<b>0.021</b>	<b>0.025</b>	<b>0.023</b>	<b>0.022</b>	<b>0.021</b>	<b>0.024</b>	<b>0.022</b>	<b>0.022</b>
<b>N<sub>2</sub>O</b>																							
<b>Total</b>	<b>0.12</b>	<b>0.13</b>	<b>0.14</b>	<b>0.16</b>	<b>0.19</b>	<b>0.19</b>	<b>0.22</b>	<b>0.22</b>	<b>0.22</b>	<b>0.21</b>	<b>0.21</b>	<b>0.25</b>	<b>0.29</b>	<b>0.33</b>	<b>0.31</b>	<b>0.25</b>	<b>0.33</b>	<b>0.33</b>	<b>0.31</b>	<b>0.29</b>	<b>0.36</b>	<b>0.34</b>	<b>0.31</b>

**Table 3.2-2** The emissions from Manufacturing industries and construction by relevant subcategory and gas (CO<sub>2</sub> eq. Tg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>Manufacturing industries</b>	<b>13.4</b>	<b>12.8</b>	<b>12.3</b>	<b>12.4</b>	<b>12.7</b>	<b>12.1</b>	<b>12.0</b>	<b>12.3</b>	<b>11.9</b>	<b>11.9</b>	<b>11.9</b>	<b>11.5</b>	<b>11.2</b>	<b>11.5</b>	<b>11.6</b>	<b>11.3</b>	<b>11.6</b>	<b>11.4</b>	<b>10.7</b>	<b>8.4</b>	<b>9.9</b>	<b>9.6</b>	<b>8.4</b>
<b>CO<sub>2</sub></b>	<b>13.2</b>	<b>12.7</b>	<b>12.2</b>	<b>12.2</b>	<b>12.5</b>	<b>12.0</b>	<b>11.8</b>	<b>12.1</b>	<b>11.7</b>	<b>11.7</b>	<b>11.7</b>	<b>11.3</b>	<b>11.0</b>	<b>11.4</b>	<b>11.4</b>	<b>11.2</b>	<b>11.4</b>	<b>11.2</b>	<b>10.6</b>	<b>8.2</b>	<b>9.7</b>	<b>9.5</b>	<b>8.2</b>
Iron and steel	2.50	2.55	2.60	2.83	2.88	2.66	2.78	3.21	3.35	3.43	3.69	3.31	3.36	3.59	3.56	3.67	3.79	3.41	3.26	2.30	2.99	2.95	2.25
Non-ferrous metals	0.34	0.23	0.14	0.17	0.14	0.11	0.12	0.13	0.13	0.14	0.14	0.15	0.13	0.12	0.11	0.10	0.10	0.10	0.10	0.09	0.11	0.10	0.10
Chemicals	1.29	1.26	1.24	1.26	1.34	1.37	1.34	1.28	1.16	1.15	1.18	1.25	1.17	1.30	1.29	1.33	0.93	0.94	0.94	0.69	0.79	0.81	0.65
Pulp, paper and print	5.34	5.16	4.98	4.95	5.17	4.83	4.63	4.57	4.25	4.18	4.06	3.92	3.68	3.81	3.93	3.58	4.09	4.32	3.85	3.19	3.65	3.33	2.96
Food processing, beverages and tobacco	0.83	0.80	0.77	0.72	0.72	0.70	0.66	0.61	0.57	0.49	0.32	0.32	0.32	0.26	0.25	0.21	0.20	0.19	0.16	0.25	0.24	0.25	0.21
Other	2.90	2.67	2.43	2.30	2.28	2.30	2.31	2.29	2.28	2.33	2.34	2.34	2.34	2.26	2.29	2.27	2.30	2.28	2.27	1.73	1.92	2.05	2.06
<b>CH<sub>4</sub></b>																							
<b>Total</b>	<b>0.013</b>	<b>0.012</b>	<b>0.012</b>	<b>0.014</b>	<b>0.014</b>	<b>0.015</b>	<b>0.014</b>	<b>0.015</b>	<b>0.014</b>	<b>0.015</b>	<b>0.015</b>	<b>0.014</b>	<b>0.014</b>	<b>0.014</b>	<b>0.014</b>	<b>0.014</b>	<b>0.015</b>	<b>0.014</b>	<b>0.013</b>	<b>0.011</b>	<b>0.014</b>	<b>0.016</b>	<b>0.016</b>
<b>N<sub>2</sub>O</b>																							
<b>Total</b>	<b>0.172</b>	<b>0.160</b>	<b>0.148</b>	<b>0.165</b>	<b>0.170</b>	<b>0.167</b>	<b>0.171</b>	<b>0.187</b>	<b>0.183</b>	<b>0.189</b>	<b>0.189</b>	<b>0.183</b>	<b>0.173</b>	<b>0.174</b>	<b>0.182</b>	<b>0.170</b>	<b>0.163</b>	<b>0.156</b>	<b>0.149</b>	<b>0.124</b>	<b>0.138</b>	<b>0.136</b>	<b>0.137</b>

Fuel combustion CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions by fuels for 1990-2012 are given in Appendix\_3b at the end of the Energy Chapter.

## 3.2.2 Methodological issues

### 3.2.2.1 Methods

Emissions from fuel combustion in point sources are calculated with the ILMARI calculation system. All emissions within CRF 1.A 1 and 1.A 2 (except working machinery in the Construction sector, see Section 3.3.5) are based on actual bottom-up data. In the ILMARI system, emissions are calculated using the annual fuel consumption data. Fuel combustion data are available by installation and by fuel type. For each point source, SO<sub>2</sub>, PM, NO<sub>x</sub> and CO<sub>2</sub> emissions are reported by plant. In the ILMARI system, SO<sub>2</sub>, PM and NO<sub>x</sub> emissions are split into each fuel. CO<sub>2</sub>, N<sub>2</sub>O, CH<sub>4</sub> and NMVOC are calculated based on fuel combustion data. The calculated CO<sub>2</sub> emissions from each fuel in a certain plant are summarised and compared with total CO<sub>2</sub> emissions reported by the same plant.

The basic calculation formulas used in the calculations are the following:

#### Carbon dioxide:

$$E = F * EF(fuel) * OF(fuel),$$

#### Other greenhouse gases:

$$E = F * EF(technology)$$

$F$  = fuel consumption (by combustion unit and by fuel type)

$EF(fuel)$  = fuel-specific emission factor

$OF(Fuel)$  = fuel-specific oxidation factor

$EF(technology)$  = technology-specific emission factor

Technology-specific emission factors depend on the type, capacity, main fuel and combustion technology of the installation (power plant/boiler/process) as well as on emission reduction equipment (for PM, SO<sub>2</sub> and NO<sub>x</sub>).

Calculation of the CO<sub>2</sub> emissions is based on a country-specific method (consistent with Tier 3<sup>5</sup>, Revised (1996) Guidelines) using detailed activity (fuel consumption) data and fuel-specific emission factors. For working machinery see Section 3.3.5.

The SO<sub>2</sub> and NO<sub>x</sub> emissions are based on the emission data reported by the plants and recorded in the VAHTI system. The emissions are allocated to fuel-based emissions (CRF 1) by each fuel and non-fuel-based, i.e. process emissions (CRF 2).

The allocation of fuel combustion and process CO<sub>2</sub> emissions in Iron and steel sector is described in Section 4.4.

The emissions of CH<sub>4</sub>, N<sub>2</sub>O and CO are based on a country-specific method (consistent with Tier 3, Revised (1996) Guidelines), using detailed activity data and technology-based emission factors for each boiler or process type (emission factors are available for approximately 250 categories of boilers and processes).

### 3.2.2.2 Emission factors and other parameters

Mainly country-specific or plant-specific emission factors are used in the calculations, although IPCC default emission factors are used for some fuels of minor importance. CO<sub>2</sub> emission factors, oxidation factors and default net caloric values for different fuels are presented in Table 3.2-3.

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<sup>5</sup> Bottom-up installation level activity and technology data; technology dependent non-CO<sub>2</sub> emission factors.

**Table 3.2-3** CO<sub>2</sub> emission factors, oxidation factors and net calorific values (NCV) by fuel

Fuels	NCV	Unit	Emission factor g CO <sub>2</sub> /MJ	Oxidation factor	Source of emission factor
<b>Liquid fuels</b>					
Town gas	16.9	GJ/1000 m <sup>3</sup>	59.4	0.995	Neste 1993
Refinery gas (+ other gases)	49.0 (45-55)	GJ/t	53-71.4	0.995	Plant-specific
LPG (liquefied petroleum gas)	46.2	GJ/t	65	0.995	Neste/ET2004
Naphtha	44.3	GJ/t	72.7	0.995	EE
Motor gasoline (fossil part)	43	GJ/t	72.9	1	VTT/Liisa Model/Neste
Aviation gasoline	43.7	GJ/t	71.3	1	EE/Neste
Jet fuel	43.3	GJ/t	73.2	1	EE /Fortum 2002
Other kerosenes (vaporising oil, lamp kerosene)	43.1	GJ/t	71.5	0.995	EE/1996 IPCC GL
Diesel oil (fossil part)	42.8	GJ/t	73.6	1	VTT/Liisa Model/Neste
Gasoil (light fuel oil, heating fuel oil) (fossil part)	42.7	GJ/t	74.1	0.995	Neste/EE
Gasoil (for non-road use) (fossil part)	42.8	GJ/t	73.6	1	EE (same as diesel oil)
Residual fuel oil (RFO, heavy fuel oil), low sulphur	41.1	GJ/t	78.8	0.995	Neste/EE
Residual fuel oil (RFO, heavy fuel oil), normal	40.5	GJ/t	78.8	0.995	Neste/EE
Other residual fuel oil (heavy bottom oil)	40.2	GJ/t	79.2	0.995	Neste/EE
Petroleum coke	33.5 (20-36)	GJ/t	97 (90-102)	0.995	Plant-specific
Recycled waste oil	41	GJ/t	78.8	0.995	EE (=RFO)
Other petroleum products	35 (30-47)	GJ/t	78.8 (65-78.8)	0.995	EE (=RFO)
<b>Solid fuels</b>					
Anthracite	33.5	GJ/t	98.3	0.99	1996 IPCC GL
Hard coal (bituminous) 1990-2007	25.2 (21-32)	GJ/t	94.6	0.99	StatFi 2005
Hard coal (bituminous) 2008-2012	24.6-25.2 (23-30)	GJ/t	93.3-94.1	0.99	ETS from 2008 onwards
Coal briquettes	30	GJ/t	94.6	0.99	EE
Coal tar	36.5	GJ/t	90.6	0.99	Plant-specific
Coke	29.3 (25-35)	GJ/t	108	0.99	1996 IPCC GL
Coke oven gas	16.7	GJ/1000 m <sup>3</sup>	41.5	0.99	Plant-specific
Blast furnace gas (BFG)	11.2-11.5 3.6	GJ/1000 m <sup>3</sup>	155 263-265	0.99	Plant-specific
<b>Gaseous fuels</b>					
Natural gas	36	GJ/1000 m <sup>3</sup>	55.04	0.995	Gasum 2005
<b>Biomass fuels</b>					
Motor gasoline (biogenic part)	27.5-32.4	GJ/t	59-69.9	1	Neste, various sources
Diesel oil (biogenic part)	38.5-43.9	GJ/t	71.1-81.0	1	Neste, various sources
Gasoil (light fuel oil, heating fuel oil) (biogenic part)	43.5-44.0	GJ/t	70.7	0.995	Neste/EE
Gasoil (for non-road use) (biogenic part)	44.1	GJ/t	70.9-71.8	1	Neste/EE
Wood fuels (solid, includes e.g. firewood, bark, chips, sawdust and other industrial wood residues, recycled wood, pellets and briquettes)	7.8-16	GJ/t	109.6	0.99	1996 IPCC GL
Black and sulphite liquors	7.3-15	GJ/t	109.6	0.99	1996 IPCC GL
Other by-products from wood processing industry (includes e.g. pine oil and tar, methanol, fibrous)	3-37 20	GJ/t GJ/1000 m <sup>3</sup>	109.6 59	0.99	1996 IPCC GL, VTT2045, EE

Fuels	NCV	Unit	Emission factor g CO <sub>2</sub> /MJ	Oxidation factor	Source of emission factor
sludge, waste paper, stink gas, etc.)					
Plant and animal residues	10-35	GJ/t	109.6	0.99	EE (=wood)
Biogas (landfill gas, biogas from wastewater treatment, industrial biogas and other biogas)	15–20.5	GJ/1000 m <sup>3</sup>	56.1	0.99	EE
Hydrogen	10.8	GJ/1000 m <sup>3</sup>	0		
<b>Other fuels, peat</b>					
Peat (milled)	10.1 [9.6]	GJ/t	105.9 [107.9]	0.99	VTT 2003 [2012:ETS]
Peat (sod peat)	12.3 [12.1]	GJ/t	102 [104]	0.99	VTT 2003 [2012:ETS]
Peat (pellets and briquettes)	18.0	GJ/t	97	0.99	VTT 2003
<b>Other fuels, wastes etc.</b>					
Mixed fuels* (REF, RDF, PDF) 1990- 2007	8.3-10.0	GJ/t	31.8	0.99	StatFi 2004
Mixed fuels* (REF, RDF, PDF) 2008-	7.8-26.3	GJ/t	21.0-78.7	0.99	StatFi 2004, ETS
Mixed fuels* (MSW) 1990-2008	10–21	GJ/t	31.8	0.99	StatFi 2004
Mixed fuels* (MSW) 2009-	9.1-10.0	GJ/t	40.0	0.99	EE
Gasified solid waste*	13.3 (7-30)	GJ/1000 m <sup>3</sup>	59	0.99	EE
Demolition wood*	8-15	GJ/t	17.0	0.99	StatFi 2004
Impregnated wood*	12	GJ/t	11.4	0.99	StatFi 2004
De-inking sludge*	4	GJ/t	60	0.99	EE
Other residues and by-products	30	GJ/t	78.8	0.99	EE
Plastics waste	33 (25-40)	GJ/t	74.1	0.99	EE
Rubber waste	33	GJ/t	90	0.99	StatFi 2004
Hazardous waste	15 (10-15)	GJ/t	117	0.99	Ekokem 2004
Other non-specified waste (industrial waste, etc.)	15–30	GJ/t	75	0.99	EE

\* Mixed fuels: contains fossil and non-fossil carbon; the CO<sub>2</sub> emission factor refers only to the fossil fraction of total energy content.

REF = recovered fuel

RDF = refuse-derived fuel

PDF = package derived fuel

MSW = municipal solid waste

#### Sources:

EE: expert estimation Kari Grönfors, Statistics Finland

ETS: aggregated data or plant level data taken from EU emission trading system

Neste 1993: Composition and properties of natural gas and liquefied petroleum gas (in Finnish, Neste 1993)

Neste: product data sheets, personal communications

Neste/ET2004: EF from Energy Statistics which is based on information from Neste (Energy Statistics, 2004)

VTT/Liisa Model: Calculation system of road traffic emissions

StatFi 2004: Mixed fuels in Finland's greenhouse gas inventory and on compilation of the energy statistics (Jokinen, M 2004)

StatFi 2005: Research of Teemu Oinonen (not published, see Annex 3, Oinonen T 2005)

Ekokem 2004: Environmental report 2004

Gasum 2005: personal communication

VTT2045: Properties of fuels used in Finland, VTT 2000 (Alakangas, 2000)

Fortum 2002: Composition of kerosenes (Fortum, 2004)

VTT 2003: Vesterinen 2003

The default NCVs are practically constant over time. There are some exceptions concerning plant-specific fuels like refinery gases, BFG and certain waste-derived fuels. For these fuels the range of the NCV values over time are given in the table above.

The operators should report to the VAHTI system both fuel quantities as well as energy contents of the fuels used. Thus in bottom-up data there are some variations in the NCVs. The annual average values of reported data are compared to the default NCVs. In addition, plant level NCVs are compared to default NCVs, as described in Section 3.2.4.

In the Finnish greenhouse gas inventory peat is reported under the category of Other fuels. There are several reasons for reporting peat separately from the Solid fuels. In our inventory Solid fuels include hard coal, coke and other fuels (BFG, coke oven gas) derived from coal. These coal-based fuels are originally imported,

whereas peat is a domestic energy source. This categorisation follows the practise used in national energy statistics as well as in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Peat is one of the main fuels in Finland. It is the fourth largest fuel (after wood, hard coal and natural gas), representing typically over 6% of Total primary energy supply (TPES) and over 8% of combustible fuels. Its share is higher than for example the share of any liquid fuel. The share of peat is generally around half of the share of hard coal, but varies considerable, like the share of hard coal, too. The CO<sub>2</sub> emission factor of peat is clearly higher than the emission factor of hard coal. If the figures of peat and hard coal were combined, this would cause significant variation in the implied emission factor of the Solid fuels. In addition, other properties of peat and hard coal are different, thus it is not reasonable to aggregate them under the same fuel category in Finland (see Table 3.2-4).

Appendix\_3b presents the shares of each fuel in the fuel combustion subsector. In the inventory and CRF Reporter peat is reported separately as a category under Other fuels. In the printed CRF tables, it becomes summarised with relatively small amounts of other fuels consisting mostly of wastes and waste derived fuels.

**Table 3.2-4** Comparison of typical properties of peat and hard coal

	<b>Peat</b>	<b>Hard coal</b>
<b>Origin</b>	Domestic, local	Imported
<b>Transport distance</b>	Less than 100 km	Thousands of kilometres
<b>Renewability</b>	Slowly renewable (growing stock)	Fossil (non-renewable stock)
<b>Geological age</b>	Less than 10 000 years	Millions of years
<b>Plant type</b>	Usually multi-fuel fired power plants using woodfuels as well	Usually single-fuel fired plants
<b>Combustion technology</b>	Usually fluidised bed combustion	Usually pulverised combustion
<b>Scale</b>	Usually mid-scale (10 - 500 MW <sub>th</sub> )	Usually large-scale (500 - 1 500 MW <sub>th</sub> )
<b>NCV</b>	10-13 GJ/t	25 GJ/t
<b>Moisture content</b>	40 - 50%	5%
<b>Emission factor, CO<sub>2</sub></b>	106	95

Due to local weather conditions in peat production and storage areas in 2012, the quality of peat has been lower than usually. This can be seen from measured plant level data: NCV and CO<sub>2</sub> emission factor have exceeded normal range of accepted values (+-1% variation has been seen as normal). In 2012 NCV of milled peat was 6% lower and CO<sub>2</sub> EF was 2% higher than default. This has been taken into account using national annual values in 2012 calculation instead of national default values (for milled peat and sod peat). These exceptional annual values are shown in square brackets in Table 3.2-3.

The CO<sub>2</sub> emission factor of natural gas (55.04 g/MJ) is clearly lower than IPCC default value (56.1 g/MJ). All natural gas used in Finland is imported from Russia and consists almost totally (>98%) of methane. The sole importer of natural gas (Gasum Oy) has started monitoring of monthly CO<sub>2</sub> EF from January 2005. Monthly emission factors from January to August 2005 varied between 54.99 and 55.09 g/MJ. Usually the emission factor is lower in the wintertime and higher in the summertime. Based on this information Statistics Finland decided to use 55.04 g/MJ as annual average emission factor, although the second decimal represents likely a “too accurate” value (personal communications with Arto Riikonen and Tuomo Saarni from Gasum Oy, 2005). During the centralised review of 2011 submission, more information on the CO<sub>2</sub> EF was requested. Gasum Oy provided monthly data for 2005-2010 (Nupponen, A 2011). The range of EF was 54.98-55.22 g/MJ and the range of NCV was 35.838-36.408 MJ/m<sup>3</sup>n. Annual average EF varied from 55.02 to 55.07 g/MJ. Based on these results, the country specific NCV and EF seem to be well chosen.

Until 2007 the national CO<sub>2</sub> EF for hard coal is based on a research study described in Annex 3. Starting from 2008 the installations in EU ETS are obliged to monitor the CO<sub>2</sub> EF. In this submission, the country specific CO<sub>2</sub> EF for hard coal has been determined based on the ETS data, starting from 2008. More details of this recalculation are provided in Section 3.2.5.

Until the previous submission national default CO<sub>2</sub> emission factors for MSW/REF were used for all plants. However, there are around 5-10 plants obliged to use measured values in ETS, starting from 2008. Other plants are allowed to use national default values (due to small amounts of these fuels). In this submission plant specific CO<sub>2</sub> emission factors for MSW/REF have been used for those plants using measured data. This change was made starting from 2008 data.



The CH<sub>4</sub>, N<sub>2</sub>O, CO and NMVOC emission factors used in the Finnish inventory were originally based on the compilation of research data by Prosessikemia Oy (Boström et al. 1992; Boström 1994) and they have been revised using the results of the research study by VTT (Tsupari et al. 2005; Tsupari et al. 2006, see below).

Prosessikemia Oy provided the emission factors for the inventory calculations of the year 1990 for Finland's first national communication to the UNFCCC. The emission factor database has been expanded to fit ILMARI's more detailed classification of boilers and processes. As new boiler types have been included in the boiler database, the emission factors have been determined based on expert judgment (when no data have been available from other sources).

The research study at VTT Technical Research Centre of Finland has evaluated the non-CO<sub>2</sub> (CH<sub>4</sub> and N<sub>2</sub>O) emission factors used in the Finnish inventory. In 2005 VTT measured the non-CO<sub>2</sub> emissions at several power plants in Finland. The power plants were selected based on a literature survey on the emissions and advice from the project's management group with representatives from administration and industry. The emissions were measured at the plants during longer periods to cover start-ups, partial loads and other exceptional conditions as well. The results of the study were published in late 2005 and in 2006 and 2007 (Tsupari et al. 2005; Tsupari et al. 2006; Tsupari et al. 2007). The results of this study have been used in the calculation of time series. All emission factors used in the ILMARI system were checked and revised according to the VTT study. The CRF tables and Inventory Report were updated accordingly at that time.

Emission factors for small combustion are partly IPCC default factors and partly taken from the reference Boström et al. (1992). Emission factors for CH<sub>4</sub> and N<sub>2</sub>O for small combustion of wood were revised taking into account the VTT study.

CH<sub>4</sub> and N<sub>2</sub>O emission factors by main category/fuel are presented in Table 3.2-5 and Table 3.2-6.

**Table 3.2-5** CH<sub>4</sub> emission factors of stationary sources in the ILMARI calculation system

Type of installation	Main category	Combustion technique* / Fuel capacity, MW	Emission factor, mg/MJ
Coal fired boiler	10 (>80% coal) and 81 (50% - 80% coal)	CFB/BFB/PFB / < 15	4
		CFB/BFB/PFB / > 15	1
		Other (grate, pulverised comb., not specified) / < 50	4
		Other (grate, pulverised comb., not specified) / > 50	1
Peat fired boiler	40 (>80% peat) and 84 (50% - 80% peat)	CFB/BFB/gasification / > 50	3
		CFB/BFB/gasification / 5 - 50	4
		CFB/BFB/gasification / < 5	10
Wood/bark fired boiler	50 (> 80% wood) and 85 (50% - 80% wood)	CFB/BFB/gasification / >50	3
		CFB/BFB/gasification / 5 - 50	4
		CFB/BFB/gasification / < 5	10
Multi-fuel fired boiler	88 (no primary fuel > 50%)	CFB/BFB/gasification / > 50	3
		CFB/BFB/gasification / 5 - 50	4
		CFB/BFB/gasification / <1	10
		Other (grate, pulverised comb., not specified) / 5 - 50	10
		Other (grate, pulverised comb., not specified) / 1 - 5	50
		Other (grate, pulverised comb., not specified) / <1	200
Oil fired boiler	30 (> 80% oil) and 83 (50% - 80% oil)	Other (grate, burner, not specified) / > 50	2
		All / > 1	1
		All / <1	5
Gas fired boiler	60 (> 80% gas) and 86 (50% - 80% gas)	All / >1	1
		All / <1	5
Soda recovery boiler	70 (> 80% black liquor)	All	1
Gas turbine	121 (gas turbine plant, oil) and 123 (gas turbine plant, other)	All / < 50	3
		All / > 50	1
Gas turbine	122 (gas turbine plant, gas) and 130	All / < 5	3

Type of installation	Main category	Combustion technique* / Fuel capacity, MW	Emission factor, mg/MJ
	(combined cycle power plant)		
Engines	141 (diesel power plant, oil) and 143 (diesel power plant, other liquid fuel)	All / > 5	1
		Diesel / < 50	4
Gas engines	142 (natural gas fired engines) and 143 (biogas fired engines)	Diesel / > 50	2
		Otto or Diesel engine	240
Processes	90 (other combustion, not specified)		1
	91 (mesa kiln)		1
	92 (hospital waste incineration)		1
	93 (asphalt station)		1
	94 (coking plant)		1
	95 (drying oven)		1
	96 (blast furnace)		1
	97 (sinter plant)		1
	98 (rolling mill)		1
	99 (melting oven)		1
	100 (brick furnace)		1
	101 (cupola oven)		1

\* CFB = Circulating Fluidised Bed,  
BFB = Bubbling Fluidised Bed  
PFB = Pressurised Fluidised Bed

Sources:

Expert estimates by Statistics Finland based mainly on the VTT studies (Tsupari et al., 2005, Tsupari et al., 2006 and Tsupari et al., 2007)

<http://www.vtt.fi/inf/pdf/tiedotteet/2005/T2321.pdf>

<http://www.vtt.fi/inf/pdf/workingpapers/2006/W43.pdf>

**Table 3.2-6** N<sub>2</sub>O emission factors of stationary sources in the ILMARI calculation system

Type of installation	Main category	Combustion technique*	Emission factor, mg/MJ
Coal fired boiler	10 (>80% coal) and 81 (50% - 80% coal)	CFB	30
	10 (>80% coal) and 81 (50% - 80% coal)	BFB/PFB	20
	10 (>80% coal) and 81 (50% - 80% coal)	Grate + combined techniques, not specified	3
Peat fired boiler	10 (>80% coal) and 81 (50% - 80% coal)	Pulverised comb.	1
	40 (>80% peat) and 84 (50% - 80% peat)	CFB	7
		BFB + combined techniques	3
		Grate + combined techniques, pulverised comb., gasification, not specified	2
Wood/bark fired boiler	50 (> 80% wood) and 85 (50% - 80% wood)	CFB	7
		BFB	3
		Grate + combined techniques, gasification, not specified	1
Multi-fuel fired boiler	88 (no primary fuel > 50%)	CFB	7
		BFB + combined techniques	3
		Grate + combined techniques, pulverised comb., not specified	2
Oil fired boiler > 50 MW	30 (> 80% oil) and 83 (50% - 80% oil)	All	1
Oil fired boiler < 50 MW	30 (> 80% oil) and 83 (50% - 80% oil)	All	3
Gas fired boiler	60 (> 80% gas) and 86 (50% - 80% gas)	All	1
Soda recovery boiler	70 (> 80% black liquor)	All	1
Gas turbine	121 (gas turbine plant, oil) and 123 (gas turbine plant, other)	All	4
Gas turbine	122 (gas turbine plant, gas) and 130 (combined cycle power plant)	All	1
Engines	141 (diesel power plant, oil) and 143 (diesel power plant, other liquid fuel)	Diesel	4
Gas engines	142 (natural gas fired engines) and 143 (biogas fired engines)	Otto or Diesel engine	1

Type of installation	Main category	Combustion technique*	Emission factor, mg/MJ
Processes	90 (other combustion, not specified)		2
	91 (mesa kiln)		1
	92 (hospital waste incineration)		1
	93 (asphalt station)		1
	94 (coking plant)		1
	95 (drying oven)		1
	96 (blast furnace)		1
	97 (sinter plant)		1
	98 (rolling mill)		1
	99 (melting oven)		1
	100 (brick furnace)		1
	101 (cupola oven)		1

\* CFB = Circulating Fluidised Bed,  
BFB = Bubbling Fluidised Bed  
PFB = Pressurised Fluidised Bed

Sources:

Expert estimates by Statistics Finland based mainly on the VTT studies (Tsupari et. al., 2005, Tsupari et. al., 2006 and Tsupari et al., 2007)

<http://www.vtt.fi/inf/pdf/tiedotteet/2005/T2321.pdf>

<http://www.vtt.fi/inf/pdf/workingpapers/2006/W43.pdf>

### 3.2.2.3 Activity data

Activity data for the ILMARI calculations are collected from several data sources. The detailed bottom-up data for point sources are collected mainly from the VAHTI system (see also Section 1.4 and Annex 2). Supplementary data are obtained from other plant level data sources.

The VAHTI data contain, for example:

- basic data like identification of plants, location, etc.
- technical data like boiler or process type, emission reduction technology, capacity, etc.
- fuel consumption data like fuels used by individual point sources (power plant units, boilers, industrial processes, etc.)
- emission data (annual emissions from these point sources.)

The VAHTI system includes detailed (boiler/process level) data, which allows emissions calculation using technology-specific emission factors for non-CO<sub>2</sub> emissions. There are numerous emission components reported directly in the VAHTI system; CO<sub>2</sub>, SO<sub>2</sub>, NO<sub>x</sub>, PM emission data are used as input for the ILMARI system. This input data from the VAHTI system are supplemented with plant level data taken from other sources like:

- fuel consumption statistics of manufacturing industries (survey by Statistics Finland)
- electricity and heat production statistics (survey by Adato Energia Oy and Statistics Finland)
- district heating statistics (survey by the Finnish District Heating Association)
- structural business statistics (survey by Statistics Finland)
- business register (by Statistics Finland)
- data from the emission trading system (by the Energy Authority).

Individual plants and boilers from the VAHTI data are linked to statistical data collection units (local kind-of-activity unit) to allow comparisons with a fuel consumption surveys and business surveys made by Statistics Finland. This linking enables the use of standard classifications, such as the NACE code, which is a pan-European classification system of economic activities. Fuel codes used in the VAHTI system are also linked to the national fuel classification ([http://tilastokeskus.fi/tup/khkinv/khkaasut\\_polttoaineluokitus.html](http://tilastokeskus.fi/tup/khkinv/khkaasut_polttoaineluokitus.html)).

The total number of plants (sites) included in the ILMARI system is ~1,000, including ~2,000 individual combustion units or process installations.

Many point sources in this category are part of the EU Emission Trading Scheme. Monitored data for CO<sub>2</sub> emissions from these sources have become available from the emission trading system for the inventory years 2005 - 2012. In the Energy sector ETS data have been mainly used in:

- identifying missing point sources
- checking, updating or verifying fuel consumption data
- verifying emission data
- verifying NCVs and CO<sub>2</sub> emission factors by fuel type
- defining national NCV and CO<sub>2</sub> emission factor for hard coal, starting from 2008
- defining plant specific CO<sub>2</sub> emission factor for MSW/REF, starting from 2008
- defining national annual NCV and CO<sub>2</sub> emission factor for peat, only for 2012.

## **Waste combustion**

Energy use of waste is increasing significantly in Finland in the near future. Only five waste incineration plants are in operation in Finland at the moment, but three new plants are under construction. Waste incineration capacity will increase from the current 300,000 t/a to about 1.5 million tons in the next five years. Waste incineration is increasing because of increased costs of other fuels and tightening regulations and increase in costs for landfilling. Waste is also co-incinerated in Finland in boilers using typically peat and biomass in addition to waste fuels. The annual amount of waste co-incinerated about 300,000 – 400,000 t/a. Different types of waste are used in incineration and co-incineration plants. Incineration plants use typically source separated municipal solid waste. In co-incineration plants, typically high quality industrial waste, solid recovered fuels and recovered wood are combusted (MEE, 2012).

All waste incineration/combustion plants are equipped with energy recovery, mostly combined heat and power production. Therefore no MSW incineration has been reported in the Waste sector.

Fuel combustion totals by fuel (PJ) as well as greenhouse gas emissions by fuel for 1990-2012 are given in Appendix\_3b at the end of the Energy Chapter.

The fuel consumption by fuel categories in Energy industries and Manufacturing industries and construction is presented in Table 3.2-7 and Table 3.2-8. “Other fuels” includes peat and waste-derived fuels, which are shown separately. These fuels can now also be found in their own categories in the CRF Reporter.

**Table 3.2-7** Fuel consumption in Energy industries (CRF 1.A 1) (PJ)

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Liquid fuels	Heavy fuel oil	16.1	16.9	17.8	19.1	23.6	21.0	24.8	19.2	19.4	21.2	17.0	19.3	21.0	21.4	17.1	16.3	17.4	16.2	13.4	15.5	17.1	11.9	10.9
	Light fuel oil	0.5	0.5	0.5	1.0	0.5	1.1	1.3	1.1	1.2	1.2	0.9	1.4	1.3	1.6	1.9	1.5	0.6	0.7	0.6	0.4	0.5	0.5	1.1
	Refinery gases	18.0	17.2	16.4	15.4	17.0	16.6	17.7	17.2	17.6	17.0	14.8	15.6	18.2	16.9	15.3	16.3	17.7	19.0	17.4	20.5	18.4	20.3	19.4
	Other liquid fuels	3.9	4.2	4.4	4.2	4.6	4.3	5.1	4.5	4.6	4.4	4.5	4.3	4.6	4.5	4.6	4.4	4.9	5.6	5.5	5.7	5.1	5.4	4.7
Solid fuels	Hard coal	99	91	82	102	137	106	151	131	88	90	88	110	128	186	161	73	159	137	89	111	139	99	80
	Other solid fuels	2.1	2.1	2.1	3.1	3.2	3.2	3.2	3.3	3.5	3.6	3.2	3.1	3.3	3.4	3.4	3.4	3.5	3.9	3.6	2.6	3.0	3.5	3.5
Gaseous fuels	Natural gas and other gaseous fuels	47.9	50.2	52.5	57.2	64.5	68.8	75.0	74.0	92.7	92.7	94.4	103.8	105.0	121.2	115.5	104.3	111.8	96.9	103.9	94.5	104.4	88.9	81.0
Biomass	Woodfuels	3.1	4.0	4.8	9.8	14.0	16.1	18.4	24.3	28.3	31.9	34.5	38.2	50.4	57.2	59.3	59.1	62.0	54.8	68.4	65.0	82.4	88.2	94.0
	Biogas	0.00	0.00	0.00	0.01	0.01	0.08	0.08	0.06	0.08	0.10	0.14	0.15	0.22	0.24	0.30	0.97	0.81	0.98	1.11	0.91	0.35	0.30	0.27
	Other non-fossil fuels	0	0	0	0	0	0	0	0	0	0	0.03	0.06	0.75	0.92	0.70	0.75	1.06	1.34	1.90	2.43	2.21	2.17	1.90
Other fuels	Peat	37.7	41.3	44.9	49.8	57.6	63.4	69.9	70.3	65.9	58.2	49.8	74.0	79.9	86.9	76.0	55.3	77.3	85.0	65.3	59.2	79.5	70.4	52.0
	Other; mixed fuels and waste	0.01	0.01	0.01	0.08	0.76	0.82	0.10	0.23	1.33	1.68	1.67	2.44	1.9	2.5	3.5	4.3	3.2	4.6	5.0	5.6	5.9	5.5	7.6

Other liquid fuels includes e.g. petroleum coke, LPG, recycled waste oil and some other oil products.

Other solid fuels includes e.g. coke, coke oven gas and blast furnace gas.

**Table 3.2-8** Fuel consumption in Manufacturing industries and construction (CRF 1.A 2) (PJ)

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Liquid fuels	Heavy fuel oil	34.2	31.3	28.3	26.6	28.3	27.7	25.8	25.4	24.0	24.0	22.6	22.5	21.7	20.0	20.9	18.4	18.5	17.1	12.9	10.4	11.1	10.5	9.7
	Light fuel oil	13.3	13.2	13.0	12.6	12.6	13.1	13.3	13.8	14.4	14.8	15.1	15.1	15.2	15.0	14.9	14.9	15.0	15.7	15.8	12.9	14.5	15.5	16.4
	LPG	4.2	3.9	3.5	4.0	4.3	4.4	4.9	5.8	7.0	7.7	8.2	8.0	8.0	8.9	9.4	9.8	10.3	9.6	9.4	7.9	9.0	8.9	8.6
	Refinery gases	5.0	5.7	6.4	4.8	5.9	5.7	5.7	4.9	6.7	7.0	6.6	6.8	5.9	7.3	7.4	7.9	6.9	7.2	8.6	8.8	9.0	8.6	7.5
	Recycled waste oil	0.5	0.4	0.3	0.5	0.4	0.5	0.7	1.0	0.9	0.9	0.9	0.8	0.9	1.3	1.4	1.3	1.1	0.8	0.9	0.9	1.2	1.0	0.9
	Other liquid fuels	2.7	2.4	2.1	2.4	1.5	2.2	2.1	2.1	2.0	2.1	1.7	1.2	1.8	1.5	2.1	2.1	2.1	2.2	2.0	1.6	1.5	2.2	2.2
Solid fuels	Hard coal	28.4	25.5	22.7	20.6	19.5	16.4	14.2	13.2	11.8	11.1	10.3	9.3	8.0	7.2	7.3	7.3	5.3	4.9	5.4	4.1	5.4	4.4	3.9
	Coke	5.9	5.4	5.0	5.1	5.3	4.9	4.3	5.5	5.4	5.5	5.4	4.7	4.7	5.1	5.6	5.6	5.2	4.9	4.7	3.9	4.5	4.7	1.0
	Other solid fuels	9.0	9.3	9.6	12.2	13.0	11.9	12.2	13.5	13.7	14.2	15.2	14.0	14.2	14.9	14.5	14.7	15.4	12.8	13.3	9.4	12.5	12.3	11.4
Gaseous fuels	Natural gas and other gaseous fuels	40.0	40.9	41.8	42.8	44.2	43.1	40.8	39.5	38.2	38.5	39.8	41.3	39.4	38.7	39.8	36.4	38.8	42.1	39.5	31.9	35.5	33.5	26.5
Biomass	Woodfuels	42.0	38.9	35.7	45.1	42.3	43.7	42.5	45.2	54.0	48.3	50.7	47.0	39.4	39.1	44.1	38.8	41.6	37.4	37.3	32.8	33.9	34.0	36.7
	Black/sulphite liquor	87.4	87.0	86.6	104.8	111.2	111.1	108.0	129.2	124.4	142.3	139.8	125.3	140.6	138.2	145.0	129.4	156.0	154.1	141.8	110.2	135.7	135.1	135.8
	Biogas	0.09	0.09	0.09	0.11	0.07	0.30	0.26	0.29	0.25	0.34	0.34	0.34	0.33	0.34	0.35	0.30	0.30	0.32	0.29	0.40	0.83	1.23	1.36
	Other non-fossil fuels	0.70	0.84	0.99	0.92	0.97	0.98	0.85	1.00	1.08	0.95	1.28	1.25	0.86	0.89	1.13	1.09	1.05	0.74	0.59	0.65	0.86	0.78	0.64
Other fuels	Peat	14.1	13.6	13.1	13.8	15.2	14.9	16.4	16.5	13.6	12.4	11.4	11.6	10.5	13.1	12.5	12.2	14.7	15.6	14.6	11.2	13.0	12.5	10.7
	Other; mixed fuels and waste	1.7	1.6	1.4	1.5	1.6	1.6	2.2	2.3	2.5	2.4	2.8	3.1	3.3	3.9	3.6	3.4	4.2	4.1	4.6	5.8	6.0	5.6	7.2

Other liquid fuels includes e.g. petroleum coke.

Other solid fuels includes e.g. coke oven gas and blast furnace gases.

### 3.2.3 Uncertainties and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

Uncertainty in fuel combustion (CRF 1.A) in total was  $\pm 1\%$  in Finland in 2012.

The uncertainty estimation of the Energy sector was completely renewed in 2013. The uncertainty analysis was carried out at a fairly detailed level, covering more than 30 fuel types mainly at the 4<sup>th</sup> CRF category level (e.g. 1.A 1a). The disaggregation level was such that uncertainties of AD and EFs (within the same year) could be considered independent (in most cases).

Uncertainties in the activity data were based on expert estimates, taking into account both observed differences and errors in the plant level fuel consumption data and statistical differences in the national fuel balances.

The aggregation of fuels follows the level shown in Table 1\_3b (around 30 fuels, aggregated from originally around 50 different fuel types).

The uncertainties in activity data vary from fuel type to another and from subcategory to another. CO<sub>2</sub> emission factors are independent on the subcategory. In most cases CO<sub>2</sub> emission factors are not studied annually, but the same EF has been used throughout the time series.

The EU ETS started from 2005 and the second period from 2008. This has provided more reliable data on both activity data and properties of fuels. These new data have been taken into account in the revised uncertainty estimation. There are three main types of changes:

- the uncertainty of the activity data has become lower
- the uncertainty of the CO<sub>2</sub> EF has become lower, although the EF itself has not changed (the same EF has been used over years)
- annual CO<sub>2</sub> EF has been taken from ETS data; in addition the uncertainty has become lower.

The first two bullets are relevant to most of the fuel types. Third bullet refers mainly to hard coal and refinery gases.

In general, the uncertainties in activity data and CO<sub>2</sub> EFs for fossil fuels (oil, gas and coal) are lower than for domestic fuels (peat and wood). There are two reasons for that. First, the national balance of domestic fuels is more uncertain, because both production and consumption figures are partly based on surveys instead of more accurate total sales statistics. Secondly, the properties of peat and wood fuels include higher variation (density, NCV, wet content, carbon content).

This variability of CO<sub>2</sub> EF for peat has been estimated using the results from a measurement project done at VTT Processes (Vesterinen, 2003). In the study, the CO<sub>2</sub> emission factor for peat combustion was measured from five different power plants. The selected power plants were located at different sites in Finland. Therefore, the peat they used represents fairly well the variation in peat quality in geographically different locations in Finland. The uncertainty estimate was based on the variation of the measured emission factors, and was  $\pm 5\%$ , which was chosen as the base year uncertainty. The uncertainty of EF for the 2012 was chosen to be 2%. As described in Section 3.2.2.2 CO<sub>2</sub> EF for peat in 2012 was decided to be slightly different compared to other years due to exceptional weather conditions. This procedure is not expected to be used in the following years; however, this subject will be annually studied based on ETS data.

Emission factors for CH<sub>4</sub> and especially N<sub>2</sub>O from combustion are highly uncertain. The nitrous oxide emission factor depends strongly on combustion technology. For example, fluidised bed combustion has higher N<sub>2</sub>O emissions than conventional combustion technologies. The emissions are also strongly dependent on fuel type, boiler design and maintenance and process conditions (e.g., temperature and residence time in furnace, air fraction, NO<sub>x</sub> reduction technologies).

The research and measurement project at VTT on non-CO<sub>2</sub> (CH<sub>4</sub> and N<sub>2</sub>O) emission factors from stationary sources in Finland (Tsupari et. al. 2005 and Tsupari et. al. 2006) has given new information on the emission factors and uncertainties of these emissions. Based on this study,  $\pm 60\%$  uncertainty was chosen for CH<sub>4</sub> and N<sub>2</sub>O emission factors in all stationary combustion categories.

Monte Carlo simulation has been used to combine the uncertainties of each calculation parameter in order to get the total uncertainty of the source category (see Section 1.7). A detailed description of the methodology of the uncertainty will be available in submission 2014.

During 2005-2007 the whole data set of fuel consumption time series was checked to remove possible inconsistencies in the earlier inventories caused by missing data of some plants, changing classifications, etc. Most of these corrections were already included in the previous submissions (2006 - 2009), but as the work has been continued, some additional minor corrections have been made in the present inventory. Overall, methodologies and data sources are now as consistent as possible with reasonable resource demands. The only exception is the year 1991; the point source data of 1991 are not included in the ILMARI system. Instead of the actual point source data, the inventory for 1991 is partly based on interpolation between 1990 and 1992 at CRF source category and fuel category level.

In the reviews of 2012 and 2013 submission the ERT has raised a question concerning the time-series consistency of CO<sub>2</sub> emission factors of coal and refinery gas (see Section 3.2.2).

In a research report described in the NIR (Annex 3) the applicability of the default IPCC CO<sub>2</sub> emission factor of coal (94,6 g CO<sub>2</sub>/MJ) in Finnish conditions was studied. The emission factor was found to be suitable for the Finnish inventory in years 1990-2003 even though there is annual variation between 93,2-94,9 g CO<sub>2</sub>/MJ due to different properties of imported coal. Also, the verified values taken from the EU ETS in 2008-2012 are considered to be accurate. The applicability of the default emission factor in Finland for years 2004-2007 could be further investigated but Finland is not considering to prioritize this matter over more urgent development needs such as implementation of the IPCC 2006 Guidelines.

Finland has begun to clarify the reasons behind the drop in the CO<sub>2</sub> IEF of refinery gas from 2004 to 2005 but a clear explanation is not yet available. Finland will likely not be able to clarify this issue in 2014 annual submission due to prioritization of more urgent development needs.

### 3.2.4 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6. The QC procedures are performed according to the QA/QC plan in the Energy sector in order to attain these quality objectives. The bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert.

#### *QC procedures for fuel data*

Several QC procedures are used in the ILMARI system.

The most resource demanding and the most important QC procedure is the checking of point sources' bottom-up fuel data, which are used for emission calculation. Automatic checking routines are included in the VAHTI data input process. For example, fuel data should be reported in physical quantities (t or 1,000 m<sup>3</sup>) as well as in energy quantities (TJ). If both quantity values are reported, the NCV is calculated and compared with the default NCV of this fuel. If the calculated value is out of range, data will be marked for checking. If either the physical quantity or energy is missing, the missing value will be calculated using the default NCV. If neither the quantity nor energy has been reported, then missing data will be taken from other available data sources. For certain non-standard fuel types both the fuel code and the fuel quantity data will be marked for checking in all cases.

Automatic SAS checks facilitate the comparison of different data sets. The checks include for example comparison with previous years' data (total and single values) and comparison with fuel data from EU ETS



and surveys of Statistics Finland. The output of the automatic check is manually looked through and several corrections to point sources' fuel data are performed.

ILMARI system is a part of the Statistics Finland's YEIS database system. The YEIS database has links between records from three different sets of bottom-up fuel data, which are included in the same database system:

- ILMARI/VAHTI, installation data
- manufacturing industry fuel survey; local kind-of-activity-unit data
- energy production survey; production site data.

The total sum of fuels is automatically summed up in appropriate unit/plant level in each data set, and the results are taken to ILMARI, where they can be compared. This checking has been performed selectively.

Both the original data from the VAHTI system and possibly corrected data are stored in the ILMARI system, thus corrections can be checked afterwards. The results of point source checks are presented in Table 3.2-9.

**Table 3.2-9** The results of the point source QC procedures for 2012 data

	Number	Quantity	PJ
Fuel records total (corrected values)	3 115	48 799	662
Fuel records original	1 937	43 218	657
Non-corrected original	1 583	24 499	301
Imputed fuel records	1 380	5 975	108
TJ corrected	197	0	-107
Quantity corrected	44	-570	0
Quantity and TJ corrected	113	-814	-33
Fuel code corrected	67	302	-30
Total corrected records (net Quantity and PJ corrections)	1 552	4 497	-32

Note: Values of corrections do not add up; there are deleted records (double values) as well as imputed records (missing data). The last row shows total net corrections. Quantity includes figures in 1,000,000 m<sup>3</sup> and 1,000 tonnes depending on the fuel type. These figures represent the first round of calculation. After the second round there will be some more corrections, mainly more imputed fuel records.

After the point sources' data have been checked, the data from the transport models and heating energy model are imported to ILMARI system and the total fuel consumption figures are compared with the total figures taken from the Energy statistics yearbook. If there are notable differences, the reasons will be studied and possible corrections made to either the Energy statistics data or the GHG inventory data, depending on the case.

Both the Energy statistics compilation and the GHG inventory are prepared side by side and they have links to each other. For example, total use of peat in Finland is mostly based on bottom-up calculation. This means that energy surveys, ETS data and GHG inventory data are used to complement each other to find out the total consumption of peat.

A comprehensive crosschecking of installations' combustion technology and other technical properties (capacity, main fuel, emission reduction equipment, process type, etc.) for point sources in CRF 1.A 1 and 1.A 2 for the whole time series was completed in 2005 inventory and reported in the following inventory submission. However, minor corrections have been (and will be) done annually after that.

### *QC procedures for emissions*

CO<sub>2</sub> emissions are also checked in the plant level data. The ILMARI system includes calculated CO<sub>2</sub> emissions from each fuel batch. It also includes plant level CO<sub>2</sub> emissions reported by the plant operators to the VAHTI system, but those data are not split between different fuels and non-fuel based emissions (although CO<sub>2</sub> from biomass is separated from fossil CO<sub>2</sub>). The reported data are compared with the calculated data and out-of-range differences are checked. However, this checking is very resource-intensive, and it will be done only for a subset of plants, depending on time available.

An important quality check is the implied emissions factor (IEF) graph in CRF Reporter. When time series of activity and emission data are fed in CRF Reporter by sub-sectors and fuel categories, IEFs are checked visually. If there are inconsistencies, the underlying data are checked and corrected if needed.

### *QA procedures*

Each year the latest inventory calculations (activity data and CO<sub>2</sub> emissions) are verified by crosschecking the results against the national energy balance (Annex 4). This reference calculation is based on energy balance and shows activity data (PJ) and CO<sub>2</sub> emissions. The idea of this crosschecking is to compare the results of bottom-up calculation (reported as the Sectoral approach in the CRF data) with top-down calculation (from the energy balance sheet). Figures based on the energy balance are aggregated to the best-matching CRF source categories and the best-matching CRF fuel categories.

Finnish Environment Institute (FEI) calculates the final data for the UNECE Air Pollutant inventories. The calculation system is separate from the GHG calculation system, but uses mostly the same basic data sources for calculation of emissions from fuel combustion. This independent calculation system is used as a verification tool for GHG inventory, and moreover, as source of additional corrections. Comparisons between the data in these two calculations systems are performed continuously during the inventory preparation. The annual calculation in FEI is performed a bit later than the GHG inventory and thus the source data set usually includes more updated data than one used in the preliminary EU GHG inventory.

A comparison and review of the emission factors in the energy sector in Swedish and Finnish inventories was carried out in 2006. The objectives of the review were to check whether the reporting and choice of emission factors were in accordance with the UNFCCC and IPCC guidelines and, in addition, to compare the emission factors used in Finland and Sweden, and to assess whether the differences (if any) were explainable and reasonable taking the national circumstances into account. In the 2011 meeting between the Finnish and Swedish inventory teams the use of EU ETS data in inventories was discussed.

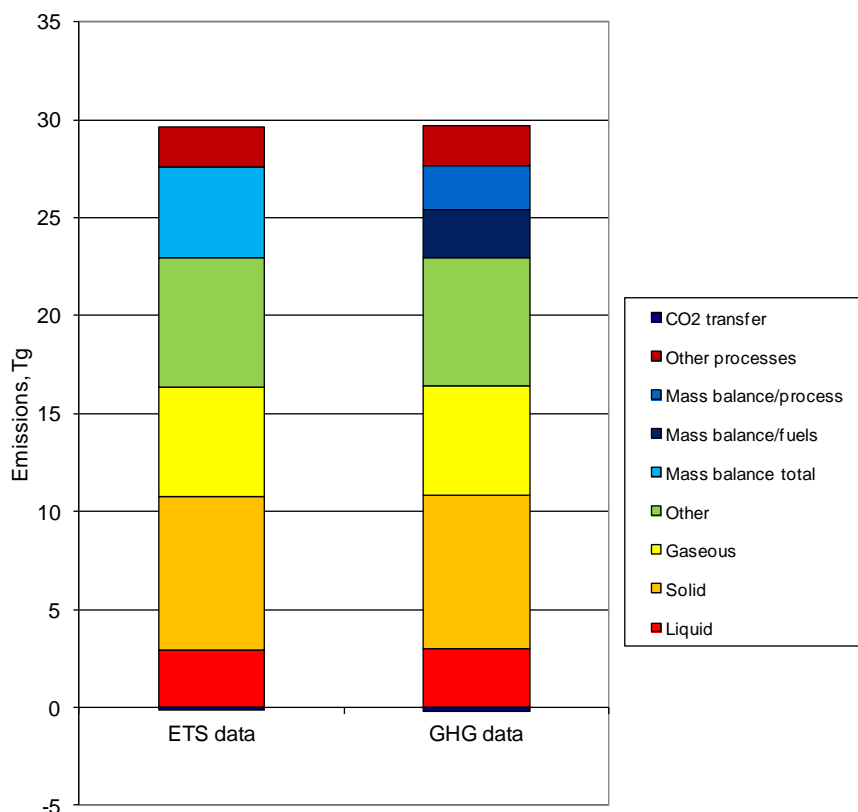
A voluntary bilateral cross-country review on the testing of adjustment procedures was conducted between Finland and Germany in 2004. The review covered emission categories 1.A 1 and 1.A 2 in the Energy sector.

### *ETS data*

CO<sub>2</sub> emission data taken from the EU ETS (Emission Trading System, see Section 1.4) are annually compared with the calculated emission data in the ILMARI system. Both systems include point source (bottom-up) data. In the ILMARI system the plants included in the ETS are marked. Thus summaries of total ETS and non-ETS plants can be made easily.

Total CO<sub>2</sub> emissions taken from the ETS data were 29.6 Tg in 2012. The corresponding amount taken from the GHG inventory data was 29.7 Tg. In the ETS data 143.8 Gg of CO<sub>2</sub> and in the GHG data 146.6 Gg of CO<sub>2</sub> was transferred out of the ETS plants. The reduced amount is different because the storage factor in the inventory is based on annual data and in the ETS a predetermined average storage factor is used (see Section 3.2.7.1). The calculation method of amount of transferred emission in the GHG data is explained in Section 3.2.7. The difference between the ETS and GHG data is 0.1 Tg, 0.2% of total ETS. There are more differences in the allocation of emissions to CRF categories, which can be seen in Figure 3.2-2.

The most important difference is in the Iron and steel sector, which is almost totally allocated to Industrial Processes in the ETS data. All iron and steel plants calculate and report their emissions according to the mass balance approach in the ETS. In the GHG inventory emissions are split between Energy and Industrial Processes. Another difference is the emissions of combustion of catalytic cracking coke in oil refineries, which is included in the Energy sector in the inventory and in Industrial Processes in the ETS.



**Figure 3.2-2** CO<sub>2</sub> emissions of ETS plants compared with the corresponding emissions reported in the greenhouse gas inventory in 2012. From 2008 onwards ETS plants have been using mostly measured plant level calorific values and emission factors.

NCVs, CO<sub>2</sub> emission factors and fuel consumption data taken from the ETS plants were aggregated to the most detailed fuel code level and compared with the corresponding data in the ILMARI system. If there were significant differences, corrections were done in the ILMARI data (either plant-specific NCVs of emission factors or both). Concerning the most common and the most important fuels, the differences in aggregated NCVs and EFs were generally less than  $\pm 1\%$ . For different types of wood fuels the differences in NCVs were somewhat larger (generally  $\pm 2-10\%$ ). This result was expected, mainly due to difficulties of plant operators in disaggregating different types of wood residues to existing fuel code system, but also due to variations in the moisture content of wood fuels. The difference in total amount of woodfuels in TJs was 0.6% in 2012.

### 3.2.5 Source-specific recalculations

The most important recalculation in this sector was the change in the CO<sub>2</sub> emission factor for MSW/REF in certain plants. There are some plants (5-10) in the ETS which are obliged to determine plant specific emission factors for these fuels (while small users are allowed to use national default EF). There are annual variations in the measured emission factors, and they are available from 2008 on. Revised emission estimates were calculated using plant-specific EFs. The new estimates were 13-33 Gg higher than previous estimates.

Other recalculation in this sector were minor corrections in the point sources' data (activity, combustion technology or allocation) to remove inconsistencies in plant level time series. These corrections were in some cases reflected also in category 1.A 5, which includes residuals of certain fuels. In the most cases the reasons for these corrections are updates in the latest years' source data or minor, previously undetected, errors in the older data.

There were also corrections in the total consumption data for woodfuels and peat. These corrections were made to take into account the latest updates in the Energy Statistics data.

### 3.2.6 *Source-specific planned improvements*

The work to input the data from the ETS system in the GHG database system (ILMARI) has started during 2010. At the moment the ETS plants and data are included in the ILMARI for plant level verification. In 2012 more routines were developed to flag differences in the plant level data. The actual corrections and imputations are still performed manually. We are looking for ways to use more automatic imputation routines.

The revision of process description and internal working manual of the Energy sector has advanced, but the work will continue to further improve the documentation. As a part of this improvement, we are planning to review of the working manual parallel with the external audit of the Energy sector.

The possibilities of reviewing Energy sector or part of it by an independent third party have been considered after the 2015 or 2016 submission. As Finland is a small country a problem lies in finding independent parties who have in-depth knowledge of Finland's energy sector and some knowledge of the greenhouse gas inventory system and calculation methodologies. An independent audit will also involve resource implications and should therefore be planned carefully in respect to contents and timing. The implementation of the 2006 IPCC Guidelines means many changes in the production of our energy inventory (mainly classifications change). A thorough review before these changes is considered not to be the best timing.

In 2013 a planning of the systematic checking of the CO<sub>2</sub> emission factors in the Energy sector was initiated and a plan for emission factor checking was established. The first focus will be on the checking whether the emission factors of major liquid fuels (motor gasoline, diesel oil, light fuel oil, heavy fuel oil, LPG) currently used in the Finnish inventory are still applicable. Based on the results received via this project a plan to check these emission factors regularly (e.g. annually or every 3/5 years) will be established. The project was launched in the autumn 2013 by contacting Finnish oil industry. Emission factors currently used in the inventory are based on information received from Neste between years 2004-2008. By the end of 2013 the inventory team was provided analysis data of certain liquid fuels. Information on other liquid fuels will be send later. Based on this information the applicability of current emission factor will be studied. Also, for background information the properties of the oil products in the Finnish market has been collected via Internet. Results of the emission factor checking of the major liquid fuels will be ready for the 2015 submission. After this, reasons behind the drop in the CO<sub>2</sub> IEF value for liquid fuels used in the petroleum refining from 2004 to 2005 will be clarified depending on the resources available.

For the whole Energy sector, the work to implement the 2006 IPCC Guidelines for the 2015 submission was started in 2013. As a part of this project possibility to provide disaggregated data on the most important fuels included in the other fuels categories will be considered for the 2015 annual submission.

### 3.2.7 *CO<sub>2</sub> capture, transfer and storage in PCC*

In Finland four pulp and paper mills and one paper mill are capturing and directing a part of their fuel combustion based CO<sub>2</sub> emissions to PCC (Precipitated Calcium Carbonate) plants nearby. One of the paper plants was permanently ceased in the end of 2011. The CO<sub>2</sub> capture in pulp production takes place in the limekiln and in paper production in associated industrial power plants. PCC is widely used in different kinds of paper and paperboard as filling or coating material. The first PCC plant using transferred CO<sub>2</sub> in Finland started its operation in 1993.

PCC in paper and paperboard will form a long-term storage for the captured CO<sub>2</sub> (see Section 3.2.7.2) except in cases where the paper or sludge from recycled paper is combusted. The emissions from combustion are taken into account separately under relevant categories in the energy sector. Long-term storage is the main criteria used for inclusion of CO<sub>2</sub> capture and storage in the inventory.

### 3.2.7.1 Methodology

In the lime kilns of the pulp production process lime mud (basically  $\text{CaCO}_3$ ) is burned back to lime ( $\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$ ) and after that lime is reused in causticising. The limekiln has been chosen for the  $\text{CO}_2$  source of PCC production because an excess amount of  $\text{CO}_2$  is produced in the process. This is captured and transferred to the PCC plant and used in the production of PCC. In addition, a part of the  $\text{CO}_2$  comes from fuels used in the kilns.

The amount of  $\text{CO}_2$  transferred to PCC is estimated based on the amount of PCC produced. This way any losses during the capture, transfer and production are accounted for. Finland exports more than 90% of paper and paperboard. In addition, the PCC included in these products is exported. Possible emissions from PCC in exported paper are not taken into account, as these emissions are not occurring with the national borders of Finland.

The plants do not measure their  $\text{CO}_2$  emissions or the amount of  $\text{CO}_2$  captured. Therefore they estimate the  $\text{CO}_2$  captured and stored using amount of PCC produced.

$$\text{CO}_2\text{captured and stored} = \text{PCCproduction} * [\text{CO}_2]/[\text{CaCO}_3]$$

The calculated amount of stored  $\text{CO}_2$  is subtracted from subcategory 1.A 2f, or actually a negative emission figure is reported in this subcategory in the CRF Reporter (see Table 3.2-10). The way of reporting is chosen to show transparently the amount deducted from the inventory each year. The calculations are presented in more detail in Appendix\_3c. This is also in accordance with the guidance for reporting given in the 2006 IPCC Guidelines (IPCC 2006).

A small amount of carbonate (either PCC or other carbonates) based  $\text{CO}_2$  is released in combustion of recycling sludge as well as part of MSW or REF (mostly in subsectors 1.A 1a, 1.A 2d and 1.A 2f). These emissions are taken into account in the corresponding emission factors.

**Table 3.2-10** PCC production and transferred  $\text{CO}_2$  in the years 1993-2012

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>PCC production, 1000 t</b>	2	46	123	167	241	290	356	413	403	401	430	473	425	482	532	485	421	449	408	333
<b><math>\text{CO}_2</math> transferred and subtracted from 1.A 2f, Gg</b>	1	20	54	74	106	128	156	182	177	176	189	208	187	212	234	213	185	198	180	147

### 3.2.7.2 Source-specific QA/QC and verification

Statistics Finland clarified the characteristics of  $\text{CO}_2$  storage in PCC in 2008 through literature and discussions with experts. According to the Finnish experts<sup>6</sup>, PCC in paper and recycled sludge disposed in landfills or used in landscaping constitute a long-term storage for  $\text{CO}_2$ . Support for the long-term nature of storage when the recycled sludge is disposed in landfills or used in landscaping is also given in the following references: Appelo and Postma, 1996, Garrels and Christ, 1965. However,  $\text{CO}_2$  will be released, when PCC containing paper or sludge is burned.

In response to the review recommendation of submission 2009, the characteristics of the captured  $\text{CO}_2$  were clarified from the calculation of the emissions of the plants capturing  $\text{CO}_2$  for PCC production. About 85% of fuels used in the plants capturing the  $\text{CO}_2$  from limekilns of pulp production process have been fossil (natural gas, different type of oils) origin, though since 2012 all  $\text{CO}_2$  emissions are fossil origin. Finland deducts all captured  $\text{CO}_2$  from the emissions in accordance with the guidance in the 2006 IPCC Guidelines, which states that once captured, there is no differentiated treatment between biogenic carbon and fossil carbon.

In the paper mills, one of the power plants capturing  $\text{CO}_2$  has used exclusively fossil fuels for the whole time series. The other power plant has used fossil fuels until 2001. Since 2001, it plant has also combusted

<sup>6</sup> Prof. Eero Hanski, University of Oulu, prof. Olli Dahl, Helsinki University of Technology and Docent Kauko Kujala, University of Oulu (see Appendix\_3d).

biomass fuels, but the total amount of captured and transferred CO<sub>2</sub> has not exceeded the CO<sub>2</sub> emissions from fossil fuels. The operation of this power plant has now been ended.

As a response to the review of Finland's inventory submission in 2009, Statistics Finland has calculated the share of fossil CO<sub>2</sub> used in PCC based on the above described plant-specific information for the last thirteen years (plant-level PCC production data were available only for years 2000-2012). For plants using fossil and biomass fuels, the share was calculated assuming that CO<sub>2</sub> captured would be proportional to the amount of fossil and biomass fuels used. Of the total transferred CO<sub>2</sub> amount, the average share of fossil CO<sub>2</sub> is 86 per cent for years 2000-2011. From 2012 all transferred CO<sub>2</sub> is fossil origin. More details can be found in Appendix\_3c.

In response to the review of the submission 2010, Finland notes that when paper (as part of MSW) and/or deinking sludge is combusted, the CO<sub>2</sub> emissions from carbonates included in PCC are reported as "fossil CO<sub>2</sub> emissions" in the Energy sector. No distinction is made whether the carbonates originate from process using fossil or biomass-based CO<sub>2</sub>.

In response to the review of submission 2011 Finland confirmed that any harvest of woody biomass is included as a C stock decrease (CO<sub>2</sub> emissions) in the LULUCF sector in accordance with GPG LULUCF 2003 (see Chapter 7). These emissions are also included under forest management (FM) under Article 3, paragraph. For energy production only small amount of wood is imported (mainly from Russia, which has also elected FM) and the biomass-CO<sub>2</sub> captured for PCC production comes from energy production. The biomass used may contain (unlikely though) small amounts of bark from imported wood (wood residue from pulp and paper production).

The PCC production data has been crosschecked with other data sources. Statistics Finland has collected plant specific data on the production amounts by PCC plant for the relevant years from the VAHTI database (national environmental permit registry) and the production statistics (plant specific data from Statistics Finland's manufacturing industry surveys). The data have also been crosschecked with the amount of captured and transferred CO<sub>2</sub> reported under the EU ETS. These data exist for 2005-2012 and include the captured and transferred amount of CO<sub>2</sub> by plant.

The differences in the PCC production data from the various sources have been very small. The amount calculated and reported by Statistics Finland in the greenhouse gas inventory has been approximately 97 per cent of the data reported to EU ETS 2005-2012. The difference is assumed to account for possible losses during transfer and production.

### 3.2.7.3 Source-specific recalculations

Amount of produced PCC was corrected for years 2010 and 2011 therefore transferred amount of CO<sub>2</sub> increased.

### 3.3 Transport (CRF 1.A 3)

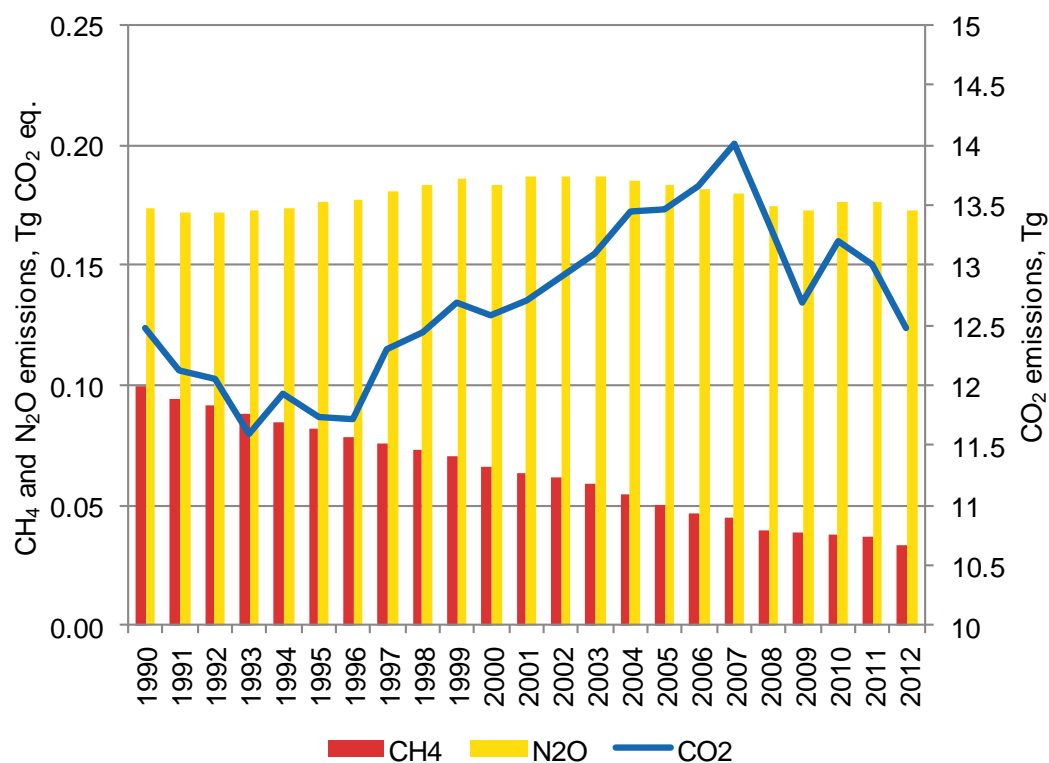
#### Source category description

In 2012, the greenhouse gas emissions from transportation amounted to 12.7 Tg CO<sub>2</sub> equivalent. The share of the transport sector of the total greenhouse gas emissions has remained fairly constant since 1990, and was approximately 18% in 1990 and 21% in 2012.

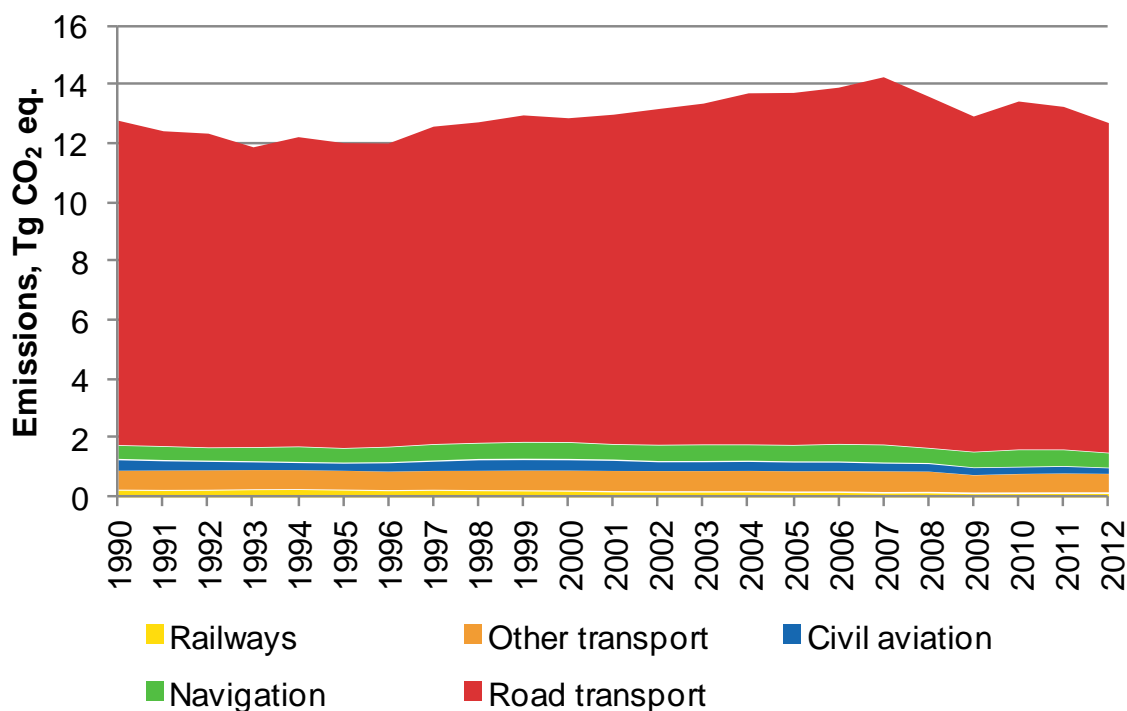
Emissions from Transport (CRF 1.A 3) include all domestic transport sectors: civil aviation, road transport, railways, domestic navigation and other mobile sources (which are not included in other sectors) (Table 3.3-1). The trend in the emissions of these categories is given in Figure 3.3-2 and in Table 3.3-2. In Figure 3.3-1 the emissions of the transport category are given by gas.

**Table 3.3-1** Reporting categories in the transport category

Reporting category	Description	Remarks
CRF 1.A 3		
a. Civil Aviation	Jet and turboprop powered aircraft (turbine engined fleet) and piston engined aircraft , domestic flights only	Emissions from helicopters are not calculated separately. These emissions are included in calculation of category 1.A 5.
b. Road Transport	Transport on roads by vehicles with combustion engines: cars, vans, buses, coaches, lorries, articulated vehicles, motorcycles and mopeds	Farm and forest tractors driving on roads are included in CRF 1.A 4c Agriculture/Forestry. Fuel consumption and emissions from military vehicles are included in category 1.A 5.
c. Railways	Railway transport operated by diesel locomotives	
d. Navigation	Sea-going ships (between domestic ports), icebreakers, working boats, cruisers, ferryboats and leisure boats	Fishing boat emissions are included in the CRF 1.A 4c.
e. Other Transportation: Off-Road vehicles and other machinery	This sub-category includes all non-road machinery and other vehicles from the TYKO model, which are not included in other categories. This category covers several types of machines, for example road maintenance tractors, forklifts, all-terrain vehicles and snowmobiles.	Non-road machinery in agriculture, forestry and construction are calculated with the same model, but reported in corresponding CRF categories 1.A 4c and 1.A 2f.



**Figure 3.3-1** Emissions from transport sector by gas (Tg CO<sub>2</sub> eq.)



**Figure 3.3-2** Emissions from transport by subcategory (Tg CO<sub>2</sub> eq.)

Road transportation is the most important emission source in transport, covering over 89% of sector's emissions in 2012. The emission trends for each sub-category are discussed in corresponding sections.

CO<sub>2</sub> emissions from transport decreased strongly after 1990. Reason for the decrease was the economic depression that was much deeper in Finland than in other European countries. The bottom was reached 1994 and after that the increase has been fairly constant reaching the 1990 emission level in 2000. The increase has happened mainly in the road transport due to the increased kilometrage. In 2008 the emissions deviated



from the upward trend. The worldwide economic downturn that began this year has decreased the kilometrage of all transport modes. At the same time, the change in Finland to CO<sub>2</sub> based taxation of cars has caused a transition from gasoline to diesel cars and lowered the specific fuel consumption of gasoline cars as well. The trend in emissions in 2012 compared to 2011 has stayed around stable due to the growing share of biofuels in fuels used in road transport which restrains the otherwise growing emissions due to increasing kilometrage.

### *Methodological issues*

In the Finnish calculation system, separate models have been developed for different categories of transport, allowing detailed use of traffic data and data on transport equipment fleet. The emissions and energy consumption of all traffic modes are calculated with the models LIPASTO developed by VTT Technical Research Centre of Finland.

The LIPASTO system is comprised of four sectoral submodels:

- road transport emissions model LIISA
- civil aviation emissions model ILMI (developed and run by Finavia)
- domestic navigation emissions model MEERI and
- railways emissions model RAILI.

Emissions from non-road machinery are calculated with the TYKO model, also developed by VTT.

VTT is responsible for running the calculation models LIISA, MEERI and RAILI. Finavia has estimated the emissions from aviation for the years 1990-2008. For 2009-2012, the emissions were estimated based on simpler calculations (see Section 3.3.1). Statistics Finland aggregates the results of these models to sub-categories of CRF sector 1.A Fuel combustion (see Section 3.2) and to national energy balances as well. MEERI and ILMI include both domestic and international transport, but only domestic part of transport is taken to ILMARI as part of greenhouse gas inventory. The definition used for international transport in ILMI and MEERI is different from the IPCC definition, thus bunker emissions are calculated separately by Statistics Finland (see Section 3.8).

The fuel consumption in the transport sector in 1990-2012 can be seen in Table 3.3-3.

There have been some changes in legislation and fuel tax decisions concerning the use of diesel oil and gasoil in the latest years. A new fuel product, non-road gasoil, was introduced during 2005. Non-road gasoil is technically the same fuel as diesel oil, but has lower taxes and includes a Euromarker to allow monitoring of illegal use.

Prior to 2005 it was allowed to use heating gasoil (= light fuel oil) in most diesel engines outside road transport, i.e. in navigation, agricultural machinery, etc. In leisure boats the use of diesel oil (instead of lower taxed gasoil) was made obligatory from the beginning of 2008.

Table 3.3-4 shows the changes in the allocation of diesel oil, non-road gasoil and heating gasoil used in different subsectors of the inventory. Although the reported changes are mostly based on changes in legislation and fuel specifications, it has partly been up to consumers, if and when they change from heating gasoil to non-road gasoil. The shift has happened gradually. The actual consumption figures of each fuel type are not available by user category, only by total sales of each fuel. The inventory experts from VTT and Statistics Finland decided to estimate the gradual shift from heating gasoil to non-road gasoil using sub-sector specific yearly changes, which can be seen in Table 3.3-4. Instead of basing the estimation on two-years' gradual change for each subsector, it is assumed, that some subsectors change in 2005 and others in 2006. This way the calculation systems could be kept simple. For the sake of completeness, the table includes also the use of diesel/gasoil type fuels in the sectors with no legislative changes. Fuel types have been indicated using different colours. When comparing to the official energy statistics, it must be noted that at the moment non-road gasoil and heating gasoil are not separated in published statistics. The changes of emission factors due to the fuel shift have been included in the transport emission calculation submodels.

Increasing shares of biogenic additives or biofuels are mixed in transport fuels and some other liquid fuels (Table 3.3-5). Data sources, calculation methods and emission factors concerning these bioshares are described in sections dealing with the main consumption categories of these fuels: 3.3.2.2 and 3.3.2.3 (gasoline, diesel oil and biogas), 3.3.5.2 and 3.3.5.3. (non-road gasoil) and 3.4.2.2 and 3.4.2.3 (heating gasoil).

The CO<sub>2</sub> emission factors for biogenic components of gasoline and diesel oil are based on the assumption of C-contents of 52% for bioethanol (C<sub>2</sub>H<sub>5</sub>OH) and 85% for biodiesel (C<sub>18</sub>H<sub>38</sub>); these give respectively 1.913 t CO<sub>2</sub>/t of bioethanol and 3.12 t CO<sub>2</sub>/ t of biodiesel. All other biogenic components are calculated using the same C-contents, but specific NCVs. Emission factors per TJ in Table 3.2-3 have been calculated using reported NCVs and shares of different biocomponents in gasoline and diesel oil (see also Section 3.3.2.2). For biogas used in transport, the same CO<sub>2</sub> EF (56.1 t/TJ) has been used as for other uses of biogas.

**Table 3.3-2** Emissions from the Transport sector by subcategory (Tg CO<sub>2</sub> eq.)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>Total</b>	<b>12.8</b>	<b>12.4</b>	<b>12.3</b>	<b>11.9</b>	<b>12.2</b>	<b>12.0</b>	<b>12.0</b>	<b>12.6</b>	<b>12.7</b>	<b>12.9</b>	<b>12.8</b>	<b>13.0</b>	<b>13.2</b>	<b>13.3</b>	<b>13.7</b>	<b>13.7</b>	<b>13.9</b>	<b>14.2</b>	<b>13.6</b>	<b>12.9</b>	<b>13.4</b>	<b>13.2</b>	<b>12.7</b>
<b>CO<sub>2</sub></b>																							
<b>3. Transport</b>	<b>12.5</b>	<b>12.1</b>	<b>12.1</b>	<b>11.6</b>	<b>11.9</b>	<b>11.7</b>	<b>11.7</b>	<b>12.3</b>	<b>12.4</b>	<b>12.7</b>	<b>12.6</b>	<b>12.7</b>	<b>12.9</b>	<b>13.1</b>	<b>13.4</b>	<b>13.5</b>	<b>13.6</b>	<b>14.0</b>	<b>13.4</b>	<b>12.7</b>	<b>13.2</b>	<b>13.0</b>	<b>12.5</b>
a. Civil aviation	0.39	0.34	0.31	0.28	0.26	0.26	0.31	0.34	0.39	0.38	0.38	0.37	0.32	0.33	0.33	0.32	0.31	0.28	0.28	0.26	0.24	0.24	0.20
b. Road transport	10.8	10.5	10.5	10.0	10.3	10.2	10.1	10.6	10.7	10.9	10.8	11.0	11.2	11.4	11.7	11.8	11.9	12.3	11.8	11.2	11.7	11.5	11.0
c. Railways	0.19	0.18	0.19	0.21	0.21	0.19	0.18	0.19	0.18	0.17	0.16	0.14	0.14	0.14	0.14	0.13	0.13	0.11	0.11	0.09	0.10	0.10	0.10
d. Navigation	0.44	0.44	0.42	0.45	0.50	0.47	0.50	0.53	0.52	0.54	0.54	0.50	0.52	0.54	0.52	0.53	0.57	0.58	0.49	0.51	0.56	0.54	0.48
e. Other transport	0.66	0.68	0.68	0.67	0.66	0.65	0.64	0.65	0.67	0.69	0.69	0.70	0.70	0.70	0.70	0.70	0.71	0.72	0.70	0.59	0.63	0.65	0.63
<b>CH<sub>4</sub></b>																							
<b>3. Transport</b>	<b>0.099</b>	<b>0.094</b>	<b>0.092</b>	<b>0.088</b>	<b>0.084</b>	<b>0.082</b>	<b>0.078</b>	<b>0.076</b>	<b>0.073</b>	<b>0.070</b>	<b>0.066</b>	<b>0.063</b>	<b>0.061</b>	<b>0.059</b>	<b>0.054</b>	<b>0.051</b>	<b>0.047</b>	<b>0.045</b>	<b>0.040</b>	<b>0.039</b>	<b>0.038</b>	<b>0.037</b>	<b>0.034</b>
<b>N<sub>2</sub>O</b>																							
<b>3. Transport</b>	<b>0.174</b>	<b>0.172</b>	<b>0.172</b>	<b>0.173</b>	<b>0.174</b>	<b>0.177</b>	<b>0.177</b>	<b>0.181</b>	<b>0.183</b>	<b>0.186</b>	<b>0.184</b>	<b>0.187</b>	<b>0.187</b>	<b>0.187</b>	<b>0.185</b>	<b>0.184</b>	<b>0.182</b>	<b>0.180</b>	<b>0.175</b>	<b>0.173</b>	<b>0.177</b>	<b>0.176</b>	<b>0.173</b>
a. Civil aviation	0.005	0.004	0.004	0.004	0.003	0.003	0.004	0.004	0.005	0.005	0.005	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.003	0.003	0.003	0.003
b. Road transport	0.160	0.159	0.160	0.160	0.161	0.164	0.164	0.167	0.169	0.171	0.169	0.173	0.173	0.173	0.172	0.170	0.168	0.166	0.161	0.161	0.164	0.163	0.161
c. Railways	0.0015	0.0014	0.0015	0.0016	0.0017	0.0016	0.0014	0.0015	0.0014	0.0014	0.0013	0.0011	0.0011	0.0011	0.0011	0.0010	0.0011	0.0009	0.0010	0.0008	0.0008	0.0008	0.0008
d. Navigation	0.0029	0.0029	0.0027	0.0029	0.0033	0.0030	0.0033	0.0035	0.0034	0.0037	0.0037	0.0033	0.0035	0.0036	0.0035	0.0036	0.0039	0.0040	0.0037	0.0039	0.0043	0.0042	0.0038
e. Other transport	0.0047	0.0048	0.0047	0.0047	0.0046	0.0045	0.0045	0.0046	0.0047	0.0047	0.0047	0.0048	0.0048	0.0047	0.0047	0.0048	0.0048	0.0049	0.0050	0.0042	0.0045	0.0047	0.0045

**Table 3.3-3** Fuel consumption by fuel type in transport (PJ)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>Civil aviation</b>																							
Aviation gasoline	0.11	0.10	0.09	0.09	0.08	0.08	0.08	0.08	0.07	0.07	0.08	0.06	0.05	0.05	0.05	0.04	0.05	0.05	0.05	0.04	0.04	0.04	0.03
Jet kerosene	5.15	4.55	4.17	3.77	3.45	3.51	4.10	4.56	5.21	5.17	5.11	5.02	4.36	4.41	4.49	4.32	4.22	3.80	3.74	3.46	3.18	3.29	2.75
<b>Road transport</b>																							
Gasoline	80.7	80.6	80.8	75.8	77.6	76.6	73.9	75.8	74.6	73.8	71.1	72.1	73.3	73.6	74.9	74.7	73.9	73.7	66.0	63.7	62.1	58.6	56.7
Diesel oil	66.9	62.7	62.0	60.6	63.2	62.1	64.1	68.8	71.4	74.9	76.5	78.1	79.8	81.9	85.5	86.2	88.9	94.3	94.5	89.5	96.9	97.9	93.9
Natural gas	NO	NO	NO	NO	NO	NO	0.002	0.006	0.013	0.044	0.048	0.059	0.107	0.131	0.120	0.113	0.155	0.162	0.173	0.208	0.198	0.164	0.161
Liquid biofuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.033	0.176	0.186	NO	0.034	0.076	3.29	5.94	5.81	8.13	10.96
Gaseous biofuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.002	0.006	0.015
<b>Railways</b>																							
Gasoil	2.58	2.46	2.53	2.78	2.85	2.61	2.38	2.53	2.39	2.30	2.17	1.92	1.85	1.84	1.88	1.71	1.75	1.47	1.56	1.25	1.29	1.34	1.34
Liquid biofuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.01	0.02	0.02	0.01
<b>Navigation</b>																							
Residual oil	1.56	1.55	1.35	1.69	2.27	1.86	2.12	2.46	2.27	2.16	2.39	1.84	2.12	2.29	2.00	1.91	2.08	2.24	1.91	2.01	2.32	2.54	2.40
Gasoil	2.52	2.52	2.40	2.42	2.46	2.39	2.52	2.54	2.51	2.87	2.71	2.66	2.68	2.68	2.79	2.98	3.20	3.20	2.27	2.35	2.59	2.51	2.20
Gasoline	1.80	1.86	1.89	1.89	1.89	1.96	1.97	2.01	2.10	2.17	2.12	2.13	2.17	2.15	2.17	2.20	2.30	2.33	1.86	1.87	1.99	1.53	1.31
Diesel oil	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.48	0.55	0.61	0.55	0.50
Liquid biofuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.08	0.14	0.16	0.17	0.14
<b>Other transport</b>																							
LPG	0.28	0.27	0.26	0.25	0.24	0.23	0.23	0.22	0.21	0.19	0.19	0.19	0.20	0.21	0.22	0.23	0.23	0.23	0.22	0.18	0.17	0.18	0.18
Motor gasoline	2.43	2.65	2.77	2.75	2.70	2.66	2.68	2.75	2.87	3.05	3.14	3.18	3.24	3.27	3.35	3.40	3.44	3.51	3.25	3.01	3.15	3.20	3.28
Gasoil	6.26	6.27	6.19	6.11	6.08	6.01	5.83	5.94	6.03	6.11	6.12	6.13	6.11	6.05	6.00	5.95	5.99	6.11	6.12	4.95	5.34	5.48	5.19
Liquid biofuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.14	0.21	0.25	0.30	0.25

**Table 3.3-4** The allocation of diesel oil, heating gasoil and non-road gasoil; numbers include bioshares (PJ)

PJ (including bio-shares)		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Road transport	Diesel oil	66.9	62.7	62.0	60.6	63.2	62.1	64.1	68.8	71.4	74.9	76.5	78.1	79.8	81.9	85.5	86.2	88.9	94.3	95.0	91.9	99.5	102.4	101.2
Leisure boats		0.45	0.46	0.47	0.47	0.47	0.48	0.49	0.50	0.52	0.54	0.52	0.53	0.54	0.53	0.54	0.54	0.56	0.56	0.48	0.57	0.63	0.58	0.54
Domestic navigation	Non-road gasoil	4.45	4.36	4.17	4.14	4.15	4.04	4.15	4.16	4.03	4.30	4.08	3.94	3.98	3.98	3.93	4.02	4.33	4.27	3.85	3.93	4.16	4.06	3.74
Railway transport		2.58	2.46	2.53	2.78	2.85	2.61	2.38	2.53	2.39	2.30	2.17	1.92	1.85	1.84	1.88	1.71	1.75	1.47	1.56	1.26	1.31	1.36	1.35
Non-road machinery		29.4	29.5	29.0	28.4	28.3	28.3	28.0	28.5	29.3	29.9	30.3	30.5	30.6	30.5	30.5	30.51	30.4	31.1	31.4	27.2	29.2	30.27	31.43
Energy prod, heating, industry	Light fuel oil (=heating gasoil)	68.9	67.6	66.7	66.1	64.0	63.2	64.9	64.1	66.0	64.8	60.5	61.8	60.8	60.2	57.8	53.1	50.6	48.0	42.4	42.8	46.0	38.0	41.0
Total gasoil + diesel oil		172.6	167.1	164.9	162.5	162.9	160.8	164.0	168.6	173.7	176.7	174.0	176.7	177.5	178.9	180.1	176.1	176.6	179.7	174.7	167.7	180.8	176.7	179.3

**Table 3.3-5** Amount of biocomponents of liquid fuels and avoided fossil CO<sub>2</sub>, 2002-2012 (TJ)

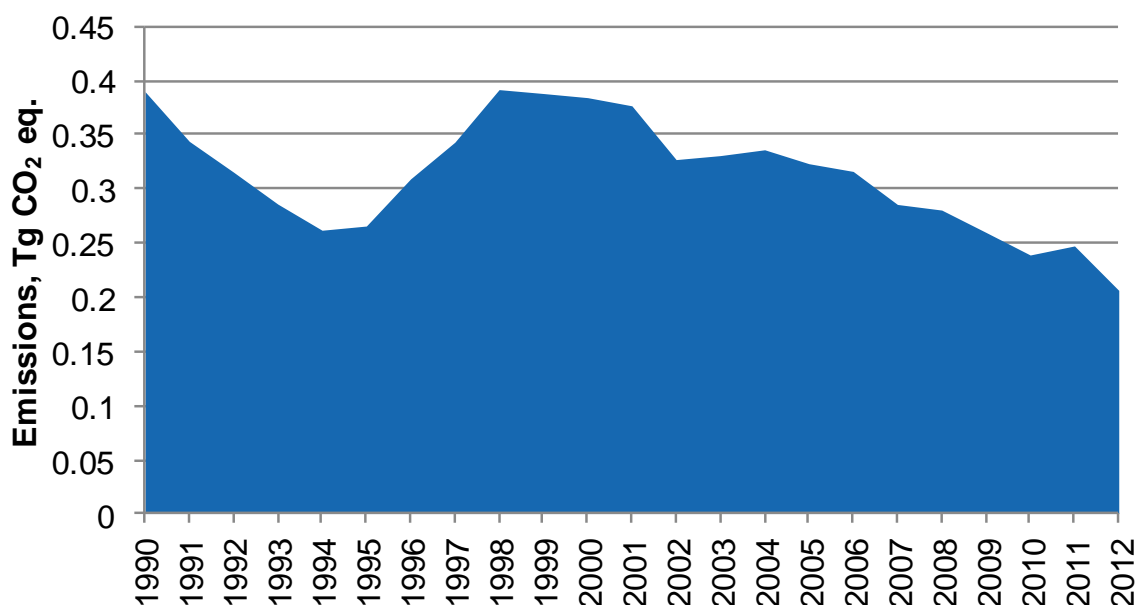
	Gasoline	Diesel oil	Non-road gasoil	Heating gasoil	Biogas	Avoided fossil CO <sub>2</sub> , Gg
2002	33	NO	NO	NO	0.0	2
2003	176	NO	NO	NO	0.1	13
2004	186	NO	NO	NO	0.1	14
2005	NO	NO	NO	NO	0.1	0
2006	34	NO	NO	NO	0.1	3
2007	71	5	NO	NO	0.2	6
2008	3 090	437	NO	NO	0.3	257
2009	3 785	2 460	415	641	1	535
2010	3 500	2 614	929	715	2	569
2011	3 891	4 583	655	665	6	718
2012	3 984	7 342	245	248	15	868

### 3.3.1 Civil aviation

Emissions from civil aviation include all domestic civil aviation: jet and turboprop powered aircraft (turbine-engined fleet in air transport) and piston engined aircraft (mostly general aviation). Helicopters are not included in the calculations of civil aviation as a separate category due to the small number of flights and lack of emission factors. However, the fuel consumption of helicopters is included as part of sector 1.A 5 (part of jet fuel consumption).

The share of the civil aviation from transport category was less than 2% and the amount of emissions was 0.21 Tg (CO<sub>2</sub> eq.) in 2012. It was 0.39 Tg in 1990. See Figure 3.3-3 and Table 3.3-6.

The variations of fuel consumption and emissions are caused by the variations of number of flights, flight hours and fleet of aircraft. The economic recession in early 1990's decreased the number of flights. In late 1990's there was increasing demand on domestic air transport and the number of commercial flights increased. During the 2000's demand decreased again. At the same time airlines renewed their fleet, and more modern and environmentally friendly aircrafts came into service. The balance between the use of turboprop-aircraft and over and under 100-seater jet aircraft has varied over the years according to market situation. These changes counterbalance each other, and therefore the emissions of domestic aviation were fairly constant until 2007 with a 9% drop in number of flights. In 2008 number of flights increased 1% but the fuel consumption decreased about 2% compared to year before. In 2009, the fuel consumption decreased further, 7% compared to 2008 while number of flights decreased less than 2%. In 2010 both number of flights and emissions reduced over 8% compared to the previous year. The fuel consumption increased about 3% in 2011, but it reduced radically, over 16%, in 2012.



**Figure 3.3-3** Emissions from domestic civil aviation (Tg CO<sub>2</sub> eq.)

**Table 3.3-6** Emissions, fuel consumption and number of flights or flight hours by fuel type in the Civil Aviation (1.A 3a) sector

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>Civil aviation, emissions, Tg CO<sub>2</sub> eq.</b>	0.39	0.34	0.32	0.29	0.26	0.27	0.31	0.34	0.39	0.39	0.38	0.38	0.33	0.33	0.34	0.32	0.32	0.29	0.28	0.26	0.24	0.25	0.21
<b>Aviation gasoline</b>																							
Fuel consumption, PJ	0.11	0.10	0.09	0.09	0.08	0.08	0.08	0.08	0.07	0.07	0.08	0.06	0.05	0.05	0.05	0.04	0.05	0.05	0.05	0.04	0.04	0.04	0.03
Flight hours (general aviation)	97 770	85 140	79 680	76 569	66 065	61 365	60 769	58 840	57 663	55 400	60 991	50 644	41 774	36 000	35 359	30 160	38 834	37 362	36 202	33 581	33 506	31 806	24 415
<b>Jet kerosene</b>																							
Fuel consumption, PJ	5.15	4.55	4.17	3.77	3.45	3.51	4.10	4.56	5.21	5.17	5.11	5.02	4.36	4.41	4.49	4.32	4.22	3.80	3.74	3.46	3.18	3.29	2.75
Number of flights (air transport)	70 256	69 881	61 894	62 121	64 874	62 599	68 010	74 233	84 386	75 035	76 658	74 066	66 745	66 876	67 132	66 509	68 951	62 458	63 266	62 282	56 984	63 358	55 059

### 3.3.1.1 Methods

For the years 1990 to 2008, the gaseous emissions and energy consumption of civil aviation within the Finnish Flight Information Region (FIR) have been calculated using the ILMI calculation model (Figure 3.3-4). The model is meant for emission studies on jet and turboprop powered aircraft (turbine-engined fleet in air transport). Furthermore, it includes a simplified routine for estimating emissions from piston-engined aircraft (mostly general aviation). The ILMI model is a submodel of the LIPASTO calculation system. The submodel has been prepared by Finavia and the data have been fed to the LIPASTO and ILMARI systems (see Section 3.3).

For years 2009-2012, the emissions from domestic aviation have been calculated using a simpler approach. The calculated estimate of the fuel consumption was received from Finavia as earlier, and all emissions were calculated by Statistics Finland using the fuel-specific emissions factors (see 3.3.1.4 and 3.3.1.7). For more information see Section 1.2.1.

The main part of the ILMI model has been produced in 1994 and 1995 in a project of the research programme MOBILE of the Ministry of Employment and the Economy (MEE). The calculation method has been described in the project report (Savola M. & Viinikainen M., 1995, in Finnish only). The model is owned by Finavia and the calculation application itself is not on offer for public use.

In the calculation of air transport each flight operation is divided into the following flight segments: taxi in, take-off, climb-out, cruise, descent, approach, taxi out. Only the flight segments and flight time of a flight within the Finnish FIR are included. It means that the full length of domestic flights is covered, but international flights and overflights are not (only the parts within the Finnish FIR). Domestic and international flights and overflights are shown separately in the summary results. The emissions from domestic flights are reported under CRF 1.A 3. The emissions from international flights, such as they are included in the ILMI model, do not follow 1996 IPCC GL. Therefore the emissions from International bunkers are calculated separately (see Sections 3.3.1.5. and 3.8).

Fuel burn and emissions are calculated separately for each aircraft type assuming fixed and representative aircraft type – engine type - pairs, more detailed information of engine type of all turbine engined fleet are not available or applicable for the model. At present the model contains approximately 140 aircraft - jet engine –pairs and 90 aircraft - turboprop engine -pairs.

The calculation is based on traffic statistics, aircraft performance data and aircraft engine emission factors (unburned hydrocarbons EF HC, carbon monoxide EF CO, nitrogen oxides EF NO<sub>x</sub> and fuel flow FF) of each flight segment from the ICAO (International Civil Aviation Organisation) database (Engine Emission Databank).

The fuel consumption per flight segment (fs) is calculated by the formula:

$$FUEL\ BURN\ per\ fs = FF\ per\ fs * FLIGHT\ TIME\ per\ fs * NUMBER\ OF\ ENGINES$$

and the emissions of HC, CO and NO<sub>x</sub> per flight segment correspondingly:

$$EMISSION\ per\ fs = EF\ per\ fs * FLIGHT\ TIME\ per\ fs * FF\ per\ fs * NUMBER\ OF\ ENGINES.$$

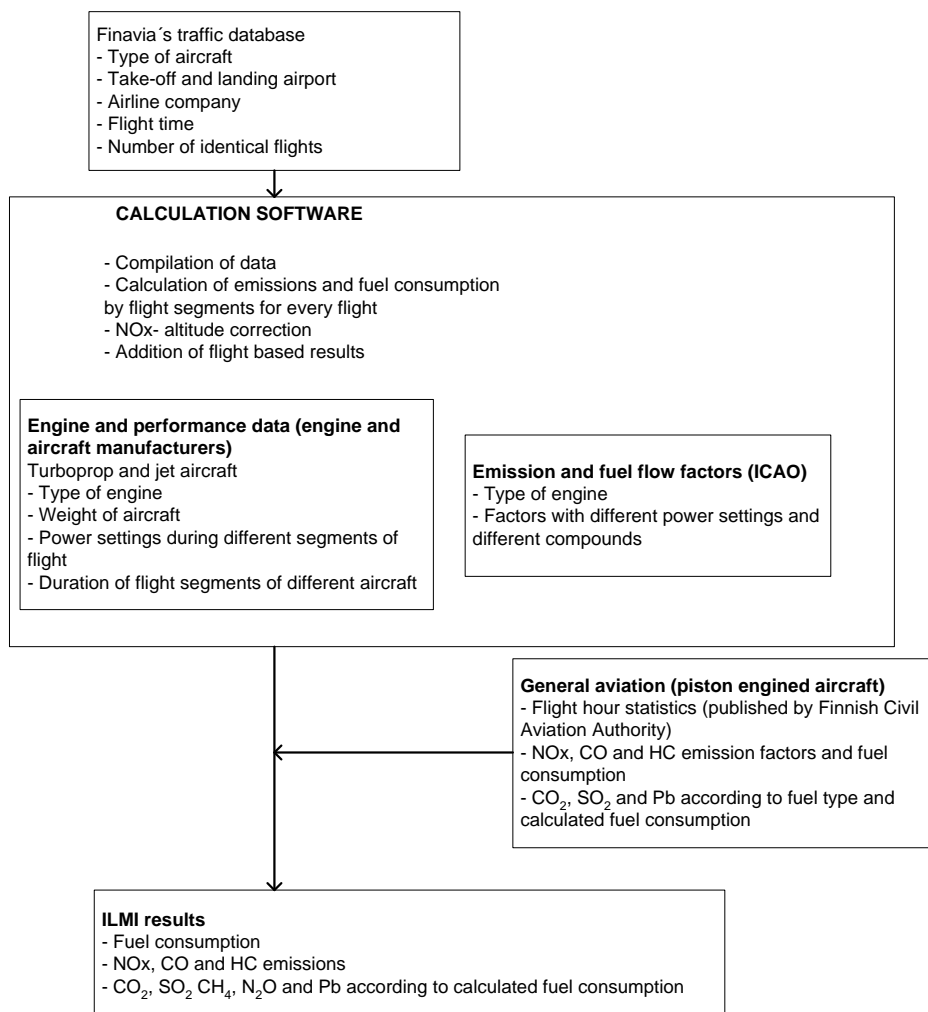
The emissions of carbon dioxide CO<sub>2</sub>, sulphur dioxide SO<sub>2</sub> and nitrous oxide N<sub>2</sub>O are derived directly from the assessed fuel consumption.

The methodology for assessing emissions from general aviation is different from the one used for air transport. It is based on the statistics of total flight hours annually published by Finnish Civil Aviation Authority. The fuel burn and emission factors used are generalised for two typical reference aircraft types only. Therefore, the results are not as reliable as for air transport.

The methods for calculating emissions from civil aviation are comparable with the IPCC Tier 3 level method for HC, CO, NO<sub>x</sub>, SO<sub>2</sub> and CO<sub>2</sub>. For CH<sub>4</sub> and N<sub>2</sub>O the methodology is comparable with the IPCC Tier 1 level method.



### Air transport (jet and turboprop powered aircraft, turbine engined fleet)



**Figure 3.3-4** The ILMI calculation model

#### 3.3.1.2 Activity data

The traffic data for calculating the air transport are taken from Finavia's database for the calculation year. The database is adopted to serve as a source of flight data for statistics and also for charging the airlines for airport and air navigation services. Some of the information comes electronically from the airlines; some is brought into the system manually at the airports.

The data include fields for:

- Aircraft type
- Engine type
- Carrier
- Departure and landing airport
- Total time of a flight
- Flight time of a flight inside the Finnish Flight Information Region (FIR)
- The number of similar flights between airports

### 3.3.1.3 *Emission factors and other parameters*

The emission calculation is based on traffic statistics, aircraft performance data and aircraft engine emission factors of each flight segment from the ICAO (International Civil Aviation Organisation) database.

The dependency on atmospheric pressure, so called altitude correction factor, is taken into consideration for the emission factors of NO<sub>x</sub> per climb-out, cruise and descent. For HC and CO it is negligible.

Emission factor for N<sub>2</sub>O (mean value 0.003 g/MJ) is derived from 1996 IPCC GL (table 1-50, p. 1.96) and the emissions of methane CH<sub>4</sub> are assumed to be 10% of HC emissions according to the table mentioned.

CO<sub>2</sub> emission factors are country specific (see Table 3.2-3: jet fuel 73.2 g/MJ and aviation gasoline 71.3 g/MJ).

### 3.3.1.4 *Uncertainties and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

A summary of the uncertainty analysis methodology used in the inventory is given in Section 1.7. Monte Carlo simulation has been used to combine the uncertainties of each calculation parameter in order to get the total uncertainty of the source category.

The emissions estimate for the years 2009-2012 are based on a simpler calculation as the previous years. For CO<sub>2</sub>, no discontinuity of time series consistency is identified, as the emissions are calculated based on the same data (fuel consumption and fuel-specific emission factors). For the other gases, the emission factors are dependent also on the technology used. In the estimation of these emissions for 2009-2012, emission factors for 2008 are used. The recent years, the annual changes in these emission factors have been small. Noting the overall minor contribution of the non-CO<sub>2</sub> emissions to this category's total emissions, the impact on time series consistency is estimated to be negligible.

### 3.3.1.5 *Source-specific QA/QC and verification*

Statistics Finland crosschecks the fuel consumption data received from Finavia. Jet fuel and aviation gasoline consumption data from Finavia are summed up in the ILMARI system with other user's estimated consumption and the calculated totals are compared to total sales of these fuels.

Finavia has verified the air transport calculation of the ILMI model with Eurocontrol's emission data for 2004. Finavia's domestic data and overflights data (not reported in the inventory) were comparable and very close to those estimated by Eurocontrol. The calculated fuel consumption by ILMI model for domestic flights was 5% higher than the estimate by Eurocontrol and the results for overflights matched completely. Only NO<sub>x</sub> in overflights was of different magnitude. Results for international flights or the bunker fuel data were not directly comparable to the results of the ILMI model, because of different definitions and geographical boundaries.

Statistics Finland calculates and reports bunker fuel emissions according to the IPCC definitions (see Section 3.8). The results of Eurocontrol were close to those reported in the greenhouse gas inventory (Graichen, 2007). The difference in the total fuel consumption (domestic flights + bunkers) between Finnish greenhouse gas inventory data and Eurocontrol data was around 3% in 2005. Also the data on the share of domestic flights from total aviation were fairly close in both sources (Graichen, 2007).

### 3.3.1.6 *Source-specific recalculations*

Time series for 2005-2010 have been recalculated. The reason for recalculation was the presumed inconsistency in fuel consumption data in these years. The corrected fuel data estimates were based on several data sources, which include partly contradictory data. The most reliable data source was the number of flights data received from Finavia. Other sources were Eurocontrol fuel consumption and number of

flights data, separate sets for 2005-2010, 2011 and 2012. In addition to these, ETS data were received for years 2010-2012, including fuel consumption and number of flights data.

Using these data sets and expert estimates, fuel consumption and CO<sub>2</sub> data were recalculated. The corrections were between -3 and -7% compared to previous estimates. This affected mainly to the allocation of emissions, because total fuel consumption data taken from the Energy Statistics was not changed.

We are still expecting slight recalculations, when Eurocontrol will provide the full time series, calculated using the same model version.

### 3.3.1.7 Source-specific planned improvements

A new system to calculate emissions from civil aviation will be considered if the Eurocontrol system will not be provided in 2013, see Section 1.2.1.

## 3.3.2 Road transportation

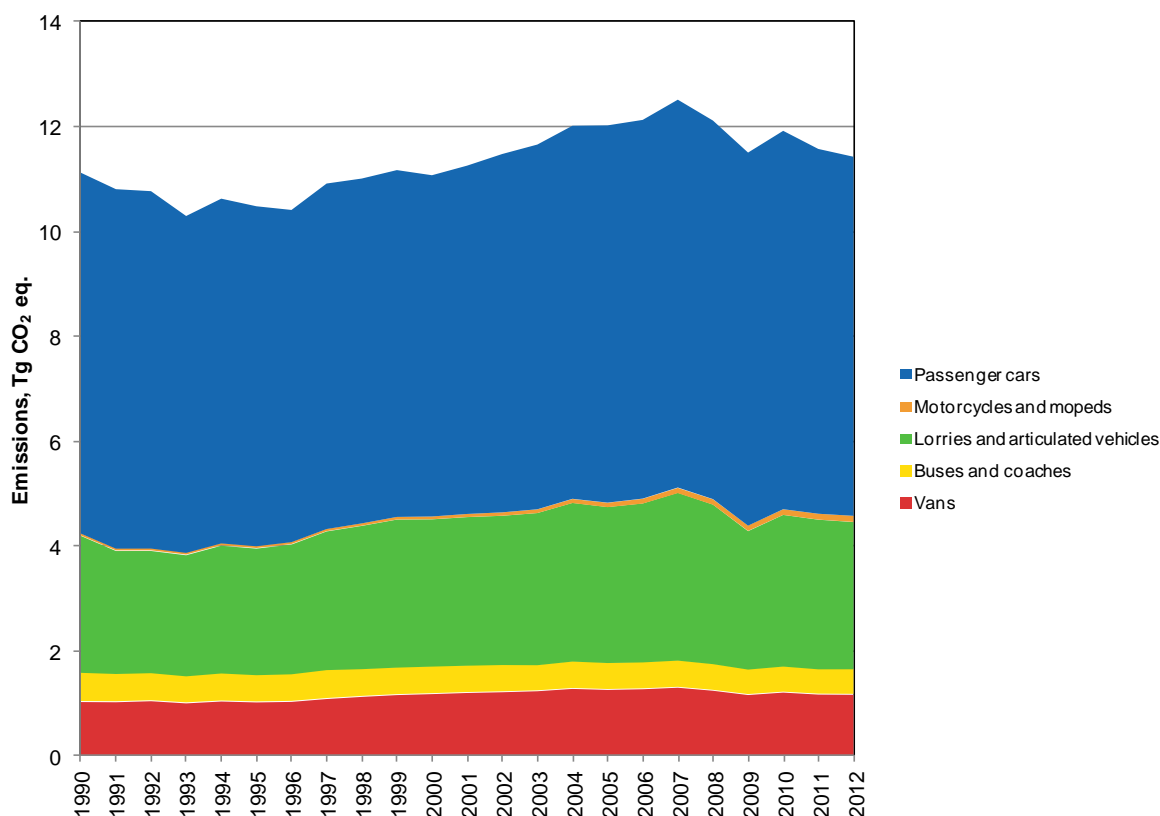
Road transportation (CRF 1.A 3b) covers all transportation on roads in Finland except farm and forest tractors driving occasionally on the roads or military vehicles. Types of vehicles with combustion engines are: cars, vans, buses and coaches, lorries and articulated vehicles, motorcycles and mopeds.

Road transportation is the most important emission source in the Transport sector. The emissions of road transportation were 11.2 Tg (CO<sub>2</sub> eq.) in 2012; that was over 89% of the sector's emissions and 18% of the total emissions. Emissions were 11.1 Tg (CO<sub>2</sub> eq.) in 1990. The lowest emission level in the road transportation was achieved 1993 because of the economic depression in Finland. After that the highest proportional increase has been in freight transportation (vans, lorries and articulated vehicles). Emissions are now 2% higher than 1990 (Figure 3.3-5).

The main reason for emission growth is increased kilometrage. Fuel consumption per vehicle has stayed quite stable (see also Table 3.3-7). Buses and coaches are the only vehicle type which kilometrage and emissions have decreased in the whole time series. Emissions of motorcycles and mopeds have doubled since 1990, but their share was in 2012 less than 1% of emissions in Road transportation.

In 2008 the emissions deviated from the upward trend. The worldwide economic downturn that began 2008 decreased the emissions of all transport modes. At the same time, the change in Finland to CO<sub>2</sub> based taxation of cars has caused a transition from gasoline to diesel cars and lowered the specific fuel consumption of new cars, both gasoline and diesel. Kilometrage of lorries and articulated vehicles decreased almost 9% and emissions over 13% in a year. The upward trend in 2010 emissions compared to 2009 is due to the recovery from the economic downturn. The increase in emissions is especially in heavy-duty transport; as the number of tonne-kilometres of goods transport increased 7%.

The trend in emissions in 2012 compared to 2011 has continued downwards because of the prolonged economic downturn.



**Figure 3.3-5** Emissions from road transportation by types of vehicle (Tg CO<sub>2</sub> eq.) (The detailed transport calculation models LIPASTO of VTT Technical Research Centre of Finland)

### 3.3.2.1 Methods

Emission estimations from road transportation are made using the road traffic emission model LIISA, which is a part of the model for all transport modes, LIPASTO of VTT Technical Research Centre of Finland. The calculations comprise the emissions of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O. The same model is also used for the calculation of SO<sub>2</sub>, CO, NMVOC, NO<sub>2</sub> and PM emissions.

The methods for calculating emissions from road transportation correspond to the IPCC Tier 3 level method. Calculation of CO<sub>2</sub> emissions is based on fuel consumption of road vehicles and the emission factors. The calculation model is described in Appendix\_3a at the end of Chapter 3. The definition of consumption of fuel on the country level is based on fuel sales. Road traffic in Finland uses basically two different fuels, reformulated gasoline and diesel oil. Besides road traffic use, the gasoline sold in Finland is also used in working machines and leisure boats and hence the amount of gasoline used for other purposes than road traffic is deducted from the total sales of gasoline before the emission calculation (see under the paragraph Activity data). Diesel fuel sold in Finland is used almost exclusively by road traffic, but starting from 2008 diesel has been used also as fuel in leisure boats. The amount of fuel imported in fuel tanks of vehicles from other countries is estimated to be small. The use of natural gas in road traffic in Finland is very small and is not included in the LIISA model. The emissions from natural gas in road traffic are calculated separately in the ILMARI model (see Section 3.1.1.3) based on activity data obtained from annual Energy Statistics.

N<sub>2</sub>O and CH<sub>4</sub> emissions are based on kilometrage data (km/a) and calculated for gasoline and diesel vehicles separately. The kilometrage (km/a) of each automobile type and model year on different road types and in different speed classes are multiplied with the corresponding CH<sub>4</sub> and N<sub>2</sub>O emission factors (g/km). Emission factors are a sum of hot driving, idle and cold start-ups. Finally, all emissions are summed up. The calculation model is described in Appendix\_3a at the end of Chapter 3.

The motorcycle and moped kilometrage is specified in a separate model using the number of motorcycles and mopeds (from Statistics Finland) and an estimation of the yearly kilometrage of each two-wheel type on two road types (roads and streets).

The kilometrage [km/a] data for automobiles consist of two main categories: kilometrage on public roads (roads governed by the Finnish Transport Agency) and kilometrage on streets (governed by municipalities).

Automobile kilometrage on public roads consists of aggregated kilometres driven by five vehicle types (cars, vans, buses and coaches, lorries and articulated vehicles) on four road types (main roads in built-up areas, classified roads in built-up areas, main roads in rural areas and classified roads in rural areas) in six speed limit classes (50, 60, 70, 80, 100 and 120 km/h). These data allow detailed calculations to be performed on a smaller area than a country because the detailed data in the model are on the municipality level. For nationwide calculations the kilometrage is summed up.

Street kilometrage is based on a total kilometrage estimation made by the Finnish Transport Agency and crosschecked by the studies made at inspection stations. The estimated street kilometrage data are further divided into subtypes by vehicle based on the current fleet composition and information from traffic calculations in some cities (cars to gasoline, cars without catalytic converters, cars with catalytic converters and diesel cars, vans to gasoline, vans without catalytic converters, vans with catalytic converters and diesel vans). Furthermore, kilometrage is divided according to vehicle age (model year) based on fleet composition, thus allowing more precise consideration of engine technology.

Motorcycle and moped kilometrage is specified in a separate model using the number of motorcycles and mopeds and estimation of yearly kilometrage of each two-wheel types on two road types (roads and streets). Mopeds have only one engine type but kilometrage is further divided according to different emission standards (Euro 1 and Euro 2). Motorcycles have two main types of engines, two-stroke and four-stroke. Kilometrage is divided into these main types and further to three engine volumes (under 250 ccm, 251-750 ccm and over 750 ccm) and according to emission standards (Euro 1 and Euro 2).

For each automobile type, the amount of idle (min/d) is estimated. The number of cold start-ups per 1,000 vehicle kilometres is determined based on a separate research projects (Mäkelä 1993 and Mäkelä 1994).

### 3.3.2.2 Activity data

The activity data in CO<sub>2</sub> calculation are the amount of fuel consumed in road traffic. Total fuel sales are from statistics compiled by the Finnish Petroleum Federation. Fuel sales statistics are very accurate in Finland. Unlike in many parts of Europe where through traffic is heavy, in Finland national fuel sales correspond well with the fuel used in Finland. Gasoline used in road transport in Finland was 60.3 PJ and in leisure boats and working machines 5.4 PJ (8.0% of total sales). Diesel fuel sales were 101.8 PJ of which use in leisure boats was 0.5 PJ (0.6% of total sales). Biodiesel and biogasoline are included in these figures.

The amount of gasoline used in other purposes than for road transportation is deducted from the total sales of gasoline. Gasoline used in working machines is calculated with the TYKO model (See Section 3.3.5). Gasoline and diesel used in leisure boats are calculated with the MEERI model (See Section 3.3.3).

For modelling purposes, the data are broken down into different vehicle types and road types. However, this does not affect the country level CO<sub>2</sub> emission calculation because at the end these sub-results are summed up and the total fuel consumption remains unchanged.

For activity data for N<sub>2</sub>O and CH<sub>4</sub> calculations, the Finnish Transport Agency has provided the kilometrage [km/a] on public roads as a database from the road register. Further division to subcategories is done at VTT. Data for total street kilometrage in Finland are obtained from the Finnish Transport Agency. Further division is made at VTT. Division of kilometrage to subcategories is based on vehicle fleet data from Statistics Finland, research done by the University of Oulu and VTT, street kilometrage systems of city of Helsinki and Espoo and population data of cities.

The motorcycle and moped kilometrage is specified in a separate model using the number of motorcycles and mopeds (from Statistics Finland) and an estimation of the yearly kilometrage of each two-wheel type on two road types (roads and streets).

Road traffic kilometrage in Finland in 1990-2012 is presented in Table 3.3-7.

**Table 3.3-7** Road traffic kilometrage in Finland [Million km/a] (LIISA)

Year	Cars	Vans	Buses	Lorries	MC+Mopeds	Total
1990	35 757	3 593	660	2 780	467	43 257
1991	35 607	3 610	650	2 530	468	42 865
1992	35 530	3 667	640	2 500	470	42 807
1993	35 156	3 655	639	2 570	463	42 484
1994	34 980	3 626	633	2 582	456	42 277
1995	35 318	3 662	633	2 632	468	42 714
1996	35 595	3 685	635	2 669	478	43 062
1997	36 542	3 744	643	2 750	491	44 169
1998	37 522	3 865	606	2 795	515	45 303
1999	38 622	3 966	596	2 867	556	46 606
2000	39 257	4 033	596	2 807	607	47 300
2001	40 122	4 106	593	2 834	663	48 319
2002	41 100	4 153	598	2 905	733	49 489
2003	41 992	4 217	568	3 012	812	50 601
2004	42 945	4 280	590	3 077	898	51 790
2005	43 617	4 335	591	3 134	989	52 665
2006	44 009	4 371	589	3 189	1 099	53 256
2007	44 948	4 432	586	3 287	1 211	54 463
2008	44 672	4 416	597	3 292	1 311	54 288
2009	45 301	4 449	601	3 001	1 358	54 709
2010	45 608	4 466	604	3 141	1 437	55 256
2011	46 135	4 504	604	3 218	1 558	56 020
2012	45 968	4 484	608	3 177	1 653	55 890

The source of the number, types and age of vehicles is the Finnish vehicle register (data obtained from Statistics Finland, the register is maintained by the Transport Safety Agency, TraFi).

The number of cold start-ups is based on research carried out at VTT (Mäkelä 1993 and Mäkelä 1994).

The activity data for natural gas used in road transport are taken from Energy Statistics.

#### *Bioshares of transport fuels*

Activity data of blended biofuels for 2002 - 2007 are based on separate survey made by Statistics Finland (Energy statistics team). The data includes the amount of blended biogasoline (ethanol), starting from 2002, as well as blended biodiesel, starting from 2007. The data of other biogenic compounds, like ETBE (ETBE = ethyl tert-butyl ether, a bioethanol based gasoline component), are not available for these years.

Due to the expiration of the periodic deduction of fuel tax there was no consumption of bioethanol in 2005 (Ministry of Employment and the Economy, 2006), but in 2006 bioethanol re-entered the market.

Starting from 2008, the activity data of blended and pure biofuels are collected by Finnish Customs. These data include the following biofuels and bio-components:

- bioethanol, NExBTL-gasoline, bioshares of ETBE, TAEE<sup>7</sup> and THxEE<sup>8</sup>
- biodiesel and synthetic biodiesel (mostly NExBTL<sup>9</sup>-diesel)
- biogasoil mixed in the non-road gasoil (mostly NExBTL-diesel)

<sup>7</sup> tertiary amyl ethyl ester

<sup>8</sup> tert-hexyl ethyl ether

<sup>9</sup> Production process for renewable diesel oil, commercialised by Neste Oil co. A small amount of bio gasoline is by-produced in the process

The consumption of biofuels is originally included in the total sales data of gasoline and diesel oil. Calculations in LIISA and other LIPASTO transport submodels are performed using total fuel consumption data, including biofuels. In the LIPASTO system, the CO<sub>2</sub> emission data include only fossil emissions. For the GHG inventory, calculated consumption data are split to fossil and biogenic parts. CO<sub>2</sub> emissions are calculated separately in the ILMARI system for fossil parts and biogenic parts of transport fuels. All other emission components are based on LIPASTO and split to fossil and biogenic parts according to TJ shares.

In 2012 bioshares of gasoline and diesel oil were 6.1% and 7.2% respectively (calculated from TJ).

Biogenic CO<sub>2</sub> emissions are calculated directly from tonnes of used biogenic fuel, because conversion factors from tonnes to TJ and TJ to CO<sub>2</sub> are considered more uncertain. Biogenic emissions are from 2008 onwards allocated to the transport and machinery subcategories using these fuel types.

Biogas consumption in transport has been very small until 2009, but now the volume has started growing. Time series on biogas data starting from 2002 is now available in the Energy statistics. The activity data are based on background data tables of annual publication of the Finnish Biogas association and the University of Eastern Finland (Huttunen and Kuittinen 2011). The share of biogas from total gas consumption in road transport was 8.3%.

### 3.3.2.3 Emission factors and other parameters

Emission factors are determined for all the activity categories mentioned above. CO<sub>2</sub> emission factors are based on national figures (Table 3.2-3). They differ slightly from those expressed in the IPCC guidelines. The emission factors are based on product analysis in Neste Oil laboratories. Neste Oil is the leading company in oil product manufacturing in Finland (market share over 90%). Reformulated gasoline and diesel oil have different CO<sub>2</sub> emission factors. The same emission factor is used for both gasoline types E95 and E98.

Country-specific net calorific values and CO<sub>2</sub> emission factors are shown in Table 3.2-3. The table includes separately data for fossil and biogenic shares of blended liquid fuels.

Emissions factors for CH<sub>4</sub> and N<sub>2</sub>O are a sum of hot driving, idle and cold start-ups. The inventory review from 2008 recommended Finland to check the N<sub>2</sub>O emission factor for gasoline. The comparison of EFs stated that all European countries have different EFs for N<sub>2</sub>O transport emissions. According to the recommendations in the review the N<sub>2</sub>O emission factors have been thoroughly checked and updated in the LIISA model. Emission factors used in the COPERT 4<sup>10</sup> program have been used as the reference values. The only vehicle categories that needed substantial modifications were gasoline cars and vans equipped with catalytic converters. Originally the LIISA model included only one N<sub>2</sub>O factor for catalytic converters. Now all the Euro-classes (i.e. each catalytic converter generation) of vehicles have own emission factor. Trend in the emission factors for vehicles with catalytic converters have been declining. As a result N<sub>2</sub>O emissions calculated with the LIISA model are substantially lower after 1990 than reported earlier.

The same CH<sub>4</sub> and N<sub>2</sub>O emissions factors are used for the fossil and biogenic share of the same fuel type.

CH<sub>4</sub> and N<sub>2</sub>O emissions factors for natural gas in road transport are taken from 1996 IPCC GL (Table 1-8 and Table 1-43). The same emission factors are used for biogas also.

### 3.3.2.4 Uncertainties and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

<sup>10</sup> [Copert 4](#) is an MS Windows software program aiming at the calculation of air pollutant emissions from road transport. The technical development of COPERT is financed by the European Environment Agency (EEA).

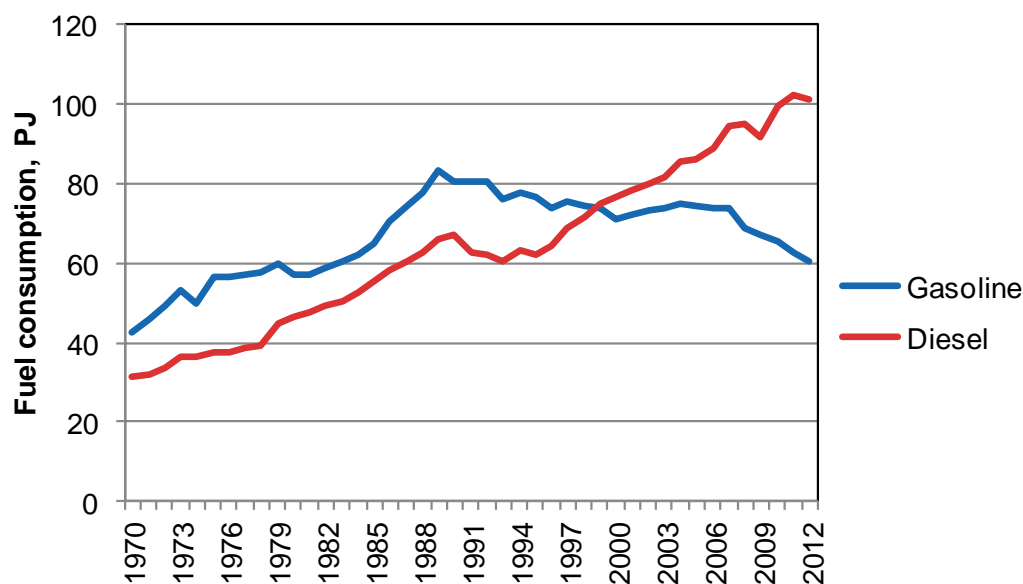
A summary of the uncertainty analysis methodology used in the inventory is given in Section 1.7. Monte Carlo simulation has been used to combine the uncertainties of each calculation parameter in order to get the total uncertainty of the source category.

The activity data for fuels used in road transportation are very accurate due to accurate total fuel sales statistics. For the purposes of the uncertainty estimate, road transportation is divided into gasoline, diesel and natural gas driven vehicles. For the estimation of N<sub>2</sub>O emissions, gasoline driven cars are divided into cars with and without catalytic converters.

Emissions of CH<sub>4</sub> and N<sub>2</sub>O depend on driving conditions and hot and cold start-ups, for example, and vary greatly during the driving cycle and between different vehicles. Emission estimates also depend on the vehicle kilometrage estimates and are thus more uncertain than CO<sub>2</sub> emissions. CH<sub>4</sub> emission factors are estimated to contain uncertainty of around  $\pm 50\%$  based on measurements of hydrocarbon emissions (Tarantola & Kioutsioukis, 2001) and IPCC default uncertainties (IPCC, 2000).

N<sub>2</sub>O emissions vary more than CH<sub>4</sub> emissions and are highly dependent on the type and age of the catalytic converters used. N<sub>2</sub>O emission factors are estimated to contain uncertainty of  $\pm 150\%$ .

The economic recession of the early 1990's in Finland may perhaps explain why road traffic emissions did not increase as rapidly in Finland as in other Annex I countries. Figure 3.3-6 shows the consumption of diesel and gasoline in road transportation. Both fuels show an increase of about 1 PJ per year during the 1970's and 1980's. Then the consumption fell rapidly from 1990 onwards. Diesel consumption has returned to the pre-recession growth rate, but gasoline consumption has decreased, on average, by 1 PJ per year since the 1991 record-high level. Had the consumption of both fuels followed the pre-recession growth rate, without the decrease of the early 1990's, then the current level of consumption would give comparable percentage growth rates to those observed for other Annex I countries.



**Figure 3.3-6** Consumption of diesel oil and gasoline (including bioshares) in road transportation in the years 1970-2012 (Energy Statistics, Statistics Finland, 2013)

The road traffic kilometrage in Finland has increased by about 20 per cent in the period of 1990-2004, but the corresponding CO<sub>2</sub> emissions have only increased by 9 per cent. The divergence is thus ca. 10%. According to the statistics the energy efficiency of new cars has increased by 4-5% during the period of 1990-2008. The remaining 5% could be explained by the overestimation of the kilometrage. The yearly kilometrage on highways in Finland is fairly accurate ( $\pm 2\%$ ) because of the very sophisticated measuring system on the road network. On the contrary, the kilometrage driven on streets is rather poorly known, as is the case in all countries. The total kilometrage in a city is not a key issue in the transport planning. However, the street kilometrage forms ca. one third of the total kilometrage. Roughly estimating the margin of error of street kilometrage could be up to  $\pm 20\%$ . The problem has been identified earlier and research efforts have



already been taken to solve it. A preliminary study was conducted in 2008. However, methods to measure the street kilometrage are all expensive and present efforts have not yet yielded proper results. The kilometrage problem is planned to be solved during the update of the LIISA road transport model in 2014.

### 3.3.2.5 Source-specific QA/QC and verification

The quality management process and the QA/QC plan for the whole inventory are presented in Section 1.6. The QA/QC plan for the transport sector includes the QC measures based on GPG 2000. These measures are implemented every year during the transport sector inventory. Potential errors and inconsistencies are documented and corrections are made if necessary. The bilateral quality meeting, which function as Tier 1 QA review, are held annually between the inventory unit and the sectoral expert.

Small differences (for most years less than 1%) in total diesel oil and gasoline consumption taken as a sum from LIPASTO transport submodels compared with total fuel sales data taken from the Energy Statistics have been identified. These differences are caused by disaggregation, conversions between quantity units and roundings in different stages of the process. These differences are corrected in ILMARI system for road transport, which is the largest subcategory of diesel oil and gasoline consumption, to ensure full consistency between Energy Statistics and GHG inventory. The corresponding CO<sub>2</sub> emissions are corrected as well.

### 3.3.2.6 Source-specific recalculations

There were minor corrections in the total gasoline consumption as well as bioshares in 2011 data.

### 3.3.2.7 Source-specific planned improvements

As already stated in Section 3.3.2.4 there exists some inconsistency in kilometrage and fuel consumption data. A preliminary study of the total kilometrage was conducted during 2008 and will be further extended to kilometrage per vehicle. This will be done by analysing the massive amount of vehicle inspection data available. The kilometrage problem is planned to be solved during the update of the LIISA road transport model in 2014.

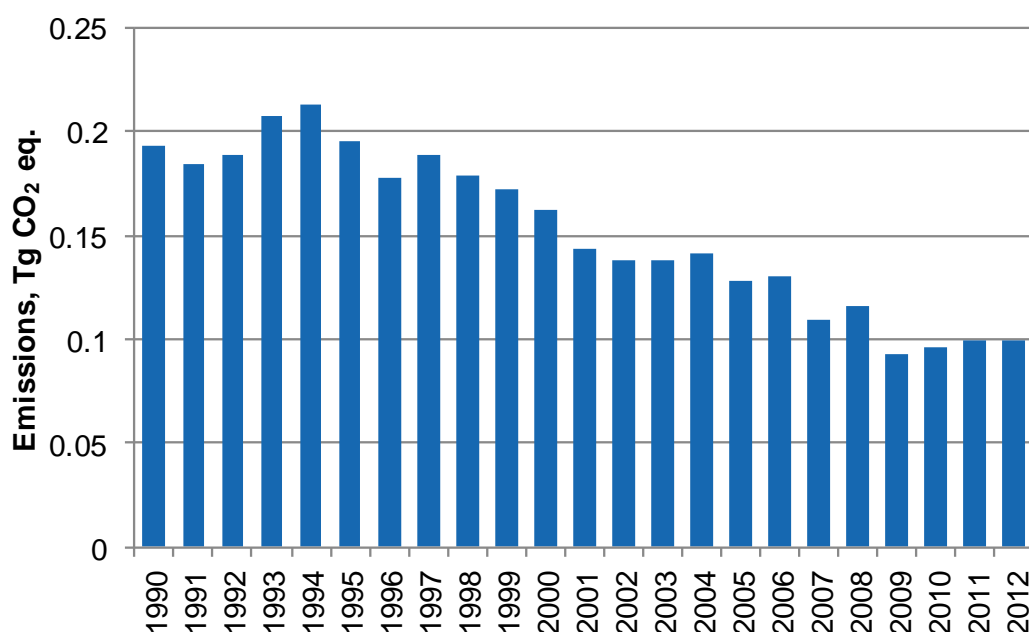
During the year 2013 transport emission calculation system LIPASTO at VTT will be thoroughly renewed. The first calculation year with the new LIPASTO will be 2013. The renewal concerns road (LIISA), railway (RAILI), domestic navigation (MEERI) and other transportation (TYKO) models. For the road transportation the kilometrage problem mentioned above is planned to be solved during the renewal. The renewal will guarantee that methodology, activity data and emission factors are up to date and in line with the 2006 IPCC Guidelines. The new LIPASTO will be applied for estimating the emissions in the 2015 submission.

## 3.3.3 Railway transportation

Emissions of railway transportation in Finland comprise railway transport operated by diesel locomotives. In 2012 electric locomotives ran 85% of railway transportation, the number has increased by 2 percentage unit since 2008. Emissions from producing electricity used in electric trains are not included this category, but in category 1.A 1. According to the Transport and Communications Statistical Yearbook produced by Statistics Finland, in 2012 rail services accounted for over 26% of all freight carryings in Finland, which is considerably higher than the average for EU countries. In 2012 the volume of freight transport in Finland totalled 35.3 million tonnes, which is 1.3% less than in 2011 (Transport and Communications Statistical Yearbook for Finland, 2013).

Railway transportation is a minor emission source in the transport sector. The emissions of railway transportation were 0.10 Tg (CO<sub>2</sub> eq.) in 2012, it was less than 1% of the sector's emissions. The emissions were 0.19 Tg (CO<sub>2</sub> eq.) in 1990 (Figure 3.3-7). Greenhouse gas emissions from diesel trains have decreased since 1994, because electrification of railway lines has progressed and transportation in minor, non-electrified railway lines has ceased. The recession and the rapid restructuring in Finland's forest industry significantly reduced freight carryings in 2008 and 2009. Finland is recovering from the recession but the economic situation elsewhere in Europe remains uncertain. As the recession eased in 2010, the volume of

carriages started to pick up. Since 2009 the emissions are increased 8% because the recovery of heavily transport-dependent industry.



**Figure 3.3-7** Emissions from railway transportation (Tg CO<sub>2</sub> eq.)

### 3.3.3.1 Methods

Calculations of emissions from railway transportation are made using the railway traffic emission model RAILI, which is a part of the model for all transport modes LIPASTO of VTT Technical Research Centre of Finland. Calculation comprises the emissions of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O. The same model is also used for the calculation of SO<sub>2</sub>, CO, NMVOC, NO<sub>2</sub> and PM emissions. In the RAILI model emissions are calculated by multiplying the amount of fuel used (kg) with emission factors (g/kg fuel). (The calculation model is described in Appendix\_3a at the end of Chapter 3). The calculation method is consistent with the IPCC Guidelines (corresponds to the Tier 3 level method.).

The amount of fuel used is calculated separately for passenger transport, freight transport and locomotives without wagons and for rail yard operations. To include the mobilisation time of the fleet, preparation and finishing times and extra transfer of the fleet, the amount of fuel is multiplied by a factor. This factor is based on an earlier study (research done by VR-Group Ltd, the Finnish railway operator) where the total energy use of these activities was calculated and then divided with the total amount of tonne kilometres resulting in a factor for the extra fuel consumption per tonne kilometre.

### 3.3.3.2 Activity data

Activity data consist of gross tonne kilometres for ten train weight classes on all rail sections (212 sections). Shunting locomotive use is expressed as time (h/a) in all rail yards. There are four separate diesel locomotive types in the model and ten train weight classes for both passenger and freight transport. For every locomotive type, specific energy consumption (litre/gross tonne km) has been determined. Shunting locomotive consumption is determined as litres per hour. Emission factors are expressed as grams per kg fuel used for each gas. Density for the diesel oil is 845 kg/m<sup>3</sup>. Emissions from wagon heating and the use of aggregates (for electricity production) are calculated by multiplying gross tonne kilometres with emission factors for wagon heating and aggregates.

Fuel oil consumption in railway transportation in Finland is presented in Table 3.3-8.

The gross tonne kilometre database and shunting locomotive statistics originate from VR-Group Ltd, the only railway operator in Finland. The calculated amount of diesel fuel is crosschecked with the information

of VR-Group Ltd on the total fuel usage. All fuel used in railway transportation is nowadays gasoil for non-road use, which is technically the same product as sulphur free diesel oil.

**Table 3.3-8** Fuel oil consumption in railway transportation in Finland (tonnes/a, VR-Group Ltd)

Year	tonnes/a
1990	57 807
1991	55 352
1992	56 865
1993	62 228
1994	63 624
1995	58 021
1996	52 917
1997	56 156
1998	53 071
1999	51 101
2000	48 132
2001	42 521
2002	41 029
2003	40 938
2004	41 869
2005	38 039
2006	40 853
2007	34 412
2008	36 508
2009	29 403
2010	30 674
2011	31 779
2012	31 563

### 3.3.3.3 Emission factors and other parameters

The emission factors used in the calculation of emissions from Railway transportation are presented in Table 3.3-9. The emission factors of CH<sub>4</sub> and N<sub>2</sub>O are based on international measurements and the IPCC guidelines. The N<sub>2</sub>O emission factor for wagon heating (0.0071 g/kg fuel) is derived from U.S. EPA (2002) (residential furnace). The CO<sub>2</sub> factor is presented in Table 3.2-3.

In 2012 0.7% share of the fuel oil consumption (calculated in TJ) is estimated to be biogasoil, which has been taken into account in CO<sub>2</sub> emission estimates.

**Table 3.3-9** Emission factors used in the calculation of emissions from Railway transportation (Neste Oil, IPCC guidelines)

Fuel type	N <sub>2</sub> O emission factor g/kg fuel	CH <sub>4</sub> emission factor g/kg fuel	Net caloric value TJ/kilotonne fuel	Density kg/m <sup>3</sup> fuel
Gasoil	0.0854	0.1708	42.7	845

The N<sub>2</sub>O emission factor for non-road diesel engines is taken from 1996 IPCC GL, but the factor given for US Non-Road Mobile Sources (0.08 g/kg<sub>fuel</sub>, Table 1-47) is used instead of the one given for Europe (1.3 g/kg<sub>fuel</sub>, Table 1-49). The factor for Europe is 16 times higher than that for the US. According to the international measurement data obtained so far, the US value seems to be more accurate and in line with automobile engines.

### 3.3.3.4 *Uncertainties and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

A summary of the uncertainty analysis methodology used in the inventory is given in Section 1.7. Monte Carlo simulation has been used to combine the uncertainties of each calculation parameter in order to get the total uncertainty of the source category.

All non-electric locomotives in Finland use gasoil as fuel. Uncertainty in fuel use is estimated at  $\pm 5\%$  based on expert judgement. As the fuel quality is rather constant and carbon in the fuel is nearly completely oxidised, uncertainty in CO<sub>2</sub> emissions is estimated to be low. This was also shown in a measurement project of Kymenlaakso Polytechnic (Korhonen & Määttänen, 1999). In the current inventory, CO<sub>2</sub> uncertainties are estimated at CRF category level 1.A.

Uncertainties of CH<sub>4</sub> and N<sub>2</sub>O emission factors are larger than those of CO<sub>2</sub>. These emissions vary depending on engine design and maintenance, and the start-ups and shutdowns of the engines are likely to affect emissions. Uncertainty in the emission factor for CH<sub>4</sub> was estimated based on variation in hydrocarbon emissions in a measurement project (Korhonen & Määttänen, 1999). Uncertainty in the N<sub>2</sub>O emission factor was based on expert judgement (see Monni et al., 2003) and on uncertainty in emission factors for diesel engines used for other purposes. Reduction of uncertainty in CH<sub>4</sub> and N<sub>2</sub>O emission estimates would require more measurement data and more information on the use of the engines of locomotives (frequency of start-ups, shutdowns, etc). However, the importance of these emissions in the Finnish greenhouse gas inventory is very small.

### 3.3.3.5 *Source-specific QA/QC and verification*

The quality management process and the QA/QC plan for the whole inventory are presented in Section 1.6. The QA/QC plan for the transport sector includes the QC measures based on GPG 2000. These measures are implemented every year during the transport sector inventory. Potential errors and inconsistencies are documented and corrections are made if necessary. The bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert.

The amount of gasoil calculated by VTT is crosschecked with the information of VR-Group Ltd on the total fuel usage. Statistics Finland crosschecks the fuel consumption data calculated within the RAILI model.

### 3.3.3.6 *Source-specific recalculations*

Erroneous formula was corrected for 2009-11.

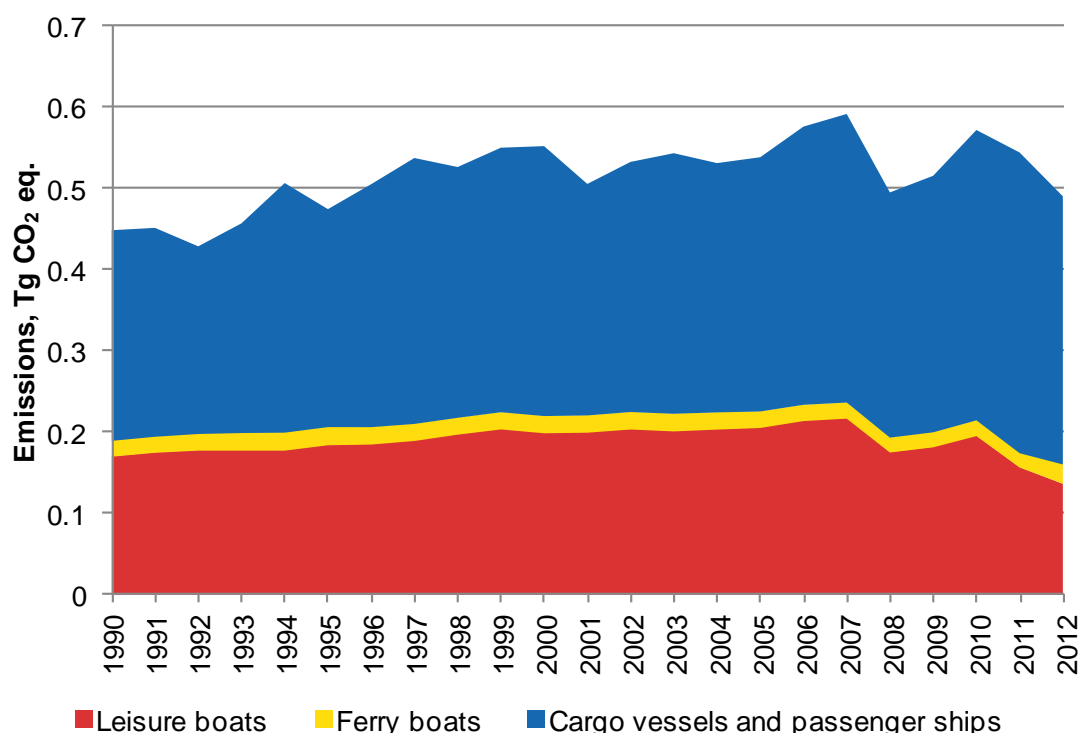
### 3.3.3.7 *Source-specific planned improvements*

During the year 2013-2014 the railway model RAILI will be renewed included in the renewal of the LIPASTO calculation system as described in Section 3.3.2.7. The inventory year 2013 will be calculated using the new LIPASTO calculation system.

## 3.3.4 *Domestic navigation*

Domestic navigation includes the most important domestic waterway transport in Finland: sea-going ships, icebreakers, working boats, cruisers, ferryboats and leisure boats. Fishing boat emissions are included in the Agriculture, forestry and fisheries' sector (CRF 1.A 4c).

Domestic navigation is a minor emission source in this category. The emissions of domestic navigation were 0.49 Tg (CO<sub>2</sub> eq.) in 2012, it was under 4% of the sector's emissions. The emissions were 0.45 Tg (CO<sub>2</sub> eq.) in 1990. Emissions from domestic navigation by ship types are presented in Figure 3.3-8.



**Figure 3.3-8** Emissions from domestic navigation by ship types (Tg CO<sub>2</sub> eq.)

Amount of leisure boats increased strongly all along in the 80's as well as visits of ships in ports. The increase was folded by the recession in the beginning of 90'. Amount of visits in ports have been fluctuating during whole time series. In Finland during 2008 two contemporaneous changes concerning leisure boating took place, namely a significant increase in fuel price and a change in legislation stating that all diesel driven boats had to use higher taxed diesel fuel. All this led up to clearly low use of the leisure boats. The methodology of leisure boat emission calculation was changed during the year 2011 as described in Section 3.3.4.7. Passenger ships show stable trend while cargo vessels have downward trend due to the prolonged economic downturn. Depending on the ice conditions at the Baltic Sea the fuel consumption of icebreakers can vary substantially as can be seen in Table 3.3-10. The winter 2007-2008 was mild and hence icebreaker emissions were low. The winter 2008-2009 was moderate and icebreaker emissions were clearly higher than in the previous year thus affecting the total emissions from navigation to be higher than in 2008. The winter 2009-2010 was cold and long thus increasing the fuel use of icebreakers substantially from the previous year. The winter 2010-2011 was again moderate and 2011-2012 mild.

#### 3.3.4.1 Methods

Calculations of emissions from civil navigation are made with the waterway traffic emission model MEERI, which is a part of the model for all transport modes LIPASTO. Calculation comprises emissions of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O. The same model is also used for the calculation of SO<sub>2</sub>, CO, NMVOC, NO<sub>2</sub> and PM emissions.

In the MEERI model, emissions are calculated by multiplying the amount of energy used (kWh) by the corresponding emission factors (g/kWh). However, emissions from icebreakers, working boats, cruisers and ferryboats are calculated by multiplying the amount of fuel used (kg/a) by emission factors (g/kg fuel). The methods for calculating emissions from domestic navigation are equivalent with the IPCC Tier 3 level method.

The activity data of ships driving in shipping channels outside ports (km/a) are calculated using the number of port visits and the distances between the ports (km). The total energy use (kWh) is calculated for every ship type using the data on engine power (kW), engine load (%) and speed (km/h).

For calculating emissions in ports, the time (h) of manoeuvring and berthing is determined. Using engine power (kW), engine load (%) and time (h) taken for manoeuvring and berthing, the total energy use in the ports (kWh) is calculated for every ship type. The total emissions are obtained by multiplying the total energy use (kWh) of ships by the emission factors (g/kWh) of different engine types (2-stroke and 4-stroke

and auxiliary engines) (g/kWh). Basic emission factors are at 1996 level and technical factors are used to describe the trend in emission factors

Icebreaker and ferryboat emissions are calculated using total fuel consumption (from operator statistics, Icebreaker consumption from Arctia Shipping Oy and ferryboat consumption from Destia) and corresponding emission factors.

Leisure boat emission estimations are based on the use of energy (kWh) and corresponding emission factors (g/kWh). Energy use is calculated by boat category (6), engine type (4), average engine power class (10) (kW), engine load (%) and average operation time per year (h/a). The total emissions are calculated by multiplying the total energy use (kWh) of engine types and corresponding emission factors (g/kWh).

The total emissions of working boats and cruisers are calculated by multiplying the total fuel use (kg/a) of boats by emission factors (g/kg fuel). Fuel consumption of these boats is calculated using the number of boats in different boat categories, engine power classes (kW) and average fuel consumption of a corresponding boat per year (kg/boat/a).

The MEERI model was modified to include a factor to handle annual changes in the leisure boat average operating hours. The results of the modification are included in 2008 data, but they did not affect the years prior to 2008.

Calculation models are described in Appendix\_3a at the end of Chapter 3.

### 3.3.4.2 Activity data

A detailed database on every ship visit in Finnish ports is obtained from the Finnish Transport Agency. The database includes data on ship type, age, size (GRT = gross register ton), engine power, speed, load, port, previous port, destination, nationality, and trip type (domestic/international). Ferry traffic between Finland and Sweden is very frequent. Since 1999 all ferries have been put in at the ports of Åland (which is an archipelago between Sweden and Finland belonging to Finland) but only a very small portion of passengers on these ferries are actually travelling between the mainland and Åland (e.g. between Helsinki and Åland 0.7% of all passengers using the Helsinki to Sweden lines). The method used to separate domestic ferry traffic from international traffic to Sweden is to define domestic ship kilometres according to the share of passengers travelling to the archipelago of Åland.

Data on total fuel consumption of icebreakers are obtained from Arctia Shipping Ltd.

Data on total fuel consumption of ferryboats are acquired from road authorities (Ferryboats are used to transport road vehicles across narrow water straits on the public road network). Amount of used fuels by ship type are described in Table 3.3-10.

The number of working boats is obtained from different official organisations (e.g. customs, sea rescue).

The number of cruisers (sightseeing boats, etc.) comes from the Finnish Transport Agency.

The number of bigger leisure boats is received from the Finnish Boat Register, the number of smaller boats is an estimation based on a thorough study made by VTT in 2004. The Boat Register data include information on type of engine(s), engine power and age.

New legislation on the Finnish Boat Register entered in October 2007. The coverage of the register has been improved. There are new groups of boats included in the register starting from 2008. The final results of the improvements will be available after the end of 2010, when also previously existing data should be updated.

Thorough renovation of the national boat register has been completed by the end of 2011. As the register is a substantial source of the number and size of the leisure boats (actually the size of engines) this renovation has affected the results of the emission calculation of leisure boats. Over the years the number of boats in the register increased more than boats existed in reality because there was no sanction if the boat was not removed from the register after the boat (engine) was scrapped. In the renovation all boats that were not reregistered were removed from the register. This concerned boats (engines) over 20 horsepower. As a result

the calculated CO<sub>2</sub> emissions of the leisure boats in Finland 2011 were decreased by ca. 21% compared to the emissions in 2010. Recalculations are planned to be done during 2014.

The database from the Finnish Transport Agency is analysed to produce power and speed classes for the ships. In addition, origin-destination matrices are produced using the data.

The Finnish Transport Agency's database is very accurate and detailed. The Boat Register is the best available source for boats.

**Table 3.3-10** Amount of used fuels in domestic navigation by ship type, PJ (MEERI)

	Leisure boats	Passenger ships (domestic)	Cruisers	Cargo vessels	Working boats	Ferryboats	Icebreakers
1990	2.25	0.16	0.10	1.19	1.42	0.27	0.48
1991	2.32	0.17	0.11	1.19	1.37	0.28	0.50
1992	2.35	0.16	0.10	1.20	1.33	0.29	0.20
1993	2.35	0.14	0.09	1.28	1.31	0.30	0.52
1994	2.35	0.12	0.09	1.47	1.28	0.31	1.00
1995	2.44	0.12	0.10	1.40	1.27	0.31	0.58
1996	2.45	0.13	0.10	1.37	1.26	0.30	0.99
1997	2.51	0.22	0.12	1.61	1.26	0.29	1.01
1998	2.70	0.44	0.14	1.66	1.26	0.29	0.70
1999	2.70	0.44	0.14	1.66	1.26	0.29	0.70
2000	2.64	0.42	0.15	1.63	1.26	0.29	0.82
2001	2.65	0.37	0.14	1.37	1.26	0.29	0.54
2002	2.71	0.37	0.13	1.54	1.26	0.29	0.67
2003	2.68	0.40	0.13	1.28	1.26	0.30	1.06
2004	2.71	0.39	0.12	1.36	1.26	0.29	0.84
2005	2.74	0.47	0.12	1.23	1.26	0.28	0.98
2006	2.85	0.36	0.12	1.50	1.27	0.27	1.19
2007	2.89	0.37	0.12	1.69	1.27	0.27	1.16
2008	2.42	0.35	0.12	1.63	1.27	0.26	0.54
2009	2.53	0.36	0.12	1.51	1.27	0.26	0.86
2010	2.73	0.34	0.12	1.67	1.27	0.27	1.28
2011	2.20	0.45	0.12	1.88	1.27	0.26	1.11
2012	1.94	0.46	0.12	1.64	1.27	0.34	0.78

### 3.3.4.3 Emission factors and other parameters

The CO<sub>2</sub> emission factors are presented in Table 3.2-3.

In 2012 bioshares of gasoline, diesel oil and gasoil oil were 6.1%, 7.2% and 0.7% respectively (calculated from TJ).

The CH<sub>4</sub> and N<sub>2</sub>O emission factors for ships are the IPCC values for Ocean-going ships (IPCC 1997, Table 1-48). CO<sub>2</sub> emission factors are based on national figures (Table 3.2-3). They differ slightly from those expressed in the IPCC Guidelines. The difference is small. The emission factors are based on product analysis in Neste Oil laboratories. Neste Oil is the leading company of oil product manufacturing in Finland (market share over 90%).

The CH<sub>4</sub> and N<sub>2</sub>O emission factors for working boats, cruisers, ferryboats and leisure boats are based on international and national sources.

The emission factors, net caloric values and densities used in the calculation of emissions from domestic navigation for CH<sub>4</sub> and N<sub>2</sub>O are presented in Table 3.3-11.

**Table 3.3-11** Emission factors, net caloric values and densities used in the calculation of emissions from domestic navigation (Neste Oil, IPCC 1997)

Fuel type	N <sub>2</sub> O emission factor g/kg fuel	CH <sub>4</sub> emission factor g/kg fuel	Net caloric value TJ/kilotonne fuel	Density kg/m <sup>3</sup> fuel
Gasoline	0.039	3.76	43.0	750
Gasoil	0.0854	0.1708	42.7	845
Heavy fuel oil HFO	0.082	0.287	41.0	970

#### 3.3.4.4 Uncertainties and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

Monte Carlo simulation has been used to combine the uncertainties of each calculation parameter in order to get the total uncertainty of the source category. A detailed description of the uncertainty analysis method has been presented in Monni & Syri (2003) and Monni (2004).

In Finland, fuels used in waterborne navigation include residual oil, gasoil and gasoline and starting from 2008, diesel oil. Diesel oil and gasoline are used mainly by leisure boats. The share of fuels sold for leisure boats is rather poorly known due to lack of consumer surveys. Uncertainty in the use of residual oil, gasoil, gasoline and diesel oil is estimated to be  $\pm 10\%$ .

As CO<sub>2</sub> emissions mainly depend on the carbon content of the fuel, uncertainty in these emissions were estimated at an upper level (CRF 1.A).

Uncertainties in CH<sub>4</sub> and N<sub>2</sub>O emission factors are larger than those in CO<sub>2</sub>. These emissions vary depending on engine design and maintenance, and the start-ups and shutdowns of the engines are likely to affect emissions. Measurements done for diesel engines in ships have shown that variation in N<sub>2</sub>O emissions is larger than in CH<sub>4</sub> emissions. Reduction of uncertainty in CH<sub>4</sub> and N<sub>2</sub>O emission estimates would require more measurement data and more information on the use of engines in ships (frequency of start-ups, shutdowns, etc).

Renovation of the national boat register, as described in Section 3.3.4.2, caused an inconsistency in the leisure boat emission trend in 2011. Recalculations solving the inconsistency will be made during the renewal of the MEERI model as described in Section 3.3.4.7.

#### 3.3.4.5 Source-specific QA/QC and verification

The quality management process and the QA/QC plan for the whole inventory are presented in Section 1.6. The QA/QC plan for the transport sector includes the QC measures based on GPG 2000. These measures are implemented every year during the transport sector inventory. Potential errors and inconsistencies are documented and corrections are made if necessary. Also, the bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert.

Statistics Finland crosschecks the fuel consumption data calculated within the MEERI model. Gasoline, gasoil and heavy fuel oil consumption data taken from MEERI are summed up in the ILMARI system with other user's estimated consumption and the calculated totals are compared to total sales of these fuels.

#### 3.3.4.6 Source-specific recalculations

There was a very small recalculation in 2011 due to corrected bioshare of gasoline.

#### 3.3.4.7 Source-specific planned improvements

During the year 2013-2014 the domestic navigation model MEERI will be renewed included in the renewal of the LIPASTO calculation system as described in Section 3.3.2.7. Recalculations of emissions of leisure boats will be done in this connection. The inventory year 2013 will be calculated using the new LIPASTO calculation system.

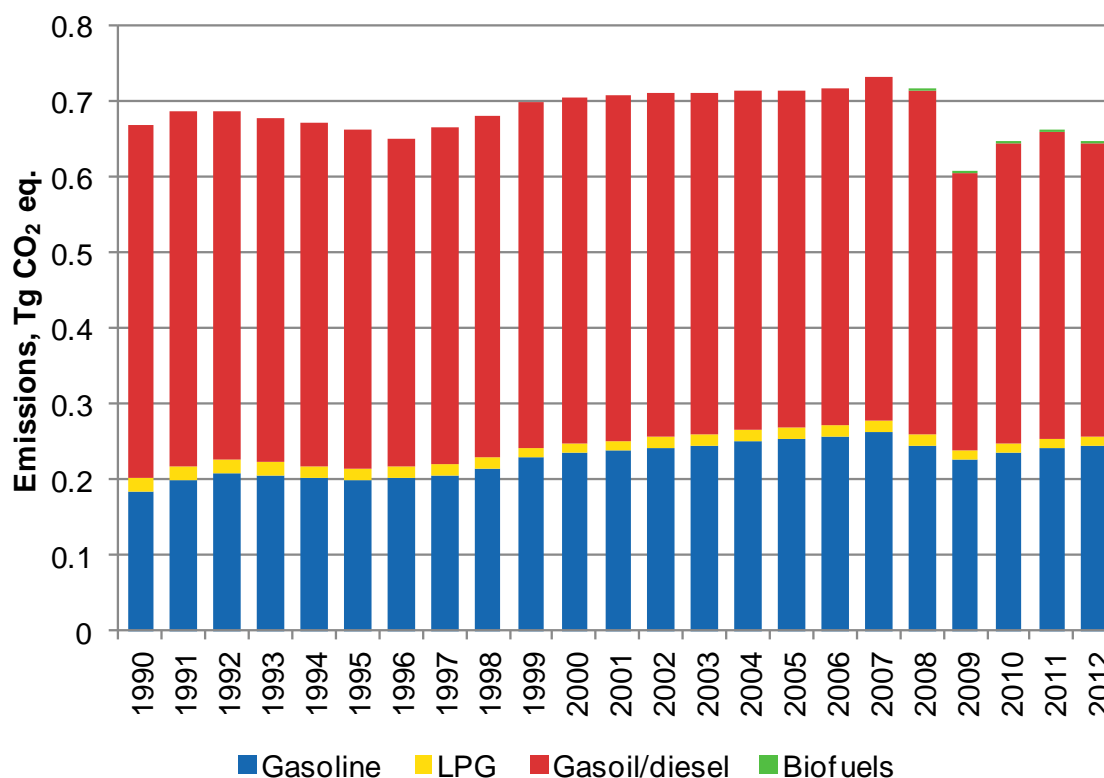


### 3.3.5 Other transportation

Emission sources of other transportation are non-road vehicles and machinery, excluding those machinery, that are allocated to CRF categories 1.A 2f Other / Construction and 1.A 4c Agriculture/Forestry/Fisheries. In this category there are several types of non-road machinery, like forklifts, snowmobiles, etc. Complete list of machine types included in each CRF category in Table 3.3-13.

Other transportation is the second largest source of emissions in the transport sector. The emissions were 0.64 Tg (CO<sub>2</sub> eq.) in 2012, it was over 5% of the sector's emissions and close to one per cent of total greenhouse gas emissions. Emissions were 0.67 Tg (CO<sub>2</sub> eq.) in 1990.

Emission trend of other transport followed the overall trend of emissions; economic depression at the beginning of 90's decreased emissions. After that especially emissions from leisure time activities has increased (gasoline; ATV (all-terrain vehicle), snowmobiles) while emissions from business activities have decreased (gasoil/diesel). Economic depression that started in 2008 has lowered the leisure time activity and hence the emissions in 2008. 2009 was the use of vehicles and machinery of the other transportation at lowest level of the total time series. In 2010 the market began to recover and the use of these vehicles and machinery increased. Prolonged economic downturn has again turned the trend downwards. The greatest increase was in vehicles and machinery using gasoil/diesel. The use of biofuels started in 2008 and in 2010 the use was doubled. Total emissions by fuel in 1990-2012 are presented in Gg CO<sub>2</sub> eq. in Figure 3.3-9.



**Figure 3.3-9** Emissions from other transportation by fuel (Tg CO<sub>2</sub> eq.)

#### 3.3.5.1 Methods

The TYKO model from VTT Technical Research Centre of Finland estimates emissions and energy consumption of non-road machinery, which are reported in the Finnish inventory under sectors 1.A 2f Other / Construction, 1.A 3e Other transportation and 1.A 4c Agriculture/Forestry/Fisheries. The machinery included in the TYKO model is divided into five main categories: Drivable diesel, drivable gasoline, moveable diesel, moveable gasoline and handheld gasoline, totalling 51 different machine types. The model calculates the machinery in the categories mentioned above. The division to different CRF source categories (construction, agriculture, forestry, other) is made afterwards for the ILMARI system (see Section 3.3.5.2) by Statistics Finland. As the TYKO model calculates emissions of all non-road machinery in Finland, this

model description is valid for all source categories that deal with machinery. The main results of the TYKO model can be seen on the website: <http://lipasto.vtt.fi/tyko/results.htm>. Emissions by CRF subcategories are presented in Table 3.3-12.

**Table 3.3-12** Greenhouse gas emissions from TYKO model by CRF subcategories (Tg CO<sub>2</sub> eq.)

	<b>1.A 2f Other / Construction</b>	<b>1.A 3e Other transportation</b>	<b>1.A 4c Agriculture</b>	<b>Forestry</b>
1990	0.84	0.67	0.70	0.24
1991	0.85	0.69	0.71	0.21
1992	0.83	0.69	0.71	0.19
1993	0.82	0.68	0.71	0.17
1994	0.81	0.67	0.72	0.16
1995	0.83	0.66	0.72	0.16
1996	0.83	0.65	0.67	0.19
1997	0.84	0.66	0.66	0.22
1998	0.87	0.68	0.65	0.26
1999	0.90	0.70	0.62	0.29
2000	0.94	0.71	0.59	0.31
2001	0.96	0.71	0.58	0.31
2002	0.96	0.71	0.59	0.31
2003	0.96	0.71	0.60	0.30
2004	0.96	0.71	0.61	0.30
2005	0.97	0.71	0.61	0.29
2006	0.99	0.72	0.60	0.26
2007	1.03	0.73	0.59	0.26
2008	1.05	0.71	0.58	0.26
2009	0.85	0.61	0.57	0.25
2010	0.96	0.64	0.55	0.26
2011	1.05	0.66	0.52	0.27
2012	1.12	0.64	0.57	0.28

Emissions are calculated separately for gasoline, diesel and LPG machinery. The main method is to sum up the product of the machinery population, engine power, load factor, activity hours and emission factors. The machinery population is based on the previous year's population, wastage factor and sales.

The calculation formula, which applies to all non-road machinery in the TYKO model, is presented in Appendix\_3a at the end of Chapter 3.

The calculation method is in general consistent with the IPCC Guidelines (corresponds to the Tier 3 level method). The method is widely used, for example, in the U.S. EPA Nonroad model (1998) and CORINAIR Off-Road vehicle and Machines model (Andrias et al., 1994).

The latest structural update for TYKO model was done in 2006. Data for the inventory year is however updated annually.

### 3.3.5.2 Activity data

Data on machine population are based on national estimations, machinery registrations, sales figures and knowledge on the life expectancy of machinery. The activity data are based on national and international research.

**Table 3.3-13** Breakdown of different machine types in TYKO model to CRF subcategories

CRF subcategory	Type of machine
1.A 2f Other / Construction	Cranes
	Bulldozers
	Rollers
	Wheel loaders
	Backhoe loaders
	Mini excavators, skid steer
	Excavators, skid steer
	Excavators, rubber tire
	Dumpers
	Telehandlers
	Generator sets, diesel
	Compressors
	Compactors, diesel
	Other moveable machines, diesel
	Plate compactors
	Generator sets, gasoline
1.A 3e Off-road vehicles and other machinery	Forklifts, diesel
	Other lifts, diesel
	Graders
	Tractors in industry
	Maintenance tractors
	Other tractors
	Skid steer loaders
	Lawn tractor, diesel
	Other drivable machines, diesel
	ATV, diesel
	Forklift, gasoline
	Forklift, gas
	Riding mowers, gasoline
	ATV, 2-stroke, professional
	ATV, 4-stroke, professional
	ATV, 2-stroke, leisure
	ATV, 4-stroke, leisure
	Snowmobiles, 2-stroke professional
	Snowmobiles, 4-stroke professional
	Snowmobiles, 2-stroke leisure
	Snowmobiles, 4-stroke leisure
	Other drivable, gasoline
	Lawn movers, handheld
	Snow blowers
	Other moveable machines, gasoline
	Chain saws, hobby
	Trimmers
	Other handheld machines
1.A 4c Agriculture	Farm tractors
	Combine harvesters
1.A 4c Forestry	Soil cultivator
	Forest harvesters
	Forwarders (forest tractors)
	Professional chain saws
	Clearing saws

### 3.3.5.3 Emission factors and other parameters

The CO<sub>2</sub> emission factors are presented in Table 3.2-3.

In 2012 bioshares of gasoline and gasoil oil were 6.1% and 0.7% respectively (calculated from TJ).

Emission factors are originally based on the CORINAIR study by Andrias et al. (1994): The Estimation of the Emissions of 'Other Mobile Sources and Machinery'. Subparts 'Off-Road Vehicles and Machines', 'Railways', and 'Inland Waterways' in the European Union. Some emission factors are based on the

publication: National Nonroad Emission Model. U.S. EPA (1998). Especially the emission factors of small engines are based on national measurements (Ahokas, J. & Elonen E., (1997). During updating in 2006 all emission factors were checked, especially emission stages II-IV.

#### *3.3.5.4 Uncertainties and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

Monte Carlo simulation has been used to combine the uncertainties of each calculation parameter in order to get the total uncertainty of the source category.

#### *3.3.5.5 Source-specific QA/QC and verification*

The quality management process and the QA/QC plan for the whole inventory are presented in Section 1.6. The QA/QC plan for the transport sector includes the QC measures based on GPG 2000. These measures are implemented every year during the transport sector inventory. Potential errors and inconsistencies are documented and corrections are made if necessary. Also, the bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert.

Statistics Finland crosschecks the fuel consumption data calculated within the TYKO model. Gasoline, gasoil and LPG consumption data taken from TYKO are summed up in the ILMARI system with other user's estimated consumption and the calculated totals are compared to total sales of these fuels.

In 2007 results of the updated TYKO model were compared with similar Danish calculations described in report (Winther M. & Nielsen O-K. (2006)).

#### *3.3.5.6 Source-specific recalculations*

There was a very small recalculation in 2011 due to corrected bioshare of gasoline.

#### *3.3.5.7 Source-specific planned improvements*

The TYKO model for other transportation is also included in the renewal of the LIPASTO calculation system (see Section 3.3.2.7), but big changes are not expected. The inventory year 2013 will be calculated using the new LIPASTO calculation system.

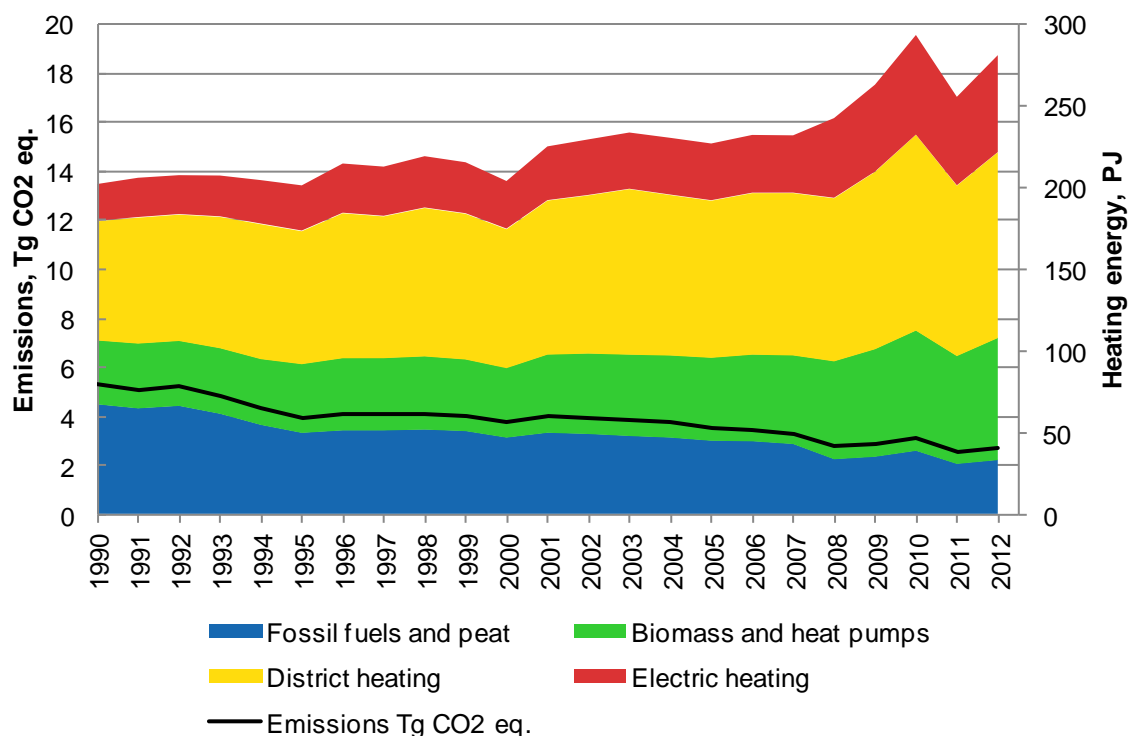
## 3.4 Other sectors and Other (CRF 1.A 4, CRF 1.A 5)

### 3.4.1 Source category description

Subcategory CRF 1.A 4 includes emissions from combustion in commercial, institutional and residential sectors. These cover mainly fuels used in heating of buildings. In addition, emissions from heating of agricultural buildings, non-road machinery in agriculture and forestry as well as fishing boats are included in this source category. Subcategory CRF 1.A 5 includes emissions from non-specified consumption of fuels, military use and statistical corrections of fuel consumption.

The emissions of Other sectors were 4.3 Tg and Other 1.6 Tg (CO<sub>2</sub> eq.) in 2012 and in 1990 emissions were 7.2 Tg and 1.8 Tg. The emissions of these subcategories were over 12% of the energy sector's emissions and almost 10% of total greenhouse gas emissions of Finland. Residential source category is the biggest one, emissions were 40% of the Other sectors in 2012. Emissions of these two sectors (1.A 4 and 1.A 5) have fallen almost 34% since 1990, the main reason for this is the increased use of district and electric heating in residential, commercial and public buildings (Figure 3.4-1). The peak in 2010 heating energy consumption is due to exceptionally high heating degree days.

Emissions of non-road machinery in agriculture and forestry have declined about 13% and fishing boats about 37% during the time series.



**Figure 3.4-1** Energy consumption of heating in residential, commercial and public buildings and CO<sub>2</sub> emissions of CRF 1.A 4a and 1.A 4b, (Energy Statistics, 2012)

The subcategory CRF 1.A 5 also includes indirect N<sub>2</sub>O emissions caused from N deposition by total NO<sub>x</sub> emissions in Finland. The main source for the NO<sub>x</sub> emissions is fuel combustion in the Energy sector, with transportation being the most significant source category. GPG 2000 states that indirect N<sub>2</sub>O from other sources of N deposited on soils, in addition to those coming from the Agriculture sectors can be accounted for and that the estimated emissions should be reported under the sector in which the originating activity is reported. The 2006 include a methodology and guidance on estimating and reporting of indirect N<sub>2</sub>O emissions from the atmospheric deposition of nitrogen in NO<sub>x</sub> and NH<sub>3</sub>.

The indirect N<sub>2</sub>O emissions from agricultural sources (mainly from NH<sub>3</sub> emissions) are included in the Agriculture sectors as was done in previous submissions and in accordance with the guidance in 1996 IPCC

GL. Indirect emissions from nitrogen deposition due to industrial NH<sub>3</sub> emissions are estimated to be of small, if not negligible, significance.

Emissions from these sectors in 1990-2012 by subcategory are presented in Table 3.4-2.

### 3.4.2 Methodological issues

#### 3.4.2.1 Methods

Emissions from subcategories 1.A 4 and 1.A 5 are calculated with the ILMARI system, which has been described in Section 3.1.1.3., Table 3.1-5 and Figure 3.1-5.

To calculate the emissions from the non-specified burning of feedstocks there is a separate module in ILMARI. The ILMARI system includes point source (bottom-up) data on feedstock combustion in the petrochemical industry as well as recycled waste oil combustion in different branches of industry, and they are reported in corresponding subcategories of 1.A 2. These specified energy uses of feedstock and lubricants are subtracted from the corresponding total amounts of feedstock and lubricants. For the rest of the feedstock 100% of carbon is estimated to be stored in products (mainly plastics). For the rest of lubricants, 33% of carbon is estimated to be stored in products (recycled lubricants) and 67% of carbon released as CO<sub>2</sub> either in burning of lubricants in motors or illegal combustion of waste oil in small boilers. These non-specified emissions from burning of feedstocks (which are not included in 1.A 2) are included in category 1.A 5. As a result to question raised by the ERT the calculation of feedstock and lubricants was checked. There were a few corrections (on missing data cell in 2002 and three non-updated preliminary data cells). Also missing additional data was added to CRF Table 1A(d) (Lubricants).

**Table 3.4-1** Reporting of carbon stored and emissions related to use of feedstock and lubricants (figures show approximate ranges for the latest years)

	Use in kt	Gg CO <sub>2</sub>	Reported in inventory
Lubricants	50-80		
Combustion of recycled waste oil	20-30	50-100	1.A 1 and 1.A2
Non-specified consumption	30-50		
- of which, estimated combustion (2/3)	20-35	50-100	1.A 5
- stored carbon (in recycled lubricants)	10-15	30-50	RA carbon stored; subtracted from lubricants 'apparent consumption emissions'
Feedstocks for petrochemical industry	900-1 000		
Combusted on site	150-200	450-600	1.A 2c
Flaring	15-30	40-100	1.B 2c
Stored in products (plastics)	700-800	-2 000--2 500	RA carbon stored; subtracted from LPG, naphtha and other oil 'apparent consumption emissions'

Emissions from natural gas used as feedstock are calculated and reported in sector 2.B 5.

Nitrous oxide (N<sub>2</sub>O) is produced in soils and surface waters through nitrification and denitrification. Increased nitrogen input to these systems enhances the production of N<sub>2</sub>O and all anthropogenic sources of NH<sub>3</sub> and NO<sub>x</sub> emissions are potential indirect sources of N<sub>2</sub>O. The emissions are estimated based on the amount of nitrogen emitted in the country multiplied with an emission factor, assuming 1% of the nitrogen in the emissions to be converted to N<sub>2</sub>O. The calculation method is the IPCC default method. The emissions are estimated at Statistics Finland based on total NO<sub>x</sub> emissions in Finland. The methodology is the same independent of the source of the nitrogen, but agricultural indirect N<sub>2</sub>O emissions are reported in the Agriculture sector, indirect N<sub>2</sub>O emissions from other sources are included in this sector, although there are some other minor sources of NO<sub>x</sub> emissions as well.

### 3.4.2.2 Activity data

The activity data for category CRF 1.A 4 are taken from annual energy statistics. The fuel consumption data for CRF 1.A 4 are presented in Table 3.4-2. It covers fuels used for the heating of commercial, institutional and residential buildings, which are estimated by the space heating estimation model (Raklam) maintained by Statistics Finland. Fuel consumption data are estimated using building stock statistics, average specific consumption ( $\text{MJ}/\text{m}^3/\text{a}$ ) and annual heating degree days.

The estimation model was partly revised during 2011. The revision was made for residential heating sector, and it covered the years 2008-2010. The revised model takes into account secondary heating systems, which are increasingly popular in Finland. For example the number of air-to-air heat pumps has grown rapidly in the last few years; they are used as secondary heat source, substituting fuel or electricity consumption of the primary heating system.

To avoid break in time series, the heating oil consumption data for 2005-2007 has been estimated using interpolation.

Activity data for forest machinery and agricultural machinery are taken from the TYKO model of VTT (See descriptions in Section 3.3.5). Activity data for fishing derive from the MEERI model of VTT (See descriptions in Section 3.3.4).

**Table 3.4-2** Emissions from sectors 1.A 4 Other sectors and 1.A 5 Other in by subcategory (Tg CO<sub>2</sub>)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>CO<sub>2</sub></b>																							
<b>4. Other sectors</b>	<b>6.9</b>	<b>6.7</b>	<b>6.8</b>	<b>6.4</b>	<b>5.9</b>	<b>5.5</b>	<b>5.6</b>	<b>5.5</b>	<b>5.6</b>	<b>5.5</b>	<b>5.2</b>	<b>5.4</b>	<b>5.4</b>	<b>5.3</b>	<b>5.2</b>	<b>4.8</b>	<b>4.7</b>	<b>4.5</b>	<b>4.0</b>	<b>4.1</b>	<b>4.3</b>	<b>3.7</b>	<b>4.0</b>
a. Commercial and institutional	1.94	1.86	2.00	1.69	1.39	1.20	1.27	1.28	1.29	1.27	1.16	1.22	1.22	1.20	1.17	1.12	1.11	1.05	0.88	0.97	1.07	0.93	1.01
b. Residential	3.11	2.97	2.98	2.93	2.71	2.53	2.57	2.56	2.60	2.54	2.35	2.51	2.46	2.39	2.33	2.12	2.07	1.92	1.61	1.61	1.75	1.32	1.43
c. Agriculture, forestry and fisheries	1.86	1.89	1.85	1.83	1.84	1.73	1.71	1.70	1.74	1.71	1.66	1.66	1.67	1.67	1.65	1.60	1.53	1.56	1.54	1.48	1.52	1.44	1.51
<b>5. Other</b>	<b>1.33</b>	<b>1.20</b>	<b>1.20</b>	<b>1.11</b>	<b>1.37</b>	<b>1.47</b>	<b>1.50</b>	<b>1.44</b>	<b>1.57</b>	<b>1.47</b>	<b>1.62</b>	<b>1.57</b>	<b>1.56</b>	<b>1.62</b>	<b>1.36</b>	<b>1.42</b>	<b>1.42</b>	<b>1.38</b>	<b>1.41</b>	<b>1.38</b>	<b>1.46</b>	<b>1.30</b>	<b>1.36</b>
Stationary, non-specified	1.06	0.93	0.92	0.81	1.03	1.17	1.23	1.19	1.33	1.21	1.33	1.29	1.27	1.34	1.15	1.16	1.15	1.08	1.11	1.10	1.17	1.07	1.10
Stationary, non-specified burning of feedstocks	0.21	0.17	0.17	0.17	0.18	0.18	0.16	0.14	0.14	0.13	0.13	0.13	0.13	0.10	0.09	0.09	0.09	0.11	0.10	0.08	0.06	0.06	0.06
Mobile	0.06	0.11	0.11	0.13	0.16	0.13	0.11	0.11	0.10	0.13	0.16	0.14	0.16	0.17	0.12	0.18	0.18	0.20	0.20	0.19	0.23	0.18	0.20
<b>CH<sub>4</sub></b>																							
<b>4. Other sectors</b>	<b>0.183</b>	<b>0.182</b>	<b>0.184</b>	<b>0.183</b>	<b>0.185</b>	<b>0.185</b>	<b>0.193</b>	<b>0.193</b>	<b>0.195</b>	<b>0.191</b>	<b>0.186</b>	<b>0.207</b>	<b>0.213</b>	<b>0.215</b>	<b>0.216</b>	<b>0.216</b>	<b>0.222</b>	<b>0.224</b>	<b>0.234</b>	<b>0.247</b>	<b>0.274</b>	<b>0.235</b>	<b>0.256</b>
<b>5. Other</b>	<b>0.003</b>	<b>0.003</b>	<b>0.003</b>	<b>0.002</b>	<b>0.003</b>	<b>0.003</b>	<b>0.004</b>	<b>0.003</b>	<b>0.004</b>	<b>0.004</b>	<b>0.004</b>	<b>0.004</b>	<b>0.004</b>	<b>0.004</b>	<b>0.003</b>	<b>0.003</b>	<b>0.003</b>	<b>0.003</b>	<b>0.003</b>	<b>0.003</b>	<b>0.004</b>	<b>0.003</b>	<b>0.004</b>
<b>N<sub>2</sub>O</b>																							
<b>4. Other sectors</b>	<b>0.086</b>	<b>0.083</b>	<b>0.085</b>	<b>0.082</b>	<b>0.078</b>	<b>0.073</b>	<b>0.076</b>	<b>0.076</b>	<b>0.077</b>	<b>0.075</b>	<b>0.072</b>	<b>0.077</b>	<b>0.078</b>	<b>0.077</b>	<b>0.076</b>	<b>0.074</b>	<b>0.074</b>	<b>0.073</b>	<b>0.070</b>	<b>0.073</b>	<b>0.080</b>	<b>0.068</b>	<b>0.074</b>
<b>5. Other</b>	<b>0.45</b>	<b>0.42</b>	<b>0.41</b>	<b>0.41</b>	<b>0.41</b>	<b>0.38</b>	<b>0.38</b>	<b>0.37</b>	<b>0.35</b>	<b>0.34</b>	<b>0.33</b>	<b>0.33</b>	<b>0.32</b>	<b>0.34</b>	<b>0.31</b>	<b>0.27</b>	<b>0.30</b>	<b>0.28</b>	<b>0.26</b>	<b>0.24</b>	<b>0.26</b>	<b>0.24</b>	<b>0.23</b>
Indirect N <sub>2</sub> O emissions from NOx	0.44	0.41	0.40	0.40	0.40	0.36	0.37	0.36	0.33	0.33	0.31	0.31	0.31	0.32	0.30	0.26	0.29	0.27	0.25	0.23	0.25	0.23	0.22

**Table 3.4-3** Fuel consumption in CRF categories 1.A 4 and 1.A 5 (PJ) (includes also fuels from non-energy use)

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Liquid fuels	Heavy fuel oil	19.3	18.8	18.3	13.8	10.8	7.5	7.5	7.3	7.7	7.9	7.3	7.8	7.7	7.5	7.1	6.8	6.5	6.4	5.7	5.8	6.3	5.3	5.4
	Light fuel oil	80.5	79.4	78.3	77.0	75.2	73.4	74.6	73.9	75.7	74.5	70.5	71.4	70.6	69.8	67.3	62.9	61.1	58.2	52.9	52.4	54.7	47.1	50.8
	LPG	2.0	2.0	2.0	1.5	2.4	2.5	2.3	2.3	2.9	1.1	2.6	2.6	2.7	2.8	2.8	2.9	3.3	2.9	3.6	2.9	3.9	3.7	3.9
	Other liquid fuels	4.1	4.0	4.0	4.2	4.8	4.3	3.7	3.5	3.3	3.5	3.8	3.6	3.9	3.6	2.9	3.4	3.5	4.0	3.9	3.5	3.7	3.0	3.5
Solid fuels	Hard coal	0.52	0.54	0.55	0.41	0.85	0.29	0.26	0.21	0.23	0.21	0.21	0.16	0.19	0.19	0.19	0.13	0.12	0.12	0.12	0.14	0.14	0.15	0.12
Gaseous fuels	Natural gas and other gaseous fuels	2.9	4.0	5.1	4.7	4.6	5.8	7.2	7.6	7.9	7.6	7.6	8.8	8.4	9.2	7.6	8.4	8.6	8.3	7.2	7.9	8.5	7.5	7.1
Biomass	Woodfuels	45.2	45.2	45.2	45.2	45.2	45.1	47.3	47.4	48.1	47.0	45.8	51.5	53.2	53.9	54.3	54.5	56.3	56.7	59.4	63.7	72.0	61.0	66.3
Other fuels	Peat	1.44	1.08	0.73	0.91	0.87	1.08	1.19	1.18	1.21	1.18	1.29	1.47	1.59	1.73	1.83	1.62	1.60	1.81	1.86	2.14	2.62	2.08	2.32
	Other; mixed fuels and waste	0.003	0.009	0.016	0.012	0.002	0.001	0.002	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	NO	NO	NO	NO	NO	NO	NO



The activity data for category CRF 1.A 5 include military fuel consumption, which are partly based on estimates. The category includes also residuals of certain commercially traded fuels (light fuel oil, heavy fuel oil, natural gas and LPG). Statistical corrections are included in these residuals.

The indirect N<sub>2</sub>O emissions are estimated at Statistics Finland based on total NO<sub>x</sub> emissions in Finland.

### 3.4.2.3 Emission factors

The CO<sub>2</sub> emission factors are presented in Table 3.2-3.

In 2012 bioshares of gasoline and gasoil oil were 6.1% and 0.7% respectively (calculated from TJ).

The other emission factors used are partly IPCC default and partly based on national sources (Table 3.4-4).

**Table 3.4-4** Emission factors of small combustion in the ILMARI calculation system

Small combustion boilers < 1 MW	CH <sub>4</sub> kg/TJ	N <sub>2</sub> O kg/TJ	CO kg/TJ	NM VOC kg/TJ
Oil	10	2	20	5
Coal	300	4	200	200
Natural gas	3	1	50	5
Peat	50	4	200	200
Wood, households and agriculture	200, 50	2	2 100	600, 200
Wood, commercial buildings	50	2	2 100	200
References	IPCC Table 1–7 Boström (1994), Tsupari et al. (2005)	IPCC Table 1–8 Boström (1994), Tsupari et al. (2005)	IPCC Table 1–10 Boström (1994), Tsupari et al. (2005)	IPCC Table 1–11 Peat: the same EF as for coal

### 3.4.3 Uncertainties and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

Uncertainties in activity data were based on energy statistics expert estimates.

In general the uncertainties in subcategories 1.A 4 and 1.A 5 are clearly higher ( $\pm 10$ -50% depending on a sector and fuel) than in other subcategories on Energy sector. In the case of natural gas the uncertainties are slightly lower,  $\pm 5$ -15%.

Uncertainties in emission factors for CH<sub>4</sub> and N<sub>2</sub>O are high, because these emissions vary largely between different boilers, furnaces, etc. Especially in biomass combustion in small-scale applications, CH<sub>4</sub> emissions depend much on the fuel and furnace used. There is also very little information available about the emissions from these sources. International data cannot be applied directly, because the design of furnaces, fuel used and the means of combustion vary. To decrease uncertainty, more measurement data would be needed from different types of furnaces. In addition, more data on currently used furnaces and small-scale boilers, and about the amount and type of fuels used, would be needed. Results from a research study done by VTT in 2005 were used to revise CH<sub>4</sub> and N<sub>2</sub>O emission factors as well as uncertainties of these emission factors.

Monte Carlo simulation has been used to combine the uncertainties of each calculation parameter in order to get the total uncertainty of the source category.

The consistency of time series of subcategory 1.A 4 is fairly good. The space-heating model (Raklam) of Statistics Finland includes years starting from 1995. Prior to that year, fuels for different subsectors of space heating are based on estimated disaggregation. As a result of model revision, there is a break in time series of residential heating model results between 2007 and 2008. This affects mostly in electricity consumption for heating. Heating oil consumption has been corrected for the GHG inventory by interpolation between 2005 and 2008.

Category 1.A 5 includes residuals and statistical corrections, which reflect the problems in the energy balance in some years. Some fuel consumption figures have been corrected to prevent negative consumption figures as well as too big annual changes in this category's total emissions. A part of these corrections may reflect not-so-well-known customers' annual stock changes. All and all, it can be said that the consistency of the original data in this subcategory is not as good as in other subcategories of the energy sector, but it has been improved using the corrections mentioned above. These corrections are checked annually by cumulative sums to prevent systematic over or under estimations. The revision of Raklam-model has somewhat reduced the need for these annual corrections.

### *3.4.4 Source-specific QA/QC and verification*

There are numerous automatic and manual QC procedures used in the ILMARI system (see Section 3.2.4).

Each year, the latest inventory calculations (activity data and CO<sub>2</sub> emissions) are crosschecked against the national energy balance (Annex 4). This reference calculation is based on energy balance, showing activity data (PJ) and CO<sub>2</sub> emissions.

### *3.4.5 Source-specific recalculations*

There were minor revisions in the fuel consumption data and emission estimates for space heating and agriculture.

There were also small corrections in the NO<sub>x</sub> emission time series, which caused recalculation of indirect N<sub>2</sub>O emissions.

Corrections in other categories' fuel data are reflected as a recalculation in this category (CRF 1.A 5)

### *3.4.6 Source-specific planned improvements*

The results of the new system for agriculture are provisional, and they may be slightly revised after thorough discussions with experts in other organisations.

Also the Raklam model may need some revision of the model parameters, as more recent data will be available from household surveys and electricity consumption survey.

### *3.5 Fugitive emissions from solid fuels (CRF 1.B 1)*

There are no emissions reported under this sector in Finland. Emissions from the peat production are reported in the LULUCF sector (category Wetlands, CRF 5.D 2) consistent with the GPG LULUCF 2003 (see Section 7.5).

There are no coalmines in Finland.

## 3.6 Fugitive emissions from oil and natural gas (CRF 1.B 2)

### 3.6.1 Source category description

This source category includes CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions from flaring at oil refineries and in the petrochemical industry, fugitive methane emissions from oil refining and methane emissions from gas transmission and distribution.

Methane emissions from oil refining result from evaporation during the refining and storage of oil. Some of the emissions from gas transmission are caused by the normal running of older compressor stations in the transmission network. Another source of emissions in transmission is the emptying of pipelines during maintenance breaks and extension work. The emissions of distribution originate mainly from leaks from valves in certain old pipeline types.

Flaring is a part of safety system in refineries and petrochemical industry and in normal situation gases are recovered, not flared. Carbon dioxide from flaring is emitted in emergency situations when pressure in any production equipment has risen over permissible pressure and gases are burned in flares. Flaring is not conditional on output and amount of it has been attempted to minimise therefore it always relate to problems in process.

In 2012 the combined fugitive and flaring emissions from oil refining (and flaring emissions from the petrochemical industry), and emissions of natural gas transmission and distribution were totally 0.17 Tg CO<sub>2</sub> eq. This is about 0.3% of Finland's total emissions.

The NMVOC emissions originate from oil refineries as well as storage of chemicals at the refineries, road traffic evaporative emissions from cars, the gasoline distribution network and refuelling of cars, ships and aircraft. Indirect CO<sub>2</sub> emissions from NMVOC in fugitive emissions from fuels have decreased mainly in evaporative emissions from road traffic due to gradual renewal of the passenger car fleet.

There is no exploration or production of oil or natural gas in Finland.

### 3.6.2 Methodological issues

#### 3.6.2.1 Methods

##### Oil refining

The fugitive methane emissions from the refining and storage of oil have been calculated on the basis of 1996 IPCC GL using the default emission factors for oil refining and data from Energy Statistics (Energy Statistics, 2013) on oil refining activities.

##### Flaring

Estimates of carbon dioxide emissions from flaring are calculated using data from VAHTI system and emission factors of used fuels in ILMARI calculation system.

##### Natural gas transmission

Fugitive emissions from gas transmission are calculated by Gasum Oy (Gasum, 2013). Calculations are based on measurements for the years 1996-2012. Emissions of earlier years have been estimated with Gasum Oy (Hyvärinen E. 2000) at Statistics Finland based on the volume of transmitted gas and knowledge of malfunctions and repairing works when gas could have been released.

##### Natural gas distribution

Emissions from gas distribution are also partly based on measurements (1996-2012) made by HelsinkiKaasu Oy (Tolonen M., 2013) and partly on rough estimates (1991-1994) based on the volume of total distributed gas. This method is close to linear interpolation in accordance with GPG 2000. There were no emissions from gas distribution in 1990. The reason for this is that natural gas has been distributed in the old parts of the distribution network beginning from 1991. So called "town gas", which was earlier distributed in those parts, did not contain substantial amounts of methane.

NMVOC emissions

NMVOC emissions from oil refineries and storage are based on emission data from the VAHTI system. Evaporative emissions from cars are based on expert estimation at VTT Technical Research Centre of Finland (Mäkelä K. 2013) and emissions from the gasoline distribution chain and refuelling of vehicles based on information from the Finnish Petroleum Federation for the years 1990-2012 (Pohjolainen, 2008 and Finnish Petroleum Federation, 2013).

Indirect CO<sub>2</sub> emissions

Indirect CO<sub>2</sub> emissions were calculated using the equation below. It was assumed for years 1990-2012 that the average carbon content is 80% by mass also under the sector fugitive emissions from oil and natural gas based on 2006 IPCC Guidelines. Used fossil carbon content fraction of NMVOC for years 1990-2012 is based on the NMVOC speciation profile provided in the EMEP/CORINAIR Emission Inventory Guidebook 2000 Section B4610-6.

In 2013 submission the share of biogenic components in fuels were included for first time in calculation of indirect CO<sub>2</sub> emissions. It is assumed based on expert estimate (Grönfors. K, 2012) that indirect CO<sub>2</sub> emissions from fuels include biogenic components from year 2008 onwards. It is assumed that in year 2008 2% of indirect CO<sub>2</sub> emissions can be considered as biogenic. In years 2009 and 2010 the share of biogenic part is assumed to be 4% and 6% in years 2011-2012.

$$Emissions_{CO_2} = Emissions_{NMVOC_s} * Percent\ carbon\ in\ NMVOCs\ by\ mass * 44/12$$

Indirect CH<sub>4</sub> emissions

Method to calculate indirect CO<sub>2</sub> emissions from methane emissions is from 2006 IPCC Guidelines. Carbon dioxide emissions have been calculated from methane emissions from oil refineries, natural gas transmission and distribution. Indirect CO<sub>2</sub> emissions from methane emissions were calculated using the equation below.

$$Emissions_{CO_2} = Emissions_{CH_4} * 44/16$$

### 3.6.2.2 Emission factors and other parameters

Emission factors for calculating emissions from the refining and storage of oil are based on the default factor given in 1996 IPCC GL, since country-specific factors are not available. The IPCC Guidelines offer a wide range for the emission factors. Due to lack of knowledge on the applicability of the factors to Finnish circumstances, the mean value of the factors is used (EF = 880 kg methane / PJ oil refined).

Plant and fuel specific emission factors are used for calculation emissions from flaring. They can be found in Table 3.2-3.

### 3.6.2.3 Activity data

Activity data for oil refining are taken from Energy Statistics (Energy Statistics, Yearbook), indicating the quantity of oil refined.

For emissions from flaring amount of used fuels in flares reported to the VAHTI system are used as activity data.

No activity data are used in calculating the emissions from gas transmission and distribution because estimates are based on measurements and expert estimates. However, the quantity of gas transmitted and distributed is reported as background information in the CRF tables.

### 3.6.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of review and update of uncertainty analysis is included in Section 1.7.

Sources of uncertainty for estimates concerning the year 2012 are:

Oil refining: - accuracy of activity data which introduces only a small uncertainty  
 - accuracy of default emission factors which introduces a very large uncertainty  
 Uncertainty in emissions from oil refining was estimated to be -90-100%.

Gas transmission and distribution:

- accuracy of measurements which introduces only a small uncertainty.

Uncertainty in emissions from gas transmission was estimated to be  $\pm 5\%$  and uncertainty in emissions from gas distribution  $\pm 3\%$ .

Flaring: - uncertainties as in the ILMARI system, see Section 3.2.3.

Transmission of gas: the figures concerning 1990-1995 are not based on measurements; instead, they are estimated by experts within the industry.

For gas distribution the emission estimates of the years 1991-1995 are also more uncertain than the measurement-based estimates of later years.

The methane emissions from oil refining and storage are calculated with the same method for the whole time series. In addition, the accuracy of activity data for oil refining and storage remains constant over all inventory years.

Uncertainty in the category Fugitive emissions from oil and natural gas is around  $\pm 25\%$ .

Uncertainty for activity data (indirect CO<sub>2</sub> calculation) is  $\pm 100\%$  and for emission factors  $\pm 20\%$ . Uncertainty for the activity data is based on the latest uncertainty analysis for NMVOC carried out for the 2011 emissions and reported in the Finnish IIR (Informative Inventory Report, 2013) to the UNECE CLRTAP Secretariat in March 2013, where the methods used for the analysis are documented.

Emission estimations for all subcategories under Fugitive emissions from fuels are calculated using the same methodology for the whole time series.

### *3.6.4 Source-specific QA/QC and verification*

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6. The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives. The bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert.

In the calculation of fugitive methane emissions from oil refining and methane emissions from gas transmission and distribution several general inventory quality control procedures have been done as mentioned in GPG 2000, table 8.1. Some of the checks are performed annually, like comparing with previous emissions of subcategory of the calculated emissions and ensuring that there are no transcription errors in calculations and some when the calculation method has been developed.

Quality control procedures, which are mentioned in Section 3.2.4 are also used calculation of emissions from flaring.

In the calculation of NMVOCs and indirect CO<sub>2</sub> emissions general inventory QC procedures mentioned in GPG 2000 Table 8.1 have been performed. For example, plant specific emissions and activity data are compared between the years. The data is reported by plants according to monitoring requirements in the environmental permits and it is checked and approved by the environmental competent authority before recording it to the VAHTI database. There is no activity data available to compare with emission factors in the EMEP EEA Emission Inventory Guidebook.

### *3.6.5 Source-specific recalculations*

Roundings of emissions in natural gas distribution were removed for the whole time series (except 1990 when no emission was included).

### 3.6.6 *Source-specific planned improvements*

As a part of updating of air emissions time series also the activity data (NMVOC emissions) of this category will be checked in 2015.

### 3.7 Reference approach

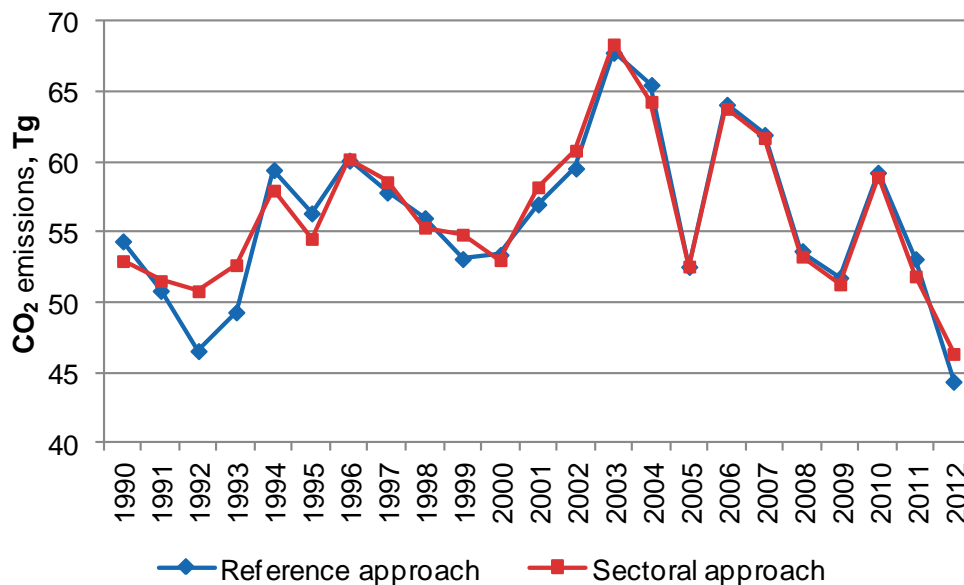
The reference approach (RA) is carried out using import, export, production and stock change data from the energy balance (EB) sheet published in the Energy Statistics Yearbook. However, the RA table requires liquid fuels reported at a more disaggregated level than in the EB sheet. These disaggregated data are taken from the background data files of the EB and for 1990-1994 from the published foreign trade statistics (National Board of Customs, 1990-1994). Another difference is that in the EB sheet stock changes and statistical differences are combined for certain fuels, whereas in the RA table only the stock changes are reported. Stock change data are not available as complete time series for each fuel separately. Therefore certain stock change figures have been estimated using available data.

A research study by Torniainen (2006) revised and updated the oil balance figures needed in the RA. The main focus of the study was in 2004, but the most important time series were also revised. There were some substantial changes especially in 1990-1994.

Main findings of the study were:

- Contents of aggregated group "Other oil products" were inconsistent
- NGL had probably been reported in a wrong category during 1990 – 1994
- some corrections to import/export figures of secondary products were made
- NCVs were corrected
- stock change data are still partly estimated
- data for petrochemical industry were also updated (split to energy and non-energy use).

After these corrections the time series in the Reference Approach are clearly more consistent than before (Figure 3.7-1).



**Figure 3.7-1** Carbon dioxide emissions of Reference and Sectoral Approach in Finland

The Reference Approach fuel mapping is different from that used in the Sectoral Approach (SA). In the SA peat is included in Other fuels, whereas in the RA it is contained in Solid fuels. In the previous inventories this summary operation was manually corrected in the CRF excel sheets, but this correction is not possible in the CRF Reporter. This problem does not have any effect on total CO<sub>2</sub> amounts, but it makes it more difficult to compare consumption figures and emissions by CRF fuel category.

The difference between the RA and SA was -4.27% for 2012 and 2.64% for 1990. The differences are high especially in 1992 and 1993. No obvious reasons for these differences have been found, although some possible explanations were identified in the background data of the study by Torniainen (2006). The final conclusions cannot be made without further, resource demanding, investigations.



The main task would be to check and revise the official Oil balance data of these years (mainly 1990 - 1997), which would require a lot of co-operation with several stakeholders (GHG inventory unit, Energy statistics, Oil industries, Foreign trade statistics, etc.). The revision could also lead to updating of IEA (International Energy Agency) time series data, which would mean recalculation of the energy balances for these years. This would be extremely resource demanding and it is not clear whether these checks and revisions would solve the problems in the RA-SA comparison for 1992 and 1993. Due to the resource demands for the tasks as well as its low significance, the task has low priority in the inventory improvement.

The difference between RA and SA in 2013 is slightly higher than in previous years. The reason for this are the product changes in national reserve stocks (National Emergency Supply Agency, 2013). These changes cause statistical differences in oil balances.

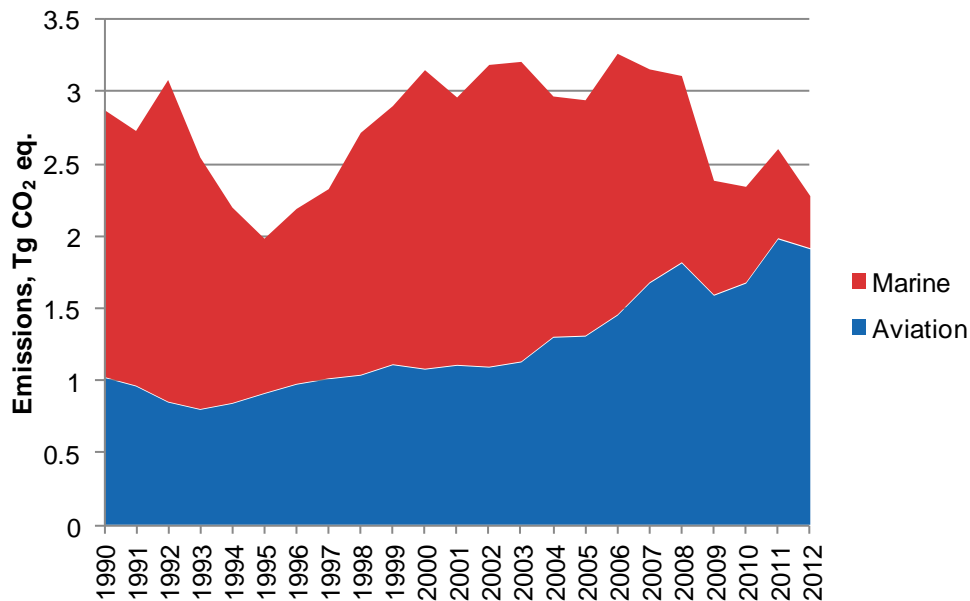
Another top-down reference calculation based on the energy balance for the 2012 inventory is included in Annex 4.

As a response to the ERT, the current practice of reporting non-energy use of fuels and carbon stored has been checked for this submission. Also the additional information Table 1A(d) has been checked and completed.

### 3.8 International bunkers

International bunkers cover international aviation and navigation according to the IPCC Guidelines.

Emissions from international bunkers were 1.9 Tg in aviation and 0.4 Tg CO<sub>2</sub> equivalents in navigation in 2012. Amount of emissions in international aviation has increased gradually for the whole time series except the beginning of the decade (Figure 3.8-1). The trend of emissions in international navigation has fluctuated during this period. The most important reason for these fluctuations is the variation in bunker fuel prices. Especially the ferries between Finland and Sweden can refuel in one or the other country depending on fuel prices. The Finnish currency was devalued in the early 1990's, which affected strongly to fuel prices. This effect was disappeared due to Finland's EU membership and common currency.



**Figure 3.8-1** Emissions from international bunker, Tg CO<sub>2</sub> eq.

The emissions are calculated using the ILMARI calculation model of Statistics Finland (see closer CRF 1.A). Fuel consumption by transport mode is obtained from the energy statistics and it includes fuel sales to ships and aircrafts going abroad. The country-specific CO<sub>2</sub> emission factors are the same as for domestic aviation and navigation. The average non-CO<sub>2</sub> emission factors have been partly selected from the IPCC Guidelines and partly (non-GHGs) derived from the ILMI calculation system (see Section 3.2.1), taking into account estimated fuel consumption and emissions from international landings, take-offs and overflights within the Finnish region. The activity data for international transport in the ILMI system do not follow the IPCC definition of bunkers, thus ILMI data cannot be used as such.

The case of Åland could be seen as an exception to the IPCC definitions. In the present inventory, all trips going to Sweden via Åland are treated as international, because the number of passengers (or cargo) leaving or entering the ships in Åland is very low. A very small share of Åland transport has been allocated to domestic navigation (see Section 3.3.4.2). The in-country and centralised reviews of the Finnish greenhouse gas inventory have accepted the allocation of bunker fuels used in the inventory to be consistent with 1996 IPCC GL and the GPG 2000.

No uncertainty estimation for international bunkers has been carried out.

European Topic Centre for Air and Climate Change has compared aviation emissions reported in inventories to the results of Eurocontrol's estimates. This comparison has been described in Section 3.3.1.1 (Graichen, 2007).

As a response to the previous reviews bunker fuel activity data and net calorific values have been checked. All quantities are taken directly from the Energy statistics. The way of calculating energy quantities (TJ) has been streamlined (previously kt -> ktoe -> TJ, now kt -> TJ), which has removed the small inconsistency

caused by roundings in conversion factors. Energy quantities have been calculated using the same NCVs for the whole time series (jet fuel 43.3 GJ/t, gasoil 42.7 GJ/t and residual fuel oil 40.5 GJ/t). The data have been checked against the data reported to the IEA Oil Questionnaire. There were small differences (< 0.5%) in physical quantities, caused probably by differing roundings during the time series. The NCVs used by the IEA may differ from those used in the inventory.

The bunker fuel figures reported in Sectoral background data for energy tables; Table 1.C 'International bunkers and multilateral operations' and Table 1.A (b) 'CO<sub>2</sub> from fuel combustion activities - Reference approach' are as consistent as possible. Note: the weighted average NCV for residual fuel oil used in the RA is slightly different from the value used for Bunker fuels in the SA which causes a small deviation.

As a response to the previous centralised reviews, Finland now reports estimated lubricant use in international shipping.

There are hardly any data available, but the following estimates were used:

- average use of lubricants: 1% of fuel use (based on data collected from icebreakers 1980-2002)
- most of lubricants are expected to be recycled after use; we estimate that 20% lubricants will be burnt on board.

Default NCV 40.2 MJ/kg and default CO<sub>2</sub> emission factor 73.3 t/TJ have been used for the calculation. The activity data varied between 17.0 and 56.6 TJ. The CO<sub>2</sub> emissions were increased by 3.5 Gg in 1990 and 1.5 Gg in 2009.

The ERT also encouraged Finland to check and remove the small inconsistency caused by the Åland correction in the bunker fuels. This was corrected by subtracting the fuel volume of Åland correction from bunkers and adding it to total domestic fuel consumption. To keep the calculation simple and transparent, the correction was allocated fully to residual fuel oil, which is the most important marine bunker fuel.

After the latest recalculations (see below), the bunker fuel volumes in the GHG inventory deviate slightly from the IEA data, which are based directly on fuel sales statistics.

## *Recalculations*

No recalculations have been done.

## *Sector-specific planned improvements*

There are no other planned improvements in this category.

## Appendix\_3a

The formulas used in calculating emissions from the transport sector (1.A 3).

### Road transportation

#### CO<sub>2</sub> emissions

$$E_y = \sum_{U=1}^U (V_{u,y} - O_{u,y}) c_u$$

$E_y$  is total CO<sub>2</sub> emissions during year y  
 $u$  is fuel type  
 $U$  is number of fuel types  
 $V$  is total sales of fuel  
 $O$  is total use of fuel for other purposes than road traffic  
 $c$  is emission factor

#### N<sub>2</sub>O and CH<sub>4</sub>

**This formula applies to all automobiles in the LIISA model.**

$$E_{v,y} = \sum_{l=1}^9 \sum_{m=1}^{20} \sum_{p=1}^8 \sum_{r=1}^6 s_{l,m,p,r,u,v,y} \left( b_{l,m,p,r,u,v,y}^a + b_{l,m,p,r,u,v,y}^j + b_{l,m,p,r,u,v,y}^k \right)$$

$E$  is total emissions  
 $S$  is kilometrage  
 $b^a$  is the emission factor for hot driving  
 $b^j$  is the emission factor for idle  
 $b^k$  is the emission factor for cold start-ups  
 $l$  is type of vehicle  
 $m$  is model year of vehicle  
 $p$  is road type  
 $r$  is speed class  
 $u$  is fuel type  
 $v$  is compound  
 $y$  is calculation year

### Railway transportation

**This formula applies to all diesel trains in the RAILI model:**

$$E_{v,y} = \sum_{l=1}^4 \sum_{m=1}^{10} \sum_{x=1}^2 s_{l,m,y} b_{l,m}^t V e_{x,v}^f + S_{x,y} b^z e_x^b + S_{x,y} b^a e_x^j + \sum_{r=1}^{123} H_{l,r,x,y} b_{l,x}^h e_{x,v}^f$$

$E$  is total emissions  
 $S$  is gross tonne kilometre  
 $V$  is a factor for extra fuel consumption of non-line (<sup>1</sup> driving)  
 $H$  is shunting time  
 $b^t$  is the specific fuel consumption per gross tonne kilometre

- $b^h$  is the specific fuel consumption per hour  
 $b^z$  is the specific fuel consumption of heating per gross tonne kilometre  
 $b^a$  is the specific fuel consumption of aggregate per gross tonne kilometre  
 $e^f$  is the emission factor per fuel used  
 $e^b$  is the emission factor per fuel used for wagon heating  
 $e^j$  is the emission factor per fuel used for aggregates

- $l$  is type of locomotive  
 $m$  is train weight class  
 $x$  is train type  
 $r$  is rail yard  
 $y$  is calculation year  
 $v$  is compound

( $l$  mobilisation time of the fleet, preparation and finishing times and extra transfer of the fleet)

### Civil navigation

**The calculation formula applies to all ships in the MEERI model (icebreakers excluded):**

$$E_{v,y} = \sum_{l=1}^9 \sum_{m=1}^7 \sum_{z=1}^3 \sum_{p=1}^7 \left( \frac{S_{l,m,x,f,y} d_{x,l,m,f,y} p_{l,z,m} g_o}{f_{l,m}} e_{l,m,v,g,z} + S_{l,m,x,y} p_{l,z,m} g_o t e_{l,m,v,g,z} \right) + u p_{l,z,m} g_o e_{l,m,v,g,z}$$

- $E$  is total emissions  
 $S$  is number of ships  
 $d$  is distance travelled (from previous port visit)  
 $e$  is the emission factor

- $l$  is type of ship  
 $m$  is gross register ton class  
 $x$  is port  
 $o$  is operation area  
 $z$  is engine type  
 $p$  is engine power class  
 $g$  is engine load  
 $f$  is speed class  
 $t$  is time used for manoeuvre and berthing  
 $y$  is calculation year  
 $v$  is compound

**The calculation formula for emission estimation of icebreakers:**

$$E_{v,y} = V_y e_v$$

- $E$  is total emissions  
 $V$  is total fuel use of icebreakers  
 $e$  is emission factor  
 $v$  is compound  
 $y$  is calculation year

**The calculation formula for working boats:**

$$E_{v,y} = \sum_{x=1}^3 S_{x,y} V_{x,y} e_v$$

- $E$  is total emissions  
 $S$  is number of working boats  
 $V$  is total fuel use of a working boat  
 $e$  is emission factor  
 $x$  is type of working boat  
 $v$  is compound  
 $y$  is calculation year

**The calculation formula for leisure boats:**

$$E_{v,y} = \sum_{l=1}^6 \sum_{m=1}^{10} \sum_{z=1}^4 S_{l,m,z,y} m_{l,z} g_l t_l e_{v,z}$$

- $E$  is total emissions  
 $S$  is number of boats  
 $e$  is the emission factor  
  
 $l$  is type of leisure boat  
 $m$  is engine power class  
 $z$  is engine type  
 $t$  is average operating time  
 $g$  is engine load  
 $y$  is calculation year  
 $v$  is compound

*Other transportation***Formula (1) applies to all off-road machinery in the TYKO model.**

$$E_{v,t} = \sum_{l=1}^{44} \sum_{r=1}^4 e_{l,r} \cdot g_{l,r} \sum_{t=1}^{40} k_{l,r,y} \sum_{m=1}^{40} \sum_{p=1}^4 \sum_{u=1}^3 \sum_{d=1}^2 S_{l,m,p,r,u,d,t} \cdot a_{l,p,r,u,m,t,v,t} \quad (1)$$

where ,

- $E_{v,y}$  is total emissions  $v$  in year  $y$   
 $S$  is number of machines (population)  
 $e$  is rated power  
 $g$  is average load factor  
 $k$  is activity (hours per year)  
 $a$  is emission factor  
 indexes  
 $l$  is type of machinery  
 $m$  is model year of machine  
 $p$  is type of engine  
 $r$  is power class (average rated power)  
 $u$  is fuel type  
 $h$  is average lifetime  
 $d$  is type of usage (professional/leisure)  
 $y$  is age of machinery  
 $v$  is compound

$t$  is calculation year

$$S_t = S_{t-1} (1 - w_t) + C_t$$

$S_t$  is machinery population in year  $t$

$w_t$  is wastage of machinery in year  $t$

$C_t$  is sales of machinery in year  $t$

## *Appendix\_3b*

### *Fuel combusted and greenhouse gas emissions from combustion by fuel*

Note: there is a change in fuel mapping compared to previous submissions. A group of Other gases has been removed from Gaseous fuels and added to Mixed fuels and other. Other gases include small (and varying) amounts of gasified wastes and off-gases from industry. The reason for this change was transparency: now Gaseous fuels include only Natural gas, and the varying share of Other gases does not influence the IEF of Gaseous fuels. In the group Other fuels there are many different types of fuels, thus the IEF has more variations anyway.



**Table 1\_3b.** Fuel combustion by fuel, PJ

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>Solid fuels</b>	<b>145.1</b>	<b>133.7</b>	<b>122.4</b>	<b>143.9</b>	<b>178.7</b>	<b>142.6</b>	<b>185.2</b>	<b>166.8</b>	<b>122.8</b>	<b>124.6</b>	<b>122.4</b>	<b>140.8</b>	<b>158.8</b>	<b>216.9</b>	<b>192.2</b>	<b>104.3</b>	<b>188.9</b>	<b>163.8</b>	<b>116.5</b>	<b>131.2</b>	<b>164.8</b>	<b>123.8</b>	<b>99.8</b>
Hard coal	128.1	116.9	105.6	123.5	157.3	122.6	165.5	144.5	100.2	101.3	98.5	119.0	136.6	193.5	168.7	80.6	164.7	142.2	94.9	115.4	144.8	103.4	83.9
Coke	5.9	5.4	5.0	5.1	5.3	4.9	4.3	5.5	5.4	5.5	5.4	4.7	4.7	5.1	5.6	5.6	5.2	5.6	4.9	4.0	4.6	4.8	1.1
Blast furnace gases	6.9	7.2	7.5	8.3	8.3	7.5	8.3	9.5	10.0	10.5	11.2	9.8	10.1	11.0	10.8	11.0	11.5	10.6	10.0	5.9	8.6	8.5	7.1
Coke oven gas	4.2	4.2	4.2	6.9	7.6	7.2	6.8	7.1	7.2	7.2	7.1	7.1	7.2	7.1	7.0	7.0	7.3	5.4	6.7	5.7	6.6	7.0	7.3
Other coal	0.02	0.04	0.05	0.16	0.34	0.38	0.20	0.11	0.05	0.11	0.08	0.19	0.15	0.14	0.13	0.13	0.10	0.11	0.13	0.28	0.26	0.08	0.49
<b>Liquid fuels</b>	<b>374.6</b>	<b>365.4</b>	<b>359.8</b>	<b>345.1</b>	<b>354.7</b>	<b>344.4</b>	<b>349.3</b>	<b>349.6</b>	<b>357.2</b>	<b>359.9</b>	<b>348.1</b>	<b>353.6</b>	<b>359.5</b>	<b>360.8</b>	<b>358.3</b>	<b>352.6</b>	<b>355.3</b>	<b>359.6</b>	<b>338.2</b>	<b>326.1</b>	<b>339.6</b>	<b>324.9</b>	<b>318.6</b>
Heavy fuel oil	71.1	68.4	65.7	61.2	65.0	58.0	60.2	54.4	53.4	55.2	49.3	51.4	52.6	51.3	47.1	43.4	44.5	42.0	33.9	33.7	36.7	30.2	28.4
Light fuel oil	105.7	104.3	102.9	101.9	99.7	98.7	99.9	99.8	102.2	101.8	97.5	98.7	97.7	97.0	94.7	89.9	87.7	85.4	79.2	74.4	79.0	72.4	77.0
Motor gasoline	85.6	85.5	85.8	80.8	82.6	81.7	79.0	81.0	80.1	79.5	76.7	77.8	79.2	79.5	80.8	80.7	80.0	80.0	71.4	68.8	67.5	63.8	61.7
Diesel oil	66.9	62.7	62.0	60.6	63.2	62.1	64.1	68.8	71.4	74.9	76.5	78.1	79.8	81.9	85.5	86.2	89.0	94.3	95.0	90.1	97.6	98.5	94.4
LPG	6.7	6.2	5.8	5.8	6.9	7.1	7.6	8.4	10.2	9.0	11.0	10.8	11.0	12.0	12.4	12.9	13.8	12.7	13.2	11.0	13.0	12.8	12.7
Refinery gases	22.9	22.9	22.9	20.2	22.9	22.4	23.4	22.0	24.4	23.9	21.5	22.3	24.1	24.2	22.7	24.2	24.7	26.2	26.0	29.3	27.3	28.9	26.9
Town gas	0.16	0.12	0.12	0.04	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Recycled waste oil	0.52	0.43	0.34	0.50	0.44	0.52	0.65	0.96	0.92	0.95	0.93	0.76	0.92	1.33	1.44	1.34	1.13	0.82	0.92	0.87	1.20	1.00	0.88
Petroleum coke	4.9	5.0	5.1	5.0	4.8	4.9	5.5	5.3	5.4	5.2	4.7	4.3	5.6	5.2	5.8	5.5	5.4	6.2	6.0	5.5	5.2	6.1	5.8
Jet fuel	5.5	5.6	5.3	5.2	5.3	4.9	5.2	5.7	6.2	6.4	6.8	6.4	6.1	6.1	5.6	6.3	6.0	5.9	5.9	5.7	5.8	5.3	5.1
Aviation gasoline	0.17	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.11	0.15	0.14	0.11	0.11	0.21	0.21	0.15	0.22	0.22	0.18	0.09	0.08	0.05	0.04
Other oil	4.5	4.1	3.7	3.8	3.8	3.9	3.6	3.1	2.8	2.8	3.0	2.9	2.5	2.0	2.0	2.0	2.7	6.0	6.3	6.7	6.0	5.8	5.7
<b>Gaseous fuels</b>	<b>90.8</b>	<b>95.0</b>	<b>99.3</b>	<b>104.6</b>	<b>113.3</b>	<b>117.6</b>	<b>123.1</b>	<b>121.1</b>	<b>138.7</b>	<b>138.9</b>	<b>141.9</b>	<b>153.9</b>	<b>152.9</b>	<b>169.2</b>	<b>163.0</b>	<b>149.1</b>	<b>159.4</b>	<b>147.5</b>	<b>150.8</b>	<b>134.6</b>	<b>148.7</b>	<b>130.0</b>	<b>114.7</b>
Natural gas	90.8	95.0	99.3	104.6	113.3	117.6	123.1	121.1	138.7	138.9	141.9	153.9	152.9	169.2	163.0	149.1	159.4	147.5	150.8	134.6	148.7	130.0	114.7
<b>Other</b>	<b>55.0</b>	<b>57.6</b>	<b>60.2</b>	<b>66.1</b>	<b>76.0</b>	<b>81.8</b>	<b>89.8</b>	<b>90.5</b>	<b>84.6</b>	<b>75.9</b>	<b>67.0</b>	<b>92.6</b>	<b>97.2</b>	<b>108.2</b>	<b>97.4</b>	<b>77.0</b>	<b>100.9</b>	<b>111.2</b>	<b>91.4</b>	<b>83.9</b>	<b>107.0</b>	<b>96.0</b>	<b>79.8</b>
Peat	53.3	56.0	58.7	64.5	73.7	79.4	87.5	88.0	80.7	71.8	62.5	87.1	92.0	101.8	90.3	69.2	93.6	102.4	81.8	72.5	95.1	84.9	65.0
Mixed fuels (MSW/REF/RDF/PDF)	0.8	0.8	0.8	0.8	1.4	1.4	0.9	1.2	1.3	1.3	2.8	3.9	3.3	4.5	5.5	6.5	6.2	7.6	8.8	10.6	10.8	10.2	13.3
Other fossil wastes etc.	0.9	0.8	0.7	0.8	0.9	1.0	1.4	1.4	2.5	2.7	1.7	1.6	1.9	1.9	1.7	1.3	1.1	1.1	0.9	0.8	1.0	0.9	1.5
<b>Biomass</b>	<b>178.6</b>	<b>176.0</b>	<b>173.5</b>	<b>205.9</b>	<b>213.7</b>	<b>217.4</b>	<b>217.4</b>	<b>247.5</b>	<b>256.2</b>	<b>270.9</b>	<b>272.6</b>	<b>263.8</b>	<b>285.8</b>	<b>291.1</b>	<b>305.3</b>	<b>284.9</b>	<b>319.1</b>	<b>306.4</b>	<b>314.4</b>	<b>282.4</b>	<b>334.6</b>	<b>331.4</b>	<b>348.4</b>
Black/sulphite liquor	87.4	87.0	86.6	104.8	111.2	111.1	108.0	129.2	124.4	142.4	139.9	125.3	140.6	138.2	145.0	129.4	156.0	154.1	141.8	110.2	135.7	135.1	135.8
Other woodfuels	90.4	88.1	85.8	100.1	101.4	104.7	107.8	116.5	130.0	126.7	130.5	136.5	142.7	149.9	157.2	151.9	159.4	148.5	164.6	160.4	186.1	181.6	195.9
Biogas	0.09	0.09	0.09	0.12	0.08	0.65	0.69	0.71	0.78	0.76	0.86	0.75	0.88	0.97	1.1	1.7	1.5	1.7	1.9	1.7	2.2	2.2	2.4
Bio diesel	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.00	0.44	2.5	2.6	4.6	7.3
Bio gasoline	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.03	0.18	0.19	NO	0.03	0.07	3.1	3.8	3.5	3.9	4.0
Bio gasoil	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.00	0.86	1.6	1.3	0.5
Hydrogen	0.62	0.79	0.95	0.88	0.94	0.96	0.82	0.93	1.03	0.87	1.1	1.1	1.3	1.2	1.3	1.1	1.4	1.2	1.1	1.0	1.1	1.1	1.0
Other non-fossil fuels	0.07	0.06	0.04	0.04	0.04	0.03	0.03	0.07	0.05	0.08	0.20	0.22	0.36	0.59	0.55	0.71	0.74	0.89	1.3	2.0	1.8	1.5	1.4
<b>Bunker fuels</b>	<b>37.4</b>	<b>35.4</b>	<b>39.8</b>	<b>33.1</b>	<b>28.7</b>	<b>26.1</b>	<b>28.7</b>	<b>30.5</b>	<b>35.5</b>	<b>37.9</b>	<b>41.0</b>	<b>38.6</b>	<b>41.3</b>	<b>41.6</b>	<b>38.6</b>	<b>38.3</b>	<b>42.5</b>	<b>41.4</b>	<b>40.9</b>	<b>31.5</b>	<b>31.1</b>	<b>34.7</b>	<b>30.4</b>
Jet fuel	13.8	13.0	11.5	10.8	11.3	12.3	13.1	13.6	14.0	14.9	14.5	14.9	14.7	15.2	17.5	17.6	19.6	22.6	24.5	21.4	22.6	26.7	25.8
Light fuel oil	5.2	4.9	5.6	6.1	6.3	6.6	6.4	6.6	6.8	6.8	6.8	6.1	4.4	4.0	2.1	2.1	2.6	3.3	3.2	2.0	2.7	2.6	1.8
Heavy fuel oil	18.4	17.6	22.7	16.1	11.1	7.3	9.2	10.2	14.6	16.0	19.6	17.5	22.1	22.3	19.0	18.5	20.3	15.4	13.2	8.0	5.8	5.3	2.8
Other oils	0.05	0.04	0.06	0.04	0.03	0.03	0.03	0.03	0.04	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.05	0.04	0.03	0.02	0.02	0.02	0.01

**Table 2\_3b.** CO<sub>2</sub> emissions from combustion by fuel, Tg

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>Solid fuels</b>	<b>14.5</b>	<b>13.5</b>	<b>12.5</b>	<b>14.5</b>	<b>17.7</b>	<b>14.2</b>	<b>18.3</b>	<b>16.8</b>	<b>12.8</b>	<b>13.0</b>	<b>12.9</b>	<b>14.4</b>	<b>16.1</b>	<b>21.7</b>	<b>19.4</b>	<b>11.2</b>	<b>19.1</b>	<b>16.8</b>	<b>12.1</b>	<b>12.8</b>	<b>16.2</b>	<b>12.4</b>	<b>10.0</b>
Hard coal	12.0	10.9	9.9	11.6	14.7	11.5	15.5	13.5	9.4	9.5	9.2	11.1	12.8	18.1	15.8	7.5	15.4	13.3	8.8	10.7	13.4	9.6	7.8
Coke	0.6	0.6	0.5	0.5	0.6	0.5	0.5	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.5	0.4	0.5	0.5	0.1
Blast furnace gases	1.7	1.8	1.9	2.1	2.1	1.9	2.1	2.4	2.5	2.6	2.8	2.4	2.5	2.7	2.7	2.7	2.8	2.6	2.4	1.4	2.0	2.0	1.7
Coke oven gas	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.2	0.3	0.3	0.3
Other coal	0.00	0.00	0.00	0.01	0.03	0.04	0.02	0.01	0.00	0.01	0.01	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.03	0.02	0.01	0.04
<b>Liquid fuels</b>	<b>27.8</b>	<b>27.1</b>	<b>26.6</b>	<b>25.6</b>	<b>26.2</b>	<b>25.5</b>	<b>25.8</b>	<b>25.8</b>	<b>26.3</b>	<b>26.6</b>	<b>25.7</b>	<b>26.1</b>	<b>26.5</b>	<b>26.6</b>	<b>26.4</b>	<b>25.8</b>	<b>26.0</b>	<b>26.0</b>	<b>24.2</b>	<b>23.3</b>	<b>24.3</b>	<b>23.2</b>	<b>22.7</b>
Heavy fuel oil	5.6	5.4	5.2	4.8	5.1	4.6	4.7	4.3	4.2	4.3	3.9	4.0	4.1	4.0	3.7	3.4	3.5	3.3	2.7	2.6	2.9	2.4	2.2
Light fuel oil	7.8	7.7	7.6	7.5	7.4	7.3	7.4	7.4	7.5	7.5	7.2	7.3	7.2	7.2	7.0	6.6	6.5	6.3	5.8	5.5	5.8	5.3	5.7
Motor gasoline	6.2	6.2	6.3	5.9	6.0	6.0	5.8	5.9	5.8	5.8	5.6	5.7	5.8	5.8	5.9	5.9	5.8	5.8	5.2	5.0	4.9	4.7	4.5
Diesel oil	4.9	4.6	4.6	4.5	4.7	4.6	4.7	5.1	5.3	5.5	5.6	5.7	5.9	6.0	6.3	6.3	6.5	6.9	7.0	6.6	7.2	7.2	7.0
LPG	0.43	0.40	0.38	0.37	0.45	0.46	0.49	0.55	0.66	0.58	0.71	0.70	0.71	0.77	0.80	0.84	0.90	0.82	0.85	0.71	0.84	0.83	0.82
Refinery gases	1.48	1.48	1.47	1.31	1.47	1.44	1.51	1.42	1.57	1.54	1.38	1.44	1.56	1.56	1.46	1.42	1.42	1.46	1.40	1.57	1.49	1.55	1.44
Town gas	0.010	0.007	0.007	0.002	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Recycled waste oil	0.04	0.03	0.03	0.04	0.03	0.04	0.05	0.07	0.07	0.07	0.07	0.06	0.07	0.10	0.11	0.11	0.09	0.06	0.07	0.07	0.09	0.08	0.07
Petroleum coke	0.47	0.48	0.49	0.48	0.47	0.47	0.53	0.51	0.52	0.50	0.45	0.42	0.54	0.51	0.56	0.56	0.56	0.62	0.56	0.50	0.50	0.58	0.55
Jet fuel	0.40	0.41	0.39	0.38	0.39	0.36	0.38	0.42	0.46	0.47	0.50	0.47	0.44	0.45	0.41	0.46	0.44	0.43	0.43	0.41	0.43	0.39	0.37
Aviation gasoline	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	0.01	0.02	0.02	0.01	0.01	0.01	0.00	0.00
Other oil	0.36	0.33	0.30	0.32	0.28	0.32	0.29	0.25	0.23	0.24	0.25	0.24	0.20	0.16	0.17	0.15	0.21	0.21	0.20	0.20	0.17	0.17	0.15
<b>Gaseous fuels</b>	<b>5.0</b>	<b>5.2</b>	<b>5.4</b>	<b>5.7</b>	<b>6.2</b>	<b>6.4</b>	<b>6.7</b>	<b>6.6</b>	<b>7.6</b>	<b>7.6</b>	<b>7.8</b>	<b>8.4</b>	<b>8.4</b>	<b>9.3</b>	<b>8.9</b>	<b>8.2</b>	<b>8.7</b>	<b>8.1</b>	<b>8.3</b>	<b>7.4</b>	<b>8.1</b>	<b>7.1</b>	<b>6.3</b>
Natural gas	5.0	5.2	5.4	5.7	6.2	6.4	6.7	6.6	7.6	7.6	7.8	8.4	8.4	9.3	8.9	8.2	8.7	8.1	8.3	7.4	8.1	7.1	6.3
<b>Other</b>	<b>5.7</b>	<b>6.0</b>	<b>6.2</b>	<b>6.9</b>	<b>7.8</b>	<b>8.5</b>	<b>9.3</b>	<b>9.4</b>	<b>8.7</b>	<b>7.8</b>	<b>6.8</b>	<b>9.5</b>	<b>9.9</b>	<b>11.0</b>	<b>9.8</b>	<b>7.6</b>	<b>10.1</b>	<b>11.1</b>	<b>8.9</b>	<b>8.0</b>	<b>10.4</b>	<b>9.3</b>	<b>7.6</b>
Peat	5.6	5.9	6.1	6.7	7.7	8.3	9.2	9.2	8.4	7.5	6.5	9.1	9.6	10.7	9.4	7.2	9.8	10.7	8.6	7.6	10.0	8.9	6.9
Mixed fuels																							
(MSW/REF/ RDF/PDF	0.04	0.03	0.03	0.03	0.06	0.05	0.04	0.05	0.05	0.05	0.13	0.19	0.13	0.17	0.20	0.22	0.21	0.24	0.29	0.37	0.38	0.36	0.48
Other fossil wastes etc.	0.09	0.08	0.08	0.09	0.09	0.11	0.16	0.14	0.23	0.25	0.17	0.16	0.18	0.19	0.16	0.13	0.12	0.12	0.10	0.09	0.10	0.10	0.14
<b>Biomass</b>	<b>19.3</b>	<b>19.0</b>	<b>18.7</b>	<b>22.2</b>	<b>23.1</b>	<b>23.4</b>	<b>23.4</b>	<b>26.7</b>	<b>27.6</b>	<b>29.2</b>	<b>29.4</b>	<b>28.4</b>	<b>30.8</b>	<b>31.4</b>	<b>32.9</b>	<b>30.7</b>	<b>34.3</b>	<b>33.0</b>	<b>33.7</b>	<b>30.0</b>	<b>35.6</b>	<b>35.3</b>	<b>37.0</b>
Black/sulphite liquor	9.5	9.4	9.4	11.4	12.1	12.1	11.7	14.0	13.5	15.5	15.2	13.6	15.3	15.0	15.7	14.0	16.9	16.7	15.4	12.0	14.7	14.7	14.7
Other woodfuels	9.8	9.5	9.3	10.8	11.0	11.3	11.7	12.6	14.1	13.7	14.1	14.8	15.4	16.2	17.0	16.5	17.2	16.1	17.8	17.4	20.1	19.7	21.2
Biogas	0.005	0.005	0.005	0.006	0.004	0.036	0.038	0.039	0.044	0.043	0.048	0.042	0.049	0.054	0.062	0.097	0.085	0.097	0.10	0.10	0.12	0.12	0.13
Bio diesel	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.000	0.032	0.17	0.19	0.33	0.53
Bio gasoline	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.002	0.012	0.013	NO	0.002	0.005	0.19	0.22	0.21	0.27	0.28
Bio gasoil	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.000	0.061	0.116	0.094	0.036	
Hydrogen	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other non-fossil fuels	0.008	0.006	0.004	0.004	0.004	0.003	0.003	0.008	0.006	0.008	0.021	0.024	0.038	0.063	0.059	0.077	0.079	0.086	0.12	0.17	0.15	0.13	0.11
<b>Bunker fuels</b>	<b>2.8</b>	<b>2.7</b>	<b>3.0</b>	<b>2.5</b>	<b>2.2</b>	<b>2.0</b>	<b>2.2</b>	<b>2.3</b>	<b>2.7</b>	<b>2.9</b>	<b>3.1</b>	<b>2.9</b>	<b>3.2</b>	<b>3.2</b>	<b>2.9</b>	<b>2.9</b>	<b>3.2</b>	<b>3.1</b>	<b>3.1</b>	<b>2.4</b>	<b>2.3</b>	<b>2.6</b>	<b>2.2</b>
Jet fuel	1.0	0.9	0.8	0.8	0.8	0.9	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.3	1.3	1.4	1.7	1.8	1.6	1.7	2.0	1.9
Light fuel oil	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1
Heavy fuel oil	1.4	1.4	1.8	1.3	0.9	0.6	0.7	0.8	1.2	1.3	1.5	1.4	1.7	1.8	1.5	1.5	1.6	1.2	1.0	0.6	0.5	0.4	0.2
Other oils	0.003	0.003	0.004	0.003	0.003	0.002	0.002	0.002	0.003	0.003	0.004	0.003	0.004	0.004	0.003	0.003	0.003	0.003	0.002	0.001	0.001	0.001	0.001

**Table 3\_3b.** CH<sub>4</sub> emissions from combustion by fuel, Mg

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>Solid fuels</b>	<b>286</b>	<b>275</b>	<b>265</b>	<b>231</b>	<b>398</b>	<b>181</b>	<b>223</b>	<b>199</b>	<b>150</b>	<b>149</b>	<b>146</b>	<b>163</b>	<b>179</b>	<b>238</b>	<b>213</b>	<b>122</b>	<b>207</b>	<b>181</b>	<b>134</b>	<b>152</b>	<b>183</b>	<b>138</b>	<b>117</b>
Hard coal	269	258	248	211	377	161	204	177	128	125	122	141	156	215	189	98	183	158	111	135	163	117	100
Coke	6.0	5.5	5.0	5.1	5.3	4.9	4.3	5.5	5.4	5.5	5.5	4.7	4.7	5.1	5.6	5.7	5.2	6.8	5.1	4.2	4.7	5.1	1.3
Blast furnace gases	6.9	7.2	7.5	8.3	8.3	7.5	8.3	9.5	10.0	10.5	11.2	9.8	10.1	11.0	10.8	11.0	11.5	10.6	10.6	6.3	9.1	9.1	7.5
Coke oven gas	4.2	4.2	4.2	6.9	7.6	7.2	6.8	7.2	7.2	7.2	7.1	7.1	7.2	7.1	7.0	7.0	7.3	5.4	6.7	5.7	6.6	7.0	7.3
Other coal	0.02	0.04	0.05	0.16	0.34	0.38	0.20	0.12	0.06	0.27	0.17	0.33	0.28	0.25	0.28	0.29	0.14	0.18	0.14	0.32	0.32	0.12	0.51
<b>Liquid fuels</b>	<b>5 879</b>	<b>5 576</b>	<b>5 420</b>	<b>5 196</b>	<b>5 010</b>	<b>4 846</b>	<b>4 704</b>	<b>4 537</b>	<b>4 432</b>	<b>4 284</b>	<b>4 023</b>	<b>3 899</b>	<b>3 777</b>	<b>3 619</b>	<b>3 392</b>	<b>3 172</b>	<b>2 963</b>	<b>2 816</b>	<b>2 460</b>	<b>2 343</b>	<b>2 356</b>	<b>2 266</b>	<b>2 154</b>
Heavy fuel oil	257.5	243.1	228.7	187.1	172.9	136.6	146.8	139.4	144.0	148.3	131.7	134.6	138.8	137.2	125.4	118.5	117.7	115.2	99.4	100.1	108.8	95.0	94.7
Light fuel oil	801	791	781	773	755	744	754	742	758	751	712	723	716	710	687	646	633	608	552	534	569	501	540
Motor gasoline	4 188	3 967	3 859	3 693	3 555	3 463	3 325	3 201	3 099	2 979	2 796	2 672	2 558	2 409	2 226	2 052	1 861	1 740	1 464	1 390	1 357	1 354	1 220
Diesel oil	546	491	471	467	446	422	396	374	344	324	300	286	278	275	268	265	261	258	250	227	229	223	210
LPG	29.0	27.8	26.7	24.5	26.5	26.5	26.4	26.6	28.9	23.1	28.1	28.3	29.2	31.1	31.9	33.2	35.5	33.7	34.8	28.6	32.2	32.2	32.6
Refinery gases	22.9	22.9	22.9	20.2	22.9	22.4	23.4	22.0	24.4	23.9	21.5	22.4	24.1	24.2	22.7	24.7	24.7	26.2	25.6	29.3	27.9	29.0	26.9
Town gas	0.49	0.37	0.37	0.12	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Recycled waste oil	0.53	0.44	0.34	0.51	0.44	0.52	0.66	0.97	0.93	0.95	0.94	0.76	0.92	1.34	1.44	1.36	1.13	0.83	0.94	0.88	1.22	1.07	0.89
Petroleum coke	4.9	5.0	5.1	5.0	4.8	4.9	5.5	5.3	5.4	5.3	4.7	4.3	5.6	5.3	5.9	5.5	5.4	6.2	6.0	5.5	5.2	6.1	5.8
Jet fuel	13.9	14.2	13.4	13.4	14.2	13.1	15.4	16.9	18.3	19.2	19.2	17.9	18.4	19.5	17.1	19.5	16.8	16.6	17.0	16.3	17.1	15.6	15.0
Aviation gasoline	0.09	0.07	0.06	0.06	0.06	0.07	0.06	0.06	0.06	0.08	0.07	0.05	0.06	0.11	0.10	0.08	0.10	0.11	0.08	0.04	0.04	0.03	0.02
Other oil	14.1	12.8	11.4	11.4	11.9	12.5	11.0	9.7	9.3	9.2	9.4	9.6	8.6	6.6	6.5	6.3	7.3	11.2	11.0	10.3	8.8	8.5	8.7
<b>Gaseous fuels</b>	<b>111</b>	<b>133</b>	<b>156</b>	<b>153</b>	<b>169</b>	<b>193</b>	<b>209</b>	<b>242</b>	<b>292</b>	<b>289</b>	<b>287</b>	<b>335</b>	<b>472</b>	<b>539</b>	<b>472</b>	<b>403</b>	<b>449</b>	<b>378</b>	<b>391</b>	<b>349</b>	<b>344</b>	<b>280</b>	<b>236</b>
Natural gas	111	133	156	153	169	193	209	242	292	289	287	335	472	539	472	403	449	378	391	349	344	280	236
<b>Other</b>	<b>240</b>	<b>231</b>	<b>223</b>	<b>251</b>	<b>280</b>	<b>315</b>	<b>349</b>	<b>357</b>	<b>342</b>	<b>305</b>	<b>301</b>	<b>380</b>	<b>406</b>	<b>452</b>	<b>413</b>	<b>353</b>	<b>451</b>	<b>492</b>	<b>438</b>	<b>436</b>	<b>536</b>	<b>480</b>	<b>444</b>
Peat	230	225	220	247	274	309	342	350	333	296	289	368	393	437	396	330	431	466	409	399	501	447	396
Mixed fuels																							
(MSW/REF/RDF/P	4.0	2.7	1.4	1.5	3.5	3.6	2.1	2.5	3.0	3.0	7.2	6.6	6.7	9.8	12.5	20.7	18.1	24.2	26.5	36.2	33.4	31.2	45.6
Other fossil wastes	5.1	3.2	1.2	2.4	2.7	1.9	4.5	4.5	6.3	6.1	5.3	5.1	5.5	5.1	4.4	2.9	2.1	2.2	1.8	1.5	1.9	1.9	2.4
<b>Biomass</b>	<b>8 087</b>	<b>8 132</b>	<b>8 178</b>	<b>8 313</b>	<b>8 362</b>	<b>8 644</b>	<b>9 016</b>	<b>9 103</b>	<b>9 200</b>	<b>9 051</b>	<b>8 862</b>	<b>9 872</b>	<b>10 212</b>	<b>10 364</b>	<b>10 456</b>	<b>10 441</b>	<b>10 788</b>	<b>10 812</b>	<b>11 457</b>	<b>11 989</b>	<b>13 486</b>	<b>11 781</b>	<b>12 834</b>
Black/sulphite liquor	87	87	87	105	111	111	108	129	125	143	140	125	141	138	145	129	156	154	142	110	136	135	136
Other woodfuels	7 998	8 044	8 090	8 195	8 243	8 472	8 839	8 899	9 005	8 834	8 645	9 678	10 000	10 140	10 231	10 233	10 557	10 575	11 169	11 709	13 038	11 252	12 302
Biogas	0.37	0.30	0.22	12.1	6.3	59	68	74	70	74	76	67	68	77	74	75	72	79	79	75	219	288	294
Bio diesel	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.01	1.14	6.2	6.1	10.3	15.8
Bio gasoline	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.91	4.5	4.2	NO	0.61	1.14	62.4	75.5	69.4	80.5	78.3
Bio gasoil	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	6.9	13.2	9.3	3.6
Hydrogen	0.62	0.80	0.97	0.88	0.96	0.96	0.82	0.93	1.03	0.87	1.1	1.1	1.3	1.2	1.3	1.1	1.4	1.2	1.1	1.0	1.1	1.2	1.2
Other non-fossil fuels	0.30	0.23	0.16	0.16	0.15	0.11	0.12	0.28	0.21	0.31	0.45	0.56	1.3	3.3	1.1	1.5	1.5	1.8	2.8	4.3	3.7	3.6	3.1
<b>Bunker fuels</b>	<b>162</b>	<b>154</b>	<b>184</b>	<b>146</b>	<b>117</b>	<b>96</b>	<b>117</b>	<b>126</b>	<b>155</b>	<b>174</b>	<b>198</b>	<b>177</b>	<b>182</b>	<b>183</b>	<b>153</b>	<b>153</b>	<b>164</b>	<b>142</b>	<b>129</b>	<b>88</b>	<b>81</b>	<b>83</b>	<b>63</b>
Jet fuel	26	24	21	21	21	23	31	33	33	39	44	40	27	28	36	32	31	35	38	33	35	41	40
Light fuel oil	22	21	24	27	27	28	28	29	30	33	31	27	20	18	9	10	12	16	15	9	13	12	8
Heavy fuel oil	113	108	139	99	68	44	57	64	91	103	122	109	135	137	108	111	120	91	76	46	33	30	16
Other oils	0.29	0.28	0.35	0.27	0.21	0.17	0.19	0.21	0.27	0.29	0.33	0.29	0.32	0.32	0.24	0.25	0.27	0.22	0.19	0.12	0.10	0.09	0.05

**Table 4\_3b.** N<sub>2</sub>O emissions from combustion by fuel, Mg

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>Solid fuels</b>	<b>293</b>	<b>279</b>	<b>265</b>	<b>300</b>	<b>321</b>	<b>274</b>	<b>313</b>	<b>300</b>	<b>247</b>	<b>248</b>	<b>240</b>	<b>274</b>	<b>294</b>	<b>361</b>	<b>336</b>	<b>241</b>	<b>324</b>	<b>300</b>	<b>236</b>	<b>228</b>	<b>256</b>	<b>196</b>	<b>200</b>
Hard coal	274	261	248	278	295	248	292	277	223	223	215	250	271	336	311	215	298	273	211	210	233	171	181
Coke	6.6	5.9	5.1	5.3	5.4	5.3	4.8	6.1	5.9	6.0	6.1	5.2	5.2	5.6	6.2	6.4	5.9	9.9	6.0	4.6	5.3	6.0	2.2
Blast furnace gases	7.1	7.4	7.7	8.3	8.3	7.5	8.3	9.5	10.0	10.5	11.2	9.8	10.1	11.1	10.9	11.2	11.5	10.6	11.9	7.2	10.3	10.4	8.5
Coke oven gas	4.2	4.2	4.2	7.5	8.2	7.9	7.4	8.0	8.0	8.0	8.0	8.0	8.1	8.0	7.8	7.9	8.2	6.2	7.4	6.4	7.3	7.8	8.0
Other coal	0.60	0.33	0.05	0.42	4.67	5.05	0.22	0.11	0.07	0.33	0.24	0.40	0.37	0.32	0.36	0.41	0.17	0.26	0.14	0.38	0.37	0.14	0.56
<b>Liquid fuels</b>	<b>971</b>	<b>958</b>	<b>950</b>	<b>935</b>	<b>945</b>	<b>935</b>	<b>946</b>	<b>944</b>	<b>967</b>	<b>977</b>	<b>944</b>	<b>961</b>	<b>964</b>	<b>960</b>	<b>942</b>	<b>927</b>	<b>919</b>	<b>915</b>	<b>862</b>	<b>843</b>	<b>869</b>	<b>831</b>	<b>817</b>
Heavy fuel oil	155	148	142	131	135	119	121	111	114	118	102	106	106	103	97	90	91	87	72	70	77	61	59
Light fuel oil	210	207	204	203	198	197	201	201	206	205	196	197	196	194	189	179	175	171	158	148	158	144	154
Motor gasoline	300	305	311	312	315	323	319	319	319	318	307	311	303	293	282	267	250	231	191	181	173	152	136
Diesel oil	220	211	208	209	208	210	214	223	230	238	244	251	260	270	277	287	296	311	326	327	346	357	356
LPG	10.0	9.3	8.7	8.7	10.0	10.0	10.8	12.2	14.0	13.2	15.6	15.3	15.7	17.3	17.9	18.4	19.5	18.5	18.8	15.1	17.7	17.5	17.1
Refinery gases	42.4	42.6	42.9	38.5	45.0	43.3	46.0	43.3	48.1	47.5	42.4	44.1	47.5	47.8	45.1	48.9	48.9	51.3	50.2	58.1	55.4	57.4	53.3
Town gas	0.16	0.12	0.12	0.04	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Recycled waste oil	0.54	0.46	0.37	0.52	0.44	0.52	0.67	1.3	1.2	1.2	1.2	1.0	1.2	2.1	2.2	2.3	2.2	1.7	1.9	1.8	2.4	2.2	1.8
Petroleum coke	9.8	10.0	10.2	10.0	9.6	9.7	10.9	10.6	10.9	10.5	9.4	8.7	11.2	10.5	11.7	11.0	10.9	12.3	12.1	11.0	10.5	12.3	11.6
Jet fuel	16.6	16.9	15.9	15.6	15.8	14.7	15.7	17.1	18.7	19.3	20.4	19.2	18.2	18.4	16.8	19.5	18.9	19.2	19.0	18.3	18.8	17.2	16.5
Aviation gasoline	0.34	0.26	0.26	0.26	0.26	0.26	0.23	0.24	0.22	0.30	0.29	0.23	0.23	0.42	0.41	0.30	0.44	0.44	0.35	0.18	0.17	0.10	0.08
Other oil	7.8	7.1	6.5	6.6	6.8	7.5	6.9	6.1	5.6	5.5	6.0	6.7	5.3	4.2	4.2	4.1	5.1	11.5	12.2	12.5	11.3	10.9	10.9
<b>Gaseous fuels</b>	<b>103</b>	<b>108</b>	<b>113</b>	<b>118</b>	<b>127</b>	<b>130</b>	<b>139</b>	<b>136</b>	<b>154</b>	<b>156</b>	<b>163</b>	<b>173</b>	<b>170</b>	<b>187</b>	<b>182</b>	<b>166</b>	<b>177</b>	<b>166</b>	<b>171</b>	<b>151</b>	<b>163</b>	<b>145</b>	<b>130</b>
Natural gas	103	108	113	118	127	130	139	136	154	156	163	173	170	187	182	166	177	166	171	151	163	145	130
<b>Other</b>	<b>172</b>	<b>186</b>	<b>200</b>	<b>225</b>	<b>258</b>	<b>296</b>	<b>348</b>	<b>352</b>	<b>332</b>	<b>285</b>	<b>267</b>	<b>379</b>	<b>421</b>	<b>465</b>	<b>416</b>	<b>337</b>	<b>424</b>	<b>465</b>	<b>381</b>	<b>344</b>	<b>456</b>	<b>420</b>	<b>324</b>
Peat	169	183	197	222	253	291	342	346	323	277	258	367	408	444	392	309	399	433	345	303	414	382	279
Mixed fuels	1.2	1.3	1.4	1.5	3.5	3.6	3.2	3.4	3.4	3.0	5.2	7.5	8.4	16.0	19.4	25.3	22.4	30.1	34.7	39.7	41.0	36.4	42.7
Other fossil wastes etc	2.0	1.7	1.4	1.6	2.1	2.2	3.1	3.2	5.5	4.8	4.0	4.5	5.3	5.0	4.6	2.6	2.2	2.3	1.7	1.5	1.9	1.8	2.8
<b>Biomass</b>	<b>283</b>	<b>275</b>	<b>267</b>	<b>329</b>	<b>345</b>	<b>357</b>	<b>382</b>	<b>447</b>	<b>477</b>	<b>509</b>	<b>524</b>	<b>517</b>	<b>546</b>	<b>552</b>	<b>595</b>	<b>565</b>	<b>612</b>	<b>574</b>	<b>647</b>	<b>606</b>	<b>730</b>	<b>751</b>	<b>794</b>
Black/sulphite liquor	88	87	87	105	111	111	108	129	125	143	140	125	141	138	145	129	156	154	142	110	136	135	136
Other woodfuels	193	186	179	223	232	244	272	316	350	364	381	388	402	409	444	430	450	413	488	466	565	579	614
Biogas	0.10	0.10	0.09	0.12	0.09	0.67	0.70	0.71	0.78	0.78	0.89	0.78	0.98	1.05	1.2	1.8	1.6	1.9	2.0	1.9	2.2	2.4	2.6
Bio diesel	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.02	1.5	8.9	9.2	16.5	26.7
Bio gasoline	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.13	0.69	0.68	NO	0.11	0.22	8.1	9.8	8.8	8.9	8.7
Bio gasoil	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	1.7	3.3	2.6	1.0
Hydrogen	0.63	0.83	1.02	0.95	1.06	1.07	0.95	1.06	1.25	0.98	1.2	1.3	1.5	1.4	1.5	1.3	1.7	1.3	1.3	1.1	1.2	1.2	1.1
Other non-fossil fuels	0.52	0.40	0.28	0.28	0.27	0.20	0.21	0.49	0.34	0.50	0.90	1.0	1.3	1.6	2.1	2.6	2.9	3.1	4.9	6.2	5.3	5.3	4.5
<b>Bunker fuels</b>	<b>89</b>	<b>85</b>	<b>92</b>	<b>78</b>	<b>69</b>	<b>65</b>	<b>71</b>	<b>75</b>	<b>86</b>	<b>93</b>	<b>98</b>	<b>93</b>	<b>98</b>	<b>98</b>	<b>92</b>	<b>94</b>	<b>105</b>	<b>106</b>	<b>108</b>	<b>86</b>	<b>86</b>	<b>97</b>	<b>88</b>
Jet fuel	41	39	34	32	34	37	39	41	42	45	44	45	44	45	53	53	59	68	75	66	69	82	79
Light fuel oil	10	10	11	12	13	13	13	13	14	14	14	12	9	8	4	4	5	7	6	4	5	5	4
Heavy fuel oil	38	36	46	33	23	15	19	21	30	34	40	36	45	45	36	37	41	31	27	16	12	11	6
Other oils	0.10	0.09	0.12	0.09	0.07	0.06	0.06	0.07	0.09	0.10	0.11	0.10	0.11	0.11	0.08	0.08	0.09	0.08	0.07	0.04	0.03	0.03	0.02

## Appendix\_3c

### Data on CO<sub>2</sub> capture and transfer to PCC production from lime kilns and industrial power plants

**Table 1\_3c** Amount of produced PCC.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Produced PCC using transferred CO <sub>2</sub> , t	1 951	45 633	123 151	167 256	241 253	290 366	355 854	413 381	402 875	401 032	429 614	473 183	424 671	481 746	532 137	484 861	420 648	449 427	408 434	333 492

The Finnish Forest Industries collected the total produced amount of PCC for years 1993-2007. Statistics Finland have collected PCC data for years 2008-2012 from Production statistics (plant specific data from Statistics Finland's manufacturing industry surveys) and compared the amount with information from VAHTI database. Annual production (years 1993-2007) has been compared with added up plant level PCC data received from production statistics, only small differences (+/-2%) were noticed (years 2000-2007).

**Table 2\_3c** The share of fossil fuels of total transferred CO<sub>2</sub>.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
The share of biological emission of total transferred CO <sub>2</sub> (%)			No plant level data of PCC production until 2000					8	16	14	15	13	13	13	11	12	17	15	11	0*
The share of fossil fuels and other emissions of total transferred CO <sub>2</sub> (%)			No plant level data of PCC production until 2000					92	84	86	85	87	87	87	89	88	83	85	89	100

All fuels used in the lime kilns and industrial power plants for the whole time series have been collected unit level and the percentage of emissions from fossil fuels have been calculated separately.

\* A plant using wood fuels was closed down in 2011.

**Table 3\_3c** Reported (negative emission figure in 1.A 2f Transferred CO<sub>2</sub>) emissions in the inventory.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Reported transferred CO <sub>2</sub> (tonnes CO <sub>2</sub> )	858	20 065	54 151	73 544	106 081	127 677	156 472	181 767	177 148	176 337	188 905	208 063	186 732	211 828	233 985	213 198	184 963	197 617	179 592	146 639

Statistics Finland has received kiln and plant level data of transferred CO<sub>2</sub> from 2005 to 2012 (emissions trading periods) from the Energy Authority. The ETS companies do not measure the amount of transferred CO<sub>2</sub> but calculate it based on the amount of produced PCC. The amount of transferred CO<sub>2</sub> from 1993 to 2004 has been calculated at Statistics Finland using the total amount of produced PCC (based on production data received from the Finnish Forest Industries). Statistics Finland has also checked that CO<sub>2</sub> amount of every single plant (years 2005 to 2012) summed up is the same as the amount calculated from the total amount of PCC production.

## Appendix\_3d

### *Statement on potential CO<sub>2</sub> emissions from Calcium Carbonate in fibre sludge*

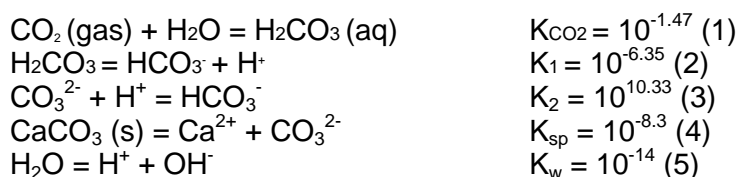
Concerning the potential emission of CO<sub>2</sub> from calcium carbonate-water interaction in fibre sludge-bearing earth structures, we state the following:

Precipitated Calcium Carbonate, also known as PCC, is a widely used artificial additive in paper making processes, particularly as filler in fine paper production. Depending on the material efficiency in papermaking, minor amounts of PCC will be carried along to effluent, where PCC will be recovered mainly by using a simple external purification method based on gravity. Since the essential part of papermaking is the use of chemical pulp, certain amounts of wood-based fibers can also be found from this recovered fraction.

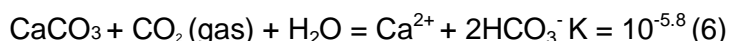
PCC-bearing fibre sludge is nowadays mainly utilized in many earth construction applications, e.g., as a hydraulic barrier in landfill cover structures, in impermeable reactive walls and in sub-base filter in roads and sport areas. Under these circumstances, it will be occasionally exposed to acid rain water. Infiltration of water into a fiber sludge layer depends on its hydraulic conductivity, which is typically lower than 10<sup>-9</sup> m/s.

The crystal forms of PCC are aragonite and calcite, depending upon manufacturing conditions. Typical for aragonite are needles and aggregates of needles, whereas calcite precipitates as scalenohedral or rhombohedral agglomerates, or prismatic particles. PCC is a very stable compound in moisture-free, neutral or alkaline conditions. When pH of water containing calcium carbonate is between 8.4 and 9.9, the solubility of calcium carbonate as such is very small, only 25 mg/dm<sup>3</sup>. However, the solubility in that case is also greatly depending on the content of dissolved carbon dioxide in water. With very high carbon dioxide concentration, the solubility could be even 1500 mg/dm<sup>3</sup>. This is due to decomposition of the bicarbonate formed in the solution. If pH drops below 6.5–7.0, the solubility increases dramatically. A complex mixture is formed including different soluble calcium cations and carbonate anions, depending on pH, concentration, and time.

Equilibrium relations between CO<sub>2</sub> in atmosphere, pH and carbonic acid components in water and precipitation/dissolution of calcium carbonate can be calculated using the following reactions and related equilibrium constants (Appelo and Postma, 1996, Garrels and Christ, 1965):



By summing up equations 1-4, the following net carbonate dissolution reaction is obtained:



From the above equation, important stoichiometric conditions can be seen:

1) for two bicarbonate ions that are formed, one carbon ion is from calcium carbonate and the other one is from CO<sub>2</sub>

2) for one Ca<sup>2+</sup> ion dissolved one CO<sub>2</sub> molecule is consumed from the solution. In the open system, this CO<sub>2</sub> is replaced from the CO<sub>2</sub> in the atmosphere. In other words, dissolution of calcium carbonate contributes to the atmospheric CO<sub>2</sub> sink rather than causes emission of CO<sub>2</sub> gas.

**What happens when rainwater is equilibrated with calcium carbonate in soil or sediment?**

This is demonstrated below under two different conditions:

- 1) a contact with atmospheric CO<sub>2</sub> is retained (open system) or
- 2) the system becomes closed to atmosphere before reaction with calcium carbonate is started.

Results are shown in the Table1. Rainwater which is in equilibrium with the present CO<sub>2</sub> pressure of the atmosphere (10–3.5 atm) has a pH value of 5.66 and a total dissolved carbon content (CT) of 10–4.9 mol. In an open soil system, calcium carbonate will dissolve until the Ca<sup>2+</sup> concentration of pore water reaches a value of ca. 20 mg/l and the total carbon content 10–3.0 mol. As far as calcium carbonate is present, the pH value of water is buffered by this reaction at 8.3. In a closed system, the dissolution of calcium carbonate is more restricted resulting in a Ca<sup>2+</sup> concentration of ca. 6 mg/l, pH of 9.9 and a lower CT content compared to the open system. Evidently, the external source of atmospheric CO<sub>2</sub> in the open system promotes the solution reaction.

Table 1. Contents of carbon species (mol) and Ca<sup>2+</sup> (mg/l), pH, and P<sub>CO2</sub> (atm) in rainwater before and after equilibration in soil with calcium carbonate in open and closed systems

	Rain water	Carbonate-water Open system	Carbonate-water Closed system
logPCO <sub>2</sub>	-3.5	-3.5	-6.0
pH	5.7	8.3	9.9
logH <sub>2</sub> CO <sub>3</sub>	-5.0	-5.0	-7.5
logHCO <sub>3</sub> <sup>-</sup>	-5.7	-3.0	-4.0
log CO <sub>3</sub> <sup>2-</sup>	-10.3	-5.0	-4.4
logCT	-4.9	-3.0	-3.9
Ca <sup>2+</sup>	-	20	5.7

**In conclusion, based on the above discussion, no CO<sub>2</sub> emission to the atmosphere can be expected from dissolution of PCC if fibre sludge is used as a material in earth construction.**

#### References

Appelo, C.A.J., Postma, D. 1996. Geochemistry, Groundwater and Pollution. A.A. Balkema, Rotterdam, 536 p.

Garrels, R.M., Christ, C.L., 1965. Solutions, Minerals, and Equilibria. Harper and Row, New York, 450 p. September 14, 2007

September 14, 2007

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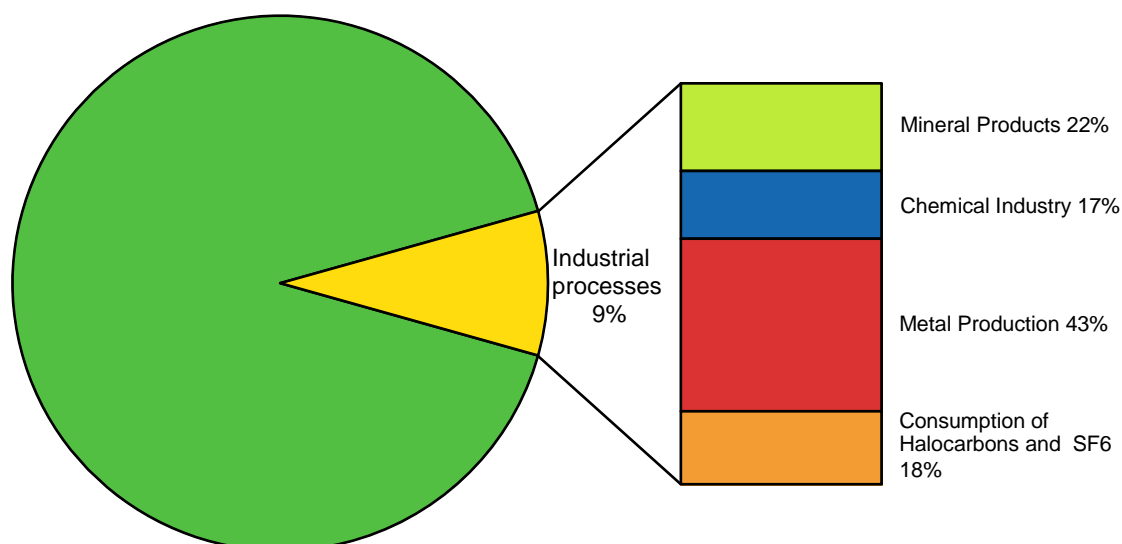
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## 4 INDUSTRIAL PROCESSES (CRF 2)

### 4.1 Overview of the sector

#### 4.1.1 Description and quantitative overview

Greenhouse gas emissions from Industrial Processes contributed 9% to the total anthropogenic greenhouse gas emissions in Finland in 2012 (Figure 4.1-1), totalling 5.3 Tg CO<sub>2</sub> equivalent.



**Figure 4.1-1** Emissions from industrial processes compared with total emissions in 2012

Finnish greenhouse gas emissions from Industrial Processes are divided into following emission categories:

- Mineral Products (CRF 2.A) includes CO<sub>2</sub> emissions from cement, lime and glass production, limestone, dolomite and soda ash use and indirect CO<sub>2</sub> emissions from NMVOC emissions from road paving with asphalt, asphalt roofing and cement production.
- Chemical Industry (CRF 2.B) includes N<sub>2</sub>O emissions from nitric acid and CO<sub>2</sub> emissions from hydrogen, phosphoric acid production and indirect CO<sub>2</sub> emissions from NMVOC emissions from chemicals production
- Metal Production (CRF 2.C) includes CH<sub>4</sub> emissions from coke production and CO<sub>2</sub> emissions from coke and heavy bottom oil used in blast furnaces and indirect CO<sub>2</sub> emissions from NMVOC emissions from iron and steel and non-ferrous metal production and from methane emissions from coke production.
- Consumption of Halocarbons and SF<sub>6</sub> (CRF 2.F) covers emissions of F-gases from refrigeration and air conditioning, foam blowing, aerosols and electrical equipment, as well as some smaller sources, such as semiconductor manufacturing and fixed fire protection systems.

General assessment of completeness can be found in Section 1.8 and more detailed assessment is included in Annex 5.

Under Other Production (CRF 2.D) Finland reports NMVOC emissions from the forest and food industries. In addition, NMVOC emissions from cement production, asphalt roofing and road paving with asphalt are reported under Mineral Products (CRF 2.A) and NMVOC emissions from iron and steel production and non-ferrous metals are reported under Metal Production (CRF 2.C). Other NMVOC emissions from the chemical industry and storage of chemicals are reported under Chemical Industry (CRF 2.B).

The emissions from Industrial Processes have fluctuated somewhat since 1990 (Figure 4.1-2). The decrease in the emissions during early 1990's was largely due to the economic recession in Finland (see Chapter 2). Since these years the overall trend in the emissions has been increasing (Table 4.1-2), however emissions decreased rapidly in 2009 (almost 26 percent in a year) due to the global recession as the demand for



industrial products diminished, but emissions increased again 8 percent in 2010. The rise of emissions was low because emissions of nitric acid production still declined due to implementation N<sub>2</sub>O abatement technology installed in 2009. Emissions from this sector turned again down in 2010, mainly due to decreasing emissions in chemical industry, total emissions of Industrial processes have declined since 10 per cent.

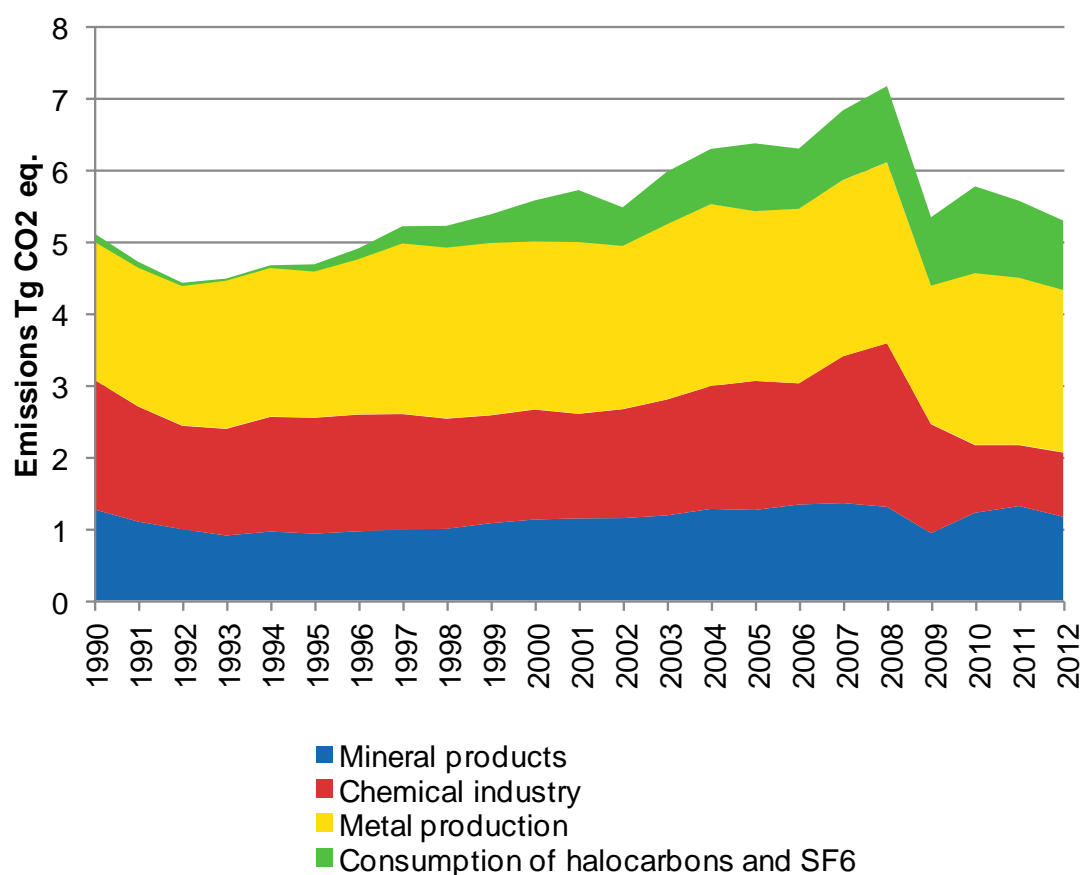
The most important greenhouse gas emission sources of Industrial Processes in the Finnish inventory in 2012 were CO<sub>2</sub> emissions from iron and steel, hydrogen and cement production with 3.8%, 1.1% and 0.8% shares of the total national greenhouse gas emissions, respectively. F-gas emissions comprised together 1.6% of the total greenhouse gas emissions in Finland. The small amount of F-gas emissions in Finland is explained by the absence of certain large industrial point sources that account for most of the F-gases emissions globally.

Industrial CO<sub>2</sub> emissions decreased considerably at the beginning of the 1990's, increased since 1996 until 2008 and fell down in 2009 being approximately 5% higher than in 1990. In 2012 CO<sub>2</sub> emissions were 8% lower than in 2008, which was the highest of this sector.

N<sub>2</sub>O emissions have fluctuated during the period 1990 to 2012; the first significant decrease due to closing of a plant and after that a slow increase of emissions, the second decrease originated above mentioned implementation of N<sub>2</sub>O abatement technology. On the whole, N<sub>2</sub>O emissions have decreased 90% since 1990.

Emissions of F-gases are increased significantly since 1990, they are now about tenfold compared with the 1990 as well as the 1995 emissions, which is the base year for these emissions under the Kyoto Protocol.

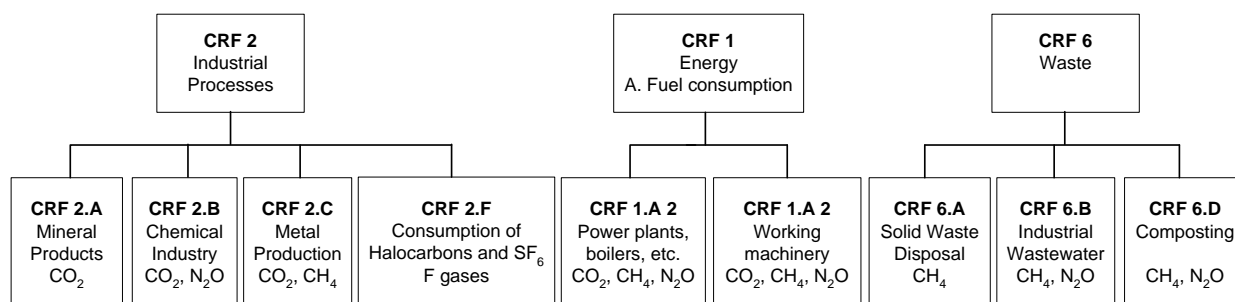
CH<sub>4</sub> emissions from coke production have increased by 70% since 1990 but their contribution to the total industrial emissions were in 2012 only 0.1%.



**Figure 4.1-2** Total greenhouse gas emission from Industrial Processes in Finland (Tg CO<sub>2</sub> eq.)

Industrial emissions are divided between three sectors:

- industrial process emissions are reported in sector 2: Industrial Processes
- emissions from fuel combustion in industry are reported in sector 1: Energy
- waste and wastewater generated emissions in industry are reported in sector 6 (Figure 4.1-3). Emissions from combusted waste are reported in the energy sector.



**Figure 4.1-3** Emissions from industrial sources and their reporting categories in the national greenhouse gas inventory

### 4.1.2 Key categories

The key categories in industrial processes in 2012 are summarised in Table 4.1-1.

**Table 4.1-1** Key categories in Industrial Processes (CRF 2) in 2012

Source Category	Gas	Criteria
2.B.2. Nitric Acid Production	N <sub>2</sub> O	L, T
2.B.5 Other: Hydrogen Production	CO <sub>2</sub>	T
2.C.1. Iron and Steel Production	CO <sub>2</sub>	L, T
2.F.1 . Refrigeration and Air Conditioning Equipment	HFCs	L, T
2.F.8. Electrical Equipment	SF <sub>6</sub>	T

**Table 4.1-2** Trend in greenhouse gas emissions from industrial processes (Tg CO<sub>2</sub> eq.)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>CO<sub>2</sub></b>																							
A Mineral Products	1.27	1.10	0.99	0.90	0.96	0.93	0.96	0.99	1.00	1.08	1.13	1.14	1.15	1.18	1.27	1.26	1.34	1.36	1.30	0.94	1.22	1.31	1.17
B Chemical Industry	0.15	0.16	0.14	0.12	0.16	0.15	0.16	0.16	0.16	0.15	0.17	0.16	0.18	0.20	0.21	0.17	0.25	0.57	0.70	0.72	0.76	0.71	0.73
C Metal Production	1.94	1.95	1.96	2.08	2.08	2.05	2.17	2.39	2.39	2.41	2.35	2.40	2.28	2.45	2.54	2.37	2.44	2.46	2.52	1.95	2.41	2.34	2.28
<b>CH<sub>4</sub></b>																							
C Metal Production	0.005	0.005	0.005	0.009	0.010	0.010	0.010	0.009	0.010	0.009	0.010	0.010	0.010	0.009	0.009	0.009	0.009	0.009	0.009	0.008	0.009	0.009	0.009
<b>N<sub>2</sub>O</b>																							
B Chemical Industry	1.66	1.44	1.30	1.36	1.43	1.46	1.46	1.44	1.38	1.35	1.36	1.29	1.33	1.41	1.50	1.63	1.44	1.48	1.58	0.79	0.17	0.13	0.17
<b>HFCs</b>	0.00002	0.00005	0.0001	0.0001	0.007	0.029	0.077	0.168	0.245	0.318	0.492	0.646	0.463	0.651	0.694	0.863	0.747	0.903	0.993	0.889	1.170	1.032	0.926
<b>PFC</b>	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0002	0.0002	0.028	0.022	0.020	0.013	0.015	0.012	0.010	0.015	0.008	0.011	0.009	0.001	0.001	0.002
<b>SF<sub>6</sub></b>	0.115	0.083	0.046	0.030	0.031	0.071	0.072	0.071	0.056	0.050	0.054	0.054	0.058	0.062	0.059	0.066	0.071	0.053	0.051	0.050	0.035	0.036	0.037
<b>Total</b>	<b>5.13</b>	<b>4.74</b>	<b>4.45</b>	<b>4.50</b>	<b>4.69</b>	<b>4.70</b>	<b>4.92</b>	<b>5.23</b>	<b>5.23</b>	<b>5.39</b>	<b>5.59</b>	<b>5.73</b>	<b>5.49</b>	<b>5.98</b>	<b>6.30</b>	<b>6.38</b>	<b>6.30</b>	<b>6.83</b>	<b>7.17</b>	<b>5.35</b>	<b>5.77</b>	<b>5.58</b>	<b>5.31</b>

## 4.2 Mineral Products (CRF 2.A)

### 4.2.1 Source category description

Non-fuel carbon dioxide emissions from cement and lime production and from limestone and dolomite use as well as emissions from soda ash use are reported in this category (Table 4.2-1 and Table 4.2-2). Indirect CO<sub>2</sub> emissions from NMVOC emissions of cement production, asphalt roofing and road paving with asphalt are also reported (asphalt roofing and cement production are included in road paving) in this source category. There are no key sources in this source category.

Soda ash is not produced in Finland. Lime production includes also lime production in the iron and steel industry. Limestone and dolomite use comprises the use in the production of tiles, ceramics, steel, calcium chloride, phosphates, mineral wool and in the wastewater handling, in neutralisation and in the energy industry for sulphur dioxide control. All soda ash which is used in Finland are included in the inventory. All other uses than use in glass production are reported in category 2.A 4, emissions from glass and glass wool production are reported in category 2.A 7. Emissions from the use of barium, lithium and potassium carbonate in glass production are also included in the inventory. Barium and potassium carbonate are used as raw materials in the production of special glasses and lithium carbonate is used to strengthen glass products.

Production capacity of clinker in Finland in the end of time series is about 1,300,000 t (1,600,000 t cement), but due to economic downturn the demand of clinker decreased fast and only 764,000 t clinker were produced in 2009. Since 2009 the demand of clinker has increased and in 2012 1,001,000 t clinker were produced (Finnsementti Oy, 2013). The production capacity has been increasing during time series when old cement kilns have been modernised or replaced, but more detailed information of changes in capacity would require a new data collection survey. As Finland indicated in the Report of the individual review of the annual submission of Finland submitted in 2010, Finland has no plans to undertake this as the capacity data are not needed in the calculation of emissions.

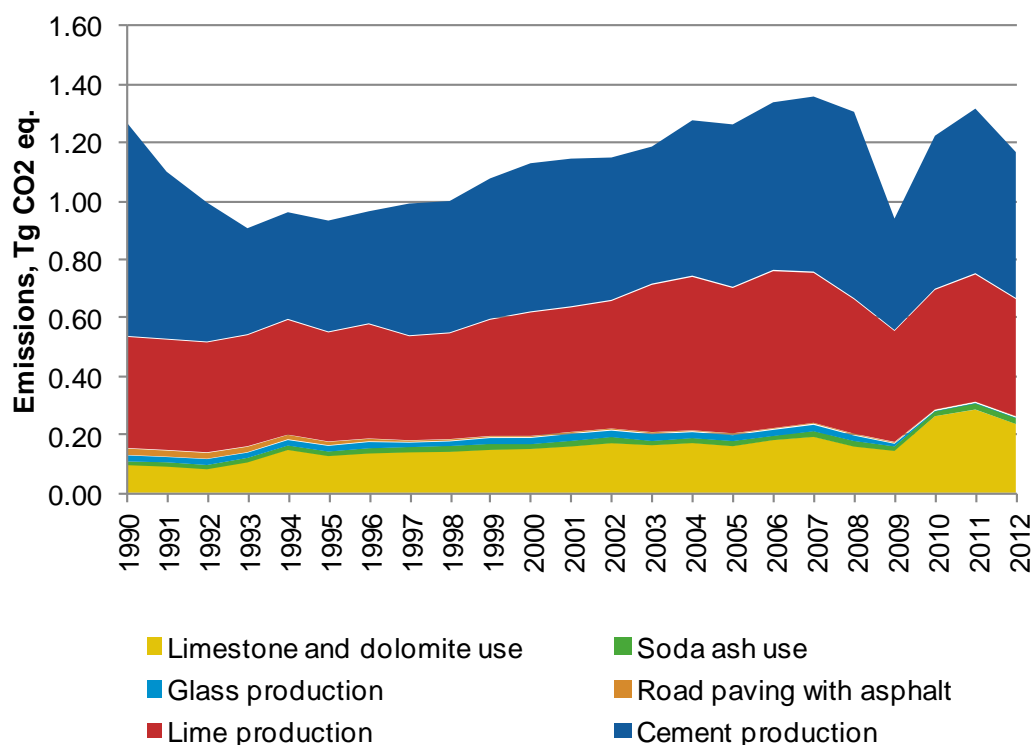
**Table 4.2-1** Reported emissions, calculation methods and type of emission factors for the subcategory Mineral Products in the Finnish inventory

CRF	Source	Emissions reported	Method	Emission factor
2.A 1	Cement production	CO <sub>2</sub>	Tier 2	CS
2.A 2	Lime production	CO <sub>2</sub>	Tier 2	CS
2.A 3	Limestone and dolomite use	CO <sub>2</sub>	Tier 2	CS
2.A 4	Soda ash use	CO <sub>2</sub>	Tier 2	CS
2.A 6	Road paving with asphalt	CO <sub>2</sub>	Tier 2	CS
2.A 7	Glass production	CO <sub>2</sub>	Tier 2	CS

In the production of cement CO<sub>2</sub> is emitted when an intermediate product, clinker, is produced. In that process limestone is heated to a high temperature, which results in CO<sub>2</sub> emissions, as the main component of limestone, calcium carbonate, breaks down, calcinates, into calcium oxide and carbon dioxide. Limestone also contains small amounts of magnesium carbonate (MgCO<sub>3</sub>), which will also calcinate in the process causing CO<sub>2</sub> emissions. CO<sub>2</sub> emissions from lime production and limestone and dolomite use are also due to calcination of calcium and magnesium carbonates at high temperatures (Slioor, 2004).

In addition, carbon dioxide is released when soda ash (Na<sub>2</sub>CO<sub>3</sub>), is heated to high temperatures.

The emissions of the category Mineral Products were over a quarter of the emissions of the Industrial Processes sector in 1990 and 22% in 2012 as well as 1.9% of Finland's total greenhouse gas emissions. The amount of emissions were 1.3 Tg in 1990 and 1.2 Tg in 2012 (Figure 4.2-1). The emissions in 2009 decreased over 40% compared to the emissions in 2008, the main reason for this being the economic downturn. The emissions have increased since with over 20%, because construction sector recovered and some new plants started production.



**Figure 4.2-1** Greenhouse gas emission from Mineral Products (Tg CO<sub>2</sub> eq.)

Cement production is the biggest source of greenhouse gas emissions in the Mineral Products category, being 0.50 Tg in 2012. Emissions were almost 15% in 1990 and over 9% in 2012 of the emissions in the Industrial Processes sector and 0.8% of Finland's total emissions in 2012. The production volume decreased rapidly at the beginning of the 90s due to the reduced need for clinker during the recession and the closing down of a plant in 1993. The output grew slightly until 2008, but due to the economic downturn in 2009 the demand of clinker decreased fast and the output in 2009 was 40% smaller than in 2008 and almost 50% smaller than in 1990. From 2009 clinker production has increased 31%.

Lime production is the second largest source in the category Mineral Products, the emissions were 0.40 Tg in 2012. The emissions have been less than 9% of this sector's emissions for the whole time series. Production has been quite constant during this period, but due to decreased demand of lime its production has decreased nearly 23% since 2004. One lime plant was not used at all in 2011 due to decreased demand of lime, in 2012 operation continued.

The contribution of limestone and dolomite use to the sector's total emissions has been around 2% during 1990 to 2009. Nevertheless, since 2010 emissions have been over 4% of Industrial Processes, because new users of limestone have started their production.

Soda ash use is a minor source, emissions have been approximately 0.4% of emissions in Industrial processes for the whole time series.

Glass production is also a minor source in the category Mineral Products. The emissions have been less than 0.5% of this sector's emissions for the whole period. The amount of used carbonates has been quite constant during the time series, however a temporary closedown of a plant decreased the amount for a couple of years (1997-98). However, due to economic downturn in 2009 two plants in Finnish glass industry were closed down. Emissions from glass production have decreased over 90% in last five years.

Indirect CO<sub>2</sub> emissions were 0.4% of the emissions of Industrial Processes in 1990. The emissions have decreased 92% since, mainly due to production volumes, for example in 1990 the use of bitumen was 475 000 tons and in 2012 it was only 158 500 tons. Also a new biobased solvent in bitumen oils was taken in use in 2011 so the NMVOC content of oils reduced, too.

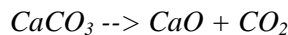
**Table 4.2-2** CO<sub>2</sub> emissions from Mineral Products (Tg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
2.A 1 Cement production	0.73	0.57	0.48	0.36	0.37	0.38	0.38	0.45	0.45	0.48	0.51	0.51	0.49	0.47	0.53	0.56	0.57	0.60	0.64	0.38	0.52	0.56	0.50
2.A 2 Lime production	0.38	0.38	0.38	0.38	0.39	0.38	0.39	0.36	0.36	0.40	0.42	0.43	0.44	0.51	0.53	0.50	0.54	0.52	0.46	0.38	0.41	0.44	0.40
2.A 3 Limestone and dolomite us	0.10	0.09	0.08	0.11	0.15	0.13	0.14	0.14	0.14	0.15	0.15	0.16	0.17	0.17	0.17	0.16	0.18	0.19	0.16	0.15	0.27	0.29	0.24
2.A 4 Soda ash use	0.013	0.015	0.015	0.016	0.016	0.016	0.018	0.019	0.021	0.021	0.017	0.020	0.022	0.015	0.018	0.018	0.015	0.020	0.020	0.016	0.017	0.021	0.021
2.A 6 Road paving with asphalt	0.021	0.020	0.019	0.018	0.014	0.011	0.008	0.004	0.004	0.003	0.003	0.003	0.003	0.003	0.002	0.002	0.002	0.003	0.002	0.002	0.002	0.001	0.002
2.A 7 Glass production	0.021	0.018	0.020	0.018	0.019	0.019	0.022	0.015	0.016	0.021	0.021	0.024	0.022	0.023	0.021	0.020	0.021	0.022	0.019	0.009	0.002	0.002	0.002
<b>Total of Mineral products</b>	<b>1.27</b>	<b>1.10</b>	<b>0.99</b>	<b>0.90</b>	<b>0.96</b>	<b>0.93</b>	<b>0.96</b>	<b>0.99</b>	<b>1.00</b>	<b>1.08</b>	<b>1.13</b>	<b>1.14</b>	<b>1.15</b>	<b>1.18</b>	<b>1.27</b>	<b>1.26</b>	<b>1.34</b>	<b>1.36</b>	<b>1.30</b>	<b>0.94</b>	<b>1.22</b>	<b>1.31</b>	<b>1.17</b>

## 4.2.2 Cement production

CRF category 2.A 1 covers CO<sub>2</sub> emissions from cement production. CO<sub>2</sub> is released when carbonaceous materials are heated in rotary kiln ovens to produce clinker. Clinker is then mixed with gypsum and other materials that together make up the cement. Also indirect CO<sub>2</sub> emissions are calculated from the NMVOC emissions of cement production, but they are reported together with other indirect CO<sub>2</sub> emissions from mineral production in category 2.A 6 Road paving with asphalt.

The mixture of raw material fed into the oven is called the raw mix. The main carbonaceous components of the raw mix are limestone (CaCO<sub>3</sub>) and dolomite (CaCO<sub>3</sub> \* MgCO<sub>3</sub>). When heated to 1,400-1,500 degrees centigrade, CO<sub>2</sub> is released. For example, the reaction for limestone is:



There are currently two operating plants in Finland. At a third plant production ceased in 1993.

### 4.2.2.1 Methods

Emissions were calculated using Tier 2 methodology from the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories 2000 (equations 3.1 and 3.3, pp. 3.10 and 3.13). Assuming 100% calcination of carbonate sources present in the raw mix, the emissions  $y$  are for any one year of the time series:

$$y = c \sum_{i=1}^3 x_i (a_i + d_i).$$

Here  $c$  is the correction factor for non-carbonate CaO sources (e.g. rolling scale from steel plant, diabase, fly and wood ash, Environmental Permit, 2006) in the raw mix,  $x_i$  is the emission factor for plant  $i$ , and  $a_i$  and  $d_i$  are the clinker and the cement kiln dust production for plant  $i$ , respectively. Fly ash is the most commonly used.

Based on recommendation by the producer (Palonen 2008), the correction factor  $c$  has been set to 0.92 throughout the time series.

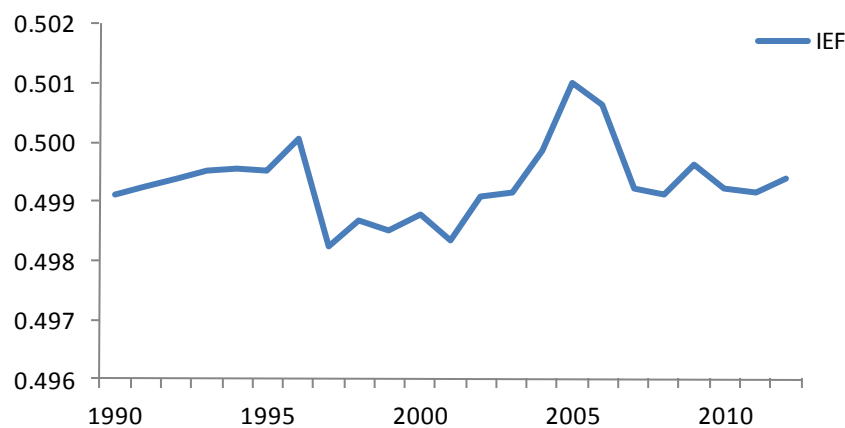
### 4.2.2.2 Emission factors

The emission factor  $x_i$  was calculated as follows:

$$x_i = w_{CaO,i} r_{CaO} + w_{MgO,i} r_{MgO},$$

where  $w(.)$  are the weight fractions in clinker and  $r(.)$  are the molecular mass ratios of CO<sub>2</sub> to CaO and MgO. The weight fractions were obtained from the producer, and were as follows: plant 1 (0.650, 0.020), plant 2 (0.647, 0.031). For plant 3 data was not available, so the mean of the two other plants (0.649, 0.026) was used.

Combined emissions factors are presented in the next figure (Figure 4.2-2). The fluctuations in the emission factors are due to differences in CaO and MgO weight fractions by plants and produced amount of clinker.



**Figure 4.2-2** Time series of implied emission factor

#### 4.2.2.3 Activity data

The cement kiln dust data was available from the companies for years 1996 - 2005 (plant 1) and 1996 - 2006 (plant 2). For plant 3, no data was available. Missing data was imputed using means of the data available. For plant 1, it was set to 0.0153 times the production; for plant two 0.00483 was used. In case of plant 3, the dust and clinker production ratios of all available data were used; thus the amount of dust for 1990 - 1993 was set to 0.0098 times the production. CKD correction factors vary from year to year and are presented in Table 4.2-3.

The clinker production data is complete and no imputation was necessary. Data for the years 1990-2006 are received directly from the company and for years 2007-2012 from EU ETS data (Table 4.2-3).

#### 4.2.2.4 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

Uncertainty for activity data is 2% and for emission factors 5%.

All activity data for years 1990-2006 have been received directly from the company, but as a result of comparison of this data and EU ETS data, it was decided to give up inquiries because data received from the company for years 2005-2007 and in EU ETS data were equal.

#### 4.2.2.5 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6. The QC procedures are performed according to the QA/QC plan in the Mineral products sector in order to attain these quality objectives. The bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert. In quality meeting 2014 for example documentation of activity data, checking of emission factors, developing a calculation system and the ERT Review report were discussed. The auditing of working instructions helped sectoral expert to develop and clarify once written instructions to be more precise for a person who will do the calculation for the first time.

Activity data have been checked using as many independent sources as possible and only slight differences between figures have been noticed. All activity data are site-specific, received from a company or reported due to monitoring of environmental or emission trading permit of a company. The emissions of the most recent eight years have been compared with EU ETS data. Differences between those figures have been less than 3%. For five years calculated emissions are higher than those reported in EU ETS and for three years lower.



#### 4.2.2.6 *Source-specific recalculations*

No source-specific recalculations were done.

#### 4.2.2.7 *Source-specific planned improvements*

For the whole Industrial processes sector, the work to implement the 2006 IPCC Guidelines for the 2015 submission has been started in 2013.

### 4.2.3 *Lime production*

#### 4.2.3.1 *Method*

There are six lime-producing plants in Finland. Emissions from lime production are calculated by multiplying emission factors with lime production. Activity data are collected mainly directly from the industry but industrial statistics have also been used for earlier years. Emissions from 2005 onwards have been calculated using production data reported to the EU ETS data. The total amount of produced lime has also been checked from industrial statistics. The calculation method was slightly updated for the 2013 submission due to new information of activity data in EU ETS, as only pure lime (=CaO+MgO amounts) are used as activity data (impurities have been written off the amount of lime). For all other years (1990-2004) production amount are calculated using the assumption (Emissions permit, 2010) that about 6 per cent of the product is impurities.

The GPG 2000 for Lime production does not give any different tier levels in this source category, but the calculation method corresponds to the Tier 2 level used in cement production.

#### 4.2.3.2 *Emission factors*

There is an emission factor for all five plants of a company and it is based on the actual CaO and MgO contents of lime derived from measurements of those five plants in Finland. It is a calculated mean value from emission and production data for the years 1998-2002. This emission factor has been used for the whole time series for those five plants.

Emissions of 2003 founded plant are calculated using emission factors which are based on the yearly average of actual CaO and MgO contents in lime (GHG emissions permit, 2011).

The implied emission factors can be found in Table 4.2-3.

#### 4.2.3.3 *Activity data*

In calculation of these emissions the amount of (quick)lime (CaO) produced annually is used as activity data. Hydrated lime,  $\text{Ca}(\text{OH})_2$ , is produced via (quick)lime by adding water to it. This process does not cause emissions and is not considered in the calculations. Activity data for the years 1990-1997 are partly collected from the industry and partly taken from industrial statistics and companies' reports (all activity data of 1997 are taken from industrial statistics and companies' reports). Activity data for the years 1998-2003 were received directly from the lime producing companies. For the year 2004 part of the activity data was collected from industrial statistics and the VAHTI system due to refusal of disclosure of one company. From the year 2005 onwards the activity data have been received from the Energy Authority, which grants emission permits to companies for the EU Emission Trading Scheme and supervises the monitoring and reporting of emission and production data. The received data have been compared with the data from industrial statistics and the VAHTI system. One lime plant was not used at all in 2011 due to decreased demand of lime. The total activity data of the time series are presented in Table 4.2-3.

All activity data prior to 2005 were recalculated for the 2013 submission multiplying previous activity data with 0.94 (assumption that there are 6 per cent impurities in lime, Emissions permit, 2010).

#### 4.2.3.4 *Uncertainty and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

For 2012 uncertainty in lime production is partly due to the small margin of error associated with the measurements of pure lime produced. Another source of uncertainty is the determination of emission factors: as opposed to the years 1998-2002 emission factors are estimated, not based on measurements of the actual amounts CaO and MgO in lime. Uncertainty in emissions was estimated to be  $\pm 4\%$ .

Due both to lack of knowledge concerning the years 1990-1997 and to better knowledge concerning the years 1998-2002 the time series for lime production is calculated using partly estimated data. The time series have been checked to be consistent by comparing calculated production to data of industrial statistics. Differences were very small, being highest in 2002, when the difference was about 4%.

#### 4.2.3.5 *Source-specific QA/QC and verification*

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6. The QC procedures are performed according to the QA/QC plan in the Mineral products sector in order to attain these quality objectives. The bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert. In the last quality meeting for example documentation of activity data, checking of emission factors, developing a calculation system and the ERT Review report were discussed. The auditing of working instructions helped sectoral expert to develop and clarify once written instructions to be more precise for a person who will do the calculation for the first time.

In the calculation of emissions from lime production general inventory quality control procedures have been done as mentioned in GPG 2000, table 8.1. Some of the checks are performed annually, like comparing with previous emissions of subcategory of the calculated emissions and ensuring that there are no transcription errors in calculations. Some of the checks have been performed when the calculation method has been developed.

In addition, source category-specific quality control procedures have been carried out during calculation. The used emission factors have been compared with the IPCC default emission factor and no large differences between the company-specific factors and the default factor have been found. Used emission factor is based on accurate measurements of a company and therefore it represents the best possible knowledge of that production process and used raw materials. Activity data have been checked using as many independent sources as possible and only very small differences between figures have been noticed. All activity data are site-specific and reported to industrial output statistics or reported due to monitoring of environmental or emission trading permit of a company.

The recalculated emission data for years 2005-2012 of all plants have been verified with ETS data (all plants are included in EU Emission Trading Scheme) and differences in emissions have been found to be about 1%.

#### 4.2.3.6 *Source-specific recalculations*

There were no recalculations done in this source.

#### 4.2.3.7 *Source-specific planned improvements*

For the whole Industrial processes sector, the work to implement the 2006 IPCC Guidelines for the 2015 submission has been started in 2013.

## 4.2.4 Limestone and dolomite use

### 4.2.4.1 Method

Emissions from limestone and dolomite use are calculated by multiplying emission factors with activity data. Activity data are collected mainly directly from the industry but industrial statistics have also been used to calculate emissions at the beginning of the time series. Emission factors are based on the IPCC's default factors, but they are modified because the calcination process is not complete.

### 4.2.4.2 Emission factors

Emission factors for calculating emissions from limestone and dolomite use are based on the IPCC default factors.

The emission factors are modified by multiplying default emission factor with correction factors (0.93-1.00, based on information from the producers, Slioor, 2004), because not all limestone and dolomite are calcinated completely in the various processes. Different factors have been used then more detailed information on the composition of limestone is available for some of the plants. If no information of composition has been received the correction factor 0.97, which is based on GPG for lime production, is used. (Default value for CaO or CaO and MgO content is 0.95, Table 3.4 Basic Parameters for the Calculation of Emission Factors for Lime Production). The average for the correction factor for the whole time series is 0.96 (range 0.95-0.98).

The time series of emission factors is given in Table 4.2-3.

### 4.2.4.3 Activity data

The consumption of limestone and dolomite has been used as activity data when calculating emissions from limestone and dolomite use. Most of the data for the whole time series have been received from individual companies and EU ETS and only a small part data of earlier years have been estimated using industrial statistics. Also data on limestone and dolomite uses for which it was previously not clear if they produce emissions or not have been checked using industrial statistics and the web sites of companies. It was confirmed that these uses do not cause CO<sub>2</sub> emissions as limestone has been used for instance as coating and filler pigments in paper and cardboard, paint and plastic industry. The amounts of used limestone and dolomite are described in Table 4.2-3.

### 4.2.4.4 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

Combined uncertainty in limestone and dolomite use was estimated to be  $\pm 6\%$ . It is partly due to uncertain activity data, as the share of MgO in dolomite has been assumed to be constant and the possibility that limestone can also include a small amount of MgO. Another source of uncertainty is the amount of carbonates that actually reacts by releasing carbon dioxide in the various processes.

Due to lack of knowledge concerning some earlier years the time series is calculated using partly estimated data (that is: all data are not as accurate as the data for years 2000-2012). For years prior to 2000 all activity data have not been gained directly from companies, but industrial statistics or estimations based on other years' data have been used.

### 4.2.4.5 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6. The QC procedures are performed according to the QA/QC plan in the Mineral products sector in order to attain these quality objectives. The bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert. In the last quality meeting for example documentation of activity data, checking of emission factors, developing a

calculation system and the ERT Review report were discussed. The auditing of working instructions helped sectoral expert to develop and clarify once written instructions to be more precise for a person who will do the calculation for the first time.

In the calculation of emissions from limestone and dolomite use several general inventory quality control procedures have been performed as mentioned in GPG 2000, table 8.1. Some of the checks are performed annually, like comparing with previous emissions of subcategory of the calculated emissions and ensuring that there are no transcription errors in calculations. Some of the checks have been performed when the calculation method has been developed.

In addition, source category-specific quality control procedures have been carried out during calculation. The default emission factor multiplied with the correction factor has been defined to be adequate for Finnish circumstances and processes, because default emission factors are stoichiometric; based on chemical equations and the content of carbonate in limestone and dolomite used in Finland is very high. The fluctuations in emission factors of limestone use have been checked and reason for it has been originated from different calcium carbonate content in used limestone. Activity data have been checked using as many independent sources as possible and only small differences between figures have been noticed, the results of the comparisons are included in the calculation sheets. This activity data are site-specific and reported to industrial output statistics or reported due to monitoring of environmental or emission trading permit of a company.

The calculated emission data of 27 plants (out of 36) have been verified with ETS data and differences have been found to be 2-5%. Higher emissions have been formed because in EU ETS companies calculate emissions using default emission factors and in the inventory emission factors are based on assumption that not all limestone and dolomite are calcinated in the process.

#### *4.2.4.6 Source-specific recalculations*

Emissions of one plant using limestone for sulphur dioxide control were included for the whole time series, emissions increased 1-7 Gg / a.

#### *4.2.4.7 Source-specific planned improvements*

For the whole Industrial processes sector, the work to implement the 2006 IPCC Guidelines for the 2015 submission has been started in 2013.

### *4.2.5 Soda ash use*

#### *4.2.5.1 Methods*

Emissions from soda ash (= sodium carbonate) use are calculated by multiplying emission factors with the amount of used soda ash. As a result of review of the submission 2011, the activity data are the total use of soda ash in Finland. However, the soda ash that is used in glass production is subtracted and corresponding emissions are reported under the category 2.A.7. Even if this methodology may lead to a slight overestimation of emissions, Finland has not planned to clarify which soda ash uses are emissive and which non-emissive because it would be too resource demanding considering the size of this category.

The emission factors are based on the IPCC's default factors.

#### *4.2.5.2 Emission factors*

The Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 1997) emission factor for soda ash use is slightly corrected by a factor of 0.99, because it not likely that all sodium carbonate is calcinated completely in the various processes (Slioor, 2004). The emission factor is 0.411 t CO<sub>2</sub> / t Na<sub>2</sub>CO<sub>3</sub>.

#### 4.2.5.3 Activity data

The total consumption of sodium carbonate is used as activity data calculating emissions from soda ash use. Activity data are calculated using Customs Statistics by subtracting annual export of soda ash from import (there is no production of soda ash in Finland). Also amount of soda ash, which is used in glass production, is subtracted from that amount. Imported and exported amounts are received from the Customs statistics database Uljas. The amount of used soda ash is given in Table 4.2-3 (soda ash used in glass production is included in Section 4.2.7).

#### 4.2.5.4 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

Uncertainty in emissions 2012 in soda ash use was estimated to be  $\pm 6\%$ . A source of uncertainty is the amount of sodium carbonate that actually reacts by releasing carbon dioxide in the various processes.

#### 4.2.5.5 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6. The QC procedures are performed according to the QA/QC plan in the Mineral products sector in order to attain these quality objectives. The bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert. In the last quality meeting for example documentation of activity data, checking of emission factors, developing a calculation system and the ERT Review report were discussed. The auditing of working instructions helped sectoral expert to develop and clarify once written instructions to be more precise for a person who will do the calculation for the first time.

In the calculation of emissions from soda ash use there have been performed general inventory quality control procedures as mentioned in GPG 2000, table 8.1. Some of the checks are performed annually, like comparing with previous emissions of subcategory of the calculated emissions and ensuring that there are no transcription errors in calculations. Some of the checks have been performed when the calculation method has been developed.

Source category-specific quality control procedures have also been carried out during calculation. The default emission factor has been defined to be adequate for Finnish circumstances and processes. The default emission factor is stoichiometric and the content of carbonate in sodium carbonate used in Finland is very high.

#### 4.2.5.6 Source-specific recalculations

No source-specific recalculation were done.

#### 4.2.5.7 Source-specific planned improvements

For the whole Industrial processes sector, the work to implement the 2006 IPCC Guidelines for the 2015 submission has been started in 2013.

### 4.2.6 Indirect CO<sub>2</sub> emissions from NMVOC emissions of cement production, asphalt roofing and road paving with asphalt

#### 4.2.6.1 Methods

NMVOC emissions (see Table 4.2-3) from cement production, asphalt roofing and road paving with asphalt are calculated at the Finnish Environment Institute. The activity data and emission factors used in the calculations for asphalt roofing and road paving with asphalt are from Nynas Oy (Blomberg, T. 2013) and

Finland Custom Statistics (ULTIKA/ULJAS). The sources of activity data have been changed since the inventory of 2006. Documentation of the calculation is presented in the Finnish IIR 2013.

Indirect CO<sub>2</sub> emissions from NMVOC emissions from the use of asphalt and from cement production have been calculated using NMVOC emissions as activity data for the time series 1990-2012. Indirect CO<sub>2</sub> emissions were calculated using the equation below. The average carbon content used is 80% by mass and it is based on 2006 IPCC Guidelines. According to the Guidelines, the fraction is based on NMVOC speciation profile provided in the EMEP/CORINAIR Emission Inventory Guidebook.

$$Emissions_{CO_2} = Emissions_{NMVOCs} * Percent\ carbon\ in\ NMVOCs\ by\ mass * 44/12$$

#### 4.2.6.2 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

Uncertainty for activity data is  $\pm 85\%$  and for emission factors  $\pm 20\%$ . Uncertainty for the activity data is based on the latest uncertainty analysis for NMVOC carried out for the 2011 emissions and reported in the Finnish IIR (Informative Inventory Report, 2013) to the UNECE CLRTAP Secretariat in March 2013, where the methods used for the analysis are documented.

NMVOC emissions from cement production, asphalt roofing and road paving with asphalt have been calculated using same method for the whole time series.

#### 4.2.6.3 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6. The QC procedures are performed according to the QA/QC plan in the Mineral products sector in order to attain these quality objectives. The bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert.

In the calculation of NMVOCs and indirect CO<sub>2</sub> emissions general inventory QC procedures mentioned in GPG 2000 Table 8.1 have been performed. For example, plant specific emissions and activity data are compared between the years. The data is reported by plants according to monitoring requirements in the environmental permits and it is checked and approved by the environmental competent authority before recording it to the VAHTI database. There is no activity data available to compare with emission factors in the EMEP EEA Emission Inventory Guidebook B4610-6.

#### 4.2.6.4 Source-specific recalculations

No source-specific recalculations were done.

#### 4.2.6.5 Source-specific planned improvements

As a part of updating of air emissions time series also the activity data of this category will be checked in 2015.

### 4.2.7 Glass production

#### 4.2.7.1 Methods

Process emissions in glass production are generated from limestone, dolomite, soda ash (= sodium carbonate), barium carbonate, lithium carbonate and potassium carbonate use and they are calculated by multiplying emission factors with the amount of used carbonates. Activity data are mainly gathered directly from the industry but industrial statistics have also been used.

Emission factors are based on the IPCC's default factors and stoichiometric ratio of chemical reactions, but they are modified because the calcination process is not complete.

#### 4.2.7.2 Emission factors

Emission factors for calculating emissions from limestone and dolomite use are based on the IPCC default factors, but they are modified because the calcination process is not complete (see Section 4.2.4.2). The time series of emission factors is given in Table 4.2-3.

The 1996 IPCC GL emission factor for soda ash use is corrected by a factor of 0.99 (Slioor, 2004), because it is likely that sodium carbonate is not calcinated completely in the various processes, see Section 4.2.5.2. The emission factor is therefore  $0.411 \text{ t CO}_2 / \text{t Na}_2\text{CO}_3$ .

Emission factors for calculating emissions from barium, lithium and potassium carbonate uses are based on the stoichiometric ratio of chemical reactions. A correction factor of 0.99 has also been used. For barium carbonate emission factor is  $0.223 \text{ t CO}_2 / \text{t BaCO}_3$ , lithium carbonate  $0.595 \text{ t CO}_2 / \text{t Li}_2\text{CO}_3$  and potassium carbonate  $0.318 \text{ t CO}_2 / \text{t K}_2\text{CO}_3$ .

#### 4.2.7.3 Activity data

The consumption of limestone and dolomite has been used as activity data when calculating emissions from limestone and dolomite use. Activity data for 2012 are collected directly from individual companies and the EU ETS data. Most of the data for the earlier years have been received from individual companies, EU ETS and a smallish part has been estimated using industrial statistics. The amounts of used limestone and dolomite are given in Table 4.2-3.

Consumption of sodium carbonate is used as activity data when calculating emissions from soda ash use. Activity data are collected directly from individual companies. For some early years not all activity data have been received directly from companies. In these cases the data of industrial statistics or estimations based on the data of other years have been used.

Consumption of barium, lithium and potassium carbonate are used as activity data when calculating emission from their use. Activity data are collected from company for years 1995-2004 and 2007-2012. Activity data for the remaining years are estimated using production data (Forsell, 2012).

#### 4.2.7.4 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

The combined uncertainty in glass production was estimated to be  $\pm 6\%$ . Uncertainty in carbonate use was estimated to be  $\pm 5\%$ . It is partly due to measurement of activity data, another source of uncertainty is the amount of carbonate that actually reacts by releasing carbon dioxide in the various processes.

Due to lack of knowledge concerning some earlier years the time series is calculated using partly estimated data (that is: all data are not as accurate as the data concerning the year 2012.) For some early years not all activity data have been gained directly from companies. In these cases the data of industrial statistics or estimations based on other years' data have been used.

#### 4.2.7.5 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6. The QC procedures are performed according to the QA/QC plan in the Mineral products sector in order to attain these quality objectives. The bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert.

In the calculation of emissions from glass production general inventory quality control procedures have been performed as mentioned in GPG 2000, table 8.1. Some of the checks are performed annually, like comparing

with previous emissions of subcategory of the calculated emissions and ensuring that there are no transcription errors in calculations. Some of the checks have been performed when the calculation method has been developed.

Also source category-specific quality control procedures have been carried out during calculation. The default emission factors have been defined to be adequate for Finnish circumstances and processes (see Sections 4.2.4.5 and 4.2.5.5). Activity data have been checked using as many independent sources as possible and only small differences between figures have been noticed. All activity data are site-specific and reported to industrial output statistics or reported due to monitoring of environmental permit of a company. The calculated emission data of 4 plants (out of 5) have been verified with ETS data and emissions have been found to be almost equal (+/-2%). Reason for difference is that in the inventory calculation not all carbonate is assumed to be calcinated in the production process.

#### *4.2.7.6 Source-specific recalculations*

No source-specific recalculations were done.

#### *4.2.7.7 Source-specific planned improvements*

For the whole Industrial processes sector, the work to implement the 2006 IPCC Guidelines for the 2015 submission has been started in 2013.



**Table 4.2-3** Activity data and emission factors for Mineral Products

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>2.A.1</b>																							
Clinker production, 1 000 t	1 470	1 146	953	727	731	760	767	906	902	964	1 017	1 015	977	940	1 064	1 110	1 147	1 201	1 279	764	1 049	1 129	1 000
EF t/t	0.499	0.499	0.499	0.499	0.5	0.5	0.5	0.498	0.499	0.499	0.499	0.498	0.499	0.499	0.5	0.501	0.501	0.499	0.499	0.5	0.499	0.499	0.499
CKD correction factor	1.009	1.009	1.008	1.008	1.008	1.008	1.009	1.006	1.008	1.007	1.008	1.007	1.009	1.009	1.009	1.012	1.011	1.009	1.009	1.008	1.009	1.009	1.008
<b>2.A.2</b>																							
Lime production, 1 000 t	488	485	483	488	504	479	501	457	468	512	540	543	559	640	667	631	683	651	590	486	524	558	513
EF t/t	0.784	0.784	0.784	0.784	0.784	0.784	0.784	0.784	0.777	0.781	0.786	0.789	0.786	0.792	0.792	0.793	0.791	0.794	0.785	0.785	0.785	0.785	0.785
<b>2.A.3</b>																							
Limestone consumption, 1 000 t	203	194	176	231	331	282	302	316	316	320	323	341	373	356	369	335	384	399	337	313	583	630	516
EF t/t	0.435	0.435	0.436	0.434	0.431	0.433	0.432	0.424	0.422	0.426	0.427	0.428	0.423	0.422	0.422	0.434	0.431	0.436	0.434	0.436	0.437	0.439	0.442
Dolomite consumption, 1 000 t	23	20	17	16	17	16	17	18	23	31	35	36	34	35	39	39	40	46	34	22	24	26	24
EF t/t	0.435	0.434	0.431	0.431	0.431	0.431	0.431	0.431	0.449	0.449	0.451	0.451	0.45	0.451	0.452	0.45	0.449	0.449	0.447	0.447	0.451	0.451	0.451
<b>2.A.4</b>																							
Soda ash consumption, 1 000 t	31	37	36	39	38	39	45	45	51	50	42	48	53	37	43	44	36	49	48	39	41	52	51
<b>2.A.6</b>																							
Amount of NMVOCs, 1 000 t	7.2	6.8	6.5	6.1	4.9	3.8	2.8	1.4	1.3	1.0	1.0	1.1	1.1	1.1	0.8	0.8	0.7	0.9	0.8	0.7	0.6	0.5	0.6
<b>2.A.7</b>																							
Limestone and dolomite consumption, 1 000 t	24	22	25	22	22	23	25	18	18	24	24	27	25	27	23	21	22	24	21	10	1.35	1.22	1.18
Soda ash consumption, 1 000 t	24	20	22	20	22	22	25	18	19	25	25	28	27	28	25	26	27	28	23	12	2.70	3.32	3.01
Other carbonate consumption, 1 000 t	0.285	0.285	0.285	0.335	0.335	0.365	0.447	0.464	0.509	0.628	0.709	0.736	0.712	0.637	0.846	0.86	0.89	0.938	0.787	0.864	0.881	0.892	0.904
EF t/t	0.434	0.433	0.432	0.433	0.432	0.432	0.431	0.425	0.425	0.43	0.429	0.429	0.428	0.428	0.429	0.428	0.428	0.428	0.431	0.426	0.39	0.391	0.382

## 4.3 Chemical Industry (CRF 2.B)

### 4.3.1 Source category description

In the Finnish inventory this category includes emissions of nitrous oxide from nitric acid production and carbon dioxide emissions from hydrogen, phosphoric acid and ammonia production. Ammonia was produced only 1990-1992. Also indirect CO<sub>2</sub> emissions from the chemicals production and storage of chemicals have been calculated from NMVOC emissions for the whole time series.

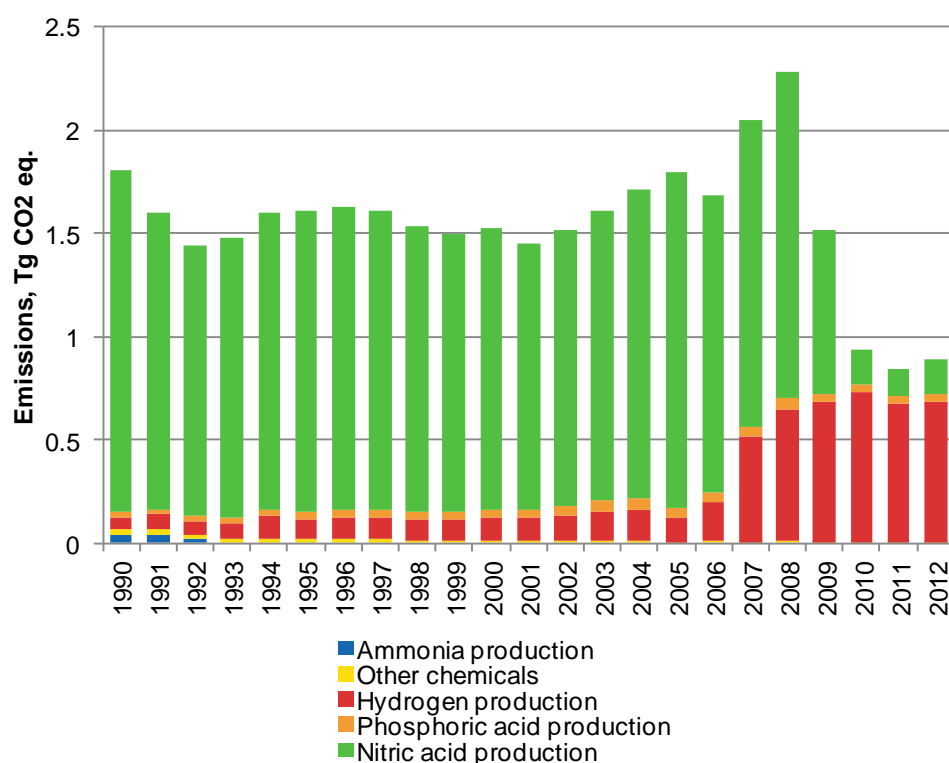
**Table 4.3-1** Reported emissions, calculation methods and type of emission factors for the subcategory Chemical Industry in the Finnish inventory

CRF	Source	Emissions reported	Methods	Emission factors
2.B 1	Ammonia Production	CO <sub>2</sub>	Tier 1	D
2.B 2	Nitric acid Production*	N <sub>2</sub> O	Tier 2	PS
2.B 5	Hydrogen Production	CO <sub>2</sub>	Tier 2	CS
	Phosphoric acid Production	CO <sub>2</sub>	CS	PS
	Chemicals Production	CO <sub>2</sub>	Tier 2	CS

\* Emissions from nitric acid production includes also emissions from fertiliser production.

Nitric acid and hydrogen production are key sources in 2012. All emissions of this category are presented in Table 4.3-2 by gas and subcategory. Ammonia, adipic acid, carbides, carbon black, dichloroethylene, styrene and methanol are not produced in Finland. Ethylene is produced in Finland, but methane emissions from that production are used as fuel in the ovens of cracking, benzene and cumene units. Total emissions of those combustion processes are reported in the Energy sector.

Process emissions of chemical industry in 2012 were 0.9 Tg CO<sub>2</sub> eq. and represented over 17% of this sector's emissions and 1.5% of Finland's total emissions. Emissions from chemical industry decreased almost 61% between 2008 and 2012, main reason for this was the installation of a new N<sub>2</sub>O abatement system for all three nitric acid plants during 2009 (the first joint implementation projects within the Finnish territory). Emissions of hydrogen production have increased 32% from year 2007 to 2012 and they are now over five-fold compared to the time before the launching of a new hydrogen plant in autumn 2006 (Figure 4.3-1).



**Figure 4.3-1** Greenhouse gas emission from Chemical Industry (Gg CO<sub>2</sub> eq.)

Emissions of N<sub>2</sub>O from nitric acid production were approximately 0.5 Gg (0.17 Tg CO<sub>2</sub> eq.) in 2012, which was 0.3% of Finland's total greenhouse gas emissions and 3% of emissions of the sector Industrial Processes. In 1990 emissions from nitric acid production represented over 30% of emissions of Industrial Processes. Emissions include also an amount of N<sub>2</sub>O emitted from two fertiliser production plants. In 1990 there were four nitric acid plants in Finland. One was closed down in 1992 that could be also seen in a rapid decrease of the emissions. In October 2004 a new plant (relocated from Belfast, Northern Ireland) was commissioned at an existing site and therefore the amount of produced acid increased. The new plant replaced an older plant, which was closed in April 2005. Finally the 2009 installed N<sub>2</sub>O abatement technology decreased emissions in all nitric acid plants, emissions are now over 90 per cent less than the time prior to instalment.

Emissions of CO<sub>2</sub> from hydrogen production were approximately 0.68 Tg in 2012, which was almost 13% of emissions of this sector. Not all hydrogen production causes CO<sub>2</sub> emissions. Emissions occur only in processes in which hydrocarbons are used as feedstock. In Finland natural gas is the most common feedstock in hydrogen production. Theoretically all the carbon contained in hydrocarbons will be emitted as CO<sub>2</sub> in the processes but in practice, a small amount of feedstock does not react. One hydrogen producing company captures formed carbon dioxide for recovery and another one bottles it, but this amount of emission has not been reduced from the total emissions.

Phosphoric acid is produced from apatite and in the production process calcite, which is a host rock in apatite deposits, calcinates and emits CO<sub>2</sub>. Calcite has also been used for neutralisation of wastewater in phosphoric acid plant. These emissions are calculated together and reported in this category due to confidentiality reasons, the emissions were approximately 0.04 Tg in 2012.

All ammonia currently used in Finland is imported. In 1990-1992 small amounts (4 - 30 Gg per year) were produced using mainly peat and heavy oil as feedstock for the needed hydrogen. From 1993 on there has been no ammonia production in Finland (Table 4.3-2). The CO<sub>2</sub> emissions from these processes have been estimated and included in the inventory.

The NMVOC and indirect CO<sub>2</sub> emissions from the chemical industry and storage of chemicals at the sites are also reported under subcategory Other (CRF 2.B 5). CO<sub>2</sub> emissions were 0.007 Tg in 2012 and they have decreased 69% since 1990. Main reasons for reduction are lower production volumes in organic chemical industry, investments on new abatement technologies of NMVOC emissions and increased use of non-solvent based products.

## 4.3.2 Nitric acid production

### 4.3.2.1 Methods

Nitric acid is nowadays produced in Finland in three single-stage medium pressure plants (3.8, 6.5 and 7.5 bar). Two of these plants are situated at the same site and the produced nitric acid is mainly used for the integrated fertiliser production.

In 2005 Statistics Finland co-operated with the nitric acid manufacturers to produce the annual emission estimates for 1990-2004. To calculate emissions of nitric acid production the manufacturers provided the activity data and emission factors (see below), and Statistics Finland carried out the calculations using an agreed methodology that corresponds to the GPG 2000 equation 3.9 (IPCC 2000, p. 3.31). For emissions of fertiliser production, data received from the producer were used for 1990-2004 (Gåpås, 2005).

Since no abatement or destruction did take place at the Finnish plants before 2009 the equation 3.9 simplifies to

$$N_2O \text{ emissions} = \text{specific emission factor} \times \text{production level}$$

**Table 4.3-2** Emissions by gas and subcategory (Tg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>CO<sub>2</sub></b>																							
2.B 1 Ammonia production	0.044	0.0445	0.0189	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.B 5 Hydrogen production	0.06	0.07	0.06	0.07	0.11	0.09	0.11	0.11	0.10	0.10	0.11	0.11	0.12	0.14	0.15	0.11	0.19	0.51	0.64	0.68	0.71	0.66	0.68
2.B 5 Phosphoric acid production	0.025	0.025	0.034	0.030	0.031	0.037	0.032	0.034	0.040	0.039	0.040	0.041	0.046	0.052	0.048	0.050	0.050	0.047	0.049	0.035	0.040	0.037	0.042
2.B 5 Indirect	0.024	0.021	0.021	0.019	0.020	0.020	0.021	0.020	0.015	0.014	0.013	0.013	0.011	0.010	0.012	0.008	0.009	0.007	0.008	0.008	0.008	0.008	0.007
<b>N<sub>2</sub>O</b>																							
2.B 2 Nitric acid production	1.66	1.44	1.30	1.36	1.43	1.46	1.46	1.44	1.38	1.35	1.36	1.29	1.33	1.41	1.50	1.63	1.44	1.48	1.58	0.79	0.17	0.13	0.17
<b>Total of subcategory, Tg CO<sub>2</sub> eq.</b>	<b>1.81</b>	<b>1.6</b>	<b>1.44</b>	<b>1.48</b>	<b>1.6</b>	<b>1.61</b>	<b>1.62</b>	<b>1.61</b>	<b>1.53</b>	<b>1.5</b>	<b>1.53</b>	<b>1.46</b>	<b>1.52</b>	<b>1.61</b>	<b>1.71</b>	<b>1.8</b>	<b>1.69</b>	<b>2.04</b>	<b>2.28</b>	<b>1.52</b>	<b>0.92</b>	<b>0.84</b>	<b>0.89</b>

In 2005-2012 both emission and activity data of nitric acid and fertiliser production have been received from the Vahti system for each plant separately. The specific emission factors rather than emissions have been calculated by the inventory unit.

Emissions are calculated for each plant separately and then summed up to give the reported figure. Emission data of fertiliser production are included in the total emissions of this subcategory; neither activity data nor emission factors of fertiliser production are reported in this inventory due to confidentiality reasons.

As the first joint implementation project in Finnish territory a project to cut down N<sub>2</sub>O emissions of nitric acid plants was started in 2009. A new N<sub>2</sub>O abatement technology - a pelleted catalyst - was installed directly in the ammonia oxidation reactor underneath the ammonia oxidation catalyst (Pt-Rh) in all the three existing nitric acid plants. Due to this new catalyst emissions have decreased by 92% in this sector in 2008-2012, which also reflects to the emission factors used in the inventory (Section 4.3.2.2). For more detailed information about the JI project see the project reports YARA, 2009-2012.

#### 4.3.2.2 Emission factors

Before 2009, only one of the three plants was equipped with a continuous N<sub>2</sub>O emission measurement unit. From 2005 the company used also a portable measurement device at the other two plants. A consultant made periodically measurements at the plants in 1999–2004. No measurements are available prior to 1999. Since 2009 all existing nitric acid plants have been equipped with automatic systems according to EU standards to continuously measure the concentration of N<sub>2</sub>O in the tail gas and gas volume.

Based on the measurements the emission factors presented in Table 4.3-3 are defined and used in the Finnish inventory for years 1990–2012.

**Table 4.3-3** N<sub>2</sub>O emission factors for nitric acid production (mass of N<sub>2</sub>O emitted per mass of nitric acid produced)

Plant	Emission factors			Plant in operation
	value (kg/t)	years	source	
A	7.6	1990-2005	Information from plant A	- 2005
B	9.5	1990-2004	Information from plant B	
	3.3-7.4 <sup>1</sup>	2005-2008	Calculated based on Vahti data	
	0.3-3.5	2009-2012	Calculated based on Vahti data	
C	9.3	1990-2008	Information from plant C	- 1992 2004 -
	0.6-4.3	2009-2012	Calculated based on Vahti data	
D	9.2 <sup>2</sup>	1990-1992	(Pipatti, 2001)	
E	8.0-10.1 <sup>3</sup>	2004-2008	Calculated based on Vahti data	
	0.6-6.6	2009-2012	Calculated based on Vahti data	

<sup>1</sup> plant B has used a new kind of catalyst from May 2005 and has succeeded to decrease the emissions. Also some process changes and adjustments have been made, which have multiplied the production amount.

<sup>2</sup> the process of a plant D was similar to plant B

<sup>3</sup> during the first years of operation the plant was not performing optimally and the emission factor was higher than expected

The average emission factor for all three plants for year 2009 is 5.4 kg N<sub>2</sub>O/t nitric acid (emissions from fertiliser plants are included). The use of the pelleted catalyst started during the inventory year. The target of the joint implementation project, which was tighten during the project, for the end of 2012 was that nitrous oxide emissions produced in those three plants will not exceed the level 1.85 kg N<sub>2</sub>O/t nitric acid (Project determination reports, 2010). These projects have been very successful and the average emission factor for all those plants was 0.9 kg N<sub>2</sub>O/t nitric acid in 2012 (emissions from fertiliser plants are included).

The GPG 2000 and 1996 IPCC GL provide default emission factors for processes similar to those used in Finland; the range for these emission factors for old, non-NSCR and medium pressure plants is 6-19 kg N<sub>2</sub>O/t nitric acid. The oldest, still operational, of our plants started the commercial nitric acid production in 1973. Our emission factors presented in Table 4.3-3 are in that range before the catalyst installation but well under the highest value.

Emission factors of two fertiliser plants are determined with FT-IR measurements. At the moment the measuring device is shared with those two plants, it first measure the N<sub>2</sub>O content of the flow of the plant 1,

then the sample line will be flushed and after that the N<sub>2</sub>O content of flow of plant 2 will be measured. N<sub>2</sub>O emission factor for fertiliser production is not presented here due to confidentiality issues.

#### 4.3.2.3 Activity data

As described in Section 4.3.2.2 the annual nitric acid and fertiliser production figures have been obtained from the production plants or from the Vahti system (see description in Annex 2). Production amounts of nitric acid are presented in Table 4.3-5. Production amounts of fertiliser are confidential and therefore not included in Table 4.3-5.

#### 4.3.2.4 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

Statistics Finland performed a sensitivity study in 2010 to explore how the different parameters used in the calculation of the emissions for 2008 affect the uncertainty. The study showed that emission factors account for most of the uncertainty. Since 2009 in the JI project it has been introduced online measurement to all plants, this have further lowered the uncertainties of the emission factors.

According to uncertainty analysis (see Section 1.7) the uncertainty of N<sub>2</sub>O emissions from nitric acid production is +/-15%.

The continuous monitoring of measurement has been done according to QAL3 requirements and a third party reviews the measurements annually. Emission calculations and quality assurance mechanisms are verified by a third party every half year.

The uncertainty estimates of nitric acid production were updated using QAL1 reports from JI projects.

#### 4.3.2.5 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6. The QC procedures are performed according to the QA/QC plan in Chemical industry sector in order to attain these quality objectives. The bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert. In the last quality meeting for example documentation of activity data, checking of emission factors, developing a calculation system and the ERT Review report were discussed. The auditing of working instructions helped sectoral expert to develop and clarify once written instructions to be more precise for a person who will do the calculation for the first time.

In the calculation of emissions from nitric acid production several general inventory quality control procedures have been performed as mentioned in GPG 2000, table 8.1. Some of the checks are performed annually, like comparing with previous emissions of subcategory of the calculated emissions and ensuring that there are no transcription errors in calculations. Some of the checks have been performed when the calculation method has been developed.

In addition, source category-specific quality control procedures have been carried out during calculation. One of them is that the used emission factors have been compared with the IPCC default emission factor and reasons for differences have been clarified and explained in Section 4.3.2.2. Secondly, emission factors are based on accurate measurements of plants and therefore it represent the best possible knowledge of that production process and equipment.

Production data have been checked with Vahti and industrial output statistics and only small differences (+/- 1%) between figures have been noticed. All activity data are site-specific and reported to industrial output statistics or reported due to monitoring of environmental or emissions permit of a company.

#### 4.3.2.6 Source-specific recalculations

There are no recalculations done.

#### 4.3.2.7 Source-specific planned improvements

For the whole Industrial processes sector, the work to implement the 2006 IPCC Guidelines for the 2015 submission has been started in 2013.

### 4.3.3 Hydrogen production

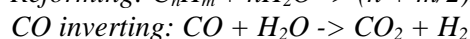
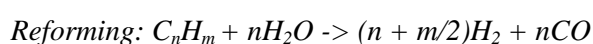
#### 4.3.3.1 Methods

Hydrogen is produced in Finland in continuous steam reforming processes, where hydrocarbons dissociate on the metal surface. Pressure swing adsorption (PSA) is used in Finland for the recovery of pure hydrogen from different hydrogen-rich streams. In the PSA purification process, the impurities in the gas are adsorbed into the fixed adsorbent bed at high pressure. The offgases (also called as purge gas) from the PSA unit may contain hydrogen and impurities as N<sub>2</sub>, H<sub>2</sub>O, CO, CO<sub>2</sub> and inert feedstock. Offgases are collected and used in reformer furnaces to heat the reformer. To avoid double-counting, the carbon in offgases is not included to the CO<sub>2</sub> emissions of combustion in Energy Sector.

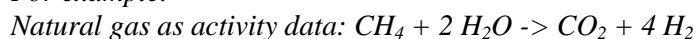
Emissions from hydrogen production are calculated by multiplying activity data with emission factors. Activity or emission data have been received directly from companies, a minor part of earlier years' data having been estimated. There are no default emission factors for hydrogen production in the 1996 IPCC GL, for which reason the stoichiometric ratio of chemical reactions is used. One company has a system to capture formed carbon dioxide for recovery and use. The transferred CO<sub>2</sub> is bottled and according to present knowledge is used in applications from which it is released to the atmosphere immediately or within a timeframe of some years after the transfer and therefore the transferred CO<sub>2</sub> is not deducted from the total emissions of this sub-category.

#### 4.3.3.2 Emission factors

No default emission factor for hydrogen production is available in the 1996 IPCC GL or GPG 2000. The emission factor for calculating emissions from hydrogen production is based on the stoichiometric ratios of chemical reactions.



For example:



Emission factors of produced hydrogen are reported in Table 4.3-4 by feedstock.

**Table 4.3-4** Average of emission factors by feedstock, Gg CO<sub>2</sub>/ Gg feedstock

Feedstock	Emission factor
Natural gas	2.74
Naphtha	3.20
Propane	3.00
Membrane gas	2.69

#### 4.3.3.3 Activity data

The consumption of hydrocarbons is used as activity data in calculating emissions from hydrogen production. The feedstocks used are natural gas, naphtha, propane and membrane gas. Activity data are collected directly from individual companies. Data for the first half of the 1990's have been partly taken

from industrial statistics and partly estimated on the basis of other years' data or output of a company. The launching of a new plant in an existing site in autumn 2006 increased the amount of used hydrocarbons. Amount of used hydrocarbons are shown in Table 4.3-5.

#### *4.3.3.4 Uncertainty and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

The uncertainty in emissions in hydrogen production was estimated at  $\pm 5\%$ . The uncertainty is partly due to uncertain activity data. Another factor that causes uncertainty is the lack of knowledge concerning the exact number of reagents that actually react in the various processes.

The data on the emissions have improved in recent years, mainly due to increased availability of measured data. Therefore uncertainties in recent years are smaller than at the beginning of the 1990's.

#### *4.3.3.5 Source-specific QA/QC and verification*

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6. The QC procedures are performed according to the QA/QC plan in Chemical Industry sector in order to attain these quality objectives. The bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert. In the last quality meeting for example documentation of activity data, checking of emission factors, developing a calculation system and the ERT Review report were discussed. The auditing of working instructions helped sectoral expert to develop and clarify once written instructions to be more precise for a person who will do the calculation for the first time.

In the calculation of emissions from hydrogen production several general inventory quality control procedures have been performed as mentioned in GPG 2000, table 8.1. Some of the checks are performed annually, like comparing with previous emissions of subcategory of the calculated emissions and ensuring that there are no transcription errors in calculations and some when the calculation method has been developed.

A few source category-specific quality control procedures have been carried out during calculation. The stoichiometric emission factors are considered to be adequate. Activity data have been checked using as many independent sources as possible and only small differences between figures have been noticed. All activity data are site-specific and reported to industrial output statistics or reported due to monitoring of environmental permit of a company.

The calculated emission data of two plants (out of 7) have been verified with ETS data and emissions have been found to be equal. These two plants are biggest emitters in this category, amount of their emissions represents almost 90% of category's emissions.

#### *4.3.3.6 Source-specific recalculations*

Amount of used hydrocarbon was corrected for years 2010 and 2011. Emissions decreased 16 Gg 2010 and 6 Gg 2011.

#### *4.3.3.7 Source-specific planned improvements*

For the whole Industrial processes sector, the work to implement the 2006 IPCC Guidelines for the 2015 submission has been started in 2013.



### 4.3.4 Phosphoric acid production

#### 4.3.4.1 Methods

Phosphoric acid is produced from phosphorus containing minerals, the most important mineral is phosphorite (=apatite  $3\text{Ca}_3(\text{PO}_4)_2 \cdot \text{CaF}_2$ ). There are two different methods to produce phosphoric acid; thermal and wet process; in Finland the wet process has been used. In the wet process the raw phosphate is dissolved in sulphuric acid and the released phosphoric acid is separated from calcium sulphate.

The most common impurity in phosphoric mineral is carbonate, and in Finland it is calcite. Sulphuric acid causes that carbonate degrades and carbon dioxide will be released. The amount of released  $\text{CO}_2$  is defined from a collected daily sample of apatite.

Calcite has also been used in phosphoric acid plant as neutraliser in waste water handling. The amount of released  $\text{CO}_2$  is also defined from a daily collected sample of calcite.

The total amount of  $\text{CO}_2$  released from phosphoric acid plant has been calculated multiplying the use of apatite and calcite with  $\text{CO}_2$  content of defined yearly average of daily samples. Emission factors, used amount of apatite and calcite and calculated  $\text{CO}_2$  emissions were received from the phosphoric acid producing company.

#### 4.3.4.2 Emission factors

Emission factors for apatite and calcite have been defined as a yearly average of daily samples. Emission factors are received directly from the phosphoric acid producing company and are confidential.

#### 4.3.4.3 Activity data

The activity data are the used amount of apatite and calcite. The amounts of them are received from the company and are also confidential.

#### 4.3.4.4 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

The uncertainty in emissions in 2012 was  $\pm 7\%$ .

#### 4.3.4.5 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6. The QC procedures are performed according to the QA/QC plan in Chemical Industry sector in order to attain these quality objectives. The bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert.

In the calculation of emissions from phosphoric acid production several general inventory quality control procedures have been planned to perform as mentioned in GPG 2000, table 8.1. Some of the checks are performed annually, like comparing with previous emissions of subcategory of the calculated emissions and ensuring that there are no transcription errors in calculations and some when the calculation method has been developed or changed.

For this inventory submission emission estimates have been compared with emissions reported to Vahti system, emissions have observed to be equal.

#### 4.3.4.6 Source-specific recalculations

No source-specific recalculations have been done.

#### 4.3.4.7 Source-specific planned improvements

For the whole Industrial processes sector, the work to implement the 2006 IPCC Guidelines for the 2015 submission has been started in 2013.

### 4.3.5 Ammonia production

#### 4.3.5.1 Methods

Ammonia has been produced only in 1990-1992 small amounts (4 - 30 Gg per year), mainly peat and heavy oil as feedstock for the needed hydrogen. CO<sub>2</sub> emissions from ammonia production are calculated by multiplying the amount of produced ammonia with the emission factor. Activity data have been received directly from the company and the emission factor is the default factor from the IPCC.

#### 4.3.5.2 Emission factors

Emissions have been calculated with the mean value of two IPCC default emission factors (1.55 tonne CO<sub>2</sub>/tonne ammonia produced).

#### 4.3.5.3 Activity data

The amount of produced ammonia has been received from a company, which was producing it at the beginning of the time series. The amount of produced ammonia is shown in Table 4.3-5.

#### 4.3.5.4 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

The uncertainty of activity data in ammonia production was estimated 5% and emission factor 50% (Forsell 2014).

### 4.3.6 Indirect CO<sub>2</sub> emissions from NMVOC emissions from chemical industry

#### 4.3.6.1 Methods

NMVOC emissions from chemical industry are estimated by the Finnish Environment Institute based on emission data from the VAHTI system. Documentation of the calculation is presented in the Finnish IIR 2013. Indirect CO<sub>2</sub> emission was calculated using the equation below. It was assumed that the average carbon content is 80% by mass for years 1990-2012 for all categories under the sector Industrial Processes based on 2006 IPCC Guidelines. The fraction of fossil carbon in the NMVOCs is based on the NMVOC speciation profile provided in the EMEP/EEA Emission Inventory Guidebook 2000 section B4610-6.

$$Emissions_{CO_2} = Emissions_{NMVOCs} * Percent\ carbon\ in\ NMVOCs\ by\ mass * 44/12$$

NMVOC emissions from chemical industry in 1990-2012 are presented in Table 4.3-5.

#### 4.3.6.2 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

Uncertainty for activity data is ±100% and for emission factors ±20%. Uncertainty for the activity data is based on the latest uncertainty analysis for NMVOC carried out for the 2011 emissions and reported in the

Finnish IIR (Informative Inventory Report, 2013) to the UNECE CLRTAP Secretariat in March 2013, where the methods used for the analysis are documented.

The uncertainty estimate is related to uncertainty of activity data from the VAHTI system, which is estimated  $\pm 100\%$ . Monitoring of NMVOC emissions is generally not included in the emissions monitoring programmes of the plants and therefore the methods used by the plant operators to estimate their NMVOC emissions are not always known.

NMVOC emissions for chemical industry have been calculated using same method for the whole time series.

#### *4.3.6.3 Source-specific QA/QC and verification*

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6. The QC procedures are performed according to the QA/QC plan in Chemical Industry sector in order to attain these quality objectives. The bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert.

In the calculation of NMVOCs and indirect CO<sub>2</sub> emissions general inventory QC procedures mentioned in GPG 2000 Table 8.1 have been performed. For example, plant specific emissions and activity data are compared between the years. The data is reported by plants according to monitoring requirements in the environmental permits and it is checked and approved by the environmental competent authority before recording it to the VAHTI database. There is no activity data available to compare with emission factors in the EMEP EEA Emission Inventory Guidebook.

#### *4.3.6.4 Source-specific recalculations*

No recalculations have been made.

#### *4.3.6.5 Source-specific planned improvements*

As a part of updating of air emissions time series also the activity data of this category will be checked in 2015.

**Table 4.3-5** Production of ammonia, nitric acid and ethylene, amount of used hydrocarbons and NMVOC emissions as activity data (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Ammonia	28.4	28.7	12.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitric acid	549	480	428	445	461	476	477	480	452	453	451	430	447	477	503	582	599	615	629	477	566	542	611
Ethylene	188	223	216	197	177	225	230	183	255	260	256	260	228	298	327	327	313	295	354	362	374	369	318
Used hydrocarbons	21	26	23	27	39	32	38	37	36	35	40	38	44	51	55	40	68	188	233	251	261	243	248
NMVOC emissions	8.3	7.1	7.1	6.4	6.7	6.8	7.1	6.9	5.0	4.9	4.4	4.4	3.8	3.4	4.0	2.6	3.0	2.3	2.9	2.6	2.7	2.6	2.5

## 4.4 Metal Production (CRF 2.C)

### 4.4.1 Source category description

This source category in the Finnish inventory includes CO<sub>2</sub> emissions mostly from coke and heavy bottom oil used in blast furnaces and CH<sub>4</sub> emissions from coke production (reported in CRF tables under Iron and steel production). CO<sub>2</sub> emissions from ferroalloys production in Finland are reported in Iron and steel production, because ferrochromium production is part of integrated stainless steel plant (Table 4.4-1 and Table 4.4-2). In addition, NMVOC emissions from iron and steel, non-ferrous metals and secondary aluminium production are reported. There is no primary aluminium production in Finland. Iron and steel production (CO<sub>2</sub> emissions) is one of the key sources in the Finnish inventory.

**Table 4.4-1** Reported emissions, calculation methods and type of emission factors for the subcategory Metal Production in the Finnish inventory

CRF	Source	Emissions reported	Methods	Emission factors
2.C 1	Iron and Steel Production			
	Steel	CO <sub>2</sub>	Tier 3, CS	CS
	Pig iron	IE (Steel)		
	Sinter	IE (Steel)		
	Coke	CH <sub>4</sub> , CO <sub>2</sub>	Tier 1	D
2.C 2	NMVOC emissions	CO <sub>2</sub>	Tier 2	CS
	Ferroalloys Production	IE (Iron and Steel Production)		
2.C 5	Non-ferrous Metals	CO <sub>2</sub>	Tier 2	CS
	NMVOC emissions	CO <sub>2</sub>	Tier 2	CS

SF<sub>6</sub> emissions from magnesium die-casting are included in the inventory. However, since there is currently only one producer in Finland, these data are confidential. Emissions and consumption data were therefore grouped with other confidential SF<sub>6</sub> data, and reported under CRF category 2.F Consumption of Halocarbons and sulphur hexafluoride.

Degreasing in metal industry is included in CRF 3.B and painting in CRF 3.A.

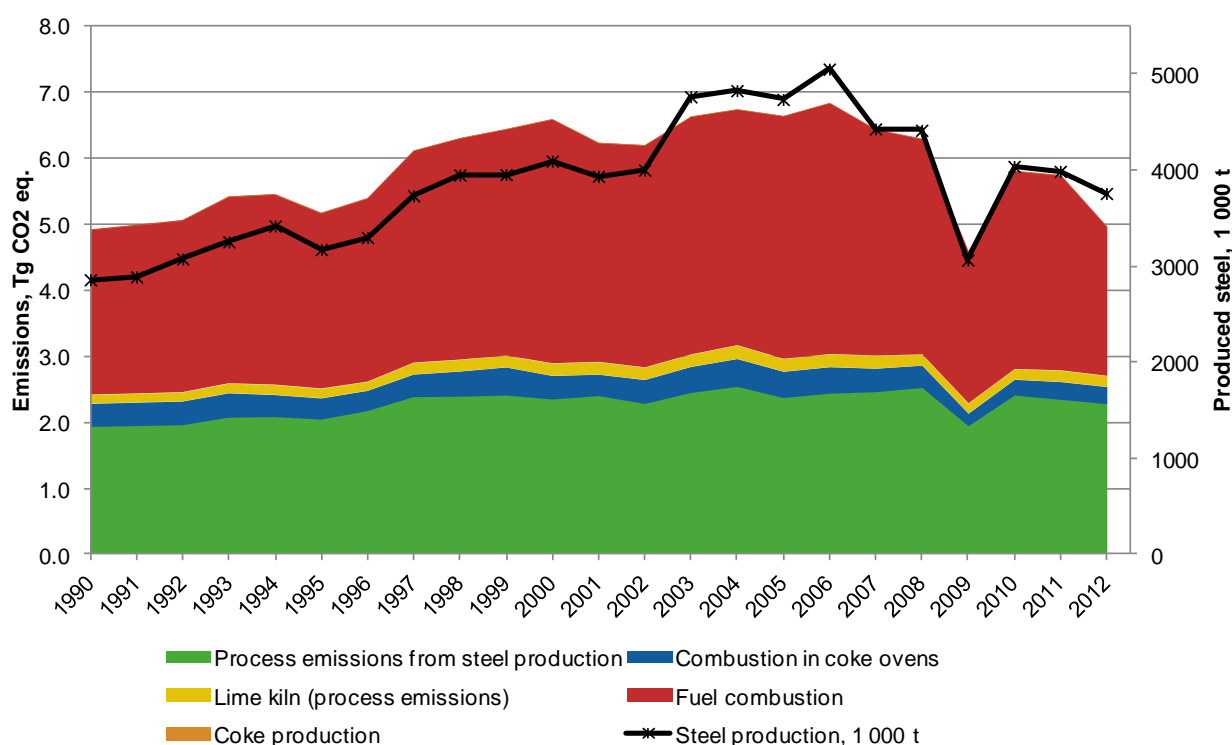
In the earlier inventories CH<sub>4</sub> emissions from pig iron and sinter production were also reported. The emissions were removed from the inventory because the GPG 2000 no longer included defaults for these emissions. Around the same period, information was received from the Finnish Iron and Steel Industry that according to measurements made at some Finnish plants, the emissions from these sources were negligible/close to zero. This supported the decision to remove the estimates from the inventory.

Process emissions of metal production were 2.3 Tg CO<sub>2</sub> eq. in 2012 and this was over 43% of sector's and about 3.8% of Finland's total greenhouse gas emissions. Iron and steel production contributes over 99% of emissions of metal production.

There was a sudden growth in production of steel in the beginning of the 2000's because one steel plant increased production and improved its energy efficiency. In 2007, 2008 and especially 2009 the production of steel was lower due to market situation (Figure 4.4-1). After three years period of declining production and emissions, the trend turned upwards in 2010 and amount of produced steel increased by 32% in a year. Until the economic downturn in 2007-2009, the amount of produced steel had increased by 54% since 1990 while total emissions of iron and steel industry increased only 36% at the same time. The economic downturn caused higher CO<sub>2</sub> IEF, because the energy efficiency of the processes becomes lower, when full capacity cannot be used (Hemminki, 2008). In 2012 fuel combustion emissions in iron and steel production declined clearly due to closing of one sintering plant. This can be clearly seen in Figure 4.4-1 and Figure 4.4.2.

Methane emissions from coke production almost doubled in 1993 due to opening of a second coke oven in a steel factory (see Table 4.4-5).

Indirect CO<sub>2</sub> emissions from metal production have been calculated from NMVOC and methane emissions for the time series 1990-2012.



**Figure 4.4-1** Total emissions of steel production and amount of produced steel

## 4.4.2 Steel production

### 4.4.2.1 Methods

The calculation method of CO<sub>2</sub> emissions from the iron and steel industry is a country-specific bottom-up methodology. Both fuel-based emissions and process emissions are calculated in connection with the ILMARI calculation system (see Section 3.2 Emissions from fuel combustion) using plant/process level data. The methodology is slightly plant-specific, because all plants differ from each other.

The plants included are:

- One iron and steel plant including coke oven, blast furnace, lime production plant and steel converter
- One iron and steel plant including blast furnace and steel converter
- One integrated ferrochromium and stainless steel plant
- One steel plant with electronic arc furnace, using scrap iron only

(In addition there are approximately 20 iron foundries; the emissions from these plants are allocated to CRF 1.A 2a; they are not included in this chapter).

The main common feature for all plants is that fuel-based emissions for each installation are calculated in the ILMARI system from the use of fuels, excluding coke and heavy bottom oil used in blast furnaces, and subtracted from total CO<sub>2</sub> emissions (described below). Fuel-based emissions are allocated to CRF 1.A 2a and CRF1.A 1c (coke ovens). The rest of emissions are allocated to process emissions in CRF 2.C 1 (and CRF 2.A 2 in the case of limekilns).

**Table 4.4-2** Emissions by gas and subcategory (Tg CO<sub>2</sub> eq.)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>CO<sub>2</sub></b>																							
2.C 1 Production of steel	1.93	1.94	1.96	2.07	2.08	2.04	2.17	2.38	2.39	2.41	2.35	2.4	2.28	2.44	2.54	2.37	2.43	2.46	2.52	1.94	2.4	2.34	2.28
2.C Indirect	0.004	0.004	0.004	0.005	0.005	0.005	0.004	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.004	0.004	0.003	0.003	0.003	0.003
<b>CH<sub>4</sub></b>																							
2.C 1Coke production	0.005	0.005	0.005	0.009	0.010	0.010	0.010	0.009	0.010	0.009	0.010	0.010	0.010	0.009	0.009	0.009	0.009	0.009	0.009	0.008	0.009	0.009	0.009
<b>Total of subcategory, Tg CO<sub>2</sub> eq.</b>	<b>1.94</b>	<b>1.95</b>	<b>1.97</b>	<b>2.09</b>	<b>2.09</b>	<b>2.06</b>	<b>2.18</b>	<b>2.4</b>	<b>2.4</b>	<b>2.42</b>	<b>2.36</b>	<b>2.41</b>	<b>2.29</b>	<b>2.46</b>	<b>2.55</b>	<b>2.38</b>	<b>2.45</b>	<b>2.47</b>	<b>2.53</b>	<b>1.95</b>	<b>2.42</b>	<b>2.35</b>	<b>2.29</b>

Total CO<sub>2</sub> emissions for each installation (coke oven, sintering plant, blast furnace, lime kiln, steel converter, rolling mills and power plants/boilers) in each plant are taken from the VAHTI system until 2004 (see also Section 1.4 and Annex 2). These emissions are basically calculated by plant operators using carbon inputs (fuel inputs and reducing materials) and they are reported by installations separately. From 2005 on, all four iron and steel plants in Finland report to the EU ETS. Starting from 2007 submission (2005 data), the total CO<sub>2</sub> emissions for GHG inventory have been taken from the ETS data, although the split between process and fuel-based emissions has been done in the same way as in the previous years' calculation.

The time series of CO<sub>2</sub> emission data are not fully complete in the VAHTI system. Emissions for 1990-1995 have not been reported to VAHTI. Therefore total CO<sub>2</sub> emissions for these years are calculated from the input of fuels, reducing agents and carbonates in each installation (excluding blast furnace gases to avoid double counting). The time series data of fuels and reducing agents are fairly consistent, although some corrections had to be made to the original fuel data taken from VAHTI system. The corrections were based on several data sources (updated time series directly from the plants, energy statistics and energy consumption survey of manufacturing industries). This fuel and carbonate based calculation was also done for later years to compare the methodology and results for 1996-2006 (cross-check calculation). The reported totals (by installations) are fairly close to the calculated emissions, and the method has been judged reliable to be used for years prior to 1995, too.

In this methodology used for 1990-2004 some streams of carbon inputs and outputs (for example, C input in scrap iron and C output in steel) are not taken into account. According to the EU ETS (Emission Trading Scheme, Section 1.4) monitoring plans of the largest iron and steel producers in Finland, these streams belong to very small streams with an overall cumulative effect on emissions of less than 1% of plants' total CO<sub>2</sub> emissions (see Section 4.4.2.4). These small streams of carbon are included in the EU ETS data which is used in the inventory from 2005 on.

Emissions are reported in the CRF categories using the allocations as mentioned in Table 4.4-3.

**Table 4.4-3** Allocation of emissions from iron and steel production in Finland

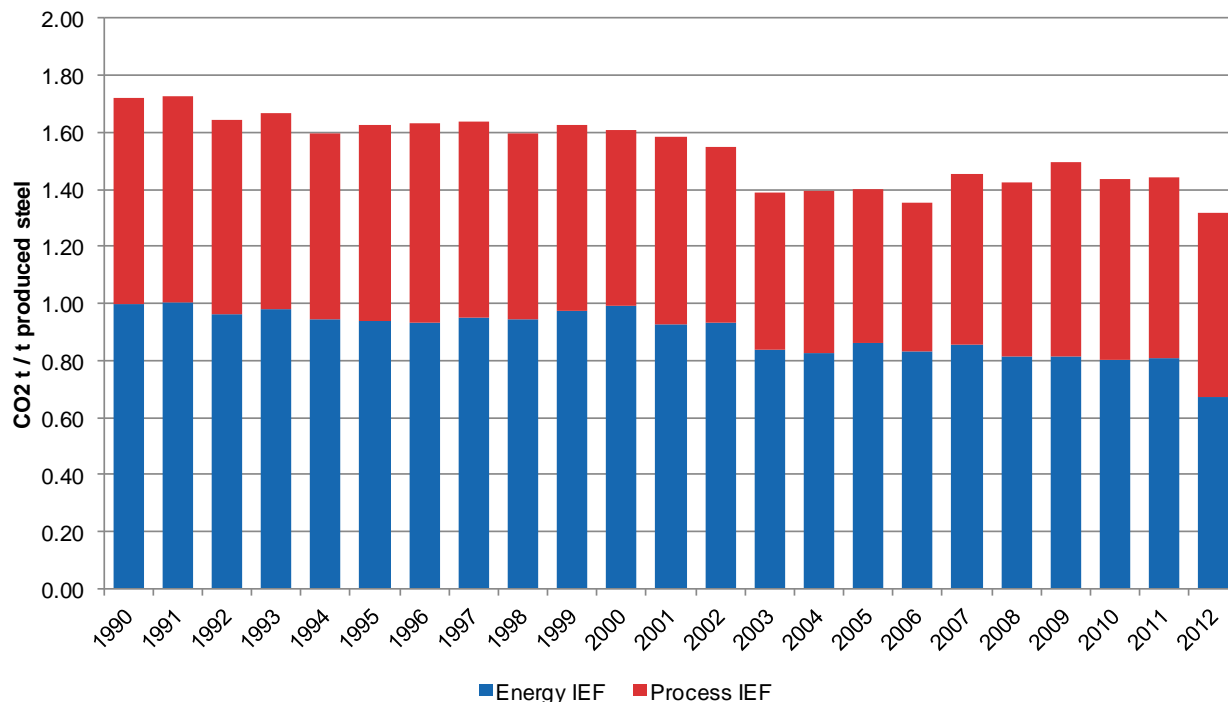
CRF category	Emission source
CRF 1.A 1c	Emissions from fuels used in coking plants (coke oven gas and BF gases)
CRF 1.A 2a	Emissions from fuels used in iron and steel plants' processes and power plants: (LPG, residual fuel oil, gasoil, coke oven gas and BF gas, excluding BF gas used for blast furnaces' air pre-heaters)
CRF 2.A 2	Process emissions from lime production in iron and steel plant
CRF 2.C 1	Process emissions from iron and steel production (includes ferroalloys production in integrated stainless steel plants)

Personal communications (Perander 2005 and 2006) with iron and steel plant staff showed that the present method used in the GHG inventory gives the best results, taking into account the availability of the data for the whole time series. The mass balance approach was in principle seen as a more accurate methodology, but the complete data are not available for earlier years. In addition, stock changes were not reported in the early 1990's accurately enough to allow for a full mass balance approach calculation. However, if data that are more accurate were to become available for historical time series, a recalculation could be considered, but now this option seems very unlikely.



#### 4.4.2.2 Emission factors

The CO<sub>2</sub> emission factors used in the calculation are presented in Table 3.2-3. Plant-specific CO<sub>2</sub> emission factors have been used as far as possible. Implied emission factors for CO<sub>2</sub> emissions can be seen in Figure 4.4-2.



**Figure 4.4-2** Implied emission factors for CO<sub>2</sub> in energy production and industrial processes in steel industry

#### 4.4.2.3 Activity data

Activity data for the calculation and comparison of CO<sub>2</sub> emissions are taken from the VAHTI system, energy statistics (Energy Statistics, Yearbook), manufacturing industry statistics and special surveys by Statistics Finland. The production of steel can be found in Table 4.4-4.

Fuel data and reducing agent data are available for all years and all plants, but this has required combining of several data sources. CO<sub>2</sub> emission data are available starting from 1996. ETS data are available from 2005 on.

There are also supplementary data for some plants and some years:

- mass balance data for 1990 and 2004 (the biggest plant)
- mass balance data and CO<sub>2</sub> emissions for all years before ETS (1990 - 2004) (the second biggest plant)

The quality of the data varies over time. Below there is a qualitative assessment of the data for the three biggest plants. These data have been used for the calculations 1990 - 2004 (before using ETS data). In addition, actions needed to complete calculations have been briefly described.

##### Plant 1

##### Time series, data quality

Data from operator (mass balance)

1979 - 2004; data set is very consistent and reliable

VAHTI data (fuels and emissions by installations)

1990 - 1995; only partial data, poor quality, 1/3 of CO<sub>2</sub> missing

1996 - 2004, fairly good

Actions: hardly any estimates needed, because data from operator could be used to complete VAHTI time series.

**Plant 2****Time series, data quality**

Data from operator (mass balance)

1990 and 2004; is very consistent and reliable

VAHTI data (fuels and emissions by installations)

1990 - 1995; only partial fuel data, poor quality, CO<sub>2</sub> data missing  
1996 - 2004, fairly good

Actions: Fuels and reducing agents for 1990 - 1994 have been complemented from many sources. The allocation for each process/installation has been partly estimated. Total CO<sub>2</sub> emissions for these years have been calculated using fuel data, reducing agents and CaCO<sub>3</sub> input data. Process emissions have been partly estimated using later years' data and supplementary information (mass balance data) for 1990.

**Plant 3****Time series, data quality**

Data from operator (mass balance)

no separate operator data available

VAHTI data (fuels and emissions by installations)

1990 - 1995; only partial data, poor quality, CO<sub>2</sub> data missing  
1996 - 2004, fairly good; (process emissions are included since 2003)

Actions: Fuels and reducing agents for 1990 - 1994 have been complemented from many sources. The allocation for each process/installation has been partly estimated. Total CO<sub>2</sub> emissions for these years have been calculated using fuel data, reducing agents and CaCO<sub>3</sub> input data. Process emissions have been partly estimated using later years' data. Recalculation in 2010 submission: coke consumption time series data were updated (see Section 4.4.2.6).

**4.4.2.4 Uncertainty and time series' consistency**

As described in the previous subchapters, there are three different periods of calculation methodologies:

1990-1995: 'coke and carbonates' method (includes fuels, reducing agents and carbonates, excludes BFG)

1996-2004: emissions taken mostly from VAHTI emission register, cross checked using 'coke and carbonates' method

2005 - : emissions taken from EU ETS data: crosschecked with VAHTI data and 'coke and carbonates' method

The results of these periods are crosschecked using several comparisons. After these crosscheckings time series can be judged consistent (read: as consistent as possible), taking into account, that there are remarkable changes in the data availability.

The most important change in the methodological point of view is, that in the pre-ETS era certain small streams of carbon are not accounted, as described in Section 4.4.2.1. We have studied the amounts of these small streams based on ETS data. 'Small streams' here include tens of streams of carbon, for example scrap iron, steel products, other by-products, graphite electrodes, slag, dust, etc., basically everything except the main reducing agents, fuels and calcium carbonates. The sum of these small streams seems to lie within +-1% of the total emissions of these plants; it varies according to plant and year. This variation is far less, than the estimated pre-ETS uncertainty level, which is mostly affected by the uncertainties in activity data of coke and heavy bottom oil inputs.

The changes in the methodologies are reflected in the uncertainty calculations as described below.

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

The uncertainty calculation was revised for the 2013 submission. The EU ETS data, which is used as the primary source for the total CO<sub>2</sub> emission of the iron and steel industry from 2005 on, has clearly lower uncertainty than the data for 1990-2004. The uncertainty estimates for 1990 has been remaining the same as in previous submissions. For the latest inventory year the total uncertainty for sectors 2.C.1+1.A.2a is deducted from the ETS information. This uncertainty is split between 2.C.1 and 1.A.2a in a way, that effect on total uncertainty does not change.

In 1990 the uncertainty of 2.C.1 was estimated at  $\pm 10\%$  (Grönfors, 2007). For 2012, the overall uncertainty of 2.C.1+1.A.2a was  $\pm 2\%$ , based on ETS data. Summary of the uncertainty analysis has been described in Section 1.7.

#### 4.4.2.5 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6. The QC procedures are performed according to the QA/QC plan in Metal Production sector in order to attain these quality objectives. The bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert..

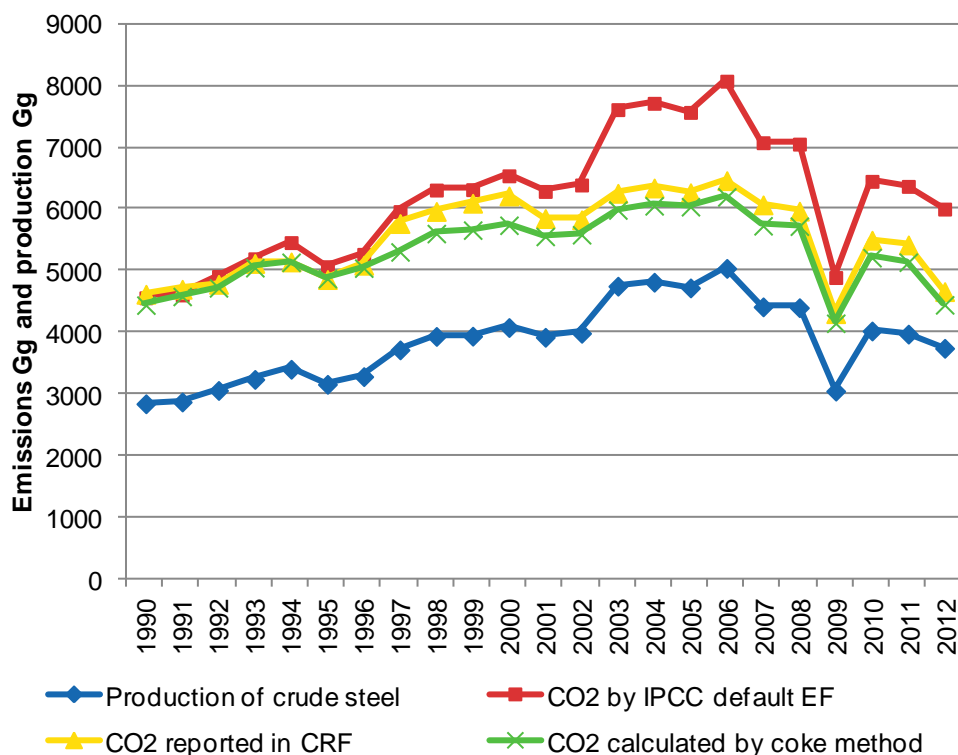
As a part of sector-specific QA/QC, energy and GHG experts from Statistics Finland made a plant visit to the most important iron and steel plant in January 2006. During the visit the monitoring methods, definitions and system boundaries of the complex integrated plant were discussed. The main object was to harmonise the reporting practises and data on energy use, production, feedstocks and emissions, so that comparable results can be achieved both in Energy Statistics and GHG inventory and also in EU ETS monitoring.

The main annual quality checks are:

- Comparison of different methodologies (reported and calculated emissions), see Figure 4.4-3
- Comparison to the mass/balance approach for certain years
- Checking of activity data from several independent sources.

In Figure 4.4-3 results of three different calculation methodologies have been compared against the production of crude steel. This comparison is one of our sector-specific QA/QC-activities. The main purpose of this cross-checking is to see whether annual variations follow the trends in production of steel and to detect unexpected variations.

The other point in Figure 4.4-3 is to crosscheck, that our reported emissions are mostly within a range - “expected minimum level” (coke method) and the “expected maximum level” (IPCC default methodology).



**Figure 4.4-3** Comparison of CO<sub>2</sub> emissions from Iron and steel, includes both energy based emissions and process emissions

#### 4.4.2.6 *Source-specific recalculations*

There was a minor correction of erroneous emission data.

#### 4.4.2.7 *Source-specific planned improvements*

For the whole Industrial processes sector, the work to implement the 2006 IPCC Guidelines for the 2015 submission has been started in 2013.

### 4.4.3 *Coke production*

#### 4.4.3.1 *Methods*

The calculation method for CH<sub>4</sub> emissions from coke production is consistent with the IPCC Guidelines.

#### 4.4.3.2 *Emission factors*

Production of coke: The emission factor 0.5 kg/t used in the calculation of CH<sub>4</sub> emissions from coke production is the 1996 IPCC GL default value.

#### 4.4.3.3 *Activity data*

Activity data for the calculation of CH<sub>4</sub> emissions from coke production are obtained from Energy Statistics. Coke production data are presented in Table 4.4-4. Coke production almost doubled in 1993 due to opening of a second coke oven; increased production substituted imported coke.

#### 4.4.3.4 *Uncertainty and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

The uncertainty for activity data in coke production was estimated to be around  $\pm 3\%$  and for emission factors around  $\pm 20\%$  in 2010 (Slioor, 2004).

#### 4.4.3.5 *Source-specific QA/QC and verification*

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6. The QC procedures are performed according to the QA/QC plan in Metal Production sector in order to attain these quality objectives. The bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert. The calculated emissions have been compared with previous emissions of the subcategory.

All activity data are site-specific and reported to industrial output statistics or due to monitoring of environmental permit of a company. Activity data have been checked using as many independent sources as possible.

#### 4.4.3.6 *Source-specific recalculations*

No recalculations have been done.

#### 4.4.3.7 *Source-specific planned improvements*

For the whole Industrial processes sector, the work to implement the 2006 IPCC Guidelines for the 2015 submission has been started in 2013.

**Table 4.4-4** Production of steel and coke, Gg

	Production of coke	Production of crude steel
1990	487	2 861
1991	471	2 890
1992	498	3 077
1993	874	3 256
1994	922	3 420
1995	920	3 176
1996	910	3 301
1997	879	3 734
1998	912	3 952
1999	900	3 956
2000	910	4 096
2001	909	3 938
2002	912	4 003
2003	895	4 766
2004	904	4 830
2005	894	4 738
2006	870	5 054
2007	865	4 431
2008	860	4 417
2009	740	3 066
2010	828	4 040
2011	852	3 989
2012	881	3 759

#### *4.4.4 Indirect CO<sub>2</sub> emissions from NMVOC and methane emissions from iron and steel and secondary aluminium production*

##### *4.4.4.1 Methods*

NMVOC emissions from iron and steel, non-ferrous metals and secondary aluminium production are calculated at the Finnish Environment Institute based on emission data from the VAHTI system and the production data from the Federation of Finnish Technology Industries. The emission factors are taken from the EMEP/EEA Emission Inventory Guidebook. Documentation of the calculation is presented in the Finnish IIR 2013.

Indirect CO<sub>2</sub> emissions from NMVOC emissions were calculated using the same equation mentioned in Section 4.3.5. In addition, indirect CO<sub>2</sub> emissions from methane emissions were calculated using equation mentioned in Section 3.6.2.1. The amounts of NMVOC and methane and indirect CO<sub>2</sub> emissions are presented Table 4.4-5.

**Table 4.4-5** NMVOC and methane emissions as activity data and indirect CO<sub>2</sub> emissions, Gg

	NMVOC emissions	Methane emissions	Indirect CO <sub>2</sub> from	
			NMVOC emissions	Methane emission
1990	1.18	0.24	3.46	0.67
1991	1.13	0.24	3.32	0.65
1992	1.15	0.25	3.38	0.68
1993	1.22	0.44	3.59	1.20
1994	1.33	0.46	3.89	1.27
1995	1.13	0.46	3.32	1.27
1996	1.05	0.46	3.07	1.25
1997	1.29	0.44	3.78	1.21
1998	1.35	0.46	3.96	1.25
1999	1.26	0.45	3.70	1.24
2000	1.41	0.46	4.14	1.25
2001	1.32	0.45	3.87	1.25
2002	1.18	0.46	3.47	1.25
2003	1.25	0.45	3.66	1.23
2004	1.13	0.45	3.31	1.24
2005	1.25	0.45	3.68	1.23
2006	1.21	0.43	3.54	1.20
2007	1.05	0.43	3.09	1.19
2008	0.97	0.43	2.84	1.18
2009	0.63	0.37	1.85	1.02
2010	0.75	0.42	2.21	1.14
2011	0.71	0.43	2.08	1.17
2012	0.55	0.44	1.62	1.21

#### 4.4.4.2 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

Uncertainty for activity data from iron and steel (CRF 2.C.1) is 87% and from secondary aluminium production (2.C.5) is 100% and for emission factors 20%. Uncertainty for the activity data is based on the latest uncertainty analysis for NMVOC carried out for the 2011 emissions and reported in the Finnish IIR (Informative Inventory Report, 2013) to the UNECE CLRTAP Secretariat in March 2013, where the methods used for the analysis are documented.

The uncertainty of emission is related to the uncertainty of activity data from the VAHTI system that is estimated  $\pm 70\%$ . Monitoring of NMVOC emissions is generally not included in the emissions monitoring programmes of the plants and therefore the methods used by the plant operators to estimate their NMVOC emissions are not always known.

NMVOC emissions and indirect CO<sub>2</sub> emissions have been calculated using same method for the whole time series.

#### 4.4.4.3 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6. The QC procedures are performed according to the QA/QC plan in Metal Production sector in order to attain these quality objectives. The bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert..

In the calculation of NMVOCs and indirect CO<sub>2</sub> emissions general inventory QC procedures mentioned in GPG 2000 Table 8.1 have been performed. For example, plant specific emissions and activity data are compared between the years. The data is reported by plants according to monitoring requirements in the

environmental permits and it is checked and approved by the environmental competent authority before recording it to the VAHTI database. There is no activity data available to compare with emission factors in the EMEP EEA Emission Inventory Guidebook.

#### *4.4.4.4 Source-specific recalculations*

No recalculations have been done.

#### *4.4.4.5 Source-specific planned improvements*

As a part of updating of air emissions time series also the activity data of this category will be checked in 2015.

## 4.5 Other Production (CRF 2.D)

### 4.5.1 Source category description

This source category includes NMVOC emissions from forest and food industries. In 2012 they amounted to 3.5 Gg. Non-fuel based CO<sub>2</sub> emissions from the pulp and paper and food industries are estimated to be negligible in Finland. All N<sub>2</sub>O and CH<sub>4</sub> emissions from the pulp and paper industry are reported as fuel-based emissions under CRF 1.

NMVOC emissions from forest industries, including chemical pulping and paper production as well as mechanical wood industry, as well as from food industry are calculated at the Finnish Environment Institute (Table 4.5-1) and the documentation of the calculation is presented in the Finnish IIR 2013. The methods are consistent over the years.

Indirect CO<sub>2</sub> emissions from forest industry as well as from food and drink processing are considered biological.

NMVOC emissions from pulp and paper industry mainly originate from storage and handling of wood, where the major sources are production of mechanical pulp and storage of woodchips. These emissions are therefore considered biological emissions (Nilsson, 2007). Since NMVOC emissions from handling of wood are from biogenic origin (Nilsson, 2007) also NMVOC emissions from mechanical wood industry are mostly biological. Based on expert estimation (Lindh, 2007) indirect CO<sub>2</sub> emissions from pulp and paper and from food and drink sectors are assumed to be of biogenic origin.

**Table 4.5-1** NMVOC emissions from categories Pulp and paper and Food and Drink, Gg. (No indirect CO<sub>2</sub> emissions are estimated for these categories as the NMVOC emissions are assumed to be biogenic origin)

	Pulp and paper	Food and drink
1990	4.54	1.43
1991	4.22	1.37
1992	3.73	1.36
1993	3.98	1.33
1994	4.06	1.36
1995	4.19	1.39
1996	4.05	1.37
1997	4.01	1.41
1998	3.61	1.36
1999	3.39	1.42
2000	3.76	1.43
2001	3.61	1.42
2002	3.71	1.38
2003	3.81	1.35
2004	4.07	1.38
2005	3.42	1.45
2006	3.58	1.40
2007	4.93	1.36
2008	3.76	1.31
2009	2.84	1.31
2010	3.28	1.29
2011	3.47	1.29
2012	2.66	1.20



## 4.6 Consumption of Halocarbons and SF<sub>6</sub> (CRF 2.F)

### 4.6.1 Source category description

In 2012, greenhouse gas emissions under the source category CRF 2.F Emissions of Consumption of Halocarbons and SF<sub>6</sub> amounted to 1.0 Tg CO<sub>2</sub> eq., which is 1.6% of the total greenhouse gas emissions in Finland. Emissions from different subcategories reported under this sector are listed in Table 4.6-1.

**Table 4.6-1** Reported emissions under the subcategory Consumption of Halocarbons and SF<sub>6</sub> in the Finnish inventory

CRF	Source	Emissions reported
2. F 1	Refrigeration and air conditioning equipment	HFC, PFC
2. F 2	Foam blowing and use of foam products	HFC
2. F 4	Technical aerosols, one-component polyurethane foam, tear gas and metered dose inhalers	HFC
2. F 8	Manufacturing, use and disposal of electrical equipment	SF <sub>6</sub>
2. F 9	Emissions reported aggregated in a separate subcategory due to data confidentiality:	
	refrigeration and air conditioning	HFC-23 (between 2003-2005, 2007-2009 and 2011-2012)
	fixed fire fighting systems	HFC-125, HFC-134a
	semiconductor manufacturing	HFC-23, CF <sub>4</sub> , c-C <sub>4</sub> F <sub>8</sub> and SF <sub>6</sub>
	magnesium die casting	SF <sub>6</sub>
	shoes	SF <sub>6</sub> (until 2007)
	research	SF <sub>6</sub>

Note that the subcategory Aerosols includes one-component polyurethane foam cans (OCF), an aerosol-like product. This practice predates the GPG 2000. In the GPG 2000, OCF is discussed together with other foam types, and the methodology is slightly different from that applied to aerosols. Finland has decided not to change the practice of including OCF in the aerosols subcategory, because this would require recalculation of both the aerosol and foam time series. The recalculation would not improve the emission estimates.

There are no fugitive emissions from manufacturing, because F-gases are not produced in Finland. There is neither any manufacturing of other fluorinated gases, such as HCFCs or HFCs, which could lead to by-product emissions (e.g. HFC-23 from HCFC-22 manufacturing). Other point sources, which make a considerable contribution to emissions elsewhere, but are absent from Finland, include the primary aluminium and magnesium industry.

The total emissions of F-gases have increased significantly since 1990. During the period 1990–1995, the emissions declined slightly due to downward trend in quantities of installed SF<sub>6</sub> in electrical equipment, which was, by that time, the main emission source of F-gases. From mid-1990's emissions have increased strongly due to the introduction of HFC and PFC substances as ODS substitutes. In 2012, the emissions were nearly ten-fold compared with the emissions of 1995, which was chosen as the base year for F-gas emissions under the Kyoto Protocol in Finland (Table 4.6-2, Figure 4.6-1 and Figure 4.6-2).

A key driver behind the growing emission trend has been substitution of ozone depleting substances (ODS) by F-gases, especially with HFCs, in many applications. Restrictions of ODS in mid-1990's led to rapid growth of the use of HFCs as refrigerant agents and simultaneously to an increase of the emissions towards the end of the decade. There are four deviations in the upward trend. Those are a temporary drop in 2002, a fall from 2005 to the inventory 2006 and the decline of emissions in 2009 compared to 2008 and in 2011-2012 compared to 2010.

There are no known changes on the market that would cause fluctuation in 2002. In the quantities of imported chemicals, a similar drop cannot be seen and the inter-annual variation in the beginning of the 2000's is expected to be a result of variation in activity data. This is elaborated more in Section 4.6.3. Closer

analytical examination of each emission estimate in relation to the trend level and in the light of uncertainties shows, however, that it is hard to assess to what extent the estimate of 2002 is too low and how large part of the fluctuation is due to high estimates in adjacent years and to what extent the changes in the emission and data are real.

Because of low response rate in the 2006 inventory, the quantities of bulk refrigerants exported and imported had to be imputed for some large companies. In the 2007 inventory answers were also received from these companies and a closer study proved that the exported HFC quantity could have been overestimated and the imported HFC quantity underestimated in some extent in the 2006 inventory. However, the study also showed that new evaluation of activity data based on 2007 responses would lead to a bit higher emission estimation but the emissions would, anyhow, be on a lower level than in 2005 or 2007. This indicates real fluctuations in the emission trend.

The peak level of HFC emissions occurred in 2010. Since then the annual decline of emissions has been approximately 10%. The main reason behind the declining trend is the falling emissions from the refrigeration and air-conditioning sector. All activities of refrigerants, with the exception of bulk export, declined compared to 2011. The emissions were still at higher level than in 2009 when there was a drop in the emissions due to economic recession but at lower level compared to the emissions in 2008.

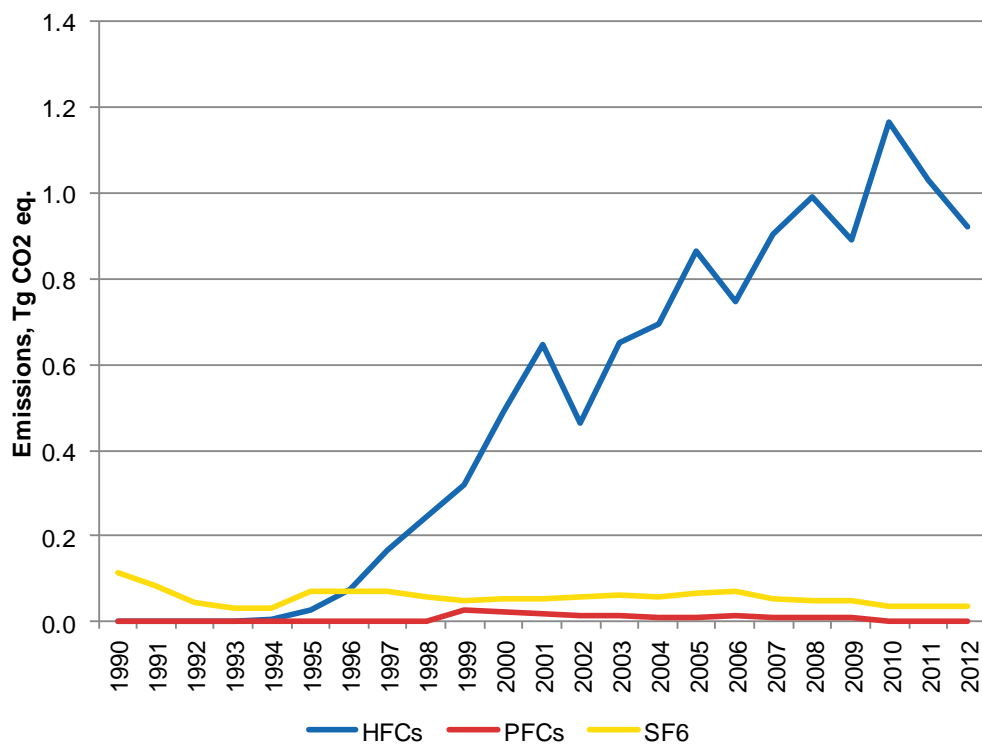
The peak level of PFC emissions in Finland occurred in the late 1990's. Since then the emissions have followed the global declining trend. In Finland the two most important sources of PFC emissions are usage of PFCs in refrigerants and in semiconductor manufacturing processes. Both, the usage of PFC-218 ( $C_3F_8$ ) for servicing refrigeration devices and the amount of PFC substances used in semiconductor manufacturing processes have decreased since the beginning of the 2000's. The decrease of the emissions from semiconductor manufacturing in the early 2000's was due to transfers of production from Finland into other countries. The imported amount of PFC's intended to be used for servicing refrigeration devices decreased clearly in 2010. Since 2010 there has been an increasing trend in the emissions due to increased amount of PFCs used both in semiconductor manufacturing and for servicing refrigeration devices. However the emissions are at the considerably lower level compared to the level before 2010.

$SF_6$  emissions from electrical equipment are an exception amongst the F-gases emission sources in Finland since emissions from this source have decreased compared to 1990 and 1995. The amount of  $SF_6$  gas used in annual activities in Finland is quite small. Therefore, changes in market activity have a significant impact on the emission level and can cause significant inter-annual fluctuation. The peak in 1990 coincides with the high level of economic activity in the country in general, and the fall of 2–4 years after the most severe years of the early 1990's recession. After the recession a rather large amount of electrical equipment was installed again in 1995, and the amount of gas used for maintenance also increased. After some years with high emissions in the mid-1990s, the trend declines again towards the end of the decade as the environmental impacts of  $SF_6$  became known and led to lower emissions. In the recent years, the imported quantity of  $SF_6$  has been used mainly in semiconductor manufacturing or in electrical equipment. The emissions from semiconductor manufacturing fluctuate slightly from year to year due to varying activity in the sector. The declining emissions from electrical equipment causes the overall declining emission trend.

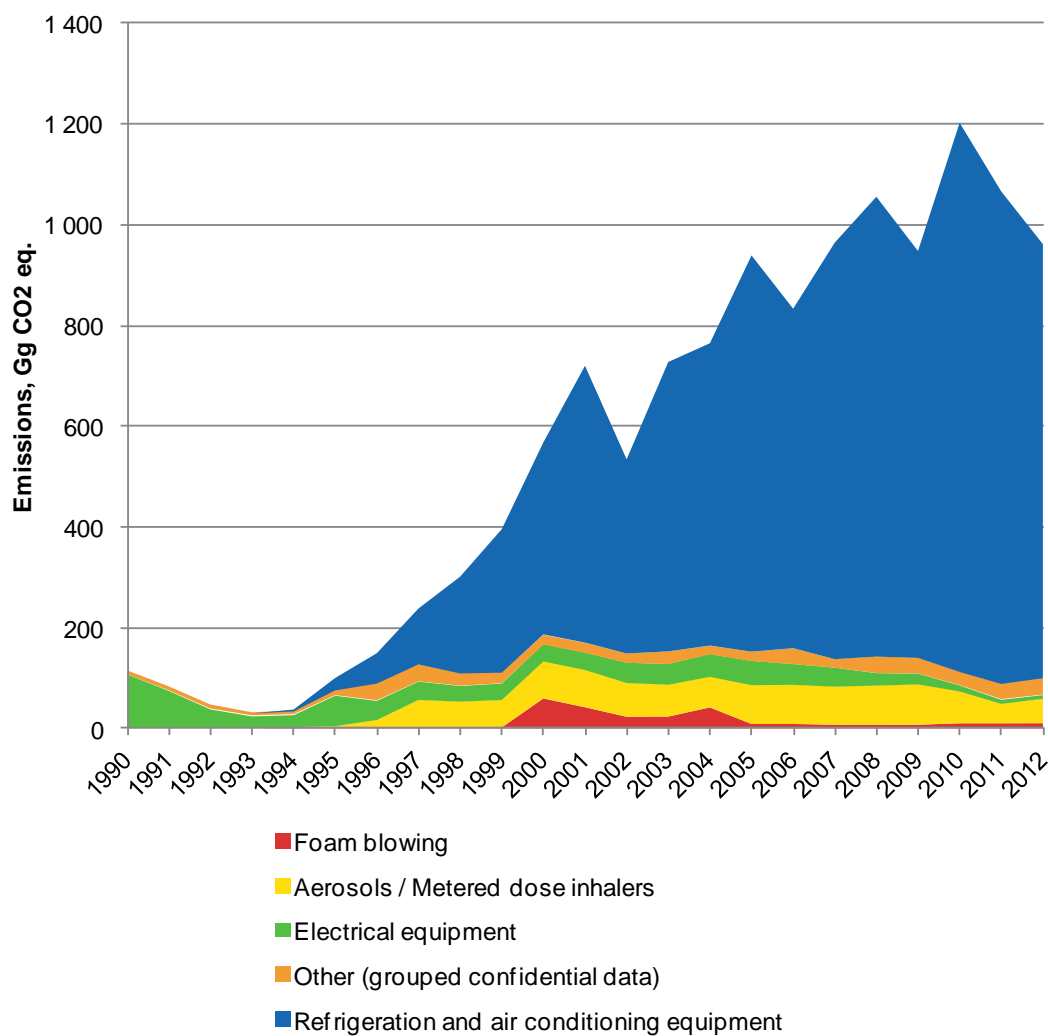
Based on the level analysis, refrigeration and air conditioning equipment and electrical equipment are key categories in 2012. Based on trend analysis, refrigeration and air conditioning equipment and electrical equipment are key categories in 2012.

**Table 4.6-2** Actual emissions of HFCs, PFCs and SF<sub>6</sub>, (CO<sub>2</sub> equivalent Gg)

	<b>HFCs</b>	<b>PFCs</b>	<b>SF<sub>6</sub></b>	<b>Total F- gases</b>
1990	0.02	0.07	115	<b>115</b>
1991	0.05	0.08	83	<b>83</b>
1992	0.10	0.09	46	<b>46</b>
1993	0.10	0.10	30	<b>30</b>
1994	6.5	0.12	31	<b>38</b>
1995	29	0.14	71	<b>101</b>
1996	77	0.16	72	<b>150</b>
1997	168	0.18	71	<b>239</b>
1998	245	0.21	56	<b>302</b>
1999	318	28.0	50	<b>396</b>
2000	492	22.5	54	<b>568</b>
2001	646	20.1	54	<b>720</b>
2002	463	13.4	58	<b>535</b>
2003	651	14.9	62	<b>728</b>
2004	694	11.9	59	<b>765</b>
2005	863	9.9	66	<b>939</b>
2006	747	15.4	71	<b>833</b>
2007	903	8.4	53	<b>965</b>
2008	993	11.2	51	<b>1 056</b>
2009	889	9.3	50	<b>948</b>
2010	1 170	0.7	35	<b>1 205</b>
2011	1 032	1.4	36	<b>1 069</b>
2012	926	1.9	37	<b>964</b>



**Figure 4.6-1** Actual emissions of HFCs, PFCs and SF<sub>6</sub> (CO<sub>2</sub> equivalent Tg)



**Figure 4.6-2** Actual emissions of F gases by subcategory (CO<sub>2</sub> equivalent Gg)

## 4.6.2 Methodological issues

### 4.6.2.1 Methods

An overview of the methods used to quantify emissions of F-gases is presented in Table 4.6-3. Emissions from each category are quantified using two or three different methods given in the GPG 2000. Finland reports both actual and potential emissions of F-gases in accordance with the UNFCCC reporting guidelines (FCCC/SBSTA/2004/8). There are two tiers for the estimation of potential emissions that describe gas consumption within a country (Tier 1a and 1b). The difference between the two is whether gases imported and exported in products are accounted for.

**Table 4.6-3** Summary of the methods used in the F-gases inventory

Source category	Methods used and gases reported	Notes
Magnesium die-casting (CRF 2.C)	Direct reporting method, Tier 1a	Tier 1b is not applicable to this category because all SF <sub>6</sub> used is imported in bulk. Emissions from this source are not reported separately due to confidentiality.
Refrigeration and air conditioning equipment (CRF 2.F 1)	Top-down Tier 2, Tier 1a, Tier 1b HFC-32, HFC-125, HFC-134a, HFC-143a, HFC-152a, PFC-218 (HFC-23 are reported in grouped data due to confidentiality)	The Tier 2 top-down method is used for all sources in this category, both stationary and mobile. Data are not collected for separate subcategories because such statistics are either not available or the preparation of such statistics would entail a very high reporting burden on companies. There is also some evidence that simpler questionnaires lead to better response activity. HFC-23 emissions from this source were not reported separately due to confidentiality 2003-2005, 2007-2009 and 2011-2012.
Foam blowing (CRF 2.F 2)	Tier 2, Tier 1a, Tier 1b HFC-134a, HFC-152a, HFC-227ea, HFC-245fa and HFC-365mfc	Emissions of HFC-245fa and HFC-365mfc are reported as additional greenhouse gases.
Fire extinguishers (CRF 2.F 3)	Tier 2, Tier 1a, Tier 1b HFC-125 and HFC-134a	Emissions from this source are not reported separately due to confidentiality.
Aerosols and one-component foam (CRF 2.F 4)	Tier 2, Tier 1a, Tier 1b HFC-134a and HFC-152a	One-component foam cans are treated as aerosols in this inventory, cf. Section 2.3.6 of Oinonen (2003). MDIs are not reported separately from other aerosols due to confidentiality.
Semiconductor manufacturing (CRF 2.F 7)	Tier 1, Tier 1a CHF <sub>3</sub> , CF <sub>4</sub> , SF <sub>6</sub> and c-C <sub>4</sub> F <sub>8</sub>	Tier 1b is not applicable to this category because all gases used are imported in bulk. Emissions from this source are not reported separately due to confidentiality.
Electrical equipment (CRF 2.F 8)	Tier 3c (country-level mass-balance), Tier 1b SF <sub>6</sub>	Tier 1a estimates cannot be calculated for this source because of lack of historical data. Tier 1b estimates have been calculated, however, based on survey and emissions data cf. Section 3.1 of Oinonen (2003).
Running shoes (CRF 2.F 9)	Method for adiabatic property applications, Tier 1b SF <sub>6</sub>	Tier 1a is not applicable to this category because all SF <sub>6</sub> used is imported not in bulk, but in products (i.e. shoes). Emissions from this source have not been reported separately due to confidentiality. The emissions from running shoes ended in 2007.

Note: Tier 1 methods are used in the calculation of potential emissions.

### HFCs and PFC-218 from refrigeration and air conditioning (CRF 2.F 1)

The source category covers HFCs and PFC-218 emissions from refrigeration and air conditioning equipment based on the vapour compression cycle. Included are *inter alia* domestic, commercial and industrial refrigeration systems, stationary and mobile air conditioning, as well as heat pumps. Emissions from refrigeration and air conditioning are reported as a single figure for all refrigeration and air conditioning subcategories (domestic, commercial, industrial, mobile, etc.).

Emissions are calculated by the IPCC Tier 2 and Tier 1a and 1b methods. In essence this means a material balance. The system under consideration is the geographic area of Finland. From the principle of conservation of mass, it follows that

$$\text{emissions} = \text{production} + \text{imports} - \text{exports} - \text{destruction} \pm \text{storage}.$$

HFC- or PFC-containing refrigerant gases are not manufactured in Finland, thus production = 0. Currently, the storage term is not equal to zero. Some of the gas imported is stored in equipment. At the same time, a proportion of the stored quantity is retired as the equipment reaches the end of its service life and is disposed of. The retiring capacity, however, is currently smaller than the new capacity. It follows that the net change given by the storage term must be deduced from the imported quantity, thus

$$\text{emissions} = \text{imports} - \text{exports} - \text{destruction} - \text{storage}.$$

This model gives the Tier 2 actual emissions. Implementation of the top-down Tier 2 approach is recommended in the GPG 2000. Emissions are not calculated for each equipment subcategory because this does not improve the inventory, but increases the companies' reporting burden. Also, respondents do not generally have data to support reporting at the level of subcategories. Current data gathering produces higher response activity and less uncertain activity data.

Potential emissions are given by the same formula, but assuming that storage is equal to zero. There are two variants of potential emissions. Tier 1a is defined to include only bulk quantities of imported and exported gases, whereas Tier 1b includes both bulk quantities and quantities imported in products. It is clear from above that actual emissions are currently smaller than potential ones.

More detailed descriptions of calculating emissions with the IPCC Tier 1a and b and Tier 2 methods (potential and actual emissions) are presented in Appendix\_4 at the end of Chapter 4.

#### HFCs from foam blowing (CRF 2.F 2)

The source category covers HFC emissions from foam blowing and use of HFC-containing foam products. Blowing agent HFC emissions in Finland result from the manufacturing and use of extruded polystyrene (XPS), polyurethane (PU) integral skin foam, PU appliance foam, injected PU foam and PU panels. Most of the production has been based on hydrocarbons since the phasing out of CFCs and HCFCs. Some smaller producers decided to use HCFCs as long as possible and switched to HFCs when HCFCs were prohibited by an EC regulation in the year 2000.

Since the majority of the producers have changed to the use of hydrocarbons or CO<sub>2</sub> as blowing agents, the HFCs emissions from this sub-category are mainly emissions from products. It is estimated that in the beginning of the 2000's over 80% of the emissions originated from manufacturing processes, whereas, in 2012 about 41% were due to manufacturing and other first year losses and the rest from the gas banked in foam products. The releases from foam products in use are expected to stay quite steady during the product lifetime, which can be up to several decades. In Finland retiring foam products are usually re-used as frost insulation or land filled without gas recovery (Alaja, 2009). Therefore the emissions are assumed to continue at the same rate as in the original use-phase until all of the blowing agent has been emitted.

Previously only HFC-134a emissions were calculated in the Finnish inventory. However, in the 2007 inventory the amount of HFC-134a used in manufacturing had decreased considerably and the consumed amounts of HFC-245fa and HFC-365mfc exceeded it. The emissions of HFC-245fa and HFC-365mfc were therefore included in the inventory and reported as additional greenhouse gases in the 2010 submissions. The small imported quantities of HFC-245fa and HFC-365mfc prior to 2007 are considered as negligible and the emissions are reported from 2007 onwards. Since 2010 HFC-152a has been used as a blowing agent in one extruded polystyrene plant. The plant was discovered from the VAHTI system (see description in Annex 2) in 2013. Therefore the emissions are now included in the inventory. The use of HFC-227ea in manufacturing has been reported since 2011. The emissions were included in the 2013 submission. HFC-152a and HFC-227ea are reported as unspecified mix of HFC's in 2012 due to confidentiality.

A small proportion of HFC-365mfc is used in the production of open-celled PU flexible moulded foam. The blowing agent used in open-cell foam blowing is released immediately. The emissions from open-celled

foams cannot be reported separately due to confidentiality. These emissions are reported together with the HFC-365mfc emissions from hard foams.

Actual emissions are calculated by IPCC Tier 2 method described in more detail in Appendix\_4. Potential emissions are calculated according to the Tier 1a and 1b models described in the 1996 IPCC GL (Reference Manual pp. 2.47-2.50) and briefly outlined above.

#### HFCs from aerosols and metered dose inhalers (CRF 2.F 4)

The source category covers HFC-134a and HFC-152a emissions from technical and novelty aerosols, one-component polyurethane foam, tear gas and metered dose inhalers. The emissions were previously reported as aggregated HFC emissions due to confidentiality reasons. In 2012 the emissions of individual HFC species could be reported without revealing confidential data.

The emissions model used is from the GPG 2000 (p. 3.85).

$$x = (1 - f)a + fb,$$

where  $f = 0.5$ ,

$a$  = Tier 1b emission in 2011, and

$b$  = Tier 1b emission in 2012.

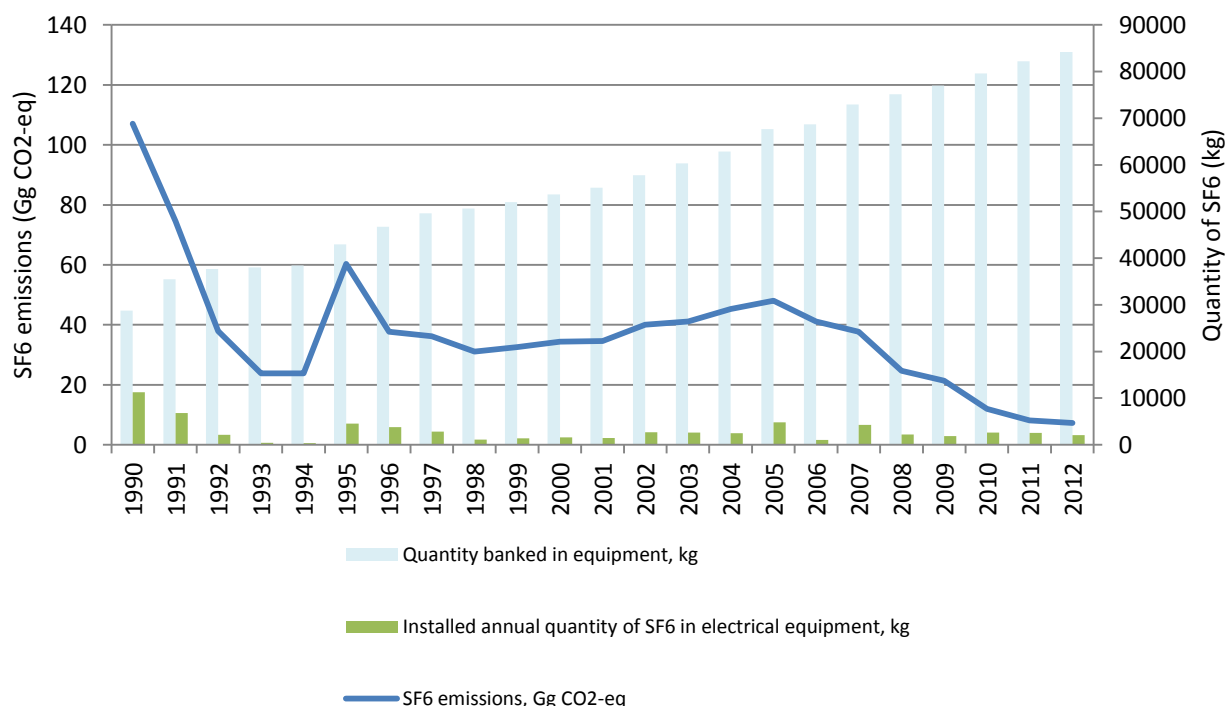
Tier 1 methodology describes potential emissions, which are equal to the amount of chemical consumed in the country minus the amount of chemical recovered for destruction or export in the year of consideration. A more detailed description of the model is given in Appendix\_4.

#### SF<sub>6</sub> from electrical equipment (CRF 2.F 8)

The source category covers SF<sub>6</sub> emissions from manufacturing, use and disposal of electrical equipment. IPCC Tier 3c, Tier 2, Tier 1a and 1b are used in the calculation. The time series of the SF<sub>6</sub> emissions from the use of electrical equipment was recalculated in the 2011 inventory in order to improve the consistency and was reported in the 2013 submission.

The inventory is based on the country-level mass-balance (Tier 3c) of the GPG 2000 (Equation 3.15, p. 3.56) from 2004 to 2012. The activity data available for the years 1990-1999 is not detailed enough to support the calculation of emission estimates with the Tier 3c method. Due to that the emission estimates from 1990 to 2003 are calculated with an emission factor based Tier 2 method and adjusted to the Tier 3c method by applying the overlap method (eq. 7.5, chapter 7.3.2.2 in the GPG 2000) to ensure time series consistency. In order to correct the unrealistic year-to-years fluctuation in emissions the emission estimates are calculated over five successive years of activity data. The fluctuations are caused by the stock changes taking place in reality but not taken into account in the calculation equation. However, as the trend of emissions is downward, the calculation model may overestimate the current emissions, since the five-year running mean is used. A detailed account of the Tier 3c approach is given in Appendix\_4. Details of the emission factor based Tier 2 methodology is documented in Oinonen (2000).

In 1990-1991 and again in 1995-1996 a rather large amount of electrical equipment was installed resulting peak in SF<sub>6</sub> emissions. After this the trend declines again towards the end of the decade as the environmental impacts of SF<sub>6</sub> became known and led to lower emissions. The downward trend in the emissions from 2005 on is partly due to reduction in the amounts of SF<sub>6</sub> imported in bulk and used in manufacturing of equipment. The only plant manufacturing equipment in Finland was closed down in the end of 2010. The improved sealing of equipment and handling of the gas also has an effect on the downward emission trend.



**Figure 4.6-3** The reported SF<sub>6</sub> emission estimates from electrical equipment in relation to the annually installed quantity of SF<sub>6</sub> and quantity banked in equipment.

#### Data grouped due to confidentiality (CRF 2.F 9)

This category includes the following sources and emissions that have been grouped due to confidentiality:

- HFC-23 from refrigeration and air conditioning equipment and semiconductor manufacturing
- HFC-125 and HFC-134a from fixed fire prevention systems
- CF<sub>4</sub> and c-C<sub>4</sub>F<sub>8</sub> from semiconductor manufacturing
- SF<sub>6</sub> from magnesium die casting, semiconductor manufacturing, shoes (until 2007) and research.

The emissions from semiconductor manufacturing are reported with the IPCC Tier 1 method (Equations 3.31 and 3.32 in the GPG 2000). The emissions of HFC-23 from refrigeration and air conditioning equipment are calculated with the Tier 2 model of the refrigeration and air conditioning sector described above.

HFC-125 and HFC-134a emissions from fixed fire fighting systems are reported with the "direct" method, i.e. the companies that sell, install and service the systems keep statistics on the quantities released in fires and the quantities released due to system malfunction. SF<sub>6</sub> from magnesium die casting is also reported with the "direct" method (Equation 3.12 GPG 2000 p. 3.48). For the reporting of SF<sub>6</sub> from shoes "adiabatic property applications" have been used (Equation 3.23 in the GPG 2000 p. 3.65), but these emissions are estimated to have ended in 2007.

#### 4.6.2.2 Emission factors

Emission factors are described below for the models that incorporate such assumptions.

#### HFCs from foam blowing (CRF 2.F 2)

The model is dependent on the use of emissions factors for each foam type. Since such national factors are not available, IPCC default factors are used (GPG 2000, p. 3.96 and 2006 Guidelines p. 7.37). The factors (probability density functions) used are shown in Table 4.6-4 below (Note that only the means of the distributions shown are from the GPG 2000 or IPCC 2006 Guidelines. The standard deviations were chosen based on expert judgement).



**Table 4.6-4** Emission factors for foam blowing

<i>i</i>	Foam type	HFC-134a, HFC-152a <sup>1</sup>		HFC-227ea		HFC-245fa/HFC-365mfc	
		$f_{M,i}$	$f_{B,i}$	$f_{M,i}$	$f_{B,i}$	$f_{M,i}$	$f_{B,i}$
1	XPS	N(0.40,0.08)	N(0.030,0.006)				
2	PU integral skin	N(0.95,0.20)	N(0.025,0.01)	N(0.95,0.20)	N(0.025,0.01)	N(0.95,0.20)	N(0.025,0.01)
3	PU injected	N(0.125,0.020)	N(0.005,0.01)	N(0.10,0.020)	N(0.005,0.01)	N(0.10,0.020)	N(0.005,0.01)
4	PU appliance	N(0.075,0.020)	N(0.005,0.01)	N(0.04,0.020)	N(0.003,0.01)	N(0.04,0.020)	N(0.003,0.01)
5	PU discontinuous panel	N(0.125,0.020)	N(0.005,0.01)	N(0.12,0.020)	N(0.005,0.01)	N(0.10,0.020)	N(0.005,0.01)

<sup>1</sup>Only XPS emission factors apply to HFC-152a

N = normal distribution, with mean (*m*) and standard deviation (*s*) given in parenthesis N(*m*,*s*).

If foam blowing was a key source in the Finnish inventory, a more reliable emission factors could be developed, placing emphasis on the most important sectors of production. Given the low level of emissions and transition of Finnish manufacturers mostly into the use of hydrocarbons or CO<sub>2</sub> as blowing agent, a detailed study has not been seen as necessary.

#### HFCs from aerosols and metered dose inhalers (CRF 2.F 4)

Emission factors were taken from the GPG 2000 referring to Gamlen et al. (1986). Both the value for the emission factor (50%) and the model itself, according to Gamlen et al. (1986), are from McCarthy et al. (1977).

#### SF<sub>6</sub> from electrical equipment (CRF 2.F 8)

The following emission factors are used in the Tier 2 method for 1990-2003: 15% emission factor for installation prior to 1996 and 6% for 1996 onwards and 1% emission factor for the whole time series for leakage. Emission factors are based on GPG 2000 and 1996 IPCC GL.

#### Data grouped due to confidentiality

The method for semiconductor manufacturing is the only one using emission factors. These were taken from Table 3.15 of the GPG 2000 (p. 3.74) and are presented in Table 4.6-5.

**Table 4.6-5** Emission factors for the semiconductor manufacturing

	CF <sub>4</sub>	C <sub>2</sub> F <sub>6</sub>	CHF <sub>3</sub>	C <sub>3</sub> F <sub>8</sub>	c-C <sub>4</sub> F <sub>8</sub>	NF <sub>3</sub>	SF <sub>6</sub>
Use rate of gas (fraction destroyed or transformed in process)	0.2	0.3	0.7	0.6	0.7	0.8	0.5
Fraction of gas remaining in shipping container after use	0.1	0.1	0.1	0.1	0.1	0.1	0.1
kg CF <sub>4</sub> created per kg of gas i	NA	0.1	NA	0.2	NA	NA	NA

#### 4.6.2.3 Activity data

##### HFCs and PFC-218 from refrigeration and air conditioning (CRF 2.F 1)

The activity data for the refrigeration and air conditioning sector were compiled by a survey conducted in January to March 2013. The survey to collect activity data for the inventory has been carried out annually since 2002 and response activity has varied from 45% to over 70%. The lowest response rate has been in 2006-7 inventories when new internet-based electronic data collection system was established. For the 2012 inventory the response activity was 69%. Since the companies have no legal obligation to report data on the use of F-gases, at least one or two reminders are needed in order to reach a good response activity level. In the 2012 survey two general reminders were sent. The main actors of the sector were further contacted if necessary.

In order to impute missing data, it has been assumed that the non-respondents behave similarly to the average respondents when it comes to installation and conversion of equipment and to destruction of

refrigerants. If the non-respondents have fewer activities than the respondents in general it is possible that the imputed quantities become oversized, which then would lower the emission estimates. The procedure used in non-response analysis and data imputation has been described in detail in Oinonen (2004) (pp. 18). Despite the uncertainty of the assumptions associated with data imputation, it has been estimated that the inaccuracy of the inventory would be higher if the missing data were not imputed. If no response is received from the largest manufacturers, importers or exporters, the activity data is estimated based on their previous responses.

In the 2013 survey ten companies reported bulk import of refrigerants for 2012. All of the major importers from the previous years responded. The activity of one smaller importer had to be imputed due to non-response. The total quantity of bulk refrigerants imported in 2012 was 487,819 kg that is 16% lower compared to 2011.

Four companies reported bulk exports in 2012. The total quantity of bulk refrigerants exported in 2012 was 19,142 kg. The quantity continued its growing trend. All in all the bulk export from Finland is rather small; most of the imported refrigerants are used in Finland.

Mobile air-conditioning systems (MACs) is the largest HFC-containing product group – in terms of refrigerant quantity – imported to Finland annually. This quantity ( $x$ ) is estimated using annual numbers of registered vehicles (passenger cars, vans, trucks and buses) ( $r$ ), the proportion of vehicles equipped with MACs ( $p$ ) and a typical refrigerant charge ( $c$ ) for each type of vehicle ( $i$ , 1 = passenger cars, 2 = vans, 3 = truck and 4 = buses)

The number of registrations  $r$  is obtained from the Transport Safety Agency (TraFi). The proportion  $p$  is based on a survey of vehicle importers. Average charges were obtained from a 1999 survey of Finnish vehicle importers (Oinonen 2000 pp. 26-27). The import of used vehicles has been taken into account in the emission estimates starting from 2007. The number of imported used cars is obtained from TraFi and the proportion of vehicles equipped with MACs is assumed the same as in the newly registered vehicles. The total quantity of HFC-134a imported in MACs decreased 14% compared to the 2011 inventory. The imported quantity was approximately at the same level as in 2010 but still clearly above the substantial drop in 2009. The drop in 2009 was due to the economic recession resulting in a rapid drop in car sales. Cars equipped with MACs containing HFO-1234yf as refrigerant were imported to Finland for the first time in 2012. Still 95% of the imported quantities consisted of HFC-134a.

Previously, in the case of MACs, the inventory was based on the assumption that the quantity exported was much smaller than the quantity imported and export was treated as negligible. The assumption and its effect on the total emissions were re-evaluated parallel with the 2007 inventory. Following that, the manufacture of cars and their export was included in the inventory. Passenger car manufacture takes place at one plant in Finland. According to the company 100% of the cars are equipped with air conditioners. The share of exported cars depends on the cars being manufactured. Until 2011, 99.9% of the cars were exported and equipped with air conditioners containing HFC-134a. In 2012, all the manufactured cars were equipped with HFO-1234yf and 97% of the them were exported. The number of manufactured passenger cars dropped by 84% compared to 2011. Due to these changes in car production the quantity of HFC-134a exported in MACs in 2012 dropped as much as 99% and consisted only of the quantity exported in trucks.

The effect of car manufacturing and export of MACs as well as import of used vehicles on the calculations of previous years was studied during the preparing of the 2007 inventory. It was concluded that the total F-gas emissions as CO<sub>2</sub> equivalents would be only slightly (~2%) smaller than the reported figures if these activities were included into the earlier years. The correction would not affect the base year. These amounts are well included in the uncertainty analysis and therefore the correction of time series was not considered essential. In addition, the old data of manufactured and exported MACs contains uncertainties and it is not certain that the correction of the time series would lead to improved emissions estimates.

Refrigerants are also imported and exported in domestic refrigeration and air conditioning equipment, heat pumps, commercial refrigeration equipment and air conditioning units, for example. These quantities are included in the survey and obtained directly from the exporters and importers. In 2012 the quantity of refrigerants imported in equipment other than MACs was 90,673 kg, which is 16% lower compared to 2011. The activity of two importers was imputed due to non-response. The quantity of refrigerants exported in equipment other than MACs decreased 16% in 2012 compared to 2011 and was 14,495 kg. The quantity

was at a higher level than in 2009 when a larger drop due to economic recession occurred. Information of three companies had to be imputed due to non-response.

The data of refrigerants charged into equipment in manufacturing, initial installation or conversion to a new refrigerant are also compiled through the survey. Most of the manufacturers responded but information of three companies had to be imputed based on previous inventory responses. In 2012 the total refrigerant quantity consumed in the manufacturing of equipment including MACs was 33,752 kg, which is 8% lower than in 2011. The installed refrigerant quantities were imputed based on the assumption that non-respondents are a random sample of the respondents. The estimated total installed quantity in 2012 was 138,218 kg, which is 11% higher than in 2011.

The final piece of information needed to quantify the emissions is the quantity of destructed refrigerants, which is also based on the survey. The destructed quantity was imputed, inferred from original reported quantities, based on the assumption that non-respondents are a random sample of all respondents and the information on destructed fluorinated compounds from the only waste treatment company in Finland that treats F-gases. The estimated total quantity of refrigerants destructed in 2012 was 74,358 kg, which is 9% lower than in 2011.

Table 4.6-6 summarises the refrigerant activity data. Note that all of the used refrigerants are included in the reported quantities, not just those consisting of or containing HFCs or PFCs. Respondents provide actual quantities identified by the refrigerant number or trade name. The known composition of each refrigerant is then used to calculate activity in terms of individual HFC and PFC species. These levels are lower than those tabulated below because some of the consumption consists of HCFC-containing refrigerants and natural refrigerants.

**Table 4.6-6** Summary of refrigerant activity data for the inventory year 2012

	Number of reporting companies	Quantity (kg)
Bulk refrigerants imported	11	487 819
Bulk refrigerants exported	4	19 142
Refrigerants in equipment imported	34	227 116
Refrigerants in equipment exported	24	15 699
Refrigerants used in manufacturing equipment	43	33 752
Refrigerants used in installation and conversion of equipment	131	138 218
Destructed refrigerant	115	74 358

<sup>1</sup>Note that the number of reporting companies does include the companies whose data were imputed but not the companies importing, exporting or manufacturing MACs even though the refrigerant quantities include the corresponding estimated amounts.

#### HFCs from foam blowing (CRF 2.F 2)

The activity data for calculating emissions from foam blowing are presented in Table 4.6-7. The data are obtained from an annual survey of the Finnish companies manufacturing, importing and exporting relevant foam products and raw materials used in foam blowing. In the 2011 inventory an internet-based data collection system was established in the foam blowing sector. In the 2013 survey, response activity was 83% and the missing data of one company was imputed based on the data of previous years. Note that the calculation model (see Appendix\_4) also requires data from the previous inventories.

In 2004 the quantity of blowing agents used in manufacturing of products was nearly double in comparison with the previous years due to the establishment of a new production plant by the biggest manufacturer in Finland. In 2005 the same manufacturer replaced the HFC-134a blowing agent with CO<sub>2</sub> in its processes, which led to a notable decline in chemical imports, emissions from manufacture and product exports in this sector. In 2007 HFC-134a emissions from manufacturing declined even more because one large manufacturer has not been using HFC-containing products in their insulations since 2006. Since the rapid changes in the market in the beginning of 2000's, the quantities of HFC compounds used in the foam blowing have stayed quite constant. Only the shares of consumed individual HFC species have changed somewhat. The only notable change is the introduction of a new XPS plant using HFC-152a as a blowing agent in 2010.

The use of HFC-152a was discovered in 2013 and are now included in the inventory. The use of HFC-227ea in manufacturing was reported for the first time in 2011 by two manufacturers. The emissions from product use increased until 2005 but have slowly declined since then due to decreased amounts of new HFC-134a containing products taken into use.

**Table 4.6-7** Foam blowing activity data for 2012

Activity	Blowing agents	Number of reporting companies	Quantity (kg)
Imported in bulk or in polyol	HFC-134a, HFC-152a, HFC-227ea, HFC-245fa, HFC-365mfc	7	124 069
Imported in products	HFC-134a, HFC-152a , HFC-227ea, HFC-245fa, HFC-365mfc	0	0
Used in manufacturing	HFC-134a, HFC-152a , HFC-227ea, HFC-245fa, HFC-365mfc	9	120 805
Exported in products	HFC-134a, HFC-152a , HFC-227ea, HFC-245fa, HFC-365mfc	5	1 370

#### CRF 2.F 4 HFCs from aerosols and metered dose inhalers

The activity data for calculating emissions from aerosols and metered dose inhalers are presented in Table 4.6-8. The data are obtained from an annual survey of the Finnish companies manufacturing, importing and exporting aerosol products (MDI, sprays for dust removal, tear gas, one-component foam). In the 2011 inventory an internet-based data collection system was established in the aerosols and metered dose inhalers sector. The response activity in the 2013 survey was 89%.

**Table 4.6-8** Activity data of HFCs agents for 2012

Activity	HFC agents	Number of reporting companies	Quantity (kg)
Imported in bulk	HFC-134a, HFC-152a	2	C
Imported in products	HFC-134a, HFC-152a	6	10 529
Used in manufacturing	HFC-134a	3	65 273
Sales	HFC-134a, HFC-152a	9	40 549
Exported in products	HFC-134a, HFC-152a	2	C

#### CRF 2.F 8 SF<sub>6</sub> from electrical equipment

The activity data for the calculation of SF<sub>6</sub> emissions from electrical equipment are obtained from an annual survey of the Finnish companies manufacturing, importing and exporting electrical equipment. In the 2011 inventory an internet-based data collection system was established in the electrical equipment sector. In the 2013 survey the response activity in this field of industry was 80%. The activity data of two non-respondent companies still known to be active was imputed based on the information of previous years.

Historical activity data was checked parallel with the 2011 inventory in order to supplement the omissions, which were detected. For the years 1990-2001 the activity data (quantity of SF<sub>6</sub> banked in equipment) was adopted to match the amount calculated at the Finnish Electrical Equipment Industry for the year 2001. Activity data for 1990-1998 is from a survey done by Finnish Environment institute in 1999. Data for 2000 and 2001 is from the annual surveys done by Finnish Environment Institute. Data for 1999 is imputed based on the data for 1998 and 2000. Between 2002-2012 the amount of SF<sub>6</sub> banked in equipment is calculated based on the information received from the annual survey and is compared to the SF<sub>6</sub> bank reported by the Finnish Electrical Equipment Industry. The difference in these figures is found to be on average only 2%.

CRF 2.F 9 Data grouped due to confidentiality

The activity data for the calculation of emissions from semiconductor manufacturing, refrigeration and air conditioning, fixed fire fighting systems and magnesium die-casting are obtained from annual surveys of companies, research institutes and importers of special gases. All the companies responded to the survey.

SF<sub>6</sub> is no longer used in running shoes. The emissions from shoes are considered to have become negligible three years after the sale of SF<sub>6</sub>-containing shoes ceased in 2004 and thus there have been no emissions from running shoes after the 2007 inventory.

### *4.6.3 Uncertainty and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

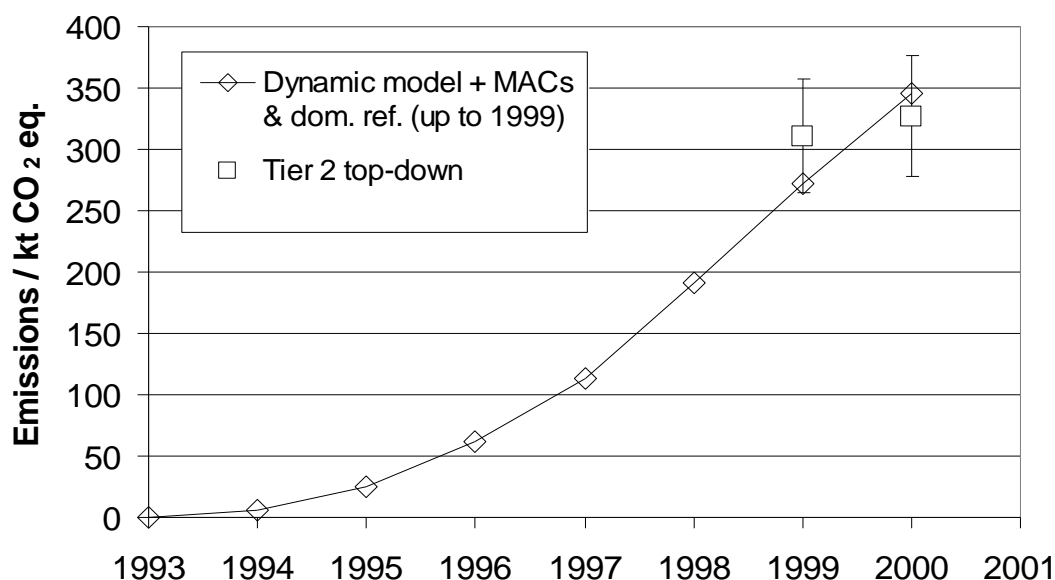
CRF 2.F 1 HFCs and PFC-218 from refrigeration and air conditioning

The uncertainty of the emission estimates has been quantified using Monte Carlo simulation (the method described in Oinonen 2003, 2004). The same methodology was applied to the 2012 inventory. Uncertainty in HFC emissions from refrigeration and air conditioning equipment was estimated at -13% to 14% and in PFC emissions at -21% to 22%.

The simulation results suggest that most of the uncertainty in HFC emissions was due to uncertainty of the factor alpha (see Appendix\_4) and uncertainty of the imported bulk quantities. In the case of PFC emissions most of the uncertainty was related to the factor alpha and the destructed amount of refrigerants.

Uncertainty has been quantified mainly for the most recent estimates and for 1990 when needed in trend analysis. For the years in between, the question regarding homogeneity (time series' consistency) must be addressed. The methodologies have not been the same for the entire time series of emissions from category 2.F 1. In the 1999 inventory (estimates for 1990-1998), a simple dynamical model in combination with the Tier 2 bottom-up emission factor based method was used. The bottom-up method was applied to mobile air conditioning systems (MACs) and domestic refrigeration. Other sources were quantified using the dynamic model (Oinonen 2000). In 2000, as the GPG 2000 was published, the recommended Tier 2 top-down sales based method was implemented for other sources of stationary refrigeration and air conditioning. Domestic refrigeration and MACs were still calculated using the bottom-up approach.

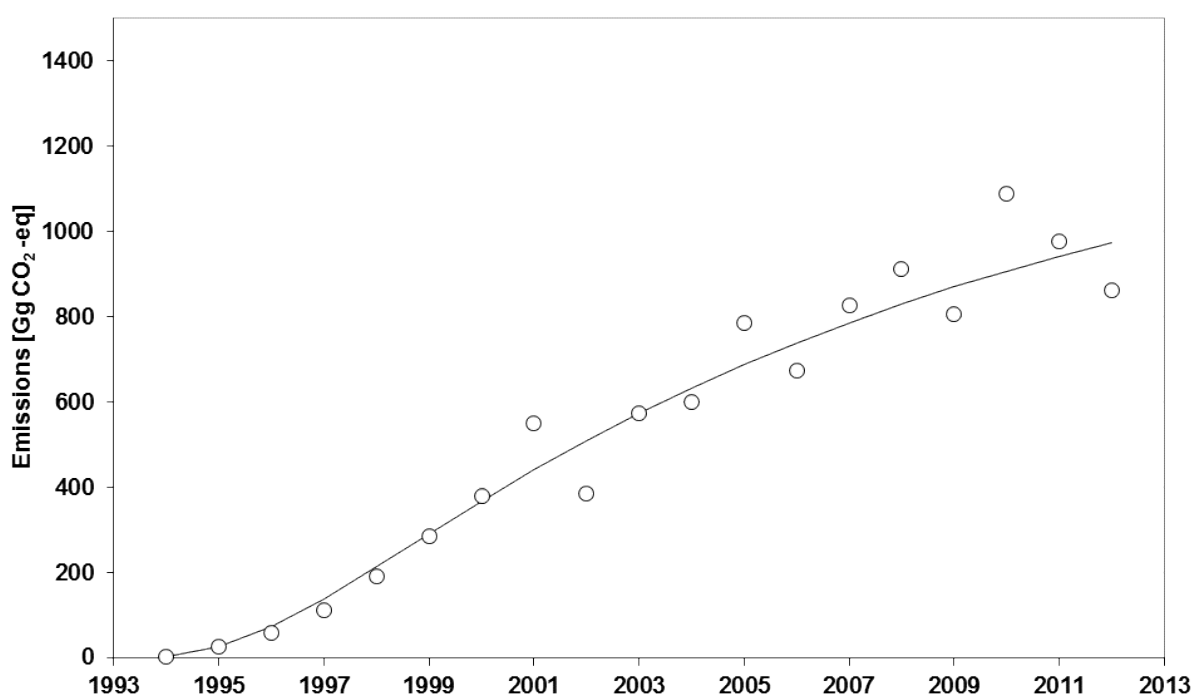
In 2001, the recommended top-down method was finally applied to all subcategories of 2.F 1. From then on, the use and refinement of the method has continued. Since the method has changed and evolved, a question of time series' homogeneity arises. This issue was tested and the results showed that although the methods do not give identical results for the two over-lapping years, the estimates are fairly close and probably within the error bounds of both approaches. The emission estimates and the error bounds are presented in Figure 4.6-4 below.



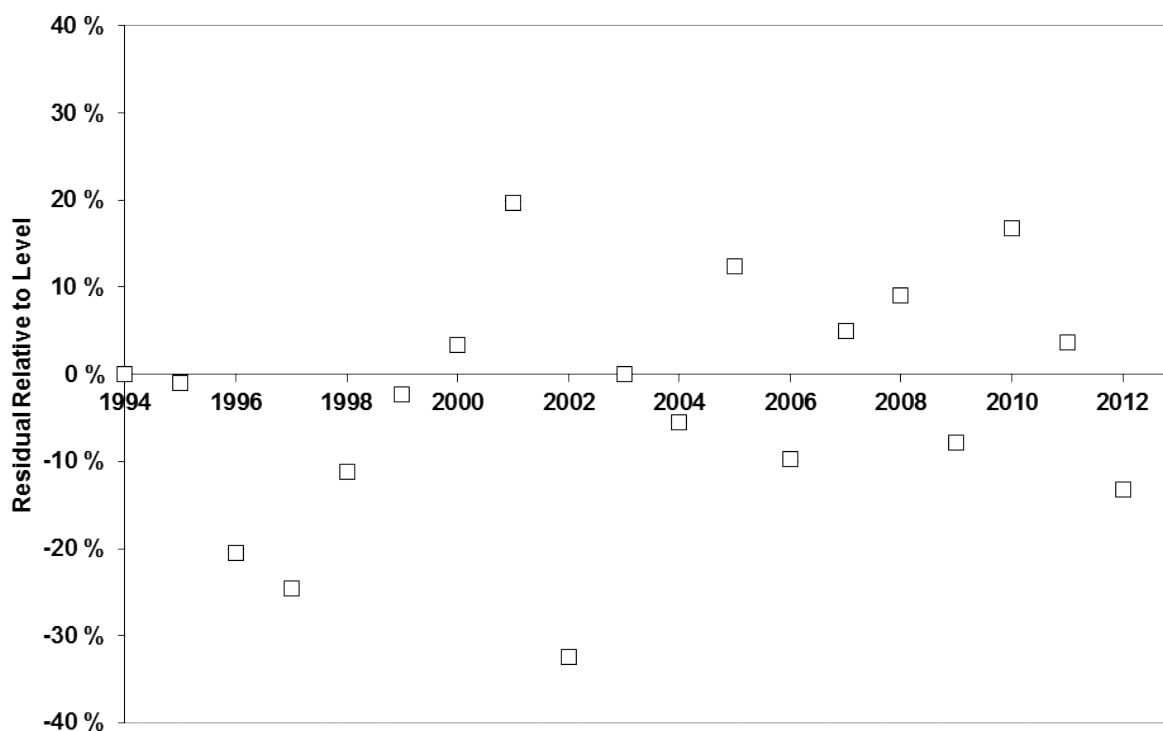
**Figure 4.6-4** Emissions calculated with the dynamic model and the Tier 2 top-down method for two overlapping years (1999 and 2000)

The comparison thus suggests that little could be gained by recalculation and that non-homogeneity should not be an issue. The uncertainties of past inventories and historical data are significant. The current time series of emissions, however, should give a reliable overview of how the emissions evolved during the 1990's: a rapid growth during the latter part of the decade and subsequent stabilisation to the current level.

This trend is depicted in Figure 4.6-5 below. At first, the largest deviations of the emission estimates from the trend curve seem to occur in 2001, 2002 and 2010. However, when these deviations are presented in relation to the emission level (Figure 4.6-6), it can be seen that the deviation of these inventory years is comparable with other fluctuations.



**Figure 4.6-5** Emission estimates for category 2.F.1 reported in inventory reports (open circles) and the emission trend curve



**Figure 4.6-6** Deviations of reported emissions relative to the emission level

Part of the inter-annual fluctuation is due to variation in activity data. In general, the survey response activity has been good (70%) but there is some alternation in the reported data. As indicated in the inventory report submitted in 2004, the explanations for deviations in Tier 2 actual emissions should be sought from the terms *N* (installation of new equipment and conversion of existing equipment) and *M* (equipment manufacturer). Moreover, most of the changes are allocated to be caused by the term *N* as it has previously been notably larger than term *M*. The referred calculation method and the Tier 2 equation are described in detail in Appendix\_4.

The changes in activity data are correlated to changes in the business activities of the reporting companies. The fluctuation between two following years has been rather high and therefore it has been estimated that not all of these changes are "real." This finding has led to a more detailed analysis of the survey respondents and non-respondents and to the conclusion that some of the inter-annual variation is due to missing data.

Nearly all importers, exporters and manufacturers have provided a survey response in previous years. On that account, the missing data concern mainly installation and service of equipment. This also supports the previous assumption where most of the changes in emission estimates were directed to the term *N*. To arrive at estimates for quantities affected by non-response missing data have to be imputed. Not imputing these quantities would lead to underestimation of installed and destructed refrigerants, which in turn, would lead to overestimated Tier 2 actual emissions.

The procedure used in the non-response analysis and data imputation has been described in detail in Oinonen 2004. Data imputation has also been documented and archived among other material for each inventory year.

#### CRF 2.F 2 HFCs from foam blowing

Monte Carlo simulation was used to quantify uncertainty of the level of HFC emissions from foam blowing. Uncertainty in HFC-134a emissions in 2012 was estimated at -15% to 16%. Correlation analysis of the simulation results suggests that most of the uncertainty is due to uncertainty of the emission factors for the use and manufacture of XPS. Uncertainty in combined HFC-152a and HFC-227ea (reported as unspecified mix of HFCs due to confidentiality) emissions was estimated at -22% to 25%. Most of the uncertainty is due to uncertainty of the emission factors and the amount of HFC-152a used for the manufacture of XPS.

Uncertainty in HFC-245fa emissions in 2012 estimated at -15% to 16% and in HFC-365mfc at -115% to 74%. Most of the uncertainty of HFC-245fa emissions is due to uncertainty of the emission factors for the manufacture of appliance foams and injected foams. In addition the amounts of HFC-245fa used for the manufacture of appliance and injected foams correspond to the uncertainty. In the case of HFC-365mfc most of the uncertainty is due to uncertainty of the emission factor and the amount of HFC-365mfc used in the manufacture of sandwich panels.

The previous inter-annual fluctuation of the foam blowing time series is caused by the changes in activity data. The changes are explained in Section 4.6.2.3 above. From 2007 onwards the emissions have stayed quite steady. Between 2009 and 2010 there was a slight increase in the emissions due to introduction of a new XPS plant as explained in Section 4.6.2.3.

#### CRF 2.F 4 HFCs from aerosols and metered dose inhalers

For the year 2012 Tier 2 actual emissions of HFC-134a from aerosols and MDIs totalled 37 tonnes and HFC-152a emissions 0.3 tonnes. The combined HFC emissions increased 26% compared to 2011 due to the increased amount of imported HFC-134a both in bulk and in products. In the time series, the drop of emissions in 2010 is due to one large company phasing out their production during that year. The inter-annual fluctuation in the time series is due to observed changes in consumption. The variation of the consumed proportions of HFC-134a and HFC-152a also affect the time series in CO<sub>2</sub> equivalents, because of the great difference in their GWPs.

Monte Carlo simulation was used to quantify uncertainty of the level of HFC emissions from aerosols and metered dose inhalers. Uncertainty in HFC-134a emissions in 2012 was estimated at -26% to 27% and in HFC-152a emissions at -14% to 13%.

#### CRF 2.F 8 SF<sub>6</sub> from electrical equipment

In 2012 the actual SF<sub>6</sub> emissions from electrical equipment totalled 0.30 tonnes. Monte Carlo simulation was used to quantify uncertainty of the level of the Tier 3c model emission estimate. Uncertainty in SF<sub>6</sub> emissions in 2012 was estimated at -52% to 53%. Correlation analysis of the simulation suggests that most of the uncertainty is due to the amount of SF<sub>6</sub> imported in bulk and to the amount sold in equipment charged when installed.

The Tier 3c emission estimates are higher than the Finnish Electrical Equipment Industry's emission estimates (0.07 tonnes in 2012) but the survey and emission estimate of the industry does not cover emissions from manufacturing or service work by subcontractors (Suur-Uski, 2009). Although the emission estimates are at different level the calculated amount of SF<sub>6</sub> banked in equipment is very close to that calculated at the Finnish Electrical Equipment Industry.

The activity data available for the years 1990-1999 is not detailed enough to support the calculation of emission estimates with the Tier 3c method. Due to that the emission estimates from 1990 to 2003 are calculated with an emission factor based Tier 2 method and adjusted to the Tier 3c method by applying the overlap method to ensure time series consistency. A detailed account of the Tier 3c approach is given in Section 4.6.2.1 and Appendix\_4.

#### CRF 2.F 9 data grouped due to confidentiality

Uncertainty for the category of grouped data was quantified using Monte Carlo simulation. Uncertainty in HFC emissions in 2012 was estimated at -14% to 14%, in PFC emissions at -20% to 19% and in SF<sub>6</sub> emissions at -19% to 18%. In the case of HFC emissions most of the uncertainty is due to emissions from fixed fire fighting systems. In the case of PFC and SF<sub>6</sub> emissions most of the uncertainty is due to emissions from semiconductor manufacturing. In semiconductor manufacturing, most of the uncertainty is related to the SF<sub>6</sub> emission factors and amount of SF<sub>6</sub> used.

There is a discontinuity in the time series for grouped data. This is mainly due to phasing-out of halons in fixed fire suppression systems and their substitution with an extinguishant that is a mixture of HFC-125, HFC-134a and CO<sub>2</sub> in the mid-1990s. First this led to the growth of HFC emissions and gas banks in this



category. When the halons had been mostly replaced in the existing systems, the installing activity and imported quantities of HFCs for this purpose decreased leading to lower emission estimates. The actual emissions from fire suppression systems occur when the system is discharged in case of fire or accidentally and there is an element of chance affecting the annual emission level as well.

In addition to the substitution of ODS in fire fighting systems, there have been changes in the trends of shoe sales, semi-conductor manufacturing and magnesium die-casting. Use of SF<sub>6</sub> in shoes and magnesium die-casting was first growing at the beginning of the 2000's and later on the activities declined. Finally, SF<sub>6</sub> was phased out in shoes in 2004 and the emissions from this source are estimated to have ended in 2007.

During the most recent years the SF<sub>6</sub> consumption in the semiconductor manufacturing is the main reason behind the fluctuating emission trend of the grouped data. After a peak in 2006 changes on the market caused the drop in 2007. Since then the emissions have been growing every year and were 17% higher in 2012 than in 2011. Generally, there is a growing trend in the use of PFCs in semiconductor manufacturing processes but in Finland the gas consumption amount of used PFC gases has remained fairly steady in the previous years even though some interannual fluctuation can be observed. The recent development of HFC-23 emissions from semiconductor manufacturing is similar to that of PFCs.

There are several trends that simultaneously affect emissions from this category and it is difficult to estimate how the category level emission trend will develop in the future.

#### *4.6.4 Source-specific QA/QC and verification*

The quality objectives and general QA/QC procedures described in Section 1.6 are implemented in the F-gases sector. The Tier 1 QC procedures are performed according to the QA/QC plan and the resulting findings, corrections and planned improvements are recorded in the yearly QA/QC form. The Tier 1 review of the F-gas sector is performed in the annual bilateral quality meeting. The documentation and archiving of the F-gases category is detailed in Section 1.6.4.

The correctness of the calculations is checked each year by reproducing a representative sample of the emission calculations manually and the use of appropriate units and conversion factors throughout the calculations is crosschecked simultaneously. In the 2012 inventory QC checks minor errors in the movement of inventory data among processing steps were detected and corrected.

The source category specific (Tier 2) QC procedures for F-gases include emission and activity data comparisons as well as uncertainty estimates. The results for each sub source category are compared with those obtained using a simpler model; i.e. actual emissions (T2 and T3) are compared with potential emissions (T1).

The emission trends are graphed and explained for all sources and the emission estimates compared with corresponding estimates by industry when available, e.g. the data of electrical equipment are compared to the data collected via the industry's own survey.

The quality of activity data for each year is checked by comparing the data with the corresponding data of the three previous years. If unrealistic changes are noted the correctness of the data is checked with the survey respondent. Where secondary data sources are used it is checked that the data source is reliable. In the refrigeration and air conditioning sector the data of destructed refrigerant quantities are collected from two sources; via a direct survey for the servicing companies and from a hazardous waste treatment company. These data are compared together and both data are utilised in the emission calculation. Additional data on the quantities of refrigerants used in regular servicing is also compiled through the survey and compared with the data used in the calculations.

Uncertainty estimates are quantified for all of the source categories and the underlying assumptions documented. Importance analysis is used to elucidate the factors that have significant bearing on the uncertainty of each category. The results are described in Section 4.6.3 above.

### 4.6.5 Source-specific recalculations

#### CRF 2.F 2 HFCs from foam blowing

A new XPS plant using HFC-152a as a blowing agent started operation in Finland in 2010. The plant was discovered in the inventory in 2013 and the emissions were therefore included in the inventory. Due to this the HFC actual and potential emissions of foam blowing for 2010 and 2011 were recalculated. As a result the total 2010 and 2011 HFC actual emissions from foam blowing increased 67% and 65%, respectively. Due to confidentiality the HFC-152a emissions are reported as unspecified mix of HFCs aggregated with HFC-227ea emissions in 2011 and 2012. In 2010, HFC-152a emissions are reported as unspecified mix of HFCs aggregated with HFC-134a emissions.

#### CRF 2.F 9 data grouped due to confidentiality

The potential emissions of SF<sub>6</sub> in 2010 and 2011 were recalculated due to discovery of a new importer of SF<sub>6</sub> in Finland. The recalculation resulted only in a minor increase of the potential SF<sub>6</sub> emissions from sector 2F9.

### 4.6.6 Source-specific planned improvements

A project for the implementation of the new UNFCCC reporting GLs including 2006 IPCC Guidelines will be finalized in 2014 and the results will be used for the 2015 submission.

## Appendix\_4

### *The models used in calculating emissions from category CRF 2.F*

#### HFCs and PFC-218 from refrigeration and air conditioning (CRF 2.F 1)

Potential emissions are equal to the amount of chemical consumed in the country minus the amount of chemical recovered for destruction or exported in the year of consideration. Potential emission calculations are regarded as the basic methodology for HFC and PFC emission estimates (Tier 1).

Tier 1a potential emissions are given by

$$X_{1a} = I_c - E_c - D,$$

where  $I_c$  = a vector of imported bulk quantities  
 $E_c$  = a vector of exported bulk quantities  
 $D$  = a vector of destructed quantities.

Tier 1b potential emissions are given by

$$X_{1b} = I_c + I_p - E_c - E_p - D,$$

where  $I_c$  = a vector of imported bulk quantities  
 $I_p$  = a vector of quantities imported in products  
 $E_c$  = a vector of exported bulk quantities  
 $E_p$  = a vector of quantities exported in products  
 $D$  = a vector of destructed quantities.

Due to confidentiality reasons, the calculation of potential emissions as tonnes by each HFC and PFC species can not be presented here.

Estimates expressed in Gg CO<sub>2</sub> equivalent are obtained as a scalar product of  $X_{1a}$  and  $X_{1b}$  with  $G$  (a vector consisting of GWP values for each species), divided by 1,000:

$$X_{1a,eq} = X_{1a} G / 1000 = \begin{bmatrix} 27.178 \\ 136.371 \\ 161.719 \\ 109.137 \\ 0.059 \end{bmatrix} * [650 \quad 2800 \quad 1300 \quad 3800 \quad 7000] / 1000 = 1025$$

$$X_{1b,eq} = X_{1b} G / 1000 = \begin{bmatrix} 57.958 \\ 166.412 \\ 307.671 \\ 107.914 \\ 0.059 \end{bmatrix} * [650 \quad 2800 \quad 1300 \quad 3800 \quad 7000] / 1000 = 1314$$

Actual emissions are given by

$$X_2 = X_{1b} - (N + M + I_p - E_p) \alpha,$$

where  $T_{1b}$  = a vector of Tier 1b potential emissions  
 $N$  = a vector of quantities used in installing new equipment and converting existing equipment to a new refrigerant  
 $M$  = a vector of quantities used in manufacturing equipment

$I_p$  = a vector of quantities imported in products

$E_p$  = a vector of quantities exported in products

$\alpha$  = a scalar to account for disposal emissions, given by

$$\alpha = 1 - \frac{1}{(1 + g)^L},$$

where  $g$  = annual growth of Tier 1a potential emissions, and

$L$  = average equipment lifetime.

For average lifetime, a value of 10 years is assumed, consistent with the previous inventories (Oinonen 2004). A value for  $g$  is calculated based on observed changes in Tier 1a potential emissions. A geometric mean of annual growth in Tier 1a emissions between 1994 and 2012 yields a value of 13.1%. Substituting these values in the above equation yields

$$\alpha = 1 - \frac{1}{(1 + 0.131)^{10}} \approx 0.709$$

Actual emissions are then

$$X_2 = \begin{bmatrix} 57.958 \\ 166.412 \\ 307.671 \\ 107.914 \\ 0.059 \end{bmatrix} - \left\{ \begin{bmatrix} 4.751 \\ 41.756 \\ 22.226 \\ 34.143 \\ 0.000 \end{bmatrix} + \begin{bmatrix} 4.889 \\ 10.668 \\ 9.612 \\ 6.544 \\ 0.001 \end{bmatrix} + \begin{bmatrix} 32.788 \\ 35.140 \\ 149.640 \\ 2.348 \\ 0.000 \end{bmatrix} - \begin{bmatrix} 2.007 \\ 5.100 \\ 3.687 \\ 3.571 \\ 0.000 \end{bmatrix} \right\} \times 0.709 = \begin{bmatrix} 29.294 \\ 107.932 \\ 181.591 \\ 79.928 \\ 0.058 \end{bmatrix}$$

The sum of the elements of  $T_2$  is equal to 398.834 tonnes.

Estimates expressed in Gg CO<sub>2</sub>-equivalent are

$$X_{2,eq} = X_2 G / 1000 = \begin{bmatrix} 29.294 \\ 107.932 \\ 181.591 \\ 79.928 \\ 0.058 \end{bmatrix} * [650 \quad 2800 \quad 1300 \quad 3800 \quad 7000] / 1000 = 862$$

The mass-balance method is based on annual consumption of each HFC and PFC species as presented above. It is not necessary to know equipment stocks in this method as also stated in the IPCC 2006 Guidelines Chapter 7.1. Emissions are either not calculated separately for each process step. Therefore the background data for calculation can not be presented in the same format as in the CRF Table 2(II)F. However, in this appendix as much of background data for 2012 emissions is provided as possible without revealing confidential data.

#### SF<sub>6</sub> from electrical equipment (CRF 2.F 8 )

Because destruction of SF<sub>6</sub> does not take place in Finland, potential emissions of SF<sub>6</sub> from electrical equipment are calculated by

$$X_{1a} = I_c - E_c,$$

where  $I_c$  = import in bulk

$E_c$  = export in bulk

and

$$X_{1b} = I_c + I_p - E_c - E_p,$$

where  $I_c$  = import in bulk  
 $I_p$  = import in products  
 $E_c$  = export in bulk  
 $E_p$  = export in products.

The Tier 3c emissions model used for actual emissions is based on the GPG 2000 (2000) (eq. 3.15 p. 3.56).

$$\text{Emissions} = \text{Annual sales} - (\text{Net Increase in Nameplate Capacity}) - (SF_6 \text{ Destroyed})$$

To simplify the equation the changes of manufacturers' and importers' stocks are not taken into account and thus *Annual Sales* is assumed equal to  $X_{1b}$ , while  $SF_6 \text{ Destroyed}$  is equal to zero. The *Net Increase in Nameplate Capacity* consists of the nameplate capacity of new equipment filled in factories and new equipment filled after installation subtracted by the nameplate capacity of retiring equipment. Therefore

$$X_{3c} = X_{1b} - (N + M + I_p - E_p - R)$$

where  $X_{1b}$  = annual sales assuming no stock changes  
 $N$  = nameplate capacity of equipment filled in installation  
 $M$  = nameplate capacity of equipment filled in manufacturing  
 $I_p$  = import in products  
 $E_p$  = export in products  
 $R$  = nameplate capacity of retiring equipment

To compensate for the stock changes taking place in reality, the annual estimates of actual emissions are calculated over five years of data.

#### HFCs from foam blowing (CRF 2.F 2)

Actual emissions of HFCs used as foam blowing agents for closed-cell foams are calculated using the Tier 2 model described in the GPG 2000 (2000) (pp. 3.93-3.97). Actual emissions are a sum of manufacturing and first year emissions in the year  $t$  and emissions from product use calculated from the gas banked at the beginning of the year  $t$ .

$$AE_{t,i} = f_{M,i} M_{t,i} + f_{B,i} B_{t-1,i} + R_{t,i} - D_{t,i}$$

where

$AE_{t,i}$  = HFC blowing agent (actual) emissions from foam type  $i$  in year  $t$ ,  
 $M_{t,i}$  = amount of HFC used in manufacturing foam type  $i$  in year  $t$ ,  
 $f_{M,i}$  = manufacturing and first-year loss emission factor for foam type  $i$  (note that the emission factor is assumed time-independent),  
 $B_{t-1,i}$  = the amount of HFC blowing agents banked in foams of type  $i$  at the end of previous year ( $t-1$ ) and hence, at the beginning of year  $t$ ,  
 $f_{B,i}$  = annual loss emission factor for the foam type  $i$ ,  
 $R_{t,i}$  = decommissioning losses of foam type  $i$  in year  $t$ , and  
 $D_{t,i}$  = the amount of HFC blowing agent destroyed in year  $t$  (recovered from foams of type  $i$ ).

In Finland retiring foam products are usually re-used as frost insulation or land filled without gas recovery. Therefore the emissions are assumed to continue at the same rate as in the original use-phase until all of the blowing agent has been emitted. Thus it is assumed that

$$R_{t,i} = 0$$

$$D_{t,i} = 0$$

The total HFC blowing agent emissions are sums of the emissions from different foam types  $i$ .

The amount of HFC blowing agent banked in foam products at the end of the year is estimated by

$$B_{t,i} = B_{t-1,i}(1 - f_{B,i}) + M_{t,i}(1 - f_{M,i}) + Ip_{t,i} - Ep_{t,i}$$

where

$$\begin{aligned} B_{t,i} &= \text{amount of HFC blowing agent banked in foam type } i \text{ at the end of year } t, \\ Ip_{t,i} &= \text{HFC import in products of foam type } i \text{ in year } t, \\ Ep_{t,i} &= \text{HFC export in products of foam type } i \text{ in year } t \end{aligned}$$

The total HFC blowing agent banked in foam products is a sum of the HFC banked in different foam types  $i$ .

HFC blowing agent emissions from open-celled foams are calculated using the Tier 2 Equation 3.37 described in the GPG 2000 (pp. 3.93). The annual emissions are equal to the annual amount of HFC blowing agent used in manufacturing.

#### HFCs from aerosols and metered dose inhalers (CRF 2.F 4)

The emissions model used is from the GPG 2000 (eq. 3.35 p. 3.85)

$$x = (1 - f)a + fb, \quad (1)$$

where  $f = 0.5$ ,  
 $a$  = Tier 1b potential emission in 2011, and  
 $b$  = Tier 1b potential emission in 2012.

$f$  is dimensionless,  $a$  and  $b$  have dimensions of mass. Note that the GPG 2000 talks about quantities of HFC and PFC contained in aerosol products sold each year.

The equation above thus assumes that consumption – as defined by Tier 1b potential emissions – equals sales of aerosol products to Finland.

Potential emissions were calculated by

$$X_{1a} = I_c, \text{ and} \quad (2)$$

$$X_{1b} = I_c + I_p - E_p. \quad (3)$$

where  $I$  denotes imports and  $E$  exports.

Both are vectors consisting of quantities of HFC-134a and HFC-152a. Subscripts  $c$  and  $p$  are used for bulk imports (imports in containers) and imports and exports in products (aerosols), respectively. Production of HFC propellants used in aerosols, bulk exports, as well as destruction, are all equal to zero ("not occurring" in the UNFCCC terminology), which is why they do not appear in (2) and (3).

Equation (3) defines  $a$  and  $b$  of Equation (1) as sums of the elements of  $X_{1b}$  calculated for 2011 and 2012, respectively.

Since all variables of (2) and (3) are vectors with two elements (quantities of HFC-134a and HFC-152a) expressed in mass units, CO<sub>2</sub> equivalent emissions are obtained by calculating the scalar product of  $X_{1a}$  and  $X_{1b}$  with vector  $G$ , which contains the GWP values:

$$X_{1a,eq} = X_{1a}G, \quad (4)$$

$$X_{1b,eq} = X_{1b}G, \quad (5)$$

where  $G = [1300 \ 140]$ .

## 5 SOLVENT AND OTHER PRODUCT USE (CRF 3)

### 5.1 Overview of the sector

#### 5.1.1 Description

Solvent and other product use contribute a small amount to greenhouse gas emissions in Finland. Share of total emissions was 0.1% in 2012. The only direct greenhouse gas source in the solvent and other product use is the use of N<sub>2</sub>O in industrial, medical and other applications reported under CRF category 3.D (Other). In Finland, N<sub>2</sub>O is used in hospitals and by dentists to relieve pain and for detoxification.

Under CRF categories 3.A (Paint application), 3.B (Degreasing and dry cleaning), 3.C (Chemical products, manufacture and processing) and 3.D (Other) Finland reports indirect greenhouse gas emissions (NMVOCs) and also indirect CO<sub>2</sub> emissions from NMVOC emissions. CRF category 3.A includes NMVOC emissions arising from the use of paints in industry and households. CRF category 3.B includes emissions from degreasing in the metal and electronics industries and dry cleaning activities. Under CRF category 3.C Finland reports NMVOC emissions from the pharmaceutical, textile, leather and plastic, industries, rubber conversion and manufacture of paints, inks and glues. NMVOC emissions from the following activities are reported under CRF category 3.D (Other) printing industry, domestic solvent use, solvent extraction of edible oils, production of glass and mineral wool, impregnation of wood and use of pesticides. General assessment of the completeness of the inventory can be found in Section 1.8 and a more detailed assessment is included in Annex 5.

The inventory of NMVOC emissions from the solvent and other product use sector is performed at the Finnish Environment Institute (SYKE). The NMVOC inventory is carried out to meet the obligations of the United Nations Economic Commission for Europe's Convention on Long-Range Transboundary Air Pollution (UNECE CLRTAP) and the EU NEC Directive.

#### 5.1.2 Quantitative overview

Indirect CO<sub>2</sub> emissions were the most important greenhouse gas emissions from solvent and other product use in the Finnish inventory in 2012. Quantity of N<sub>2</sub>O emissions as CO<sub>2</sub> equivalent from the use of N<sub>2</sub>O was less than half of the indirect CO<sub>2</sub> emissions in this sector (Table 5.1-1).

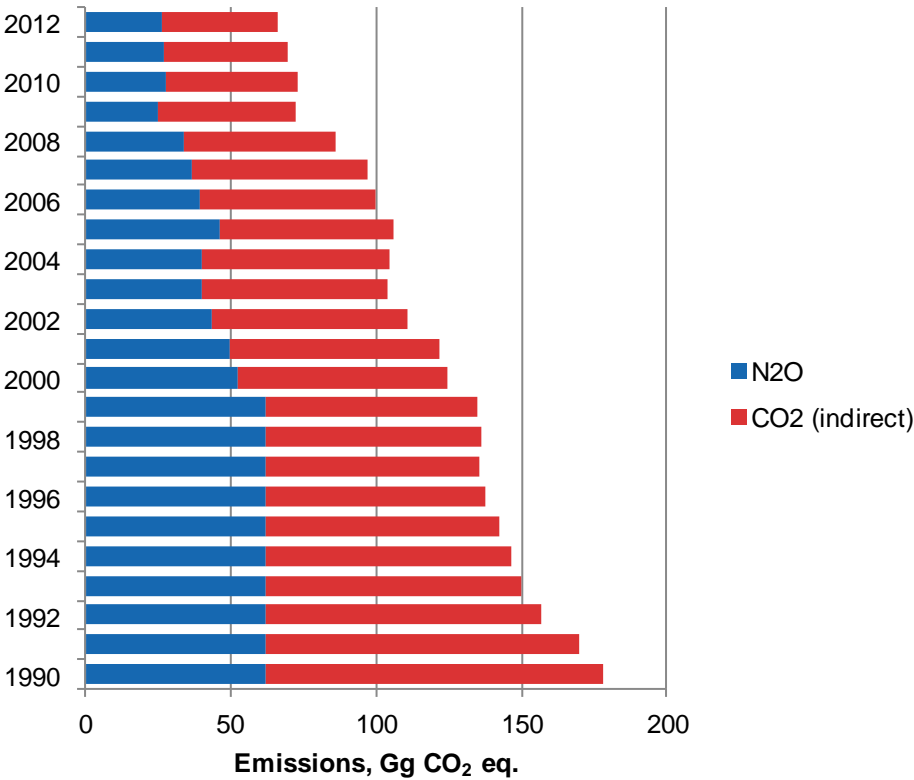
NMVOC emissions from the solvent and other product use sector accounted for 17% of the total NMVOC emissions of Finland.

The emission trends in CRF 3 Emissions from Solvent and other product use (Figure 5.1-1) are decreasing: N<sub>2</sub>O emissions from CRF 3 have decreased by 58% and NMVOC emissions by 66% compared to 1990.

Two categories with the largest decreases in NMVOC emissions are paint application and printing industry. NMVOC emissions from paint application have been decreasing due to the introduction of low-NMVOC products in the 1990's. In the beginning of the 1990's the market-share of waterborne and low-NMVOC products in paint products rapidly grew. Some typical product types where changes occurred were indoor paints and road marking paints, from the use of which NMVOC emissions were reduced by 20-50%. At the same time the sales of thinners for paint products also decreased. In printing industry processes were improved and new abatement technologies as well as substitution and recovery of NMVOC containing substances took place in the beginning of the 1990's.

#### 5.1.3 Key categories

As identified in trend assessment, indirect CO<sub>2</sub> emissions in Solvent and Other product use are a key category in 2012.



**Figure 5.1-1** Trend in GHG emissions from solvents and other product use (Gg CO<sub>2</sub> eq.)



**Table 5.1-1** N<sub>2</sub>O, indirect CO<sub>2</sub> and NMVOC emissions reported under the category Solvent and other product use (Gg)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>N<sub>2</sub>O</b>																							
Use of N <sub>2</sub> O in industrial, medical and other applications	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.17	0.16	0.14	0.13	0.13	0.15	0.13	0.12	0.11	0.08	0.09	0.09	0.08
<b>CO<sub>2</sub> (indirect)</b>																							
From NMVOC emissions	116	108	95	88	84	80	76	73	74	73	72	72	67	64	65	60	60	60	52	47	45	43	40
<b>NMVOC</b>	<b>52.9</b>	<b>49.3</b>	<b>43.4</b>	<b>40.2</b>	<b>38.4</b>	<b>36.7</b>	<b>34.5</b>	<b>33.5</b>	<b>33.8</b>	<b>33.2</b>	<b>32.7</b>	<b>32.9</b>	<b>30.8</b>	<b>29.2</b>	<b>29.5</b>	<b>27.2</b>	<b>27.6</b>	<b>27.6</b>	<b>23.9</b>	<b>21.6</b>	<b>20.8</b>	<b>19.6</b>	<b>18.2</b>
Paint application	27.5	26.0	22.0	20.5	20.0	19.0	18.0	18.0	18.0	17.9	17.9	17.0	15.8	14.7	14.6	14.0	14.5	14.4	12.5	11.4	10.3	8.7	8.2
Degreasing and dry cleaning	2.6	2.3	2.1	1.8	1.7	1.5	1.3	1.3	1.3	1.2	1.2	0.7	1.0	1.0	0.8	0.9	0.8	0.6	0.6	0.6	0.4	0.2	0.3
Chemical products, manufacture and processing	4.3	4.2	3.6	3.9	3.9	4.4	3.4	3.3	3.4	3.2	2.9	3.8	4.2	3.2	3.9	3.3	3.5	3.7	2.8	2.4	2.9	3.5	2.6
Other	18.5	16.8	15.8	14.0	12.8	11.8	11.9	10.9	11.1	10.9	10.8	11.4	9.7	10.3	10.2	9.0	8.8	8.9	7.9	7.2	7.2	7.2	7.1
- Wood preservation	0.75	0.75	0.70	0.65	0.64	0.46	0.40	0.50	0.65	0.55	0.78	0.79	0.60	0.66	0.74	0.61	0.71	0.59	0.60	0.48	0.35	0.40	0.41
- Printing industry	8.8	8.0	7.3	6.2	6.0	6.0	6.0	5.5	5.5	5.5	5.2	5.6	3.8	4.1	4.2	3.1	2.7	2.8	1.8	1.3	1.4	1.2	1.2
- Use of pesticides	0.9	0.6	0.6	0.3	0.3	0.4	0.6	0.2	0.3	0.2	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.6	0.7	0.7
- Glass wool induction	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.15	0.09	0.10	0.12	0.16	0.12	0.07	0.09	0.13	0.11	0.04	0.03	0.03	0.01
- Mineral wool induction	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.10	0.08	0.07	0.07	0.09	0.07	0.08	0.08	0.08	0.06	0.06	0.06	0.06	0.06
- Domestic solvent use	7.7	7.1	6.8	6.5	5.5	4.5	4.5	4.3	4.3	4.2	4.2	4.5	4.6	4.8	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6
- Fat and oil extraction	0.20	0.20	0.19	0.16	0.15	0.18	0.19	0.17	0.18	0.20	0.15	0.13	0.20	0.16	0.10	0.15	0.16	0.13	0.17	0.13	0.16	0.12	0.11
<b>Total emissions* (Gg CO<sub>2</sub> eq.)</b>	<b>178</b>	<b>170</b>	<b>157</b>	<b>150</b>	<b>146</b>	<b>142</b>	<b>138</b>	<b>135</b>	<b>136</b>	<b>135</b>	<b>123</b>	<b>121</b>	<b>111</b>	<b>104</b>	<b>104</b>	<b>104</b>	<b>100</b>	<b>97</b>	<b>86</b>	<b>72</b>	<b>73</b>	<b>70</b>	<b>66</b>

\* Total emission is the sum of the N<sub>2</sub>O emissions and the indirect CO<sub>2</sub>.

## 5.2 Paint application (CRF 3.A), Degreasing and dry cleaning (CRF 3.B) and Chemical products, manufacture and processing (CRF 3.C)

### 5.2.1 Source category description

No N<sub>2</sub>O emissions occur in these source categories, only indirect CO<sub>2</sub> emissions are calculated from NMVOC emissions (Table 5.2-1).

**Table 5.2-1** Reported emissions, calculation methods and types of emission factors for these subcategories in the Finnish inventory

CRF	Source	Emissions	Method	Emission factor
3.A	Paint application	NMVOC, CO <sub>2</sub>	Tier 2	CS
3.B	Degreasing and dry cleaning	NMVOC, CO <sub>2</sub>	Tier 2	CS
3.C	Chemical products, manufacture and processing	NMVOC, CO <sub>2</sub>	Tier 2	CS

Paint application is the main source of NMVOC emissions of this sector. Emissions have been calculated from the use of paint and varnish in industry and households. Most Finnish paint producers or importers are members of the Association of Finnish Paint Industry, which is following the annual sales of paint products in Finland. The Association calculates emissions from the use of paint by using the amount and solvent content of sold paint and varnish. The rest of the emissions from the use of paint and varnish have been estimated using a questionnaire sent to non-members of this association and emission data from the VAHTI system (detailed information in Annex 2). Detailed data of these calculations are included in Finland's Informative Inventory Report under the UNECE CLRTAP (Finnish Environment Institute, 2013)

Degreasing and dry-cleaning is a minor source of NMVOCs. Chlorinated organic solvents are used in the metal and electronics industries to clean surfaces of different components and in dry cleaning activities. Emissions are calculated using import statistics of pure chlorinated solvents, amount of products containing chlorinated organic solvents and amounts of solvent waste processed in the hazardous waste treatment plants.

NMVOCs are also emitted from the use of solvents in different industrial processes. In Finland these processes include pharmaceutical industry, textile and leather industry, plastic industry, rubber conversion and manufacture of paints, inks and glues. Emission data used in the inventory is mainly reported by the plants. Questionnaires are sent to companies in the textile, plastic and paint industries, which report either the amount of used solvent or emissions from production processes.

### 5.2.2 Methodological issues

Indirect CO<sub>2</sub> emissions from solvents and other product use have been calculated from NMVOC emissions for the time series 1990-2012 using the equation below. It was assumed that the average carbon content is 60% by mass for all categories under the sector of solvents and other products use in accordance with the 2006 IPCC Guidelines. As described in the Guidelines, the used fossil carbon content fraction of NMVOC is based on limited published national analyses of speciation profile.

$$Emissions_{CO_2} = Emissions_{NMVOC_s} * Percent\ carbon\ in\ NMVOCs\ by\ mass * 44/12$$

### 5.2.3 *Uncertainty and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

Uncertainty for activity data is  $\pm 100\%$  and for emission factors  $\pm 10\%$ . Uncertainty for the activity data is based on the latest uncertainty analysis for NMVOC carried out for the 2011 emissions and reported in the Finnish IIR (Informative Inventory Report, 2013) to the UNECE CLRTAP Secretariat in March 2013, where the methods used for the analysis are documented. A default value presented in 2006 IPCC Guidelines is used for emission factors uncertainty.

The methods over the years are mainly consistent, however, no recalculation of emissions 1990-2007 has yet been carried out, but is scheduled in the next years.

### 5.2.4 *Source-specific QA/QC and verification*

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6. The QC procedures are performed according to the QA/QC plan in the Solvent and Other Product Use sector in order to attain these quality objectives. The bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert..

In the calculation of NMVOCs and indirect CO<sub>2</sub> emissions general inventory QC procedures mentioned in GPG 2000 Table 8.1 have been performed. For example, plant specific emissions and activity data are compared between the years. The data is reported by plants according to monitoring requirements in the environmental permits and it is checked and approved by the environmental competent authority before recording it to the VAHTI database. There is no activity data available to compare with emission factors in the EMEP EEA Emission Inventory Guidebook.

### 5.2.5 *Source-specific recalculations*

No recalculations have been done.

### 5.2.6 *Source-specific planned improvements*

As a part of updating of air emissions time series also the activity data of this category will be checked in 2015.

## 5.3 Other (CRF 3.D)

### 5.3.1 Source category description

The N<sub>2</sub>O emissions in this category are from the medical use of N<sub>2</sub>O. In 2012 these emissions totalled 26.2 Gg CO<sub>2</sub> eq. The activities generating NMVOC and therefore indirect CO<sub>2</sub> emissions under this category are the printing industry, preservation of wood, use of pesticides, glass and mineral wool enduction, domestic solvent use and fat and oil extraction (Table 5.3-1). As a result of 2011 inventory review indirect CO<sub>2</sub> emissions from fat and oil extraction are considered to be biological. Vegetable oils produced in Finland are cold-drawn oils and no NMVOCs are emitted during the production process. The earlier reported indirect CO<sub>2</sub> emissions were therefore removed from whole time-series. The recommendation raised by previous ERT Finland consider that is not possible to develop on a system which would identify CO<sub>2</sub> emissions between fossil and biological. These separations must be done case by case.

**Table 5.3-1** Reported emissions, calculation methods and types of emission factors for the subcategory Other in the Finnish inventory

CRF	Source	Emissions reported	Method	Emission factor
3.D 1	Use of N <sub>2</sub> O in anaesthesia	N <sub>2</sub> O	CS	CS
3.D 2	Fire extinguishers	IE (3.D 1)		
3.D 3	N <sub>2</sub> O from aerosol cans	IE (3.D 1)		
3.D 4	Other use of N <sub>2</sub> O	IE (3.D 1)		
3.D 5	Other	NMVOC, CO <sub>2</sub>	Tier 2	CS
	- Wood preservation			
	- Printing Industry			
	- Use of pesticides			
	- Glass wool induction			
	- Mineral wool induction			
	- Domestic solvent use			
	- Fat edible and non-edible oil extraction			

### 5.3.2 Use of N<sub>2</sub>O

#### 5.3.2.1 Methods

The N<sub>2</sub>O emissions are calculated by Statistics Finland. The country-specific calculation method is consistent with a Tier 2 method. In the estimation of the N<sub>2</sub>O emissions sales data are obtained from the companies delivering N<sub>2</sub>O for medical use and other applications in Finland. For the years 1990 to 1999 the emissions have been assumed constant based on activity data obtained for the years 1990 and 1998. Since 2000 annual and more precise data have been received from the companies. The emission estimation is based on the assumption that all used N<sub>2</sub>O is emitted to the atmosphere in the same year it is produced or imported to Finland. A very small part of emissions is estimated due to non-response.

#### 5.3.2.2 Activity data

For the estimation of N<sub>2</sub>O emissions production or importation data are obtained from companies for the years 1990, 1998 and all years starting from 2000. In 2012 one company reported that they have continued to export and that has been also taken into account in the calculations.

#### 5.3.2.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

The uncertainty of emissions from N<sub>2</sub>O use in 2012 was estimated at  $\pm 10\%$ .

#### 5.3.2.4 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6. The QC procedures are performed according to the QA/QC plan in the Solvent and Other Product Use sector in order to attain these quality objectives. The bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert..

#### 5.3.2.5 Source-specific recalculations

No recalculations have been made since the last inventory submission.

#### 5.3.2.6 Source-specific planned improvements

For the whole Solvent and other product use sector, the work to implement the 2006 IPCC Guidelines for the 2015 submission has been started in 2013.

### 5.3.3 Indirect CO<sub>2</sub> emissions from NMVOC emissions

#### 5.3.3.1 Source category description

NMVOC emissions originate from solvent use in printing houses, domestic solvent use (other than paint application) and other product use, which includes glass and mineral wool enduction, fat and edible oil extraction, preservation of wood and application of glues and adhesives.

#### 5.3.3.2 Methods

NMVOC emissions from printing industry are based on emission data reported by the plants (detailed information in Annex 2) and a questionnaire to presses that do not report their emissions to the environmental authorities. Activity data for NMVOC emissions are received from the Finnish Safety and Chemicals Agency's (Tukes) database: amount of used creosote oil (Huhtala, L. 2013) and amount of used pesticides (Savela M. 2013). Information from Finnish Cosmetics, Toiletry and Detergents Association are used to estimate emissions from domestic solvent use. The detailed description of these calculations is included in the Finnish IIR (Finnish Environment Institute, 2013).

Indirect CO<sub>2</sub> emissions from this category have been calculated from NMVOC emissions for the time series 1990-2012. Indirect CO<sub>2</sub> emissions were calculated using the equation below. It was assumed that the average carbon content is 60% by mass for all categories under the sector of solvents and other products use according to the 2006 IPCC Guidelines.

$$Emissions_{CO_2} = Emissions_{NMVOC_s} * Percent\ carbon\ in\ NMVOCs\ by\ mass * 44/12$$

#### 5.3.3.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

Uncertainty for activity data is  $\pm 100\%$  and for emission factors  $\pm 10\%$ . Uncertainty for the activity data is based on the latest uncertainty analysis for NMVOC carried out for the 2011 emissions and reported in the Finnish IIR (Informative Inventory Report, 2013) to the UNECE CLRTAP Secretariat in March 2013, where the methods used for the analysis are documented.

#### 5.3.3.4 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6. The QC procedures are performed according to the QA/QC plan in the Solvent and Other Product Use sector in order to attain these quality objectives. The bilateral quality

meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert.

In the calculation of NMVOCs and indirect CO<sub>2</sub> emissions general inventory QC procedures mentioned in GPG 2000 Table 8.1 have been performed. For example, plant specific emissions and activity data are compared between the years. The data is reported by plants according to monitoring requirements in the environmental permits and it is checked and approved by the environmental competent authority before recording it to the VAHTI database. There is no activity data available to compare with emission factors in the EMEP EEA Emission Inventory Guidebook.

#### *5.3.3.5 Source-specific recalculations*

Indirect CO<sub>2</sub> emissions from fat and oil were removed from whole time-series as they were considered to be biological.

#### *5.3.3.6 Source-specific planned improvements*

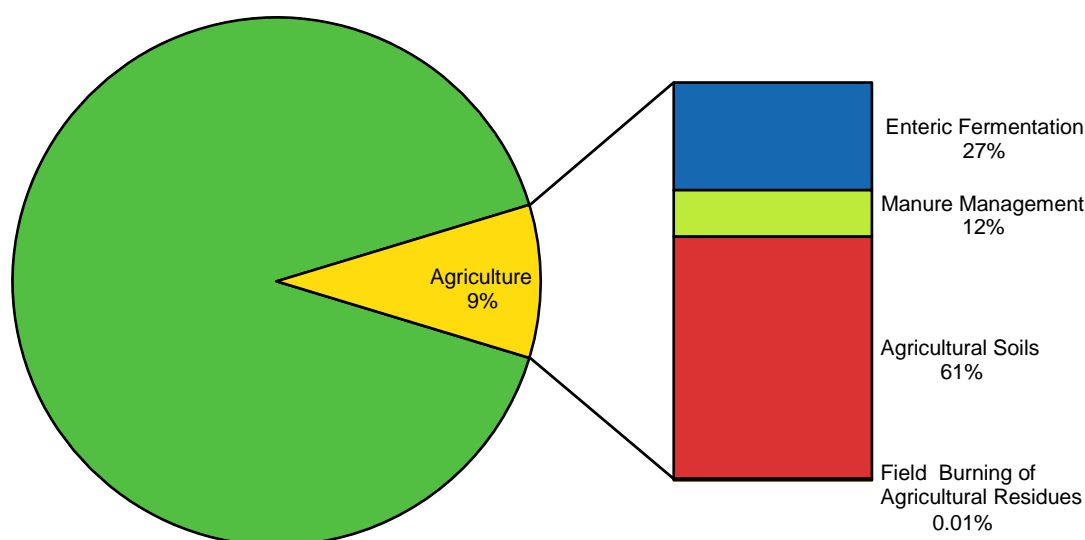
As a part of updating of air emissions time series also the activity data (NMVOC emissions) of this category will be checked in 2015.

## 6 AGRICULTURE (CRF 4)

### 6.1 Overview of the sector

#### 6.1.1 Description and quantitative overview

Finland's greenhouse gas emissions reported in the Agriculture sector in 2012 were 5.7 Tg CO<sub>2</sub> equivalents in total. Agriculture is the second largest greenhouse gas emission source sector after the energy sector with a 9% share of the total greenhouse gas emissions in 2012 (Figure 6.1-1).



**Figure 6.1-1** Agricultural emissions from the total greenhouse gas emissions in 2012

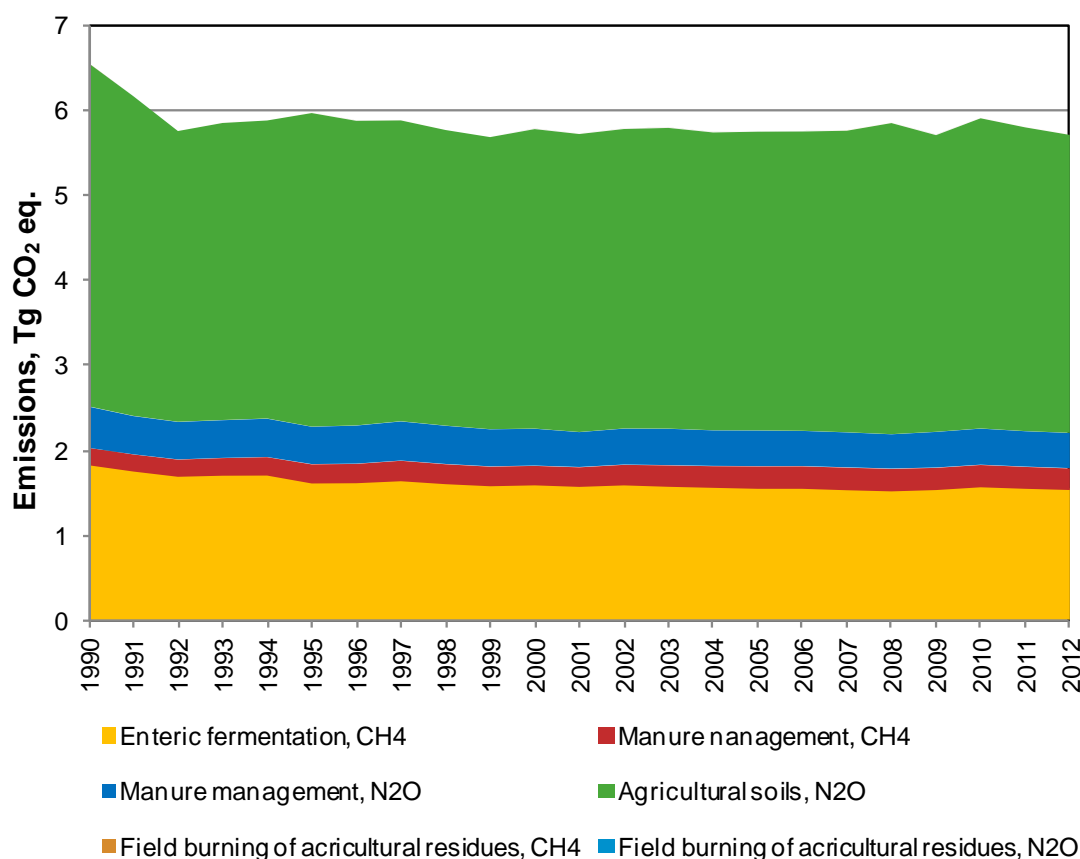
Agricultural greenhouse gas emissions in Finland consist of methane emissions from enteric fermentation of domestic livestock and methane and nitrous oxide emissions from manure management as well as direct and indirect nitrous oxide emissions from agricultural soils, and field burning of agricultural crop residues. Direct nitrous oxide emissions from agricultural soils include emissions from synthetic fertilisers, manure applied to soils, biological nitrogen fixation of N-fixing crops, crop residues, sewage sludge application and cultivation of organic soils. Indirect nitrous oxide emission sources include emissions from atmospheric deposition and from nitrogen leaching and run-off to watercourses. Indirect emissions are estimated also for manure management. Figure 6.1-4, Figure 6.3-2 and Figure 6.4-1 present sources and flows of nitrogen and magnitude of nitrous oxide emissions in the sector Agriculture from different sources according to the IPCC classification.

The methane emissions from enteric fermentation were 27%, methane emissions from manure management 4%, nitrous oxide emissions from manure management 7% and nitrous oxide emissions from agricultural soils 61% of the total agricultural emissions. The share of emissions from field burning of agricultural crop residues is under 0.01% altogether. Rice is not cultivated in Finland and savannas do not exist in Finland. A general assessment of completeness can be found in Section 1.8 and more detailed assessment is included in Annex 5.

Emissions in the Agriculture sector have decreased by about 13% over the period 1990-2012 (Figure 6.1-2). Finland's membership in the EU since 1995 has resulted in changes in the economic structure in the Agriculture sector followed by a decrease in the number of farms and an increase in the average farm size (Farm Register 2010) and general reduction in the livestock numbers. The reduced use of nitrogen fertilisers and improved manure management resulting from the measures taken by the farmers as part of an agri-environmental programme aiming to minimise nutrient loading to water courses has also decreased the emissions in the Agriculture sector. For example, the amount of mineral fertilisers used (based on sales statistics) has decreased 39% 1990-2012 and is the most important factor for the reduced emissions.

However, the area of cultivated organic soils has increased during the period 1990-2012 which has increased nitrous oxide emissions.

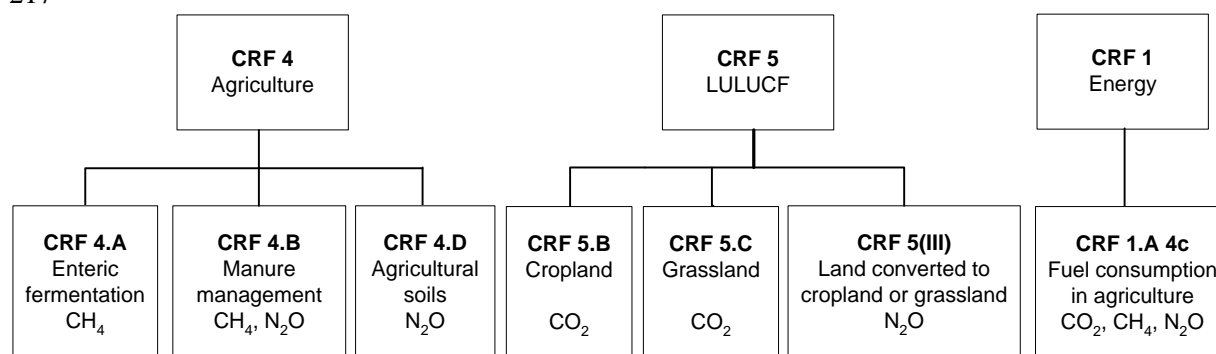
Some inter-annual variation between the years can be noticed from the time series (Table 6.1-1). This is mainly caused by fluctuations in activity data between the years due to changes in animal numbers. Changes in animal numbers are largely affected by agricultural policy and subsidies. Especially methane and nitrous oxide emissions from manure management are affected by the fluctuation in animal numbers as well as the proportion of manure managed in different manure management systems, which vary depending on animal species. Nitrous oxide emissions from agricultural soils are affected by the amount of synthetic fertilisers used annually, animal numbers and crop yields of cultivated crops, for example, which may have large variation between the years.



**Figure 6.1-2** Trend in agricultural emissions by source category (Tg CO<sub>2</sub> eq.). The CH<sub>4</sub> and N<sub>2</sub>O emissions from field burning of agricultural residues are very small and therefore not seen in the figure

Carbon dioxide emissions from agricultural soils including CO<sub>2</sub> emissions from liming are reported in the Land Use, Land-Use Change and Forestry (LULUCF) sector (Chapter 7) under Cropland and Grassland categories. Emissions from energy use in agriculture (e.g. fuel combustion in agricultural machinery, heating of agricultural buildings, etc.) are reported in the Energy sector (Chapter 3) and are not included in the emissions reported in the Agriculture sector (Figure 6.1-3). Emissions from the energy use in agriculture were 1.8 Tg CO<sub>2</sub> eq. and agricultural emissions reported in the Land Use, Land Use Change and Forestry sector 7.3 Tg CO<sub>2</sub> eq. in 2012. When all agricultural emission sources from different reporting sectors (Agriculture, LULUCF and Energy) are taken into account, agricultural emissions totalled 14.8 Tg CO<sub>2</sub> eq. in 2012.





**Figure 6.1-3** Emissions from agricultural sources and their reporting in the Common Reporting Format (CRF) categories in the national greenhouse gas inventory

**Table 6.1-1** Finland's greenhouse gas emissions from sector Agriculture by source and gas, Tg CO<sub>2</sub> eq.

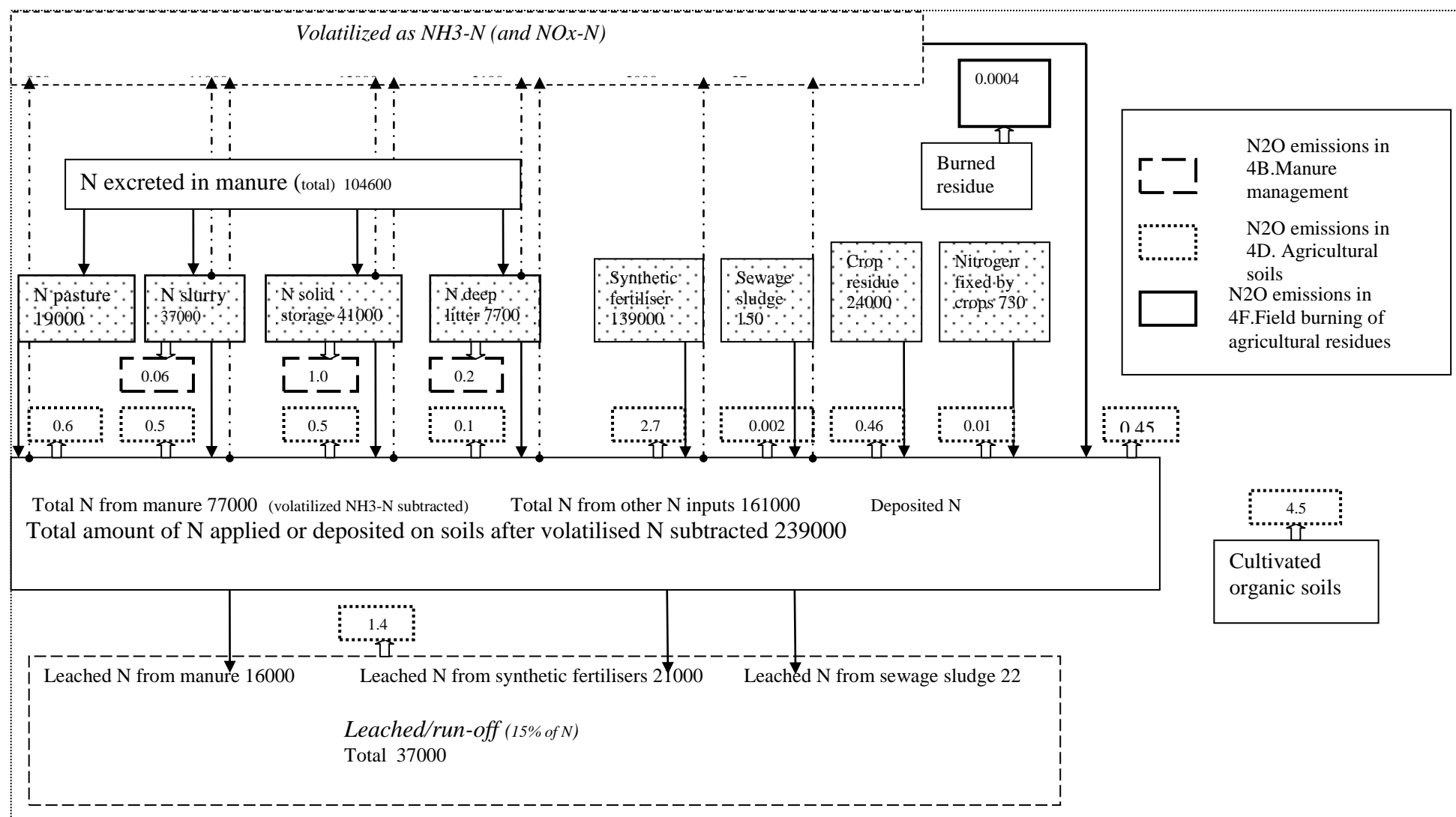
	Enteric fermentation	Manure management	Agricultural soils	Burning of agri- cultural residues	Total CH <sub>4</sub> emissions*	Total N <sub>2</sub> O emission	Total emissions
	CH <sub>4</sub>	CH <sub>4</sub>	N <sub>2</sub> O	N <sub>2</sub> O	CH <sub>4</sub>	N <sub>2</sub> O	CH <sub>4</sub> , N <sub>2</sub> O
1990	1.83	0.20	0.49	4.03	0.0019	0.0006	2.04
1991	1.76	0.20	0.45	3.75	0.0002	0.0000	1.96
1992	1.70	0.20	0.44	3.41	0.0001	0.0000	1.90
1993	1.71	0.21	0.45	3.49	0.0004	0.0001	1.92
1994	1.71	0.21	0.45	3.50	0.0001	0.0000	1.93
1995	1.62	0.22	0.44	3.68	0.0003	0.0001	1.84
1996	1.62	0.22	0.45	3.58	0.0006	0.0002	1.85
1997	1.65	0.24	0.46	3.53	0.0003	0.0001	1.88
1998	1.61	0.23	0.45	3.47	0.0002	0.0001	1.84
1999	1.59	0.23	0.44	3.43	0.0001	0.0000	1.82
2000	1.60	0.23	0.44	3.52	0.0008	0.0002	1.83
2001	1.58	0.23	0.41	3.50	0.0004	0.0001	1.81
2002	1.60	0.24	0.42	3.51	0.0005	0.0001	1.84
2003	1.58	0.25	0.43	3.53	0.0005	0.0001	1.83
2004	1.57	0.25	0.42	3.50	0.0004	0.0001	1.82
2005	1.56	0.26	0.42	3.51	0.0002	0.0001	1.82
2006	1.56	0.26	0.42	3.51	0.0003	0.0001	1.82
2007	1.54	0.26	0.41	3.54	0.0006	0.0002	1.80
2008	1.53	0.26	0.40	3.65	0.0005	0.0001	1.79
2009	1.54	0.26	0.42	3.48	0.0005	0.0001	1.80
2010	1.58	0.26	0.43	3.64	0.0003	0.0001	1.84
2011	1.56	0.25	0.42	3.57	0.0004	0.0001	1.81
2012	1.54	0.25	0.42	3.50	0.0004	0.0001	1.80

*Key categories*

The key categories in agriculture in 2012 are summarised in Table 6.1-2.

**Table 6.1-2** Key categories in Agriculture (CRF 4) in 2012 (quantitative method used: Tier 2)

<b>IPCC source category</b>	<b>Gas</b>	<b>Identification criteria</b>
4.A. Enteric Fermentation	CH <sub>4</sub>	L, T
4.B. Manure Management	N <sub>2</sub> O	L, T
4.D.1. Agricultural Soils, Direct Soil Emissions	N <sub>2</sub> O	L, T
4.D.2. Agricultural Soils, Pasture, Range and Paddock Manure	N <sub>2</sub> O	L, T
4.D.3. Agricultural Soils, Indirect Emissions	N <sub>2</sub> O	L, T



**Figure 6.1-4** Nitrogen flows and emissions of nitrous oxide in Agriculture sector 2012 (Bulk arrows stand for N<sub>2</sub>O emissions, thin arrows for N flows and broken arrows mean N volatilization as ammonia (NH<sub>3</sub>-N) during application on soil. Nitrogen amounts are in Mg/year and emissions (fragmental line) in Gg/year

## 6.2 Enteric Fermentation (CRF 4.A)

### 6.2.1 Source category description

Methane emissions from enteric fermentation of domestic livestock comprised 27% of total emissions in the sector Agriculture in Finland, being 1.5 Tg CO<sub>2</sub> equivalents in 2012.

This source category includes emissions from cattle (dairy cows, suckler cows, bulls, heifers and calves), horses, swine (fattening pigs, weaned pigs (pigs 20-50 kg), boars, sows and piglets, sheep, goats, reindeers and fur animals. Emissions from poultry are not estimated since a default method for the estimation of these emissions is lacking (see Table 6.2-1).

**Table 6.2-1** Reported emissions, calculation methods and types of emission factors for the subcategory Enteric Fermentation in the Finnish inventory

CRF	Source	Emissions reported	Method	Emission factor
4.A 1	Cattle			
	Dairy Cattle	CH <sub>4</sub>	Tier 2	CS
	Non-Dairy Cattle	IE (4.A 10)		
4.A 2	Buffalo	NO	NA	NA
4.A 3	Sheep	CH <sub>4</sub>	Tier 2	CS
4.A 4	Goats	CH <sub>4</sub>	Tier 1	D
4.A 5	Camels and Llamas	NO	NA	NA
4.A 6	Horses	CH <sub>4</sub>	Tier 1	D
4.A 7	Mules and Asses	NO	NA	NA
4.A 8	Swine	CH <sub>4</sub>	CS	CS
4.A 9	Poultry	NE <sup>1)</sup>	NA	NA
4.A 10	Other			
	- Reindeers	CH <sub>4</sub>	Tier 2	CS
	- Heifers	CH <sub>4</sub>	Tier 2	CS
	- Bulls	CH <sub>4</sub>	Tier 2	CS
	- Calves	CH <sub>4</sub>	Tier 2	CS
	- Fur farming	CH <sub>4</sub>	Tier 1	OTH
	- Cow <sup>2)</sup>	CH <sub>4</sub>	Tier 2	CS
	- Ponies	CH <sub>4</sub>	Tier 1	D

<sup>1)</sup> No methodology is available to estimate emissions from enteric fermentation of poultry.

<sup>2)</sup> Suckler cow

Methane emissions from enteric fermentation are produced as a by-product of the normal livestock digestive process. Feed consumed by the animal is fermented by the microbes in the animal's digestive system. This process is called enteric fermentation. Methane that is produced is exhaled by the animal (Gibbs et al. 2002). The most important animal group producing methane is ruminants (e.g. cattle and sheep) but other animals may also be significant emission sources if their number is large (Pipatti 1994).

The emissions have decreased by 16% since 1990 especially due to the decreasing number of cattle (Table 6.2-2 ). The number of dairy cattle, for example, declined from 490,000 in 1990 to 284,000 in 2012 (Table 6.2-2 ). The number of cattle was slightly lower in 2012 than 2011 causing 0.01 Tg CO<sub>2</sub> eq. decrease in emissions from cattle in 2012 compared to 2011. The emissions from other livestock in total decreased 3 Gg in 2012 compared to 2011.

**Table 6.2-2** Methane emissions (Gg) from enteric fermentation by animal type

	Cattle			Other livestock								Total	
	DC	SC	B	H	C	Sw	Sh	G	Ho	Po	F	R	
1990	48.8	0.9	6.5	8.8	14.2	1.3	0.7	0.03	0.7	0.1	0.3	4.8	87.2
1991	44.8	1.3	6.4	8.6	14.3	1.3	0.7	0.03	0.8	0.1	0.3	5.2	83.8
1992	42.8	1.8	6.4	8.5	13.6	1.2	0.7	0.02	0.8	0.1	0.3	4.6	80.9
1993	43.4	2.1	6.3	9.0	13.2	1.2	0.8	0.02	0.8	0.1	0.3	4.3	81.5
1994	43.4	2.1	6.5	9.0	12.9	1.2	0.8	0.03	0.8	0.1	0.3	4.3	81.5
1995	41.8	1.9	5.0	7.9	12.8	1.3	1.1	0.03	0.8	0.1	0.4	4.1	77.2
1996	41.3	2.0	5.2	8.4	12.4	1.3	1.0	0.03	0.8	0.1	0.4	4.2	77.3
1997	42.1	2.1	5.5	8.4	12.4	1.4	1.0	0.04	0.9	0.1	0.4	4.0	78.4
1998	41.4	2.0	5.3	8.1	12.3	1.4	0.9	0.04	0.9	0.1	0.4	3.9	76.8
1999	41.0	2.0	5.4	8.0	11.8	1.3	0.7	0.04	0.9	0.1	0.4	3.9	75.6
2000	41.6	1.8	5.4	8.1	11.6	1.3	0.7	0.04	0.9	0.1	0.3	4.0	76.1
2001	41.2	1.8	5.4	8.1	11.7	1.2	0.7	0.04	0.9	0.1	0.3	3.7	75.3
2002	41.2	1.9	5.7	8.2	11.7	1.3	0.7	0.03	0.9	0.1	0.3	4.0	76.1
2003	40.2	1.9	5.9	8.2	11.6	1.4	0.7	0.03	1.0	0.1	0.4	3.9	75.3
2004	39.7	2.1	5.8	8.1	11.3	1.4	0.8	0.04	1.0	0.1	0.4	4.0	74.7
2005	39.2	2.4	5.6	7.9	11.3	1.4	0.7	0.03	1.0	0.1	0.4	4.1	74.2
2006	38.6	2.7	5.9	8.1	11.0	1.4	1.0	0.03	1.0	0.1	0.3	3.9	74.2
2007	37.6	3.0	5.9	8.0	11.0	1.5	1.0	0.03	1.1	0.2	0.3	3.8	73.4
2008	36.8	3.3	5.9	8.0	10.8	1.5	1.0	0.03	1.1	0.2	0.3	3.9	72.8
2009	37.2	3.6	5.9	7.9	10.9	1.4	1.0	0.03	1.1	0.2	0.3	3.8	73.5
2010	37.6	3.9	6.3	8.1	11.1	1.4	1.1	0.02	1.2	0.2	0.3	3.9	75.0
2011	37.1	4.1	6.1	8.1	10.9	1.3	1.1	0.02	1.2	0.2	0.3	3.9	74.2
2012	36.9	4.0	5.9	7.9	11.0	1.3	1.1	0.02	1.2	0.2	0.3	3.8	73.5
Share of total (%) in 2012	50.2	5.5	8.0	10.7	14.9	1.8	1.5	0.0	1.6	0.2	0.4	5.2	100.0

DC=Dairy cows, SC=Suckler cows, B=Bulls, H=Heifers, C=Calves, Sw=Swine, Sh=Sheep, G=Goats, Ho=Horses, P=Ponies, F=Fur animals, R=Reindeer, Poultry not estimated.

## 6.2.2 Methodological issues

### Methods

Emissions from enteric fermentation of domestic livestock have been calculated by using the IPCC Tier 1 and Tier 2 methodologies presented in the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 1997) and the IPCC GPG 2000 and Uncertainty Management in National Greenhouse Gas Inventories (IPCC 2000).

Methane emissions from enteric fermentation of horses, ponies and goats have been calculated with the IPCC Tier 1 method by multiplying the number of the animals in each category with the IPCC default emission factor of the respective animal category as no national emission factor is available. The total emission is the sum of emissions from each category (IPCC 2000, Eq. 4.12 and Eq. 4.13, see Appendix\_6 at the end of Chapter 6). The emissions from fur animals were calculated by multiplying the number of fur animals (minks, fitches, foxes, racoons) with an emission factor used in the inventory of Norway. The contribution of emissions from horses, swine, goats and fur animals to the total emissions from enteric fermentation is minor.

In the Tier 2 method the emissions have been calculated as in the Tier 1 method above, but the emission factors have been calculated by using the equations presented in the 1996 IPCC GL and GPG 2000. The Tier 2 method has been used for cattle. Methane emissions from enteric fermentation have been identified as a key category, but only emissions from cattle meet the rule of thumb given in the GPG 2000 for significant sub-categories. Methane emissions from enteric fermentation of reindeer have been calculated by estimating the gross energy intake (GE) on the basis of literature (McDonald et al. 1988) by using national data for estimating dry matter intake and its composition (hay and lichen) and calculating the respective emission

factor with the IPCC equation  $EF = (GE \cdot Y_m \cdot 365 \text{ days/year}) / (55.65 \text{ MJ/kg CH}_4)$ . The same methodology has been used for estimating the GE and EF for sheep. For swine, a national equation for the methane energy was used. Equations used for calculating the GE for swine, sheep and reindeer are presented in more detail in the Appendix\_6.

### Activity data

Animal numbers are presented in Table 6.2-3.

The number of *cattle, sheep, swine, poultry and goats* were received from the Matilda database maintained by the Information Centre of the Ministry of Agriculture and Forestry (<http://www.agriculturalstatistics.fi/en/>) as well as from the Yearbook of Farm Statistics published annually by the Ministry of Agriculture and Forestry. The number of animals describes the number of animals on 1 May until the year 2003. After that statistics have changed slightly and now the numbers describe animal numbers on 1 April (poultry, swine), 1 May (cattle) and 1 June (goats and sheep). The animal group of swine is divided into subgroups (fattening pigs, boars, weaned pigs, sows and piglets) except when calculating N<sub>2</sub>O emissions from manure management where sows and piglets are counted as one unit “sows and piglets” (See Section 6.3.2.2).

The number of horses (number on 31 December) was received from the Finnish Trotting and Breeding Association (Suomen Hippos, [http://www.hippos.fi/in\\_english](http://www.hippos.fi/in_english)).

The number of fur animals was obtained from the Finnish Fur Breeders' Association and it describes the number of pelts produced annually. (<http://www.stkl-fpf.fi/>)

The number of reindeer was taken from the Yearbook of Farm Statistics and it describes the number of counted reindeer left alive during the reindeer herding year.

### Emission factors and other parameters

Emission factors for methane emissions from enteric fermentation are presented in Table 6.2-4. Emission factors for cattle are updated annually. EFs for other animal groups will be updated if more national data become available.

IPCC default emission factors were used for calculating methane emissions from enteric fermentation of swine, goats and horses (Tier 1 method). As no separate EF is available for ponies, the same EF is used as for horses.

Because no national or IPCC default emission factor for fur animals is currently available, the Norwegian emission factor was used (0.1 kg/animal/a). According to the NIR of Norway, the emission factor was derived from the default emission factor of swine by scaling based on a comparison between the average weights of swine and fur animals. The digestive systems of swine and fur animals are similar (both are monogastric animals).

National emission factors for cattle (divided into subcategories dairy cows, suckler cows, bulls, heifers and calves) were calculated with the Tier 2 method for cattle by using IPCC equations presented in Appendix\_6. For cattle, the gross energy intake (GE) has been calculated by using the IPCC method. The calculation is based on e.g. the development of animal weight and milk production. According to the calculations, for example the GE for dairy cows has changed from the value 250 MJ/animal/day in 1990 to 330 MJ/animal/day in 2012 resulting in a change in the emission factor being 100 in kg CH<sub>4</sub>/animal/a in 1990 and 130 kg CH<sub>4</sub>/animal/a in 2012 (Figure 6.2-1).

The IPCC gives no default emission factor for reindeer, thus it has been calculated by using the national methodology for estimating gross energy intake of reindeer based on their forage. The same equation has been used for sheep, too. The national EFs for swine subgroups were calculated based on their feed consumption and empiric equations on the energy of methane. The equations used for calculating emission factors are presented in the Appendix\_6 (Source: Nousiainen, J.).

Additional information needed for calculating emission factors for each cattle species includes animal weight, average daily weight gain, milk production per dairy cow and suckler cow, digestible energy of forage and length of pasture season (for this see Section 6.3.2.1). This information has been received from the Association of Rural Advisory Centres (ProAgria) and experts of MTT Agrifood Research Finland (Huhtanen, P. & Nousiainen, J.).

Cattle weights and mature weights of dairy cow, suckler cow and bull are presented in Table 6.2-5 (Source: Nousiainen, J.). The amount of milk produced per dairy cow and the fat content of milk are given in Table 6.2-6. Data on milk production (l/animal/a) have been obtained from the Yearbook of Farm Statistics or from the Matilda database of the Information Centre of the Ministry of Agriculture and Forestry. Coefficient 1.03 has been used to express the amount of milk produced as kg/animal/a for the whole time series. The milk production of suckler cow has been estimated to remain constant in 1990-2012, being 1,620 kg/a (Source: Nousiainen, J.). Average daily weight gain for cattle increase in 1990-2012 proportionally to the animal weights. They are (kg) 0.04-0.06 for dairy cow 0.02-0.025 for suckler cow, 0.56-0.07 for bull, 0.37-0.47 for heifer and 0.8-1.01 for calf (Source: Nousiainen J.). See details in Appendix 6\_b.

**Table 6.2-3** Animal numbers in Finland (x 1 000)

	<b>Cattle<sup>1</sup></b>	<b>Horses<sup>2</sup> Ponies Sheep Goats<sup>3</sup></b>				
		Dairy cows	Suckler cows	Bulls	Heifers	Calves
1990	<b>1 360</b>	490	14	149	219	488
1991	<b>1 310</b>	446	21	144	214	486
1992	<b>1 273</b>	428	28	143	211	463
1993	<b>1 252</b>	426	33	139	217	437
1994	<b>1 233</b>	417	33	144	215	425
1995	<b>1 148</b>	399	29	109	189	422
1996	<b>1 146</b>	392	31	115	201	407
1997	<b>1 142</b>	391	32	121	197	402
1998	<b>1 117</b>	383	31	115	190	398
1999	<b>1 087</b>	372	30	118	188	379
2000	<b>1 057</b>	364	28	115	185	365
2001	<b>1 037</b>	355	27	111	182	362
2002	<b>1 025</b>	348	28	115	180	354
2003	<b>1 000</b>	334	28	115	179	344
2004	<b>969</b>	324	31	110	173	330
2005	<b>959</b>	319	35	108	169	329
2006	<b>949</b>	309	39	112	171	318
2007	<b>927</b>	296	43	110	166	311
2008	<b>915</b>	289	48	109	165	305
2009	<b>918</b>	290	52	110	163	304
2010	<b>926</b>	289	55	114	164	303
2011	<b>914</b>	286	57	111	162	299
2012	<b>913</b>	284	58	109	160	303

	Swine <sup>4</sup>					Poultry <sup>5</sup>		Fur	Reindeer
		Fattening pigs	Weaned pigs	Boars	Sows	Piglets		animals <sup>6</sup>	
		(50- kg)	(20-50 kg)						
1990	1 381	438	313	5.9	179	446	9 663	3 283	239
1991	1 344	426	305	5.8	174	434	8 929	2 597	260
1992	1 298	411	294	5.6	168	419	9 356	2 849	232
1993	1 273	403	289	5.5	165	411	9 639	2 880	215
1994	1 298	411	294	5.6	168	419	9 906	3 284	214
1995	1 400	451	306	6.5	161	476	10 358	3 749	208
1996	1 395	445	309	6.6	180	456	9 935	4 145	213
1997	1 467	470	367	7.1	185	438	10 827	4 322	203
1998	1 401	421	357	7.8	187	429	11 050	3 968	196
1999	1 351	431	297	5.8	180	437	11 034	3 705	195
2000	1 296	405	289	6.0	184	412	12 570	3 361	203
2001	1 261	391	292	5.4	164	409	10 554	2 943	186
2002	1 315	405	296	5.3	172	437	10 734	3 410	200
2003	1 375	444	297	5.0	178	451	10 997	3 583	197
2004	1 365	441	291	4.7	175	452	10 405	3 530	201
2005	1 401	460	309	4.4	177	451	10 538	3 786	207
2006	1 436	457	327	4.0	171	478	10 239	3 448	198
2007	1 448	497	345	4.1	175	428	9 791	3 481	193
2008	1 483	504	354	3.9	169	452	10 522	2 700	195
2009	1 381	492	337	3.2	153	396	9 369	3 443	193
2010	1 367	488	316	3.1	151	409	9 587	3 474	194
2011	1 335	471	327	3.3	143	392	10 236	2 898	196
2012	1 290	477	302	2.7	133	375	10 761	2 898	192

<sup>1</sup> Includes dairy cows, suckler cows, bulls (>1 year), heifers and calves (<1 year) on 1 May (Source: Yearbook of Farm Statistics).

<sup>2</sup> Source: Finnish Trotting and Breeding Association (Suomen Hippos).

<sup>3</sup> The number of goats was not available for 1991, and the average of numbers for 1990 and 1992 was used.

<sup>4</sup> 1990-1994: Distribution of swine into sub-groups is estimated according to average distribution in 1995-2005

<sup>5</sup> Includes laying hens, chickens, cockerels, broiler hens, broilers, turkeys and other poultry. The number of broilers, cockerels, turkeys and other poultry for 1991-1994 was not available, data obtained by linear interpolation. The number of broiler hens was not available for 1990-1994, data obtained by linear extrapolation. Data for turkeys and other poultry for 1996 were not available; the average for 1995 and 1997 was used.

<sup>6</sup> Includes minks, fitches, foxes and racoons (number of pelts produced annually). The number in marketing year 2011/2012 was used as the information for marketing year 2012/2013 was not available yet.

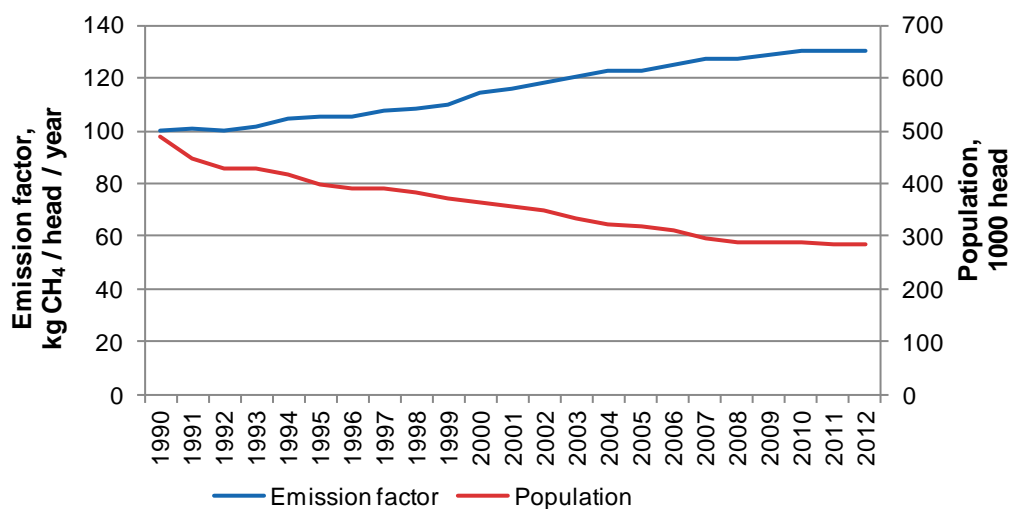


Figure 6.2-1 Development of the emission factor and population of dairy cows



**Table 6.2-4** Emission factors for methane emissions from enteric fermentation in 2012

Animal type	Emission factor (kg CH <sub>4</sub> / animal/a)	EF type	Method for calculating EF
Dairy cow	130.12	National	IPCC, Tier 2
Suckler cow	69.53	National	IPCC, Tier 2
Bull	53.92	National	IPCC, Tier 2
Heifer	49.42	National	IPCC, Tier 2
Calf	36.26	National	IPCC, Tier 2
Sows	3.56	National	National
Non-dairy cattle IEF	45.72	National	National
Piglets	0.13	National	National
Fattening pigs (>50 kg)	1.22	National	National
Boars	3.47	National	National
Veaned pigs (20-50 kg)	0.61	National	National
Reindeer	19.90	National	National
Sheep	8.39	National	National
Goat	5.00	IPCC default	IPCC, Tier 1
Horse	18.00	IPCC default	IPCC, Tier 1
Fur animals	0.10	Modified IPCC default*	IPCC, Tier 1

\*see 'Emission factors and other parameters'

**Table 6.2-5** Cattle live weights and mature weights (Source: MTT Agrifood Research Finland)

Year	Dairy cow		Suckler cow		Bull (>1 year)		Heifer	Calf (<1 year)
	Live weight (kg)	Mature weight (kg)	Live weight (kg)	Mature weight (kg)	Live weight (kg)	Mature weight (kg)	Live weight (kg)	Live weight (kg)
1990	520	540	585	596	442	815	351	187
1991	520	542	591	602	454	819	354	189
1992	515	538	596	608	451	816	353	188
1993	531	556	601	613	454	842	363	194
1994	535	561	607	619	463	851	368	196
1995	533	559	612	624	460	848	366	195
1996	535	561	618	630	466	853	368	197
1997	545	571	623	636	463	867	373	200
1998	547	575	629	641	460	872	375	200
1999	552	580	634	647	464	880	378	202
2000	569	596	640	652	474	903	387	207
2001	577	605	645	658	487	916	394	211
2002	585	613	651	663	508	927	403	215
2003	594	623	652	664	525	941	410	219
2004	605	634	675	684	538	959	417	224
2005	607	636	668	680	537	962	418	224
2006	613	642	674	687	547	972	424	227
2007	624	654	674	687	560	988	431	231
2008	628	658	684	698	563	997	436	234
2009	634	663	687	1 005	567	1 005	440	236
2010	645	675	710	723	581	1 027	449	241
2011	649	678	716	729	577	1 033	450	242
2012	649	679	692	703	567	1 026	447	239

**Table 6.2-6** Data of milk properties used for calculating methane emissions from enteric fermentation

Year	Fat content of milk <sup>1</sup> (%)	Milk production/ dairy cow <sup>2</sup> (kg/a)
1990	4.35	5 713
1991	4.35	5 788
1992	4.34	5 781
1993	4.38	5 817
1994	4.35	6 045
1995	4.34	6 161
1996	4.33	6 173
1997	4.32	6 368
1998	4.31	6 412
1999	4.24	6 636
2000	4.23	6 990
2001	4.23	7 140
2002	4.22	7 331
2003	4.24	7 469
2004	4.23	7 626
2005	4.16	7 330
2006	4.16	7 875
2007	4.18	8 030
2008	4.21	8 000
2009	4.21	8 086
2010	4.26	8 133
2011	4.26	8 095
2012	4.27	8 112

<sup>1</sup> Source: Publication of the Ministry of Agriculture and Forestry (Tietokappi, Matilda database). Assumed to be the same for dairy cows and suckler cows.

<sup>2</sup> Source: Yearbook of Farm Statistics, Matilda database (Coefficient 1.03 used to express l/animal/a as kg/animal/a).

### 6.2.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. A description of uncertainty analysis is included in Section 1.7.

The uncertainties in emissions from enteric fermentation are estimated by applying Tier 2 Monte Carlo simulation directly to the MTT emission calculation model. Total uncertainty in methane emissions from enteric fermentation of domestic livestock has been estimated at  $\pm 25\%$ . Uncertainty estimates of animal numbers were based on knowledge on the reliability and coverage of data collection. For example, cattle has individual earmarks that enable very accurate assessment of animal numbers (uncertainty of  $\pm 3\%$  in 2012) but uncertainty in animal numbers for other species in farms is higher ( $\pm 5\%$ ). The uncertainty in animal numbers is estimated to be the highest for reindeer ( $\pm 10\%$ ).

The uncertainty in the Tier 2 method for evaluating emissions from enteric fermentation of cattle was assessed by estimating uncertainty in each calculation parameter (except coefficients, whose importance was expected to be minor) and combining uncertainties using Monte Carlo simulation.

Uncertainty in animal weight, weight gain, milk production and fat content of milk for each cattle subgroup was estimated utilising knowledge of the deviation in weights of the animal population and in milk production. Information on measurement instruments reflecting a possible systematic error was also used. Uncertainties in different coefficients used for calculating energy related parameters (e.g. GE) were estimated based on expert judgement, except methane conversion rate for which uncertainty is from IPCC Guidelines 2006. The most important parameters affecting the uncertainty were methane conversion rate ( $Y_m$ ) and net energy used for maintenance ( $NE_m$ ).

For the species for which IPCC default emission factors are used (other species than cattle, reindeer, sheep and fur animals), the default uncertainty of  $\pm 50\%$  is used for the emission factor. For the national EFs of

reindeer and sheep the uncertainties are estimated at -90...+250% and  $\pm 40\%$ , respectively. For fur animals the EF is from Norway, and its uncertainty is estimated at -70...+150%.

As the same calculation methods are used for the whole time series 1990-2012, the time series can be considered consistent. However, for some years animal numbers have not been available (e.g. the number of goats in 1991 and the number of broilers in 1991, 1992, 1993, 1994), so linear interpolation of the data from adjacent years has been used to obtain the data. The estimates of uncertainty did not change due to the latest changes in emission calculations since the changes were small and mainly related to different categorisation of animals.

## 6.2.4 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6. The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives. The bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert.

In the quality meeting 2014 for example the ERT Review and future improvements were discussed and some clarifications were made to the inventory report text, especially in description of the QA/QC measures. The steering group of MTT discussed the coming needs for

General (Tier 1) Quality Control (QC) procedures applied to the category Enteric fermentation (CRF 4.A). The results from the N model are compared with a more simple calculation periodically to examine possible problems with the model. The animal numbers in the UNFCCC reporting and ammonia reporting were compared and they are now the same in both reports. The differences were caused by different methods of rounding the values for animal numbers. It was agreed that no roundings are used in either of the reports.

The QA/QC plan for the agricultural sector includes the QC measures presented in the GPG 2000 (Table 8.1, p. 8.8-8.9). These measures are implemented every year during preparation of the agricultural inventory. If errors or inconsistencies are found they are documented and corrected. The QC checklist is used during the inventory.

Tier 2 QC for activity data:

A checklist is used for ensuring consistency of the activity data in different sections of the agricultural inventory. The checklist is a list of the activity data with a column for marking the result of the check.

Tier 2 QC for emission factors:

It is checked annually if new data for updating emission factors has been published. New national data are compared with the emission factors used in the inventory and the applicability of current emission factors in Finland's circumstances is evaluated. Some new data were available for this inventory for updating the emission factors (see recalculations). The new daily growth rates for cattle were compared with the values in 2006 IPCC Guidelines and the new EFs for pigs were compared with those used in Denmark. Both comparisons gave evidence of the suitability of the new EFs.

The agricultural inventory has been reviewed annually by the UNFCCC Expert Review Teams, and improvements to the inventory have been made according to the recommendations. No specific verification process has been implemented for the agricultural inventory. However, a case study between Finland and Germany was arranged in August 2004 where the German experts reviewed Finland's agricultural inventory. The purpose of the case study was to find potential adjustment cases and to test specific methods to calculate adjustments. The experiences of this exercise have been taken into account in the development of the inventory. Statistics Finland audited the inventory in autumn 2009 and it focused especially on recalculations. The results of the audit have helped to further improve the inventory.

### 6.2.5 Source-specific recalculations

The number of fur animals was updated for the year 2011 because it was not available before.

To increase consistency between the emission estimates of manure and enteric fermentation, the daily weight gain of cattle was updated and the values are calculated separately for each year based on functions of mature weight and age. The mature weight of heifers and calves was updated so that the simple averages were replaced with weighed averages. Now the mature weight of heifers and calves are based on the weighted average of dairy and suckler cows and bulls.

New EFs for different swine classes were taken to use to increase the accuracy of the emission estimates.

**Table 6.2-7** Daily weight gain of cattle in 2012

	Old values	New values in 1990	New values in 2012
Dairy cows	0	0.04	0.06
Suckler cows	0	0.02	0.03
Heifers	1.1	0.37	0.47
Bulls	0.7	0.56	0.70
Calves	0.85	0.80	1.01

**Table 6.2-8** The effect of the changes in cattle weights and updated EFs for swine on the total emissions from enteric fermentation

	1990	2000	2008	2009	2010	2011
New method (Gg CH <sub>4</sub> )	87.2	76.1	72.6	73.3	74.9	74.1
Old method (Gg CH <sub>4</sub> )	92.0	78.9	74.7	75.3	76.7	75.9
Old minus new (Gg CO <sub>2</sub> eq.)	101.1	59.1	44.5	41.5	39.0	37.3

### 6.2.6 Source-specific planned improvements

No improvements are planned at the moment but the 2006 IPCC Guidelines will be taken into use for the 2015 submission.

## 6.3 Manure Management (CRF 4.B)

### 6.3.1 Source category description

Nitrous oxide and methane emissions from manure management were 1.3 Gg and 12.1 Gg in 2012, respectively, and their emissions as CO<sub>2</sub> equivalents were 0.7 Tg altogether. Nitrous oxide emissions from manure management were about 7% and methane emissions about 4% of total emissions in sector Agriculture in 2012.

This emission source covers manure management of domestic livestock. Finland reports both nitrous oxide (N<sub>2</sub>O) and methane (CH<sub>4</sub>) emissions from manure management of cattle (including dairy cows, suckler cows, heifers, bulls and calves), swine (including fattening pigs, weaned pigs (20-50 kg), boars, sows and piglets), horses, goats, sheep and poultry. Emissions from manure of reindeer and fur animals are also included. Methane emissions are reported in the CRF tables per each animal group but N<sub>2</sub>O emissions are reported per animal waste management system (Table 6.3-1).

**Table 6.3-1** Reported emissions according to the classification of the CRF tables, calculation methods and types of emission factors for the subcategory CRF 4.B Manure Management in the Finnish inventory

CRF	Source	Emissions reported	Method	Emission factor
4.B 1	Cattle			
	Dairy Cattle	CH <sub>4</sub>	Tier 2	CS
		N <sub>2</sub> O	D	D
	Non-Dairy Cattle	IE (4.B 10)	NA	NA
4.B 2	Buffalo	NO	NA	NA
4.B 3	Sheep	CH <sub>4</sub>	Tier 2	CS
		N <sub>2</sub> O	D	D
4.B 4	Goats	CH <sub>4</sub>	Tier 2	CS
		N <sub>2</sub> O	D	D
4.B 5	Camels and Llamas	NO	NA	NA
4.B 6	Horses	CH <sub>4</sub>	Tier 2	CS
		N <sub>2</sub> O	D	D
4.B 7	Mules and Asses	NO	NA	NA
4.B 8	Swine	IE	NA	NA
4.B 9	Poultry	CH <sub>4</sub>	Tier 2	CS
		N <sub>2</sub> O	D	D
4.B 10	Other			
	- Reindeers	CH <sub>4</sub>	Tier 2	CS
		N <sub>2</sub> O	D	D
	- Heifers	CH <sub>4</sub>	Tier 2	CS
		N <sub>2</sub> O	D	D
	- Bulls	CH <sub>4</sub>	Tier 2	CS
		N <sub>2</sub> O	D	D
	- Calves	CH <sub>4</sub>	Tier 2	CS
		N <sub>2</sub> O	D	D
	- Fur farming	CH <sub>4</sub>	Tier 2	CS
		N <sub>2</sub> O	D	D
	- Cows	CH <sub>4</sub>	Tier 2	CS
		N <sub>2</sub> O	D	D
	- Ponies	CH <sub>4</sub>	Tier 2	CS
		N <sub>2</sub> O	D	D
	- Sows	CH <sub>4</sub>	Tier 2	CS
		N <sub>2</sub> O	D	D
	- Piglets	CH <sub>4</sub>	Tier 2	CS
		N <sub>2</sub> O	D	D
	-Boars	CH <sub>4</sub>	Tier 2	CS
		N <sub>2</sub> O	D	D
	-Fattening pigs	CH <sub>4</sub>	Tier 2	CS
		N <sub>2</sub> O	D	D
	-Weaned pigs	CH <sub>4</sub>	Tier 2	CS
		N <sub>2</sub> O	D	D

CRF	Source	Emissions reported	Method	Emission factor
4.B 11	Anaerobic Lagoons	NO	NA	NA
4.B 12	Liquid Systems <sup>1</sup>	N <sub>2</sub> O	D	D
4.B 13	Daily spread	NO	NA	NA
4.B 14	Solid Storage and Dry Lot <sup>1</sup>	N <sub>2</sub> O	D	D
4.B 15	Pasture range and paddock <sup>2</sup>	N <sub>2</sub> O	IE	IE
4.B 16	Other AWMS <sup>1,3</sup>	N <sub>2</sub> O	D	D

<sup>1</sup> Indirect N<sub>2</sub>O emissions from manure management systems are not included in the emissions from manure management but reported in the CRF subcategory 4.D 3.1 Agricultural soils/Atmospheric deposition.

<sup>2</sup> Emissions from pasture are calculated under manure management but reported in the CRF subcategory 4 D.2 Agricultural soils/ Pasture, range and paddock manure.

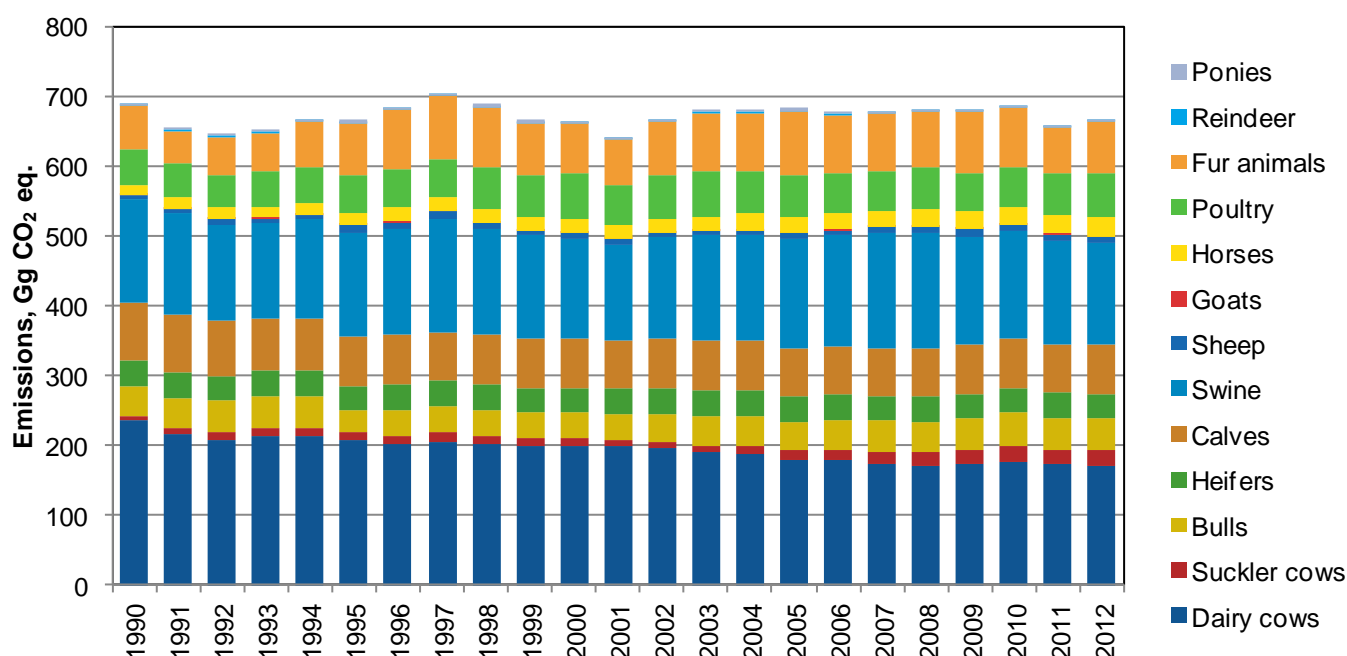
<sup>3</sup> Other AWMS is deep litter.

N excretion rate is national data.

Cow means suckler cow.

Nitrous oxide is produced by the combined nitrification-denitrification processes occurring in the manure nitrogen (Jun et al., 2002). Nitrification is an aerobic process where ammonium is converted to nitrate. In anaerobic denitrification nitrate is converted to nitrous oxide. Methane is produced in manure during decomposition of organic material by anaerobic and facultative bacteria under anaerobic conditions (Jun et al., 2002). The amount of emissions is dependent on the amount of organic material in the manure, manure management system and climatic conditions, for example.

Nitrous oxide emissions from manure management have decreased by 15% over the time series (Table 6.3-2 and Figure 6.3-1). Methane emissions from manure management have been fluctuating during 1990-2012 but overall there is an increase of 24% in the emissions in 2012 compared with 1990 (Table 6.3-3). This is due to an increase in the number of animals kept in a slurry-based system. Total emissions from manure management (Gg CO<sub>2</sub> eq.) have decreased about 3% 1990-2012. The fluctuation in the emissions from manure management is related to both changes in animal numbers, which is largely dependent on agricultural policy, as well as changes in the distribution of the manure management systems used. Slurry-based systems increase methane emissions per animal tenfold compared with solid storage or pasture (IPCC 2000). On the other hand, nitrous oxide emissions are higher from solid storage than from slurry.



**Figure 6.3-1** Emissions of manure management by animal type, Gg CO<sub>2</sub> eq.

**Table 6.3-2** Direct nitrous oxide emissions (Gg) from manure management by animal type (emissions from pasture not included, they are reported under CRF 4.D Agricultural soils/Pasture, range and paddock manure)

Year	Cattle		Other livestock										Total	
	DC	SC	B	H	C	Sw	Sh	G	Ho	Po	P	F		R
1990	0.53	0.01	0.11	0.09	0.20	0.23	0.02	0.001	0.04	0.00	0.15	0.17	0	1.57
1991	0.48	0.02	0.11	0.09	0.20	0.21	0.02	0.001	0.05	0.01	0.14	0.13	0	1.46
1992	0.46	0.03	0.11	0.09	0.19	0.19	0.02	0.001	0.05	0.01	0.14	0.15	0	1.43
1993	0.47	0.03	0.11	0.09	0.18	0.18	0.02	0.001	0.05	0.01	0.15	0.15	0	1.44
1994	0.47	0.03	0.11	0.09	0.18	0.17	0.02	0.001	0.05	0.01	0.15	0.18	0	1.46
1995	0.45	0.03	0.08	0.08	0.17	0.16	0.03	0.001	0.05	0.01	0.16	0.20	0	1.42
1996	0.43	0.03	0.09	0.09	0.17	0.17	0.03	0.001	0.06	0.01	0.15	0.24	0	1.45
1997	0.43	0.03	0.09	0.09	0.17	0.17	0.03	0.002	0.06	0.01	0.16	0.25	0	1.49
1998	0.41	0.03	0.09	0.09	0.17	0.17	0.02	0.002	0.06	0.01	0.18	0.23	0	1.46
1999	0.40	0.03	0.09	0.08	0.17	0.16	0.02	0.002	0.06	0.01	0.17	0.21	0	1.41
2000	0.39	0.02	0.09	0.09	0.17	0.16	0.02	0.002	0.06	0.01	0.19	0.20	0	1.40
2001	0.37	0.02	0.09	0.09	0.17	0.15	0.02	0.002	0.06	0.01	0.17	0.17	0	1.33
2002	0.35	0.02	0.10	0.09	0.17	0.15	0.02	0.002	0.06	0.01	0.18	0.22	0	1.37
2003	0.32	0.02	0.11	0.09	0.17	0.16	0.02	0.002	0.06	0.01	0.19	0.24	0	1.39
2004	0.30	0.03	0.11	0.09	0.17	0.15	0.02	0.002	0.07	0.01	0.18	0.24	0	1.35
2005	0.27	0.03	0.10	0.09	0.17	0.16	0.02	0.002	0.07	0.01	0.18	0.26	0	1.36
2006	0.27	0.03	0.11	0.09	0.17	0.15	0.02	0.002	0.07	0.01	0.17	0.24	0	1.34
2007	0.26	0.04	0.11	0.09	0.17	0.16	0.03	0.001	0.07	0.01	0.17	0.23	0	1.33
2008	0.26	0.04	0.11	0.09	0.17	0.16	0.03	0.001	0.07	0.01	0.18	0.19	0	1.31
2009	0.26	0.05	0.11	0.09	0.17	0.15	0.03	0.001	0.08	0.01	0.16	0.25	0	1.36
2010	0.27	0.05	0.12	0.09	0.17	0.15	0.03	0.001	0.08	0.01	0.17	0.24	0	1.38
2011	0.26	0.05	0.11	0.09	0.17	0.15	0.03	0.001	0.08	0.01	0.18	0.21	0	1.35
2012	0.26	0.05	0.11	0.09	0.17	0.14	0.03	0.001	0.08	0.01	0.19	0.21	0	1.34
Share of total (%) in 2012*	19	3	8	7	12	11	2	0.1	6	0.6	12	19	0	100

**Table 6.3-3** Methane emissions from manure management by animal type (Gg)

Year	Cattle			Other livestock										Total
	DC	SC	B	H	C	Sw	Sh	G	Ho	Po	P	F	R	
1990	3.45	0.05	0.44	0.40	0.97	3.58	0.02	0.001	0.05	0.01	0.21	0.44	0.03	9.64
1991	3.20	0.08	0.45	0.41	0.98	3.70	0.02	0.001	0.06	0.01	0.20	0.35	0.03	9.47
1992	3.11	0.10	0.46	0.41	0.93	3.77	0.02	0.001	0.06	0.01	0.21	0.38	0.03	9.50
1993	3.20	0.12	0.47	0.44	0.91	3.90	0.02	0.001	0.06	0.01	0.22	0.38	0.03	9.77
1994	3.24	0.12	0.51	0.46	0.90	4.19	0.02	0.001	0.06	0.01	0.23	0.44	0.02	10.19
1995	3.16	0.11	0.40	0.41	0.90	4.72	0.03	0.001	0.06	0.01	0.24	0.50	0.02	10.57
1996	3.24	0.12	0.43	0.44	0.87	4.71	0.03	0.001	0.06	0.01	0.23	0.55	0.02	10.71
1997	3.43	0.13	0.45	0.44	0.87	5.06	0.03	0.001	0.07	0.01	0.25	0.57	0.02	11.33
1998	3.50	0.13	0.43	0.42	0.87	4.78	0.02	0.001	0.07	0.01	0.26	0.53	0.02	11.04
1999	3.58	0.14	0.44	0.42	0.83	4.55	0.02	0.001	0.07	0.01	0.26	0.49	0.02	10.84
2000	3.76	0.14	0.44	0.42	0.82	4.36	0.02	0.001	0.07	0.01	0.29	0.45	0.02	10.79
2001	3.95	0.14	0.43	0.42	0.82	4.32	0.02	0.001	0.07	0.01	0.24	0.39	0.02	10.84
2002	4.16	0.14	0.47	0.43	0.82	4.54	0.02	0.001	0.07	0.01	0.25	0.45	0.02	11.38
2003	4.28	0.14	0.48	0.43	0.81	4.84	0.02	0.001	0.07	0.01	0.25	0.48	0.02	11.83
2004	4.44	0.16	0.47	0.42	0.79	4.86	0.02	0.001	0.07	0.01	0.23	0.47	0.02	11.98
2005	4.58	0.18	0.46	0.41	0.79	5.10	0.02	0.001	0.08	0.01	0.23	0.50	0.02	12.40
2006	4.51	0.21	0.48	0.42	0.77	5.22	0.02	0.001	0.08	0.01	0.23	0.46	0.02	12.44
2007	4.40	0.23	0.48	0.42	0.77	5.39	0.02	0.001	0.08	0.01	0.22	0.46	0.02	12.51
2008	4.31	0.26	0.48	0.42	0.76	5.51	0.02	0.001	0.08	0.01	0.23	0.36	0.02	12.47
2009	4.36	0.28	0.48	0.41	0.76	5.21	0.02	0.001	0.09	0.01	0.21	0.46	0.02	12.32
2010	4.40	0.31	0.51	0.42	0.78	5.11	0.02	0.001	0.09	0.01	0.21	0.46	0.02	12.36
2011	4.34	0.32	0.49	0.42	0.77	5.02	0.02	0.001	0.09	0.01	0.23	0.39	0.02	12.12

Year	Cattle					Other livestock								Total
	DC	SC	B	H	C	Sw	Sh	G	Ho	Po	P	F	R	
2012	3.45	0.05	0.44	0.40	0.97	3.58	0.02	0.001	0.05	0.01	0.21	0.44	0.03	11.94
Share of total (%) in 2012*	36.2	2.6	4.0	3.4	6.5	40.8	0.2	0.0	0.7	0.1	2.0	3.2	0.2	100

\* The sum of the shares differs from 100 due to rounding. DC=Dairy cows, SC=Suckler cows, B=Bulls, H=Heifers, C=Calves, Sw=Swine, Sh=Sheep, G=Goats, Ho=Horses, Po=Ponies, P=Poultry, F=Fur animals, R=Reindeer

## 6.3.2 Methodological issues

### 6.3.2.1 Methods

#### Nitrous oxide – Nitrogen mass flow model

Nitrous oxide emissions from manure management have been calculated with a national calculation model for gaseous agricultural nitrogen emissions developed in a separate project of MTT and Finnish Environment Institute. The model is described in more detail in the publication by Grönroos et al. (2009) (available at <https://helda.helsinki.fi/handle/10138/38030>). The model integrates both ammonia and nitrous oxide emissions from manure management (including indirect N<sub>2</sub>O from manure management systems) in the same calculation model. Model calculates emissions in each phase of the manure management chain: N excreted from animals-> animal shelter-> manure storage -> application on fields or deposition on pastures. It takes into account NH<sub>3</sub> abatement techniques (e.g. storage covers) and manure spreading techniques in each phase as applicable. In addition, emissions from mineral fertilisers (including NO, which share is calculated as 0.7% of fertiliser N) are calculated in the model. The aim of using the model has been to increase transparency in the calculations and to ensure that the same activity data and parameters are used consistently in both greenhouse gas and air pollutant inventories.

Direct nitrous oxide emissions from manure management (CRF 4.B) are calculated in the model by using the IPCC methodology (IPCC 2000, Eq. 4.18). The equation is presented in the Appendix\_6. The amount of nitrogen excreted annually per animal has been divided between different manure management systems (slurry, solid storage (dung & urine or urine and dung separated), deep litter) and multiplied with the IPCC default emission factor for each manure management system. Nitrogen excretion during the year per animal and the distribution of manure management systems are national data (Table 6.3-4 and Table 6.3-5).

The amount of N volatilised as NH<sub>3</sub>-N from total manure N (Frac<sub>GASM</sub> being ca. 25%) is calculated in the model for the whole manure management chain (animal shelter, manure storage, field) and is used for calculating indirect N<sub>2</sub>O emissions from atmospheric deposition (CRF 4.D 3.1). Volatilisation from dung and urine on pasture are assessed in the model separately resulting in a total loss of 4.4% of nitrogen as ammonia from pastures. Calculating manure excreted on pasture requires data of length of pasture season and time spent outside. For dairy cattle it has been estimated that 25% of cows spend nights inside (14 hours) during pasture season. The length of pasture season has been estimated as 140 days for suckler cows, heifers, horses and ponies 125 days for dairy cows, 100 for calves, 130-140 for sheep and goats, 365 for reindeer and 0 for bulls, swine (some exceptions), poultry and fur animals.

Volatilised N from manure (as NH<sub>3</sub>-N and as N<sub>2</sub>O-N from manure management) is subtracted from the amount of N applied to fields before calculating direct N<sub>2</sub>O emissions from manure applied to soils (CRF 4.D 1.2). When calculating direct emissions from pasture, range and paddock manure (CRF 4.D 2), volatilisation is not subtracted first.

Nitrogen volatilised as NH<sub>3</sub>-N and NO<sub>x</sub>-N from synthetic fertilisers (Frac<sub>GASF</sub>) is calculated and used for calculating indirect emissions from atmospheric deposition (CRF 4.D 3.1) and subtracted from the amount of N remaining which is used for calculating direct emissions from synthetic fertiliser application (CRF 4.D 1.1). Sewage sludge is not included in the model but emissions from sludge application (CRF 4.D 1.6) are calculated separately. The amount of NH<sub>3</sub>-N volatilised is also subtracted from sewage sludge (Frac<sub>GASM</sub> ca. 25%) before calculating direct emissions from sludge application. Indirect emissions from atmospheric deposition (CRF 4.D 3.1) are calculated by using the total N volatilised (manure, synthetic fertilisers and



sewage sludge) which is then multiplied with the IPCC default EF. Indirect N<sub>2</sub>O emissions from leaching and run-off are not included in the model but calculated separately and reported under CRF 4D.3.2 Agricultural soils/ Indirect N<sub>2</sub>O from leaching and run-off.

Fraction of N leached (Frac<sub>LEACH</sub>) is calculated from the total N input into the soil (volatilised N not subtracted as guided by the GPG 2000) and is used for calculating N<sub>2</sub>O emissions from leaching and run-off. Reporting of manure and synthetic fertiliser N is presented in Figure 6.3-2. N flows and N<sub>2</sub>O emissions from sector Agriculture are presented in Figure 6.4-1.

The emission factors for calculating N<sub>2</sub>O emissions from manure management are presented in Table 6.3-6.

### Methane

Methane emissions from manure management are calculated in the same generic way as emissions from enteric fermentation, i.e. by multiplying the number of the animals in each category with the emission factor for each category (IPCC 2000, Eq. 4.15). In Finland the Tier 2 method is used for all animal categories, which requires developing national emission factors for calculations based on detailed data on animal characteristics and manure management systems. The equations used for calculating methane emissions from manure management are presented in the Appendix\_6.

#### 6.3.2.2 Activity data

##### Animal numbers

Animal categories included in the N flow model are the same as for enteric fermentation (cattle, swine, sheep, horses, goats and reindeer) and also fur animals and poultry are included.

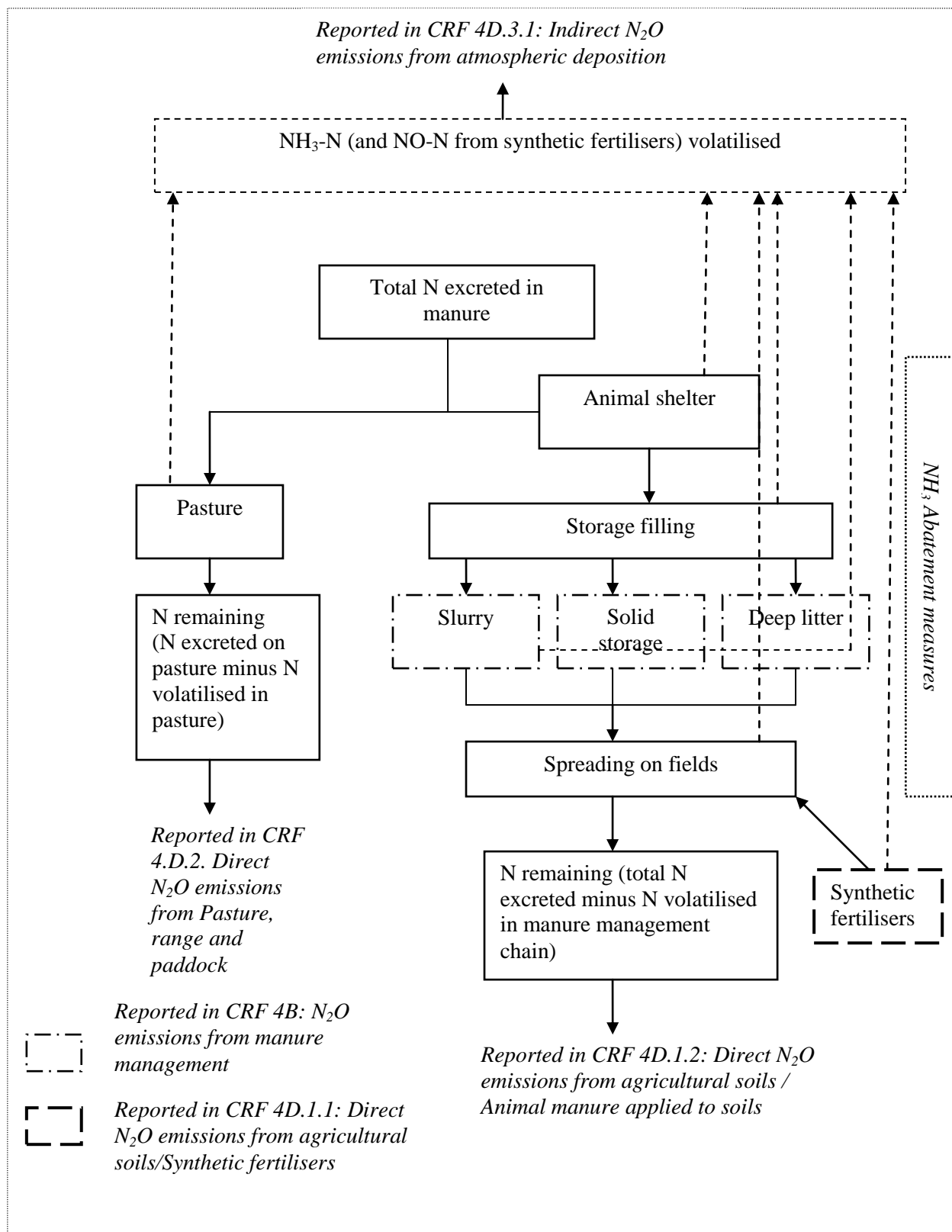
Animal numbers used for calculating nitrous oxide and methane emissions from manure management are the same as those used for calculating methane emissions from enteric fermentation except for sows and piglets for calculating N<sub>2</sub>O emissions from manure management. N excretion for sows and piglets is calculated for the one unit “sows and piglets”, the number of piglets is subtracted from the total amount of swine to avoid double counting.

##### Nitrogen excretion per animal

Annual nitrogen excretion per animal has been calculated by animal nutrition experts of MTT Agrifood Research Finland (Appendix\_6b). The values of animal specific nitrogen excretion rates were based on nutrient balance calculations. Excretion rate is obtained by subtracting the nitrogen included in animal products and growth from the nitrogen intake through feeding. For all the animal groups, excluding horses and fur animals, the main sources of information are the agricultural statistics. Most important of these are the number of farm animals, the milk, meat and egg production and the slaughter weights.

In the case of animals that live less than one year (swine, poultry), replacement of animals with new ones is taken into account in the calculations.

The reason for the increasing trend in N excretion rates is the increased production level of animals demanding higher nitrogen intake. Thus, nitrogen excretion has increased despite the fact that N utilisation has improved. The need to update the N excretion rates is evaluated annually in cooperation with the animal nutrition experts.



**Figure 6.3-2** Distribution of manure N in the N flow model and reporting of direct and indirect N<sub>2</sub>O emissions from manure and synthetic fertilisers. Solid arrows describe N flows and broken arrows describe volatilised N as NH<sub>3</sub>-N (and NO<sub>x</sub>-N in case of synthetic fertilisers). The magnitude of N<sub>2</sub>O emissions from each source is not presented here but in Figure 6.1-4.

### *Cattle*

The feed intake of dairy cows is calculated according to the feeding recommendations. In suckler cows feed intake is estimated based on feeding experiment results (Manninen 2007) and diet examples (Komulainen 1997). For calves, heifers and bulls at first the yearly Richards' function growth curves (DeNise and Brinks 1985 for beef cattle, Perotto et al. 1992 for dairy cattle) were estimated from the dairy and beef cow mature weights. The higher growth rate of bulls in relation to heifers was estimated according to Hafez and Dyer (1969, page 66, figure 3-1, Hereford). The heifers are divided to slaughtered and recruitment animals. The exact ages of slaughtered animals are available from the year 2000 onwards; in previous years they were estimated according to the situation in 2000 and 2001. With the growth curve, daily weight and growth values can be calculated. The energy requirement is based on these values. The feed nitrogen content was obtained from the feed consumption data of Finnish milk recording that contain also information of growing cattle.

### *Swine*

The values of animal category specific nitrogen excretion rates (Nex) are based on animal feeding nutrient balance calculations. The calculation method is close to the one presented by Fernández et. al 1999. Excretion rate is obtained by subtracting the nitrogen included in animal products and growth (N retention) from the nitrogen intake (N intake) through feeding. In the balance calculations, N excretion of piglets and N excretion of farrowed sows together is the first unit. The second unit in the calculations is N excretion of sows not farrowed (gilts). The N excretion value for sows with piglets (given in Table 6.3-4 in the NIR) is derived as weighted average of N excretion of sows farrowed (including piglets) and of gilts, and the relative proportion of number of animals in the both units is received from the official agricultural statistics. Finally, this N excretion value of sows with piglets is multiplied with the total number of sows (which includes both sows farrowed and gilts) in the official agricultural statistics.

For sows with piglets, the necessary information is obtained from agricultural statistics. For growing pigs, calculations are based on feed conversion results of FABA breeding central station testing, estimated difference in farm conditions and several feeding experiments. The nitrogen content of feed is estimated from the digestible protein recommendations. Also feeding examples (Komulainen 1989, Kyntäjä et al. 1999 and Siljander-Rasi et al. 2006) are utilised.

### *Horses and ponies*

For horses and ponies, the statistics of Suomen Hippos are used. Nitrogen excretion is in most cases calculated with nitrogen balance estimation and is close to the methods described by Smith and Frost (2000) and Smith et al. (2000). The feed tables and feeding recommendations, later only referred to as feeding recommendations, by Salo et al. (1990), Tuori et al. (1996), Tuori et al. (2000), MTT (2004), and MTT (2006) are used. The nitrogen consumption of horses and ponies is estimated according to the feeding recommendations and example feeding presented in Saastamoinen and Teräväinen (2007). The calculations are based on the group distribution and estimated use of horses and ponies according to the statistics of Suomen Hippos. The nitrogen excretion is the difference between nitrogen intake of horses and ponies and nitrogen amount in culled horses and ponies (about 7% of horse and pony population) divided by the total horse population.

### *Sheep with lambs*

For sheep, the information of Finnish sheep production recording, example feeding (Savolainen and Teräväinen 2000) and feeding recommendations were used in the nitrogen intake and retention calculations. The wide variation in sheep production systems and seasonality make these calculations challenging.

### *Goats with gilts*

The feed intake of goats was calculated according to the feeding recommendations and diet examples (Komulainen 1997). Milk production per goat was assumed as 741 kg and live weight as 50 kg.

*Poultry*

For poultry, nitrogen intake is estimated with feed consumption per kg eggs, one slaughtered or full-grown bird. The feed utilisation values were obtained from commercial poultry breeders and several Finnish feeding experiments. The nitrogen content of feed originates from commercial concentrate manufacturers and feeding recommendations. The nitrogen excretion of other poultry, which includes ducks, geese, ranched pheasant, ranched mallards, guinea fowl, quails, ostriches and emus, is estimated equal to that of laying hens.

*Fur animals*

For the fur animals nitrogen intake is based on the amount of feed consumed per one produced pelt according to the feeding recommendations. Nitrogen content of feed is available from laboratory results published in the journal "Turkistalous" between 1990 and 2007. N excretion for fur animals is calculated from the basis of feeding recommendations (MTT 2004; MTT 2006) and the pelt production statistics of Finnish Fur Breeders Association.

*Reindeer*

For reindeer, nitrogen excretion is not estimated but the value for goats is used.

**Table 6.3-4** Annual average N excretion per animal (kg N/animal/year). Cockerels 1.0, broiler hens 1.0, goats 10.7 and reindeer 10.7 kg N/animal/year are for whole time series (Nousiainen, J. MTT)

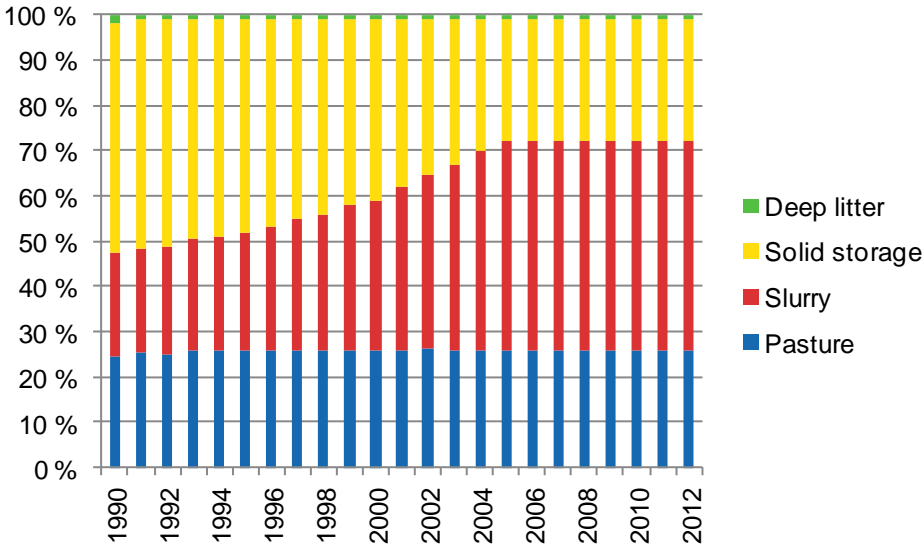
Year	Dairy cows	Suckler cows	Bulls	Heifers	Calves	Fattening pigs (50- kg)	Weaned pigs (20-50 kg)	Boars	Sows (including piglets) <sup>1</sup>	Piglets
1990	91.3	62.5	47.1	39.5	27.2	18.3	8.8	19.6	27.8	IE
1991	91.5	62.8	47.8	40.0	27.4	18.0	8.8	19.7	27.3	IE
1992	92.0	63.2	47.7	39.9	27.5	17.8	8.7	19.4	27.5	IE
1993	93.7	63.5	49.0	41.6	28.5	17.6	8.8	19.3	27.4	IE
1994	96.1	63.9	49.9	42.2	28.9	17.5	8.8	19.1	27.1	IE
1995	96.6	64.2	50.0	42.3	29.1	17.4	8.5	19.1	26.5	IE
1996	96.8	64.6	50.6	42.6	29.3	17.3	8.4	19.1	26.5	IE
1997	99.4	65.0	51.1	43.3	29.7	17.3	8.5	19.8	26.5	IE
1998	100.6	65.3	51.7	43.6	30.1	17.4	8.5	19.9	26.6	IE
1999	103.8	65.6	52.4	44.1	30.9	17.5	8.6	17.9	26.7	IE
2000	107.7	66.0	54.1	45.5	32.0	17.5	8.6	17.8	26.8	IE
2001	110.5	66.3	56.0	46.6	32.9	17.5	8.6	18.9	26.6	IE
2002	112.9	66.7	58.9	47.8	33.9	17.6	8.7	19.2	27.3	IE
2003	115.4	66.8	61.5	48.8	35.1	17.5	8.8	19.4	27.8	IE
2004	118.3	68.3	63.3	50.1	36.2	17.5	8.8	19.6	28.2	IE
2005	120.0	67.8	63.8	50.4	36.6	17.5	8.9	20.1	28.4	IE
2006	121.7	68.1	64.9	51.2	37.1	17.6	8.9	20.5	28.7	IE
2007	123.5	68.1	66.7	52.2	38.0	17.6	9.0	20.5	29.1	IE
2008	124.7	68.7	66.9	52.8	38.3	17.6	9.0	20.3	29.5	IE
2009	126.9	68.9	67.1	53.6	39.1	17.5	9.0	20.3	29.5	IE
2010	129.2	70.3	68.7	54.9	40.1	17.6	9.0	20.5	29.9	IE
2011	129.6	70.7	68.1	55.1	40.2	17.5	9.0	20.7	30.9	IE
2012	129.8	69.3	66.8	54.6	39.7	17.5	9.1	20.4	30.2	IE

<sup>1</sup> The N excretion value for sows includes N excretion of piglets.

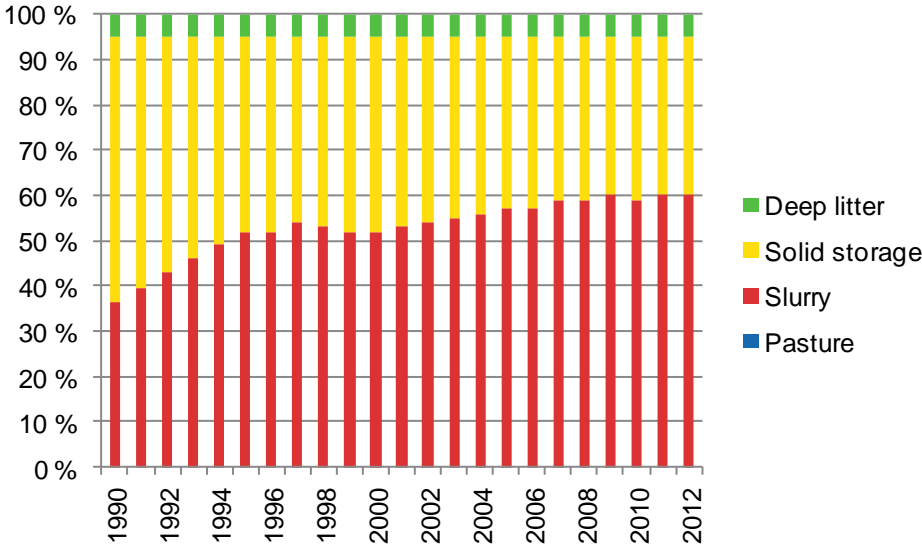
Year	Laying hens	Broilers	Chickens	Turkeys	Other poultry	Horses	Ponies	Sheep	Minks & fitches	Foxes & racoons
1990	0.6	0.4	0.4	1.1	0.6	59.4	43.4	8.5	1.2	2.1
1991	0.6	0.4	0.4	1.2	0.6	59.2	43.2	8.5	1.3	2.2
1992	0.6	0.4	0.4	1.2	0.6	59.1	43.2	8.6	1.3	2.2
1993	0.6	0.4	0.4	1.3	0.7	59.6	43.4	8.7	1.3	2.2
1994	0.6	0.4	0.4	1.2	0.7	60.1	43.9	8.7	1.3	2.2
1995	0.6	0.4	0.4	1.3	0.6	60.5	44.4	8.7	1.3	2.2
1996	0.6	0.4	0.4	1.3	0.7	60.5	44.2	8.9	1.3	2.3
1997	0.6	0.4	0.4	1.3	0.7	60.3	44.4	8.9	1.3	2.3
1998	0.6	0.4	0.4	1.3	0.7	60.0	44.3	9.0	1.3	2.3
1999	0.6	0.4	0.4	1.4	0.7	60.0	44.2	9.2	1.3	2.3
2000	0.6	0.4	0.4	1.4	0.7	60.1	44.1	9.3	1.3	2.3
2001	0.6	0.4	0.4	1.4	0.7	60.3	44.1	9.5	1.3	2.4
2002	0.6	0.4	0.4	1.5	0.6	60.5	44.2	9.6	1.3	2.5
2003	0.6	0.4	0.4	1.5	0.7	60.8	44.2	9.6	1.3	2.6
2004	0.6	0.4	0.4	1.5	0.7	61.0	44.0	9.6	1.3	2.7
2005	0.6	0.4	0.4	1.5	0.7	61.0	43.6	9.9	1.3	2.8
2006	0.6	0.4	0.4	1.5	0.6	60.9	43.5	10.0	1.3	2.8
2007	0.6	0.4	0.4	1.5	0.6	61.0	43.3	10.0	1.3	2.9
2008	0.6	0.5	0.4	1.5	0.6	60.9	43.2	10.0	1.3	3.0
2009	0.6	0.5	0.4	1.6	0.6	61.2	43.4	10.0	1.3	3.0
2010	0.6	0.5	0.4	1.6	0.6	61.1	43.5	10.0	1.3	3.0
2011	0.6	0.5	0.4	1.6	0.6	61.3	43.5	10.0	1.3	3.0
2012	0.6	0.5	0.4	1.6	0.6	61.3	43.5	10.0	1.3	3.0

#### Manure management systems

The distribution of manure management systems is estimated by using different data sources as no statistics available for the inventory purposes exists in Finland. Previous data sources were the study by Seppänen & Matinlassi (1998) and expert judgement from the Rural Advisory Centres (ProAgria) and MTT Agrifood Research Finland. The distribution of manure management systems was re-estimated using data from the Information Centre of the Ministry of Agriculture and Forestry, the results of a questionnaire sent to Regional Employment and Economic Development Centres and to Regional Environment Centres, and estimates of two experts (Sipilä, I. and Kapuinen, P. MTT) in 2009. The method has been described in Grönroos et al. (2009). However, as the study did not result in enough new information, the distribution of different manure management systems is still quite uncertain. A new project concerning manure management and spreading data has started, and the results will be utilized if the quality and amount of information is sufficient. For greenhouse gas inventory, the manure management systems reported are slurry, solid storage, deep litter and pasture, 'solid' includes urine and dung either together or separated (Table 6.3-5).



**Figure 6.3-3** Fraction of manure of dairy cows in different manure management systems



**Figure 6.3-4** Fraction of manure of swine in different manure management systems

**Table 6.3-5** Fraction of manure managed in each manure management system (Original source: Seppänen & Matinlassi (1998); Rural Advisory Centres (ProAgria); MTT Agrifood Research Finland, updated source: Grönroos et al. (2009))

	1990	1995	2000	2005	2010	2011	2012		1990	1995	2000	2005	2010	2011	2012
<b>Dairy cows</b>								<b>Horses</b>							
Pasture	0.25	0.26	0.26	0.26	0.26	0.26	0.26	Pasture	0.36	0.36	0.36	0.36	0.36	0.36	0.36
Slurry	0.23	0.26	0.33	0.46	0.46	0.46	0.46	Slurry	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solid storage	0.51	0.47	0.40	0.27	0.27	0.27	0.27	Solid storage	0.64	0.38	0.38	0.64	0.64	0.64	0.64
Deep litter	0.02	0.01	0.01	0.01	0.01	0.01	0.01	Deep litter	0.00	0.25	0.25	0.00	0.00	0.00	0.00
<b>Suckler cows</b>								<b>Reindeer</b>							
Pasture	0.35	0.36	0.36	0.36	0.36	0.36	0.36	Pasture	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Slurry	0.03	0.03	0.16	0.19	0.19	0.19	0.19	Slurry	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solid storage	0.36	0.36	0.23	0.20	0.20	0.20	0.20	Solid storage	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Deep litter	0.26	0.25	0.25	0.25	0.25	0.25	0.25	Deep litter	0.00	0.00	0.00	0.00	0.00	0.00	0.00
<b>Bulls (&lt;1 year)</b>								<b>Laying hens</b>							
Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slurry	0.30	0.40	0.40	0.40	0.40	0.40	0.40	Slurry	0.00	0.02	0.02	0.02	0.02	0.02	0.02
Solid storage	0.64	0.54	0.54	0.54	0.54	0.54	0.54	Solid storage	0.95	0.93	0.93	0.95	0.95	0.95	0.95
Deep litter	0.06	0.06	0.06	0.06	0.06	0.06	0.06	Deep litter	0.05	0.05	0.05	0.05	0.05	0.05	0.05
<b>Heifers</b>								<b>Chickens</b>							
Pasture	0.36	0.35	0.35	0.35	0.35	0.35	0.35	Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slurry	0.19	0.24	0.24	0.24	0.24	0.24	0.24	Slurry	0.00	0.01	0.01	0.00	0.00	0.00	0.00
Solid storage	0.43	0.40	0.40	0.40	0.40	0.40	0.40	Solid storage	0.95	0.94	0.94	0.95	0.95	0.95	0.95
Deep litter	0.02	0.02	0.02	0.02	0.02	0.02	0.02	Deep litter	0.05	0.05	0.05	0.05	0.05	0.05	0.05
<b>Calves (&lt;1 year)</b>								<b>Cockerels</b>							
Pasture	0.08	0.07	0.07	0.07	0.07	0.07	0.07	Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slurry	0.28	0.35	0.35	0.35	0.35	0.35	0.35	Slurry	0.00	0.01	0.01	0.00	0.00	0.00	0.00

	1990	1995	2000	2005	2010	2011	2012
Solid storage	0.55	0.55	0.55	0.55	0.55	0.55	0.55
Deep litter	0.09	0.03	0.03	0.03	0.03	0.03	0.03
<b>Swine</b>							
Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slurry	0.36	0.52	0.52	0.57	0.59	0.60	0.60
Solid storage	0.58	0.43	0.43	0.38	0.36	0.35	0.35
Deep litter	0.05	0.05	0.05	0.05	0.05	0.05	0.05
<b>Sheep</b>							
Pasture	0.36	0.32	0.32	0.32	0.32	0.32	0.32
Slurry	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solid storage	0.06	0.07	0.07	0.07	0.07	0.07	0.07
Deep litter	0.57	0.61	0.61	0.61	0.61	0.61	0.61
<b>Goats</b>							
Pasture	0.36	0.32	0.32	0.32	0.32	0.32	0.32
Slurry	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solid storage	0.06	0.07	0.07	0.07	0.07	0.07	0.07
Deep litter	0.57	0.61	0.61	0.61	0.61	0.61	0.61

	1990	1995	2000	2005	2010	2011	2012
Solid storage	0.95	0.94	0.94	0.95	0.95	0.95	0.95
Deep litter	0.05	0.05	0.05	0.05	0.05	0.05	0.05
<b>Broiler hens</b>							
Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slurry	0.00	0.01	0.01	0.00	0.00	0.00	0.00
Solid storage	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Deep litter	1.00	0.99	0.99	1.00	1.00	1.00	1.00
<b>Broilers</b>							
Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slurry	0.00	0.01	0.01	0.00	0.00	0.00	0.00
Solid storage	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Deep litter	1.00	0.99	0.99	1.00	1.00	1.00	1.00



### 6.3.2.3 Emission factors and other parameters

#### Nitrous oxide

The IPCC default nitrous oxide emission factors have been used for each manure management system. Defaults were used as no national emission factors were available. The manure management systems included in the inventory are pasture, solid storage, deep litter and slurry (Table 6.3-6). Ammonia volatilisation parameters during manure management have been taken from a thorough literature review, including reduction potentials of different abatement measures (Grönroos et al. 2009). EF for dung and deep litter is the same as for solid storage and urine's EF is the same as for slurry. The EF for slurry was used for separated urine because the conditions in urine tank were considered similar to those in a slurry container with restricted aeration and slow diffusion of N<sub>2</sub>O through the media. No EF for urine exists in either the 1996 IPCC GL or the GPG 2000. Because of the use of slurry EF for separated urine, the N<sub>2</sub>O IEF for solid storage is smaller than the default value.

**Table 6.3-6** IPCC default emission factors for nitrous oxide from manure management and related uncertainties

Manure management system	Emission factor (kg N <sub>2</sub> O-N/kg )	Uncertainty range of EF	Source of the Uncertainty Estimate
Pasture	0.02	-85% / +15% (beta)	Monni & Syri (2003)
Slurry	0.001	-50% / +100% (lognormal)	Penman et al. (2000)
Solid storage	0.02	-85% / +15% (beta)	Monni & Syri (2003)
Urine	0.001	-50% / +100% (lognormal)	Penman et al. (2000)
Dung	0.02	-50% / +100% (lognormal)	Penman et al. (2000)
Deep litter	0.02	-50% / +100% (lognormal)	Penman et al. (2000)

#### Methane

The national emission factors for each cattle subcategory have been calculated by using the IPCC Tier 2 methodology (IPCC 2000, Eq. 4.17). Equations are presented in the Appendix\_6. In calculation of emission factors, both IPCC default values and national data have been used. Emission factors are presented in Table 6.3-7.

For cattle, emission factors have been calculated by using the IPCC (IPCC 1997; IPCC 2000) default values for ash content of manure, Methane Producing Potential (Bo) and Methane Conversion Factor (MCF). Gross energy intake (GE) has been calculated by using national values for digestible energy (DE%), fraction of animal's manure managed annually in each manure management system (MS), average milk production and animal weight. The same values for gross energy intake (GE) for cattle have been used as in calculating methane emissions from enteric fermentation. Volatile solids excretion (VS<sub>i</sub>) has been calculated by using the GE values mentioned above.

For other animals, emission factors have been calculated using the IPCC (IPCC 1997; IPCC 2000) default values for ash content of manure, Methane Producing Potential (Bo), Methane Conversion Factor (MCF) and volatile solids excretion (VS<sub>i</sub>). For MCF, a default value of 10% (IPCC 1997) has been used for slurry instead of 39% (IPCC 2000) due to Finland's climatic conditions. Support for the use of this value is found from a Swedish review (Dustan, 2002) as well as from the IPCC 2006 Guidelines. For deep litter three different values were used, for cattle and swine 10% (see GPG 2000, pg. 4.37 "MCF's are similar to liquid/slurry", also GL06 supports smaller value than 39%, pg.10.46), horses, sheep and goats 1% (GL06 pg. 10.82) and poultry 1.5% (GPG 2000, pg. 4.37). No information about VS<sub>i</sub> for reindeer was available so the IPCC default value for goats was used. For fur animals, the VS<sub>i</sub> value is based on expert judgement, being 0.17 kg/head/day. No default value for Bo for fur animals exists, so the IPCC default value for poultry was used. For reindeer it is assumed that all manure is deposited on pastures and for fur animals it is assumed that all manure is managed as solid.

**Table 6.3-7** National emission factors in 2012 used for calculating methane emissions from manure management

Animal category	Emission factor (kg CH <sub>4</sub> /head/year)
Dairy cows	15.22
Suckler cows	5.44
Bulls	4.38
Heifers	2.58
Calves	2.54
Swine	3.78
<i>Fattening pigs</i>	4.76
<i>Boars</i>	2.28
<i>Weaned pigs</i>	4.76
<i>Sows</i>	2.28
<i>Piglets</i>	2.28
Sheep	0.19
Goats	0.12
Horses	1.39
Poultry	0.02
Reindeer	0.12
Minks and fitches	0.13
Foxes and racoons	0.13

### 6.3.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. A description of uncertainty analysis is included in Section 1.7.

The uncertainties in manure management are estimated by applying Tier 2 Monte Carlo simulation directly to the emission calculation models (MTT calculation model and Nitrogen mass flow model). Uncertainty in methane emissions from manure management has been estimated at  $\pm 12\%$  and uncertainty in nitrous oxide emissions at  $-43\ldots +67\%$ . Animal numbers and related uncertainties used for manure management are the same as for enteric fermentation.

Uncertainties in the direct nitrous oxide emission factors from manure management,  $-60\ldots +100\%$ , are the same as in previous submissions. This is also in line with uncertainty range presented by 2006 IPCC Guidelines. The uncertainty estimate of the methane emission factor for manure management for all species ( $\pm 30\%$ ) was based on uncertainty estimates of other countries, i.e. Norway, the Netherlands, the USA (Rypdal & Winiwarter 2001) and the UK (Charles et al. 1998), complemented with expert judgement. Uncertainty could be reduced by collecting more information about the distribution of different manure management systems used in Finland and by gathering data from gas flux measurements in order to study the suitability of the IPCC default emission factors to the boreal climate, as for nitrous oxide.

The uncertainty in nitrogen excretion values varies between animal species, from 2 to 15%, except for reindeer and other poultry (25%). The amount of N excreted annually by the reindeer is very uncertain. Currently, because of lack of data, the value for goats has been used. Also,  $B_o$  and  $VS_i$  for fur animals and  $VS_i$  for reindeer are uncertain. However, the amount of these emissions is very small and therefore the contribution to the total uncertainties is also small.

As the same calculation method has been used for the years 1990-2012, the time series are considered consistent. For some years animal numbers have not been available (e.g. the number of goats in 1991 and the number of broilers in 1991, 1992, 1993, 1994), so linear interpolation of the data from adjacent years has been used to obtain the data.

### 6.3.4 Source-specific QA/QC and verification

The overview of the quality objectives and QA/QC plan for the Finnish greenhouse gas inventory is given in Section 1.6. The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives. The bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert. In the quality meeting 2014, for example the ERT Review, time schedule and future improvements were discussed and some clarifications were made to the description in the inventory report.

#### General (Tier 1) Quality Control (QC) procedures applied to the category Manure management (CRF 4.B):

The QA/QC plan for the agricultural sector includes the QC measures presented in the GPG 2000 (Table 8.1). These measures are implemented every year during the agricultural inventory. If errors or inconsistencies are found they are documented and corrected. The QC checklist is used during the inventory.

#### Tier 2 QC for activity data:

A checklist is used for ensuring consistency of the activity data in different sections of the agricultural inventory.

#### Tier 2 QC for emission factors:

It is checked annually if new data for updating emission factors have been published. New national data are compared with the emission factors used in the inventory and the applicability of current emission factors in Finland's circumstances is evaluated. The new N excretion value for sows was compared with those in Sweden and Norway and they were found to be in line with each other.

The agricultural inventory has been reviewed annually by the UNFCCC Expert Review Teams, and improvements to the inventory have been made according to the suggestions. No specific verification process has been implemented for the agricultural inventory. However, a case study between Finland and Germany was arranged in August 2004 where Finland's agricultural inventory was reviewed by the German experts. The purpose of the case study was to find potential adjustments cases and to test specific methods to calculate adjustments. The experiences of this exercise have been taken into account in the development of the inventory. Statistics Finland audited the inventory in autumn 2009 and the audit focused especially on recalculations. The results have helped to further improve the inventory.

For the Nitrogen mass flow model, a thorough literature review was made to update the ammonia volatilization parameters (e.g. the reduction potential of different abatement measures). Ammonia measurements were carried out in animal shelters (pig houses and cowsheds) in order to verify the selected emission factors for ammonia and thus the estimates of indirect nitrous oxide emissions and the mass flow of nitrogen. The results suggest that the emission factors chosen for the model in general represent values typical for Finland (Grönroos et al. 2009).

### 6.3.5 Source-specific recalculations

Number of fur animals for 2011 was updated. This affects both CH<sub>4</sub> and N<sub>2</sub>O emissions from manure management. Nitrogen excretion for the whole time series of sows was updated since the data source of the amount of feed digested by sows was changed. The earlier erroneous value of VS of poultry was corrected from 0.2 to 0.02 for the whole time series. The new value was calculated as a weighted average of different poultry groups in a national data set of poultry feed (the same data as for N excretion, see 6.8.2.2).

**Table 6.3-8** Effect of the recalculations on the emissions from manure

	1990	2000	2008	2009	2010	2011
New (Gg CH <sub>4</sub> )	9.64	10.79	12.47	12.32	12.36	12.12
Old (Gg CH <sub>4</sub> )	11.76	13.56	14.62	14.23	14.31	14.28
Difference (Gg CO <sub>2</sub> eq.)	44.5	58.2	45.2	40.3	41.0	45.3
New (Gg N <sub>2</sub> O)	1.5699	1.4044	1.3054	1.3568	1.3751	1.3476
Old (Gg N <sub>2</sub> O)	1.5720	1.4112	1.3050	1.3557	1.3731	1.3737
Difference (Gg CO <sub>2</sub> eq.)	0.63	2.11	-0.11	-0.36	-0.62	8.10

### 6.3.6 Source-specific planned improvements

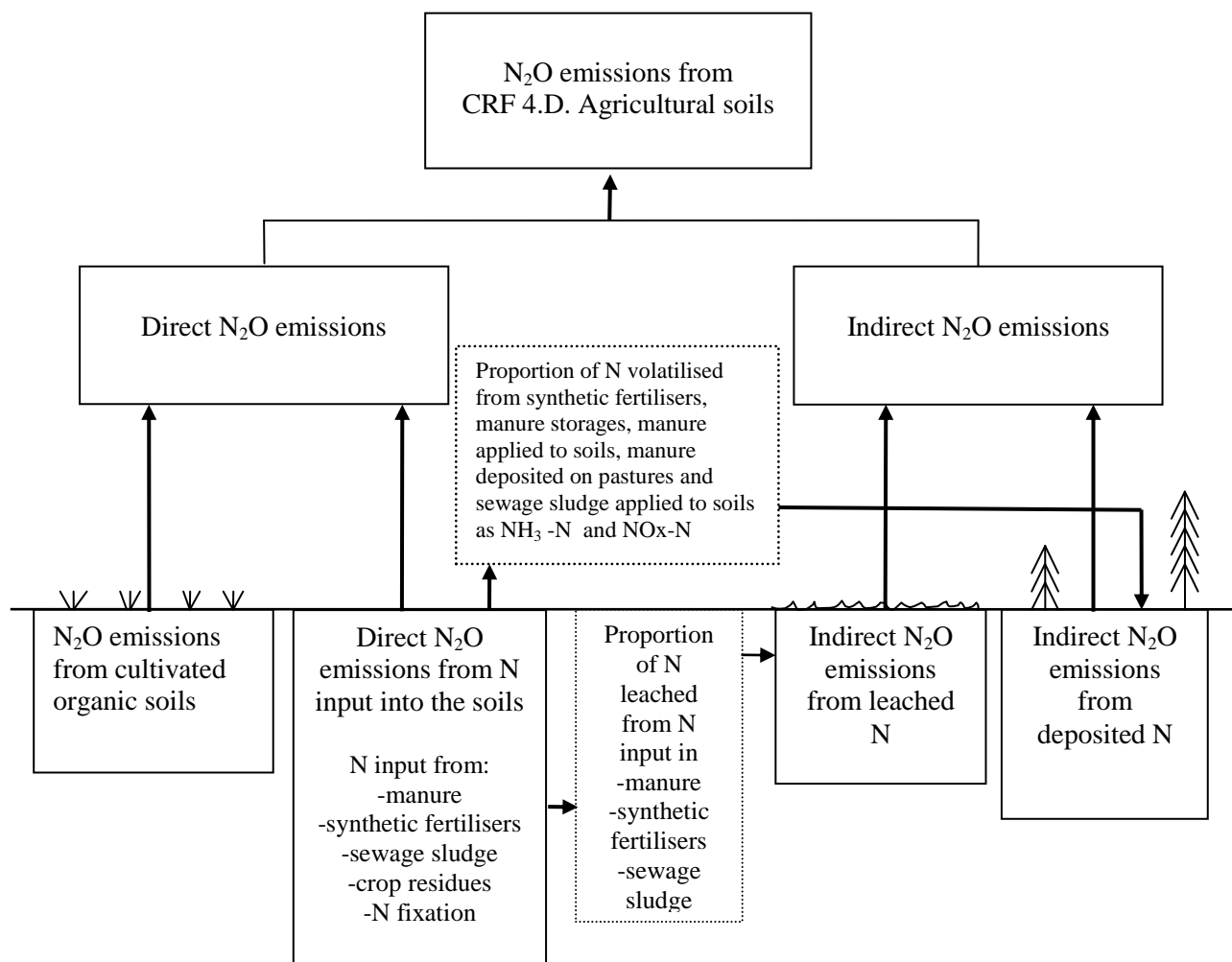
Possibility of updating the AWMS will be explored as a new dataset becomes available in 2014. The 2006 IPCC Guidelines will be taken into use for the 2015 submission.

## 6.4 Agricultural Soils (CRF 4.D)

### 6.4.1 Source category description

Nitrous oxide emissions from agricultural soils (CRF 4.D) are a significant emission source comprising about 60% of total agricultural emissions in 2012, being 3.5 Tg as CO<sub>2</sub> equivalents.

Direct N<sub>2</sub>O emissions include emissions from synthetic fertilisers, animal manure applied to soils, crop residues, N-fixing crops, sewage sludge and cultivation of organic soils. Indirect N<sub>2</sub>O emissions include emissions arising from nitrogen volatilised as ammonia (NH<sub>3</sub>) and other oxides of nitrogen (NO<sub>x</sub>) as well as nitrogen leached from synthetic fertilisers, manure and sewage sludge applied to soils. Also indirect emissions from NH<sub>3</sub> volatilised from manure management systems are included into calculation of indirect N<sub>2</sub>O from atmospheric deposition. Methane emissions or removals from agricultural soils are not estimated because no methodology exists (IPCC 2003, p. 3.83).



**Figure 6.4-1** Reported emissions under the subcategory Agricultural Soils CRF 4.D in the Finnish inventory

**Table 6.4-1** Reported emissions, calculation methods and types of emission factors for the subcategory Agricultural Soils in the Finnish inventory

CRF	Source	Emissions reported	Methods	Emission factor
4.D 1	Direct Soil Emissions			
	- Synthetic Fertilisers	N <sub>2</sub> O	Tier 1	D
	- Animal Manure Applied to Soils	N <sub>2</sub> O	Tier 1	D
	- N-fixing Crops	N <sub>2</sub> O	Tier 1	D
	- Crop Residue	N <sub>2</sub> O	Tier 1	D
	- Cultivation of Histosols	N <sub>2</sub> O	Tier 2	CS
	- Municipal Sewage Sludge Applied to Soils	N <sub>2</sub> O	Tier 1	D
4.D 2	Pasture, Range and Paddock Manure	N <sub>2</sub> O	D	D
4.D 3	Indirect Emissions			
	- Atmospheric Deposition	N <sub>2</sub> O	Tier 1	D
	- Nitrogen Leaching and Run-off	N <sub>2</sub> O	Tier 1	D
4.D 4	Other	NO	NA	NA

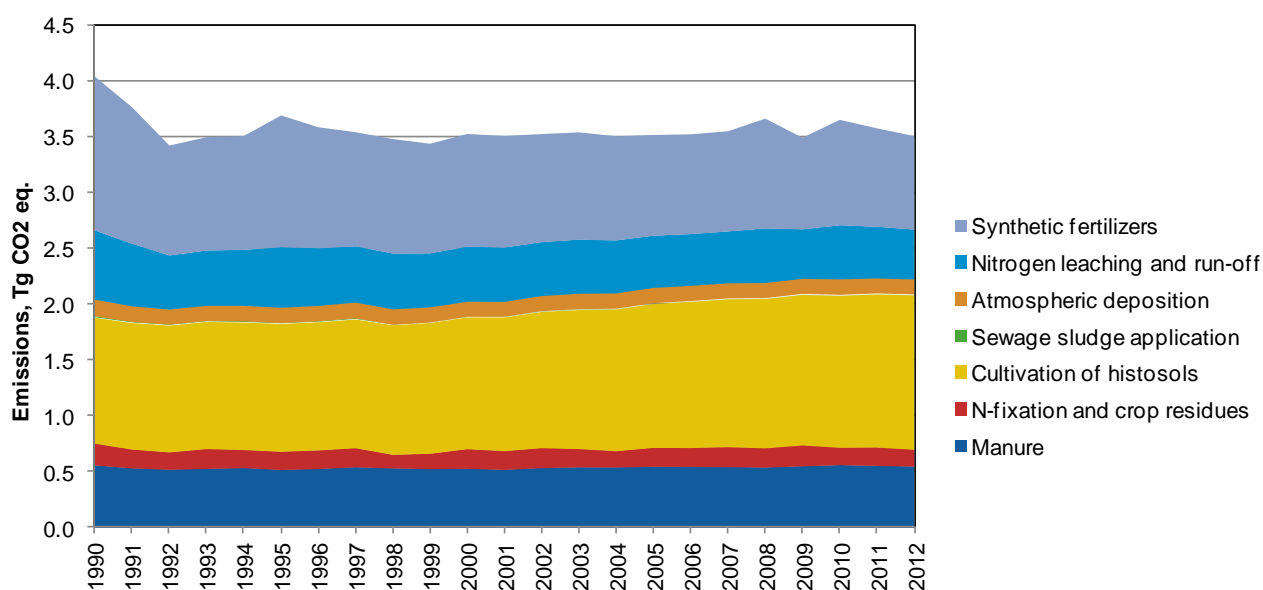
Nitrous oxide is produced in agricultural soil as a result of microbial nitrification-denitrification processes. The processes are driven by drivers like the availability of mineral nitrogen substrates and carbon, soil moisture, temperature and pH. Thus, addition of mineral nitrogen in the form of synthetic fertilisers, manure, crop residue, N-fixing crops and sewage sludge enhances the formation of nitrous oxide emissions (Smith et al., 2004). Nitrous oxide emissions also arise as a result of the mineralisation of soil organic matter, which is particularly intensive in cultivated organic soils.

Nitrous oxide emissions from agricultural soils have decreased by 13%, from 13.0 Gg in 1990 to 11.3 Gg in 2012 (Table 6.4-2 and Figure 6.4-2). The main reasons for the decreasing trend are the reduction in animal numbers, which affects the amount of nitrogen excreted annually to soils and the fall in the amount of synthetic fertilisers used annually. Some parameters, such as the annual crop yields affecting the amount of crop residues produced, cause the fluctuation in the time series but as the share of these emissions is minor this does not have much effect on the overall nitrous oxide emissions trend. The emissions from cultivated organic soils have increased as a result of the increased area of these soils.

**Table 6.4-2** Direct and indirect nitrous oxide emissions from agricultural soils by source category (Gg)

Year	Direct emission sources							Indirect emission sources		Total
	S	MS	MP	C	N	O	SW	A	L	
1990	4.42	1.18	0.61	0.01	0.60	3.65	0.03	0.49	1.99	12.99
1991	3.92	1.11	0.60	0.04	0.49	3.66	0.03	0.45	1.80	12.10
1992	3.16	1.09	0.58	0.04	0.44	3.67	0.02	0.44	1.56	11.01
1993	3.26	1.10	0.59	0.05	0.52	3.68	0.02	0.44	1.59	11.25
1994	3.27	1.13	0.59	0.02	0.49	3.69	0.03	0.45	1.61	11.28
1995	3.78	1.10	0.57	0.02	0.49	3.70	0.02	0.44	1.74	11.87
1996	3.48	1.12	0.58	0.02	0.51	3.71	0.02	0.45	1.66	11.53
1997	3.28	1.16	0.58	0.02	0.52	3.73	0.02	0.46	1.62	11.39
1998	3.29	1.14	0.57	0.01	0.38	3.75	0.01	0.45	1.61	11.19
1999	3.15	1.12	0.57	0.01	0.42	3.78	0.01	0.44	1.56	11.06
2000	3.24	1.12	0.58	0.02	0.54	3.82	0.01	0.44	1.58	11.34
2001	3.21	1.10	0.57	0.02	0.51	3.87	0.01	0.43	1.56	11.28
2002	3.10	1.14	0.58	0.02	0.55	3.94	0.01	0.44	1.55	11.34
2003	3.08	1.16	0.58	0.02	0.50	4.02	0.01	0.45	1.56	11.39
2004	2.99	1.16	0.58	0.01	0.45	4.10	0.01	0.45	1.52	11.28
2005	2.90	1.17	0.58	0.01	0.52	4.17	0.00	0.45	1.50	11.31
2006	2.87	1.17	0.59	0.01	0.52	4.23	0.00	0.45	1.49	11.33
2007	2.88	1.17	0.58	0.02	0.55	4.28	0.00	0.45	1.49	11.42
2008	3.15	1.15	0.58	0.01	0.53	4.32	0.00	0.45	1.57	11.78
2009	2.63	1.18	0.59	0.02	0.58	4.36	0.00	0.45	1.42	11.23
2010	3.03	1.19	0.61	0.02	0.48	4.40	0.00	0.46	1.56	11.75
2011	2.83	1.18	0.61	0.02	0.50	4.43	0.00	0.45	1.48	11.50
2012	2.69	1.16	0.60	0.01	0.46	4.47	0.00	0.45	1.44	11.28
Share of total(%) in 2012 *	23.8	10.3	5.3	0.1	4.1	39.6	0.0	4.0	12.7	100

\* The sum of the shares differs from 100 due to rounding. S=synthetic fertilisers, MS= manure applied to soils, MP=manure deposited on pastures, C=crop residues, N=N-fixation, O=cultivation of organic soils, SW=sewage sludge application, A=atmospheric deposition, L=leaching and run-off

**Figure 6.4-2** Nitrous oxide emissions from agricultural soils (atmospheric deposition, nitrogen leaching and run-off are indirect emissions, all other direct), Tg CO<sub>2</sub> eq.

## 6.4.2 Methodological issues

### 6.4.2.1 Methods

Direct soil emissions (CRF 4.D 1) include emissions from synthetic fertilisers, animal manure applied to soils, N fixing crops, crop residues, sewage sludge applied to soils and cultivation of organic soils. Manure deposited on pastures is reported under CRF 4.D 2 Pasture, range and paddock manure. Indirect emissions include emissions from atmospheric deposition (CRF 4.D 3.1) and leaching and run-off (CRF 4.D 3.2). Emissions have been calculated by using the IPCC methodology (IPCC 1997, 2000). Direct emissions have been calculated using Equation 4.20 in the GPG 2000. Indirect emissions have been calculated using Equation 4.32 for atmospheric deposition and 4.36 for leaching and run-off (IPCC 2000). Detailed equations are provided in the Appendix\_6. Activity data sources of this category are presented in Table 6.4-3 and emission factors in Table 6.4-9.

#### *Direct soil emissions and pasture, range and paddock manure*

N input data from synthetic fertilisers, manure, sewage sludge and N fixation as well as crop residues is used for calculating direct soil emissions. According to the GPG 2000 the amount of nitrogen applied to soils has been corrected with the fraction of nitrogen volatilised as  $\text{NH}_3$  and  $\text{NO}_x$  from the synthetic fertilisers ( $\text{Frac}_{\text{GASF}}$ ) and from manure and sewage sludge ( $\text{Frac}_{\text{GASM}}$ ) (Table 6.4-10) and subtracted from the total amount of nitrogen excreted by animals to get the amount of N applied on fields. The fractions of volatilised  $\text{NH}_3$ -N from manure and synthetic fertilisers have been calculated with the N mass flow model (Grönroos et al. 2009, see Section 6.3.2.1).  $\text{Frac}_{\text{GASM}}$  includes ammonia emissions also from manure management systems. For sewage sludge, the same  $\text{Frac}_{\text{GASM}}$  as for manure has been used (GPG 2000, pg. 4.74) because no data are available to use different value. Ammonia from pasture manure now accounts ca. 4.4% of nitrogen.  $\text{Frac}_{\text{GASM}}$  is ca. 25% and  $\text{Frac}_{\text{GASF}}$  ca. 1.5%.

Synthetic fertilizers and manure are divided in different groups and two field types (arable and grass).  $\text{NH}_3$  emissions depend on the type of fertilizer and application method. The model takes into account various  $\text{NH}_3$  abatement measures (e.g. incorporation with ploughing, injection) and their ability to reduce ammonia emissions on fields. More detailed information about the model parameters are found in Grönroos et al. (2009). The amount of nitrogen applied on fields after subtracting the volatilized  $\text{NH}_3$ -N is multiplied with the default EF for direct soil emissions. Nitrous oxide emissions from sewage sludge, crop residues (burned amount subtracted) and N-fixation are also calculated with the IPCC methodology. Nitrous oxide emissions from cultivated organic soils have been calculated with the IPCC methodology by dividing the area into grasses and other crops and using national EFs for both crop types.

#### *Indirect emissions*

Nitrous oxide emissions from the atmospheric deposition are calculated from the total amount of  $\text{NH}_3$ -N volatilized in manure storages and during spreading of manure, sewage sludge and mineral fertilizers as well as manure excreted on pastures (see Section 6.3.2 1) by multiplying the total amount of N volatilised with the specific emission factor for atmospheric deposition (see Table 6.4-9).

Nitrous oxide emissions from leaching and run-off are calculated from the amount of N input from fertilisers (synthetic, manure and sewage sludge) of which estimated fraction is leached into the watercourses. Fraction of N leached ( $\text{Frac}_{\text{LEACH}}$ ) is calculated from the total N input into the soil (volatilised N not subtracted as guided by the GPG 2000) and is used for calculating  $\text{N}_2\text{O}$  emissions from leaching and run-off. Emission factors for calculating indirect emissions are presented in Table 6.4-10.

### 6.4.2.2 Activity data

Activity data are national and received mainly from the annual agricultural statistics of the Ministry of Agriculture and Forestry (Table 6.4-3). Other data sources are the Finnish Environment Institute (the amount of nitrogen in sewage sludge) and Finnish Forest Research Institute (area of cultivated organic soils). Animal numbers are the same as those used for calculating enteric fermentation and manure management emissions



(Table 6.2-3). The distribution of different manure management systems and the amount of nitrogen excreted per animal are the same as those used for calculating nitrous oxide emissions from manure management. The amount of synthetic fertilisers sold annually has been received from the annual agricultural statistics of the Ministry of the Agriculture and Forestry and the amount of sewage sludge applied annually has been obtained from the VAHTI system (Section 1.4 and Annex 2) see Table 6.4-4. Crop yields of cultivated plants have been taken from agricultural statistics (Ministry of Agriculture and Forestry) (Table 6.4-5). Vegetables grown in the open have also been included in the emission estimate of crop residues. Vegetable yields were taken from literature (Horticultural Enterprise Register) and Yearbook of Farm Statistics (Table 6.4-6). The area of cultivated organic soils was derived as described in Section 7.1.2. The division of the area to area under grass vs. other crops was obtained from the statistics of the Ministry of Agriculture and Forestry for years 1995 and 2008 and the result for the other years was derived by interpolation or extrapolation. There are no statistics for the whole data series on the distribution of fertiliser types but Table 6.4-8 shows that most mineral fertilisers are sold as NPK. The total amount of nitrogen sold annually in Finland was divided by fertiliser type using the information obtained from Yara Finland Ltd (Marko Toimela, pers.comm. 21.11.2007). In Finland, placement fertilisation is typically used for cereals. Based on the emission reduction efficiencies of different manure application and emission abatement methods, it was supposed that placement fertilisation reduces ammonia volatilization by 50% compared to surface application of mineral fertilisers. Thus, emission factors for arable land were multiplied by 0.5 except for nitrogen solutions for which placement fertilisation is not used.

**Table 6.4-3** Activity data sources for calculating nitrous oxide emissions from agricultural soils

Activity data	Data source
Number of cattle, sheep, goats, poultry, reindeer	Information Centre of the Ministry of Agriculture and Forestry (Matilda Database, Yearbook of Farm Statistics)
Number of horses	Finnish Trotting and Breeding Association ( <a href="http://www.hippos.fi">http://www.hippos.fi</a> )
Number of fur animals	Finnish Fur Breeders Association
Distribution of manure management systems	Rural Advisory Centres, MKL (1993); Seppänen & Matinlassi (1998), Grönroos et al. (2009)
Nitrogen excretion by animal type	MTT Agrifood Research Finland
Amount of sewage sludge applied annually in agricultural soils	VAHTI system
Crop statistics	Information Centre of the Ministry of Agriculture and Forestry (Matilda Database, Yearbook of Farm Statistics, Horticultural Enterprise Register)
Ammonia emission estimates	Nitrogen mass flow model, Grönroos et al.(2009)
Area of cultivated organic soils	Finnish Forest Research Institute
The amount of synthetic fertilisers sold annually	Yearbook of Farm Statistics

**Table 6.4-4** Nitrogen input to soils via synthetic fertilisers, manure and sewage sludge application (Mg N a<sup>-1</sup>) (the fraction lost as NH<sub>3</sub> and NO<sub>x</sub> has not been subtracted)

Year	Synthetic fertilisers <sup>1</sup>	Manure <sup>2</sup>	Sewage Sludge <sup>3</sup>
1990	228 470	106 749	2 202
1991	202 462	101 259	1 749
1992	163 229	99 232	1 532
1993	168 199	100 365	1 404
1994	169 138	101 940	2 063
1995	195 460	99 139	1 316
1996	179 529	100 665	1 548
1997	169 345	103 920	1 696
1998	169 928	102 016	575
1999	162 700	100 644	644
2000	167 276	101 023	513
2001	165 621	99 010	725
2002	160 403	102 248	616

Year	Synthetic fertilisers <sup>1</sup>	Manure <sup>2</sup>	Sewage Sludge <sup>3</sup>
2003	159 288	103 926	754
2004	154 708	103 583	441
2005	149 562	104 951	143
2006	148 161	104 489	156
2007	148 784	104 309	147
2008	162 905	103 423	257
2009	136 009	105 443	266
2010	156 523	107 126	338
2011	146 189	105 595	148
2012	138 900	104 587	148*

<sup>1</sup> Sales of fertilisers on farms. Source: Yearbook of Farm Statistics

<sup>2</sup> Includes manure applied to agricultural soils as well as deposited on pastures.

<sup>3</sup> Source: Finnish Environment Institute, VAHTI system

\*Data not available at the time of inventory preparation, assumed to be the same as in 2011

**Table 6.4-5** Total yields of the most important crops in Finland (Gg a<sup>-1</sup>)

Year	WW	SW	R	B	O	MC	FC	T	Pe	Po	S	C
1990	137	490	244	1 720	1 662	44	-	117	9	881	1 125	0.2
2008	87	701	61	2 129	1 213	37	121	89	7	684	468	0.2
2009	64	824	42	2 170	1 114	45	174	140	11	731	569	0.2
2010	89	636	69	1 340	810	47	103	179	13	659	542	0.2
2011	173	801	78	1 514	1 043	47	163	115	12	673	676	0.2
2012	105	782	64	1 581	1 073	47	184	73	9	490	399	0.2

Source: Yearbook of Farm Statistics WW=winterwheat, SW=spring wheat, R=Rye, B=Barley, O=Oats, MC=Mixed grain, FC=Cereals harvested green, T=Turnip rape/rape, Pe=Peas, Po=Potatoes, S=Sugar beet, C=Clover seed. C assumed to stay at the level of 2005 in 2005-2010. FC is included in wheat, barley, oats and mixed grain for the period 1990-2006.

**Table 6.4-6** Total yields of the most important vegetables grown in the open in Finland (Gg a<sup>-1</sup>)

Year	Garden pea	White cabbage	Cauliflower	Carrots	Red beet	Swede	Celeriac	Total
1990	5.8	21.1	4.4	31.4	10.7	9.3	1.7	84.3
2008	5.7	18.8	2.8	60.5	11.0	12.5	0.5	111.8
2009	6.1	23.8	3.7	70.4	12.6	14.0	0.8	131.4
2010	4.6	22.2	2.3	67.3	12.3	11.0	0.7	120.3
2011	6.3	23.2	2.9	72.6	14.3	15.6	0.7	135.5
2012	6.3	21.3	3.0	55.6	9.8	12.1	0.6	108.6

**Table 6.4-7** Area of cultivated organic soils in Finland (ha)

Year	Total area of cultivated organic soils, ha	Organic soils on cereals, ha	Organic soils on grass, ha
1990	309 918	140 417	169 501
1991	309 601	141 940	167 661
1992	308 632	143 158	165 474
1993	307 695	144 380	163 315
1994	306 828	145 625	161 203
1995	306 194	146 973	159 221
1996	305 152	148 116	157 036
1997	304 972	149 671	155 301
1998	305 249	151 450	153 799
1999	306 280	153 611	152 669
2000	307 339	155 797	151 542
2001	310 208	158 922	151 286
2002	314 276	162 698	151 578
2003	319 052	166 889	152 163
2004	323 686	171 056	152 630
2005	327 017	174 577	152 440
2006	330 353	178 137	152 216
2007	332 562	181 118	151 444
2008	334 060	183 733	150 327
2009	335 091	186 104	148 987
2010	336 417	188 652	147 765
2011	337 511	191 083	146 428
2012	309 918	140 417	169 501

**Table 6.4-8** Distribution of mineral N-fertilizers used in Finland by fertilizer type (Source: Yara Finland)

Fertilizer type	% of applied N
Ammonium sulphate	0.0
Ammonium nitrate	0.0
Calcium ammonium nitrate	19.6
Anhydrous ammonia	0.0
Urea	0.0
Nitrogen solutions <sup>1)</sup>	0.04
Ammonium phosphates	0.13
Other NK and NPK	80.2
Nitrate only	0.05

#### 6.4.2.3 Emission factors and other parameters

IPCC default emission factors have been used for calculating nitrous oxide emissions from agricultural soils (Table 6.4-9) as no national emission factors were available. However, the emission factors for organic soils on grass and other crops are based on national data (Monni et al. 2007). The emission factors were calculated based on published results on annual fluxes measured with flux chambers on five different peat fields. There were ten annual flux results measured year-around from grass fields and ten from fields growing other crops. The means of the measurement results minus the proportion of the emissions arising from the use of mineral fertilisers are used as the emission factors. The IEF of organic soils is increasing in the time series as more land is used for other crops and less for grass.

The values for  $\text{Frac}_{\text{GASF}}$ ,  $\text{Frac}_{\text{GASM}}$  and  $\text{Frac}_{\text{LEACH}}$  are national values differing from the IPCC default values.

The parameters used in the Nitrogen mass flow model, e.g. for ammonia abatement measures and emission factors can be found in Grönroos et al. 2009 (see also Section 6.3.2.1 “Nitrogen mass flow model”).

It is estimated that nitrogen leaching is less than the IPCC default value in Finnish conditions. The value used in the inventory is 15% and estimated based on Rekolainen et al. (1993). Finland does not assume leaching from deposited nitrogen. In Finland most of the nitrogen is deposited on forest land (and other non-agricultural land). The GPG on LULUCF assumes that leaching from forests is small. This is very small figure when compared to leaching from agricultural land (about 16.6 kg/ha in 2007).

IPCC default values (IPCC 2000, Table 4.16), and if a default value was not available, values based on expert judgement, for residue/crop product ratio, dry matter fraction and nitrogen fraction for each crop species have been used (Table 6.4-11).

**Table 6.4-9** Emission factors used for calculating direct and indirect nitrous oxide emissions from agricultural soils

Emission source	Emission factor	Reference
<b>Direct soil emissions</b>		
Synthetic fertilisers	0.0125 kg N <sub>2</sub> O-N/kg N	IPCC (2000), Table 4.17
Animal wastes applied to soils	0.0125 kg N <sub>2</sub> O-N/kg N	IPCC (2000), Table 4.17
N-fixing crops	0.0125 kg N <sub>2</sub> O-N/kg N input	IPCC (2000), Table 4.17
Crop residue	0.0125 kg N <sub>2</sub> O-N/kg N input	IPCC (2000), Table 4.17
Cultivation of organic soils on cereals	11.7 kg N <sub>2</sub> O-N/ha/a	Monni et al. (2007)
Cultivation of organic soils on grass	4.0 kg N <sub>2</sub> O-N/ha/a	Monni et al. (2007)
Atmospheric deposition	0.01 kg N <sub>2</sub> O-N/kg NH <sub>3</sub> -N & NO <sub>x</sub> -N deposited	IPCC (2000), Table 4.18
Nitrogen leaching and run-off	0.025 kg N <sub>2</sub> O-N/kg N/a	IPCC (2000), Table 4.18
Sewage sludge spreading	0.0125 kg N <sub>2</sub> O-N/kg N load	IPCC (1997) (EF <sub>1</sub> )
<b>Animal production</b>		
N excretion on pasture range and paddock	0.020 kg N <sub>2</sub> O-N/kg N/a	IPCC (1997)

**Table 6.4-10** Fraction of N lost through leaching and run-off and volatilisation from synthetic fertilisers, manure and sewage sludge

Parameter	Abbreviation	Value	Reference
Fraction of N input that is lost through leaching or run-off	Frac <sub>LEACH</sub>	0.15	Rekolainen (1989), Rekolainen et al. (1993) Rekolainen et al. (1995)
Fraction of N input that volatilises as NH <sub>3</sub> and NO <sub>x</sub> from synthetic fertilisers	Frac <sub>GASF</sub>	0.015	Based on Nitrogen mass flow model, Grönroos et al. (2009)
Fraction of manure N input that volatilises as NH <sub>3</sub> and NO <sub>x</sub>	Frac <sub>GASM</sub>	0.25	Based on Nitrogen mass flow model, Grönroos et al. (2009)

**Table 6.4-11** Residue to crop ratio, dry matter fraction and nitrogen content of crops included in the inventory

Crop	Resi/Crop <sub>i</sub>	Frac <sub>DM</sub>	Frac <sub>NCR</sub>
Winter wheat	1.30 <sup>1)</sup>	0.83 <sup>1)</sup>	0.0028 <sup>1)</sup>
Spring wheat	1.30 <sup>1)</sup>	0.83 <sup>1)</sup>	0.0028 <sup>1)</sup>
Rye	1.60	0.83 <sup>1)</sup>	0.0048
Barley	1.20	0.83	0.0043
Oats	1.30	0.83	0.0070
Mixed grain, cereals	1.34 <sup>2)</sup>	0.83 <sup>1)</sup>	0.0140 <sup>2)</sup>
Cereals harvested green	1.27	0.83	0.005
Turnip rape/rape	3.00 <sup>4)</sup>	0.83 <sup>4)</sup>	0.0150 <sup>4)</sup>
Peas	1.50	0.87	0.0350 <sup>3)</sup>
Potatoes	0.40	0.45	0.0110

Crop	Res/Crop <sub>i</sub>	Frac <sub>DM</sub>	Frac <sub>NCR</sub>
Sugar beet	0.20 <sup>4)</sup>	0.15	0.023 <sup>4)</sup>
Clover seed	1.30 <sup>4)</sup>	0.83 <sup>4)</sup>	0.048 <sup>4)</sup>
Vegetables <sup>5)</sup>	0.20 <sup>6)</sup>	0.15 <sup>7)</sup>	0.015 <sup>8)</sup>

<sup>1)</sup> The IPCC default value for wheat used.

<sup>2)</sup> Average of winter wheat, spring wheat, rye, barley and oats.

<sup>3)</sup> National value, obtained by expert judgement.

<sup>4)</sup> No IPCC default value available, the value obtained by expert judgement.

<sup>5)</sup> Includes garden pea, white cabbage, cauliflower, carrots, red beet, swede and celeriac.

<sup>6), 7)</sup> Assumed to be the same as for sugar beet.

<sup>8)</sup> The IPCC default value used.

### 6.4.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. A description of uncertainty analysis is included in Section 1.7.

The uncertainties in N<sub>2</sub>O emissions from agricultural soils are estimated by applying Tier 2 Monte Carlo simulation directly to the emission calculation models (MTT calculation model and Nitrogen mass flow model). The uncertainty in direct nitrous oxide emissions from agricultural soils was estimated at -71...+118%, from pasture at -70...+194% and uncertainty in indirect nitrous oxide emissions at -80...+294%.

The uncertainty in direct nitrous oxide emission factor for agricultural soils was revised since last inventory submission based on the uncertainty range given in IPCC 2006 Guidelines (0.03-3%). Compared to the emission factor used (1.25%) the uncertainty range is -76...+140% (lognormal distribution). The uncertainty in direct nitrous oxide emission factor for manure in pasture was updated to -65...+200% based on the uncertainty range given in IPCC 2006 Guidelines. Uncertainties in the national emission factors for nitrous oxide from histosols (grass and cereals) are estimated at -100...+210% (lognormally distributed) based on Monni et al. (2006). The uncertainty in indirect nitrous oxide emission factor from atmospheric deposition is estimated at -90...+400% based on uncertainty range in IPCC 2006 Guidelines and the uncertainty in indirect nitrous oxide emission factor for leaching is the same as in previous submissions, -94...+380%. Uncertainty of emission factors is due to both lack of knowledge of the emission generating processes and high natural variability, which make estimation of the average annual emission factor difficult.

Activity data and related uncertainties used for calculating nitrous oxide emissions from agricultural soils were partly the same as in the calculation of nitrous oxide emissions from manure management (CRF 4.B). Uncertainty estimates of other activity data were based on expert judgement.

Due to consistent use of data sources the time series are considered consistent.

### 6.4.4 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6. The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives in Agriculture sector. The bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert. In the quality meeting 2014, for example the ERT Review, time schedule and future improvements were discussed and some clarifications were made to the description in the inventory report.

#### General (Tier 1) Quality Control (QC) procedures applied to the category Agricultural soils (CRF 4.D):

The QA/QC plan for the agricultural sector includes the QC measures based on the guidelines of the GPG 2000 (Table 8.1). These measures are implemented every year during the agricultural inventory. If errors or inconsistencies are found they are documented and corrected. The QC checklist is used during the inventory.

Tier 2 QC for activity data:

A checklist is used for ensuring consistency of the activity data in different sections of the agricultural inventory.

Tier 2 QC for emission factors:

It is checked annually if new data for updating emission factors have been published. New national data are compared with the emission factors used in the inventory and the applicability of current emission factors in Finland's circumstances is evaluated. No new data were available for this inventory for updating the emission factors.

The agricultural inventory has been reviewed annually by the UNFCCC Expert Review Teams, and improvements to the inventory have been made according to the suggestions. No specific verification process has been implemented for the agricultural inventory yet. However, a case study between Finland and Germany was arranged in August 2004 where Finland's agricultural inventory was reviewed by the German experts. The purpose of the case study was to find potential adjustments cases and to test specific methods to calculate adjustments. The experiences of this exercise have been taken into account in the development of the inventory. Statistics Finland audited the inventory in autumn 2009 and the audit focused especially on recalculations. The results have helped to further improve the inventory.

### *6.4.5 Source-specific recalculations*

Area of cultivated organic soils was updated for whole time series. Fur animal number was updated (2011). The amount of crop residues of mixed cereals was increased since the amount of grain+pulse mixtures was added. The time series are consistent.

### *6.4.6 Source-specific planned improvements*

No source-specific improvements are planned at the moment.

## 6.5 Field Burning of Agricultural Residues (CRF 4.F)

### 6.5.1 Source category description

Field burning of crop residues is a source of methane and nitrous oxide. Carbon dioxide from biomass burning is not reported as it is assumed that carbon is reabsorbed by the biomass during growing season. Also, non-greenhouse gases carbon monoxide and nitrogen monoxide are emitted from burning of residue biomass. They are reported separately and not included in the total amount of greenhouse gas emissions.

According to the Decree 189/2009 of the Ministry of Agriculture and Forestry field burning of crop residues has to be avoided and is allowed only if it is necessary in order to succeed in sowing or to prevent weeds or pests. According to several agricultural experts residue burning on fields occurs only in small scale in Finland and is becoming increasingly rare. The machinery is usually able to manage the excess straw left on fields after harvesting. Cereal (especially rye) straw is the most important crop residue that may be burned on fields. Straw is mainly left on field but a minor part is used for feed, litter in animal shelters or burning in boilers.

The small emissions of estimated occasional field burning of cereal straw (wheat, barley, oats, rye) are included in the inventory.

**Table 6.5-1** Reported emissions, calculation methods and types of emission factors for the subcategory Field Burning of Agricultural Residues in the Finnish inventory

CRF	Source	Emissions reported	Method	Emission factor
4.F 1	Cereals	CH <sub>4</sub> , N <sub>2</sub> O	D	D
4.F 2	Pulses	NO	NA	NA
4.F 3	Tubers and Roots	NO	NA	NA
4.F 4	Sugar Cane	NO	NA	NA
4.F 5	Other	NO	NA	NA

### 6.5.2 Methodological issues

#### 6.5.2.1 Methods

The emissions were calculated according to the guidelines in the 1996 IPCC GL reference manual and the default workbook was used for the calculations. The amount of C and N released from the burned residue was determined based on the C fraction and C/N ratio given in the manual. The N and C values were converted to nitrous oxide and methane emissions by multiplying with the conversion ratios 44/28 and 16/12, respectively.

#### 6.5.2.2 Activity data

The annual crop yields for cereals and other crops were based on data from the Yearbook of Agricultural Statistics. The share of straw burned in 2012 was estimated as 0.2% of the total amount of straw.

The share of burned residue from total cereal residue on the fields for the years 1990-2012 rely on the 2007 estimate made by several experts on crop cultivation in different parts of Finland and is estimated on the basis of the annual rye yield. The trend of residue burning is assumed to follow the trend of rye crop yield as rye is the most common straw burned on fields. The rye crops fluctuate from year to year. The annual fractions of cereal residue burned are listed in Table 6.5-2. The IPCC default values were used for residue-crop ratio (1.2-1.6), fraction oxidised (0.9), carbon fraction (0.471, average of wheat and barley), nitrogen-carbon ratio (0.012), and dry matter fraction (0.83). In addition, the default values for emission rates and molecular weight conversion factors were used.

The fraction of burned residue of all residues (IPCC 2000, eq. 4.29,  $\text{Frac}_{\text{BURN}}$ ) was calculated by dividing the amount of nitrogen in burned straw with the amount of nitrogen in total residue left on the field.

**Table 6.5-2** Estimation of the burned fraction

Year	Rye yield, Gg	Frac of residue burned, cereals	Frac of residue burned, total residue
1990	244.2	0.007	0.00058
1991	28.2	0.001	0.00048
1992	26.6	0.001	0.00122
1993	62.9	0.002	0.00046
1994	22.2	0.001	0.00115
1995	57.7	0.002	0.00189
1996	86.9	0.003	0.00101
1997	47.3	0.001	0.00108
1998	49.3	0.001	0.00048
1999	23.6	0.001	0.00245
2000	108.2	0.003	0.00137
2001	64.1	0.002	0.00159
2002	73.1	0.002	0.00160
2003	72.8	0.002	0.00139
2004	62.4	0.002	0.00069
2005	32.4	0.001	0.00102
2006	50.9	0.001	0.00185
2007	86.7	0.0025*	0.00136
2008	60.8	0.0018	0.00123
2009	41.7	0.0018	0.00105
2010	69.0	0.0018	0.00122
2011	78.4	0.0018	0.00133
2012	64.1	0.0018	0.00058

\*an estimate based on judgement by national experts. Other values are estimated based on rye yield and burned fraction in 2007. Value for 2008 was used in 2009, 2010 and 2011.

### 6.5.2.3 Emission factors and other parameters

The default values for emission rates (0.007 for  $\text{N}_2\text{O}$  and 0.005 for  $\text{CH}_4$ ) and molecular weight conversion factors were used.

### 6.5.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. A description of uncertainty analysis is included in Section 1.7.

The uncertainties in emissions from field burning of agricultural residues are estimated by applying Tier 2 Monte Carlo simulation directly to the MTT emission calculation models. Uncertainties in emission factors are based on the ranges presented in 1996 IPCC GL, whereas the uncertainties in activity data are based on expert judgement. Uncertainty in methane emissions from field burning of agricultural residues is estimated at -46...+55% and uncertainty in nitrous oxide emissions at -38...+44%.

### 6.5.4 Source-specific QA/QC and verification

QA/QC and verification are the same as in 6.4.4.

### 6.5.5 Source-specific recalculations

The fraction of total residue burned changed a little due to the addition of mixed grain with pulses to the amount of total residue.



### 6.5.6 *Source-specific planned improvements*

No source-specific improvements are planned at the moment but the 2006 IPCC Guidelines will be taken into use for the 2015 submission.

## Appendix\_6a

### *The equations used in the calculation of greenhouse gas emissions from the Agriculture sector*

#### *1) Equations for calculating methane emissions from enteric fermentation of horse, swine, fur animals and goat*

The IPCC Tier 1 approach, Equations 4.12 and 4.13 in IPCC 2000,

Methane emission (Gg/year) = emission factor (*EF*) (kg/animal/year) x number of animals/(10<sup>6</sup> kg/Gg)

Total CH<sub>4</sub> emissions =  $\sum_i E_i$

*Index<sub>i</sub>* = sums all livestock categories and subcategories

*E<sub>i</sub>* = emissions for the *i*<sup>th</sup> livestock categories and subcategories

#### *2) Equations for calculating methane emissions from enteric fermentation of cattle*

In the IPCC Tier 2 approach, the emission factor for each cattle subcategory has been calculated according to Equation 4.14 in the GPG2000:

$EF = (GE * Y_m * 365 \text{ days/year}) / (55.65 \text{ MJ/kg CH}_4)$ , where

*GE* = Gross energy intake (MJ/animal/day)

*Y<sub>m</sub>* = Methane conversion rate, fraction of gross energy in feed converted to methane (IPCC default value 0.06 used)

The national value for gross energy intake (*GE*) of cattle has been used. The value of *GE* for each cattle subgroup has been calculated by using a slightly modified version of Eq. 4.11 in the GPG 2000.

$GE = \{[(NE_m + NE_a + NE_l + NE_p) / (NE_{ma}/DE)] + [(NE_g) / (NE_{ga}/DE)]\} / (DE/100)$

where,

*NE<sub>m</sub>* = Net energy required by the animal for maintenance, MJ/day

*NE<sub>a</sub>* = Net energy for animal activity, MJ/day

*NE<sub>l</sub>* = Net energy for lactation, MJ/day (dairy cows, suckler cows)

*NE<sub>p</sub>* = Net energy required for pregnancy, MJ/day (dairy cows, suckler cows)

*NE<sub>g</sub>* = Net energy needed for growth, MJ/day (bulls, heifers, calves)

Note that the original IPCC equation also has the following terms that have now been excluded: *NE<sub>mobilised</sub>*, *NE<sub>w</sub>*, and *NE<sub>wool</sub>*

The equations for calculating *NE<sub>m</sub>*, *NE<sub>a</sub>*, *NE<sub>l</sub>*, *NE<sub>p</sub>* and *NE<sub>g</sub>* are as follows:

$NE_m = C_{fi} * (\text{Weight})^{0.75}$

$NE_a = [C_{ap} * t_p/365 + C_{ao} * (1 - (t_p/365))] * NE_m$

$NE_l = M_y/365 * (1.47 + 0.40 * \text{Fat})$

$NE_p = C_p * NE_m$

$NE_g = 4.18 * \{0.0635 * [0.891 * (BW * 0.96) * (478 / (C * MW))]^{0.75} * (WG * 0.92)^{1.097}\}$

$NE_{ma}/DE = 1.123 - (4.092 * 10^{-3} * DE) + [1.126 * 10^{-5} * (DE)^2] - (25.4/DE)$

$NE_{ga}/DE = 1.164 - (5.160 * 10^{-3} * DE) + (1.308 * 10^{-5} * (DE)^2) - (37.4/DE)$

where,

$C_f$  = Coefficient, the IPCC default value 0.335 for dairy cattle and the IPCC default value 0.322 for other cattle used

$t_p$  = Length of pasture season, 140 days for suckler cows and heifers, 125 days for dairy cows and 100 for calves

$C_{ap}$  = Coefficient for pasture, the IPCC default value 0.17 used

$C_{ao}$  = Coefficient for stall, the IPCC default value 0.00 used

$M_y$  = The amount of milk produced per year, kg a<sup>-1</sup>/cow

Fat = Fat content of milk (%)

$C_p$  = Pregnancy coefficient, the IPCC default value 0.10 was used (default for 281 days' pregnancy time)

$C$  = Coefficient related to growth, bulls 1.2, heifers 0.8 and calves an average of these, 1, was used

MW = Mature weight, (see IPCC 2000, p. 4.12)

WG = Average weight gain, (IPCC 2000, p. 4.12) (kg/day), 0 for dairy and suckler cows, 1.1 for bulls, 0.7 for heifers, 0.85 for calves were used

DE = Digestible energy (see IPCC 2000, p. 4.13), the proportion of feed energy (%) not excreted with feces, 70 was used

National data for average milk production, animal weight and fat content of milk and the IPCC default value for methane conversion rate ( $Y_m$  = 0.06) have been used.

### 3) Equations for calculating methane emissions from enteric fermentation of sheep and reindeer

$$EF = (GE * Y_m * 365 \text{ days/year}) / (55.65 \text{ MJ/kg CH}_4) \text{ (IPCC)}$$

where

GE = Gross energy intake (MJ/animal/day)

$Y_m$  = Methane conversion rate, fraction of gross energy in feed converted to methane (the IPCC default value 0.06 used)

The equation for calculating the GE for sheep and reindeer (McDonald et al. 1988):

$$GE \text{ (MJ/kg)} = 0.0226 * \text{crude protein (CP)} + 0.0407 * \text{ether extract (EE)} + 0.0192 * \text{crude fibre (CF)} + 0.0177 * \text{nitrogen free extracts (NFE)}$$

where CP, EE, CF and NFE are expressed as g/kg (McDonald et al. 1988, p. 349)

#### Reindeer

It has been estimated (Nieminen et al., 1998) that reindeer eats lichen in winter (215 days) and hay in summer (150 days) (no other plant species are taken into account). The total number of feed units has been estimated (for male reindeer being 420 for hay and 409 for lichen, for female reindeer 420 for hay and 366 for lichen). The amount of total feed units has been divided with 0.8 feed unit/kg dm.

The GE has been calculated for both hay and lichen. For hay, CP=120, EE=25, CF=360 and NFE=420. For lichen CP=30, EE=20, CF=350 and NFE=580.

For male and female reindeer, the GE (MJ/animal/day) has been calculated as follows:

$$((GE \text{ (MJ/kg)} \text{ for lichen} * \text{kg dm lichen} + GE \text{ (MJ/kg)} \text{ for hay} * \text{kg dm hay}) / 365 \text{ days})$$

The EF for both animal types has been calculated from the IPCC equation above. The EF is an average of male and female reindeer being 19.9 kg CH<sub>4</sub>/animal/a.

## Sheep

The emission factor for average sheep has been calculated annually on the basis of forage consumption and the number of animals. In the calculation of the EF the number of lambs and ewes has been taken into account separately. Interannual fluctuation of the EF is dependent on the fluctuation in animal numbers.

Sheep annual food consumption has been estimated based on literature (MTT 2004 (feeding tables and feeding recommendations), Maatalouskalenteri 2002). Equation of MacDonald et al. (1988) has been used to calculate the GE for each forage separately. For cereals CP=130, EE=41, CF=79 and NFE=716. For concentrate CP=379, EE=44, CF=126 and NFE=371. For hay CP=120, EE=25, CF=360 and NFE=420. For silage CP=145, EE=40, CF=350 and NFE=390. For pasture CP=180, EE=35, CF=280 and NFE=405. This total GE has been divided with the total amount of each forage (kg dm) to get the annual GE (MJ/kg dm).

The amount of forage (kg dm) consumed annually has been estimated for average sheep (including lambs). This has been multiplied with the GE (MJ/kg dm) to get the GE (MJ/animal/a).

### 4) Equations for calculating methane emissions from enteric fermentation of swine

The EFs of swine are calculated for the subgroups of sows, piglets, fattening pigs, boars and veaned pigs based on their feed uptake. The Evapig program is used for calculating the net energy content of feed (Evapig 2008). The EF is based on equations derived from the Evapig data:

$$EF \text{ (kg CH}_4\text{/head/yr)} = (\text{Age factor} + 0.02997 * \text{crude fiber (\%)} + \text{interaction} * \text{crude fiber (\%)}) * NE * 365 \text{ days/yr} / 55.65 \text{ MJ/kg CH}_4$$

Age factors: growing pigs 0.004479, adult pigs 0.01075

Interaction: growing pigs -0.01748, adult pigs 0.000

### 5) Equations for calculating nitrous oxide emissions from manure management

Nitrous oxide emissions from manure management have been calculated as follows:

$$N_2O\_Emissions\_manure \text{ management} = \sum_{(S)} \{ [\sum_{(T)} (N_{(T)} * Nex_{(T)} * MS_{(T,S)})] * EF_{(S)} \} * 44/28$$

Where,

$N_{(T)}$  = Number of head of livestock species/category T in the country

$Nex_{(T)}$  = Annual average N excretion per head of species/category T in the country, (kg N/animal/year)

$MS_{(T,S)}$  = Fraction of total annual excretion for each livestock species/category T that is managed in manure management system S in the country

$EF_{(S)}$  = Emission factor for manure management system S (kg N<sub>2</sub>O-N/kg N)

S = Manure management system

T = Species/category of livestock

Annual average N excretion has been received from MTT Agrifood Research Finland. The distribution of manure management systems is national data, based on Nitrogen mass flow model.

### 6) Equations for calculating methane emissions from manure management

In the IPCC Tier 2 approach, the emission factor for each cattle subcategory has been calculated according to Equation 4.17 in the GPG 2000:

$$EF_i = VS_i * 365 \text{ days/year} * Bo_i * 0.67 \text{ kg/m}^3 * \sum_{(jk)} MCF_{jk} * MS_{ijk}$$

where,

$VS_i$  = Volatile solid excretion per day on a dry-matter weight basis (kg-dm/day)

$Bo_i$  = Maximum methane producing capacity for manure produced by an animal within defined population  $i$ ,  $m^3 CH_4/kg$  VS (IPCC default values used)

$MCF_{jk}$  = Methane conversion factors for each manure management system  $j$  by climate region  $k$

$MS_{ijk}$  = Fraction of animal species/category  $i$ 's manure handled using manure system  $j$  in climate region  $k$

For cattle, VS has been calculated with the IPCC equation (IPCC 2000, Eq. 4.16). For other animals (swine, sheep, goats, horses and poultry) IPCC default values for VS have been used. For reindeer no data available so the VS value for goats was used. For fur animal the VS value is based on expert judgement.

$$VS_{cattle} = GE * (1 \text{ kg-dm}/18.45 \text{ MJ}) * (1-DE/100) * (1-ASH/100)$$

where,

$GE$  = Gross energy intake (MJ/animal/day) (see methane emissions from enteric fermentation)

$DE$  = Digestible energy (%) (see methane emissions from enteric fermentation)

$ASH$  = Ash content of manure (%) (IPCC default values used)

Data about the distribution of different manure management systems have been received from Nitrogen mass flow model. For the MCF (slurry) coefficient, the IPCC default value 10% (IPCC 1997) instead of the updated value 39% (IPCC 2000) has been used. For deep litter (cattle, swine) MCF is also 10%, for deep litter (poultry) MCF is 1.5% and for sheep, goats and horses 1%.

## 7) Equations for calculating direct and indirect nitrous oxide emissions from agricultural soils

Direct nitrous oxide emissions from agricultural soils include emissions from synthetic fertilisers and manure applied to soils, crop residues, animal production (manure deposited on pasture), sewage sludge applied to soils, N-fixation and cultivation of organic soils. Emissions from manure deposited on pasture are calculated under manure management (Section 6.3).

### Direct emissions (IPCC 2000, Eq.4.20)

**Nitrous oxide emissions from synthetic fertilisers** (IPCC 2000, Eq. 4.22):

*Calculated with Nitrogen mass flow model, which divides fertilizers to different types and takes into account field type (arable/grass) and placement fertilizing.*

$$N_2O_{fert} = N_{fert} * (1 - Frac_{GASF}) * EF * 44/28$$

where,

$N_{fert}$  = The amount of synthetic fertilisers consumed annually (Gg N/year)

$Frac_{GASF}$  = The fraction that volatilises as  $NH_3$  and  $NO_x$

$EF$  = Emission factor (0.0125 kg  $N_2O$ -N/kg N-load)

National value c. 0.015 for  $Frac_{GASF}$  has been used (from Nitrogen mass flow model).

**Nitrous oxide emissions from manure applied to soils** (IPCC 2000, Eq. 4.23):

$$N_2O_{manure} = \sum (T) (N_{(T)} * N_{ex(T)}) * (1 - Frac_{GRAZ}) * (1 - Frac_{GASM}) * (1 - Frac_{FUEL-AM}) * EF * 44/28$$

where,

$N_{(T)}$  = Number of head of livestock species/category  $T$  in the country

$N_{ex(T)}$  = Annual average N excretion per head of species/category  $T$  in the country, (kg N/animal/year)

$Frac_{GRAZ}$  = Fraction of manure that is deposited on pasture

$Frac_{GASM}$  = Fraction that volatilises as  $NH_3$  and  $NO_x$

$Frac_{FUEL-AM}$  = Amount of manure that has been burned for fuel (not existing in Finland)

$EF$  = Emission factor (0.0125 kg  $N_2O$ -N/kg N load)

Average annual N excretion per animal is national data (Source: MTT Agrifood Research Finland)

National value c. 0.25 for  $Frac_{GASM}$  has been used (See Nitrogen mass flow model).

**Nitrous oxide emissions from crop residue** (IPCC 2000, Eq. 4.29, modified):

$$N_2O_{CR} = \sum_i (Crop_i * Res_i / Crop_i * Frac_{Dmi} * Frac_{NCRi}) * (1 - Frac_{Burn}) * EF * 44/28$$

where,

$Crop_i$  = Crop production

$Res_i / Crop_i$  = Residue to crop product mass ratio

$Frac_{Dmi}$  = Dry matter content of the aboveground biomass

$Frac_{NCRi}$  = Nitrogen content of the aboveground biomass

$EF$  = Emission factor (0.0125 kg  $N_2O$ -N/kg N load)

$Frac_{Burn}$  = Fraction of crop residue that is burned and not left on field (kg N/kg cropres-N)

IPCC default values, and if IPCC default values were not available, national values as  $Crop_i$ ,  $Res_i / Crop_i$ ,  $Frac_{Dmi}$  and  $Frac_{NCRi}$  have been used (IPCC 2000, Table 4.16, Table 6.5.8, Chapter 6.5 ).  $Frac_{Burn}$  was calculated by dividing the amount of nitrogen in burned straw with the amount of nitrogen in total residue left on the fields.

**Nitrous oxide emissions from nitrogen fixation** (IPCC 2000, Eq.4.26):

$$N_2O_{BN} = \sum_i [Crop_i * (1 + Res_i / Crop_i) * Frac_{Dmi} * Frac_{NCRi}] * EF * 44/28$$

The parameters used are the same as for calculating emissions from crop residue but only N-fixing crops are included

**Nitrous oxide emissions from sewage sludge applied to soils** (IPCC 2000, Eq.4.20, modified):

$$N_2O_{sludge} = N_{sludge} * (1 - Frac_{GASM}) * EF * 44/28$$

where,

$N_{sludge}$  = Amount of nitrogen applied annually in sewage sludge, Gg

$EF$  = Emission factor (0.0125 kg  $N_2O$ -N/kg N load)

$Frac_{GASM}$  = same as with manure

The amount of nitrogen applied annually in sewage sludge has been received from the Finnish Environment Institute.

**Nitrous oxide emissions from cultivated organic soils** (IPCC 2000, Eq.4.20, modified):

$$N_2O_{FOS} = F_{OS} * EF * 44/28$$

$F_{OS}$  = Area of organic soils cultivated annually, ha (50% assumed as cereals and 50% grasses)

$EF$  = Emission factor (11.7 kg  $N_2O$ -N/ha/year for other crops and 4.0 kg  $N_2O$ -N/ha/year for grasses)

The area of cultivated organic soils has been received from Finnish Forest Research Institute.

## **Indirect emissions**

**Nitrous oxide emissions from atmospheric deposition** (IPCC 2000, Eq. 4.32):

$$N_2O_{\text{indirect-G}} = [(N_{\text{fert}} * \text{Frac}_{\text{GASF}}) + (\sum(N_{(T)} * \text{Nex}_{(T)}) + N_{\text{sludge}}) * \text{Frac}_{\text{GASM}}] * EF * 44/28$$

where,

$N_{\text{fert}}$  = The amount of synthetic fertilisers consumed annually (Gg N/year)

$\text{Frac}_{\text{GASF}}$  = The fraction of synthetic fertilisers that volatilises as  $\text{NH}_3$  and  $\text{NO}_x$

$N_{(T)}$  = Number of head of livestock species/category T in the country

$\text{Nex}_{(T)}$  = Annual average N excretion per head of species/category T in the country, (kg N/animal/year)

$N_{\text{sludge}}$  = Amount of nitrogen applied annually in sewage sludge, Gg N/year

$\text{Frac}_{\text{GASM}}$  = The fraction of animal manure that volatilises as  $\text{NH}_3$  and  $\text{NO}_x$

$EF$  = Emission factor (0.01 kg  $\text{N}_2\text{O-N}$  / kg  $\text{NH}_4\text{-N}$  &  $\text{NO}_x\text{-N}$ )

**Nitrous oxide emissions from leaching and run-off** (IPCC 2000, Eq. 4.34, modified):

$$N_2O_{\text{indirect-L}} = [N_{\text{fert}} + \sum_T(N_{(T)} * \text{Nex}_{(T)}) + N_{\text{sludge}}] * \text{Frac}_{\text{LEACH}} * EF * 44/28$$

where,

$N_{\text{fert}}$  = The amount of synthetic fertilisers consumed annually (Gg N/year)

$N_{(T)}$  = Number of head of livestock species/category T in the country

$\text{Nex}_{(T)}$  = Annual average N excretion per head of species/category T in the country, (kg N/animal/year)

$N_{\text{sludge}}$  = Amount of nitrogen applied annually in sewage sludge, Gg N/year

$\text{Frac}_{\text{LEACH}}$  = The fraction of N input that is lost through leaching or runoff.

$EF$  = Emission factor (0.025 kg  $\text{N}_2\text{O-N}$  / kg N load)

National value 0.15 for  $\text{Frac}_{\text{LEACH}}$  has been used (See Pipatti, 2001).

8) *Equations for calculating field burning of agricultural residues (cereal straw) (1996 IPCC GL, Reference Manual p. 4.81 & Workbook p.4.28):*

$$B_{\text{tot}} = \sum_i (\text{Crop}_i * \text{Res}_i / \text{Crop}_i * \text{Frac}_{\text{Dmi}} * \text{Frac}_{\text{Burn}} * \text{Frac}_{\text{ox}})$$

$$C_e = B_{\text{tot}} * \text{Frac}_C * ER * CR$$

$$N_e = B_{\text{tot}} * \text{Frac}_C * R_{\text{N/C}} * ER * CR$$

where,

i denotes the different cereal species (rye, barley, oats, wheat)

$B_{\text{tot}}$  = The amount of crop residue biomass burned (Gg dry matter)

$\text{Crop}_i$  = Annual production of crop<sub>i</sub> (Gg crop biomass)

$\text{Res}_i / \text{Crop}_i$  = Residue-crop ratio of crop *i*

$\text{Frac}_{\text{Dmi}}$  = Dry matter fraction of the aboveground biomass of crop *i*

$\text{Frac}_{\text{Burn}}$  = Fraction of crop residue burned in fields

$\text{Frac}_{\text{ox}}$  = Fraction of crop residue oxidised

$\text{Frac}_C$  = Carbon fraction of crop residue

$C_e$  = Emissions as Gg methane (and carbon monoxide)

$N_e$  = Emissions as Gg nitrous oxide (and  $\text{NO}_x$ )

$ER$  = Emission ratio

$CR$  = Conversion ratio

$R_{\text{N/C}}$  = Nitrogen-carbon ratio

## Appendix\_6b

### Calculation methods of cattle weights and nitrogen excretion from animals

#### Calculation of cattle weights

The information needed for calculating emission factors for each cattle species includes animal weight, average daily weight gain, milk production per dairy cow and suckler cow, digestible energy of forage and the length of pasture season. The live weights are estimated based on slaughter weights and ages from agricultural statistics. The daily weight gain of cattle is calculated separately for each year based on functions of mature weight and age. The mature weight of heifers and calves are based on the weighted average of dairy and suckler cows and bulls. Average daily weight gain for cattle increased in 1990-2012 proportionally to the animal weights. They are (kg) 0.04-0.06 for dairy cow 0.02-0.025 for suckler cow, 0.56-0.07 for bull, 0.37-0.47 for heifer and 0.8-1.01 for calf.

#### Calculation of nitrogen excretion from animals

N excretion for different animal classes is calculated as N intake minus N in growth and output (e.g. milk/eggs/calf). Finnish feeding recommendations or experimental data are used in calculating nitrogen intake. Nitrogen content of feed is estimated either per dry matter or per energy unit. The ratio of digestible protein to total protein is calculated on the basis of several feed mixtures. For example, for growing cattle growth curves are utilized obtaining the energy need from feed and then nitrogen content in feed is estimated from feed consumption data (per energy unit). Nitrogen utilization has improved and has been incorporated into the calculations via feeding recommendations. The reasons for improved utilization are e.g. selective breeding (fodder for production: fodder for maintenance -ratio has improved) and specified feeding (feed protein content has declined for some animals due to addition of pure amino acids).

**Table 1\_App\_6b** Source of data for calculating N excretion

Animal category	Data source	Data provider
Cattle	Feed tables	Pro Agria advisory service, <a href="http://www.proagria.fi">http://www.proagria.fi</a>
Swine	Feed tables and protein recommendations	<a href="https://portal.mtt.fi/portal/page/portal/Rehutaulukot/feed_tables_english">https://portal.mtt.fi/portal/page/portal/Rehutaulukot/feed_tables_english</a>
	Feed contents	Feed producers
Sheep	Feed tables	Pro Agria advisory service, Savolainen and Teräväinen 2000
Goats	Feed tables	Pro Agria advisory service
	Agricultural calendar	
Horses/ponies	Feed tables	Pro Agria advisory service, Saastamoinen and Teräväinen 2007
Poultry	Feed tables	Lohmann Tierzucht <a href="http://www.ltz.de/">http://www.ltz.de/</a>
	Feed contents	Feed producers
Reindeer	Guidebook on reindeer feeding	Nieminen et al. 1998
Minks, fitches, foxes and raccoons	Feed tables	<a href="http://www.profur.fi/Laboratorio">http://www.profur.fi/Laboratorio</a>
	Feed contents	

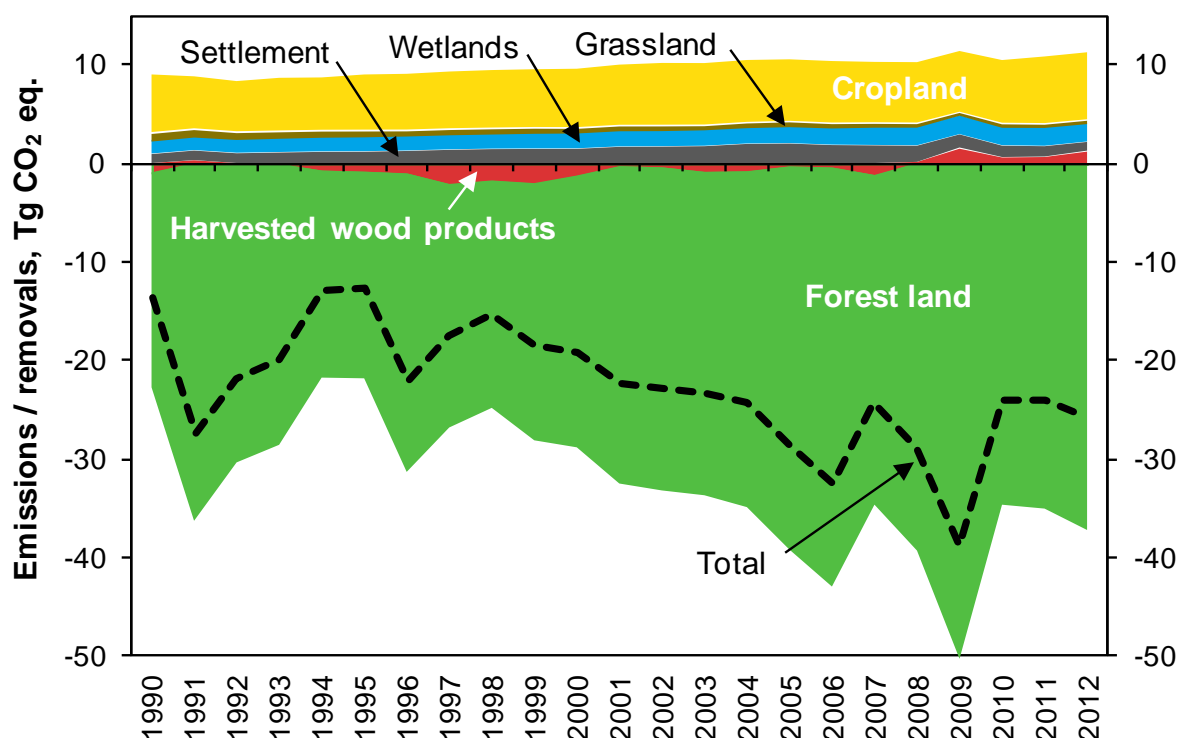


## 7 LAND USE, LAND-USE CHANGE AND FORESTRY (CRF 5)

### 7.1 Overview of the sector

#### 7.1.1 Description and quantitative overview

The Land Use, Land-Use Change and Forestry (LULUCF) sector in 2012 as a whole acted as a CO<sub>2</sub> sink for -25.9 million tonnes of CO<sub>2</sub> equivalent because the total emissions resulting from the sector were smaller than the total removals (Figure 7.1-1, Table 7.1-2). The sink in 2012 was 37% of the total national emissions, not including the LULUCF sector.



**Figure 7.1-1** Net emissions and removals in the LULUCF sector by land-use category, Tg CO<sub>2</sub> eq.

For the calculation and reporting of emissions and removals from the LULUCF sector, the IPCC Good Practise Guidance on Land Use, Land-Use Change and Forestry (IPCC 2003) and 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006) have been used. Land area is divided into six land-use categories according to the GPG LULUCF 2003 guidelines and into the subcategories “lands remaining in the same land-use category for the last 20 years” and “lands converted to present land use during the past 20 years”. The land-use categories are forest land, cropland, grassland, wetlands, settlements and other land (IPCC 2003).

The carbon stock changes and greenhouse gas emissions reported for the LULUCF sector in Finland are listed in Table 7.1-1. Other land is considered as unmanaged land and the emissions and removals are not reported for that category.

A general assessment of completeness can be found in Section 1.8 and a more detailed assessment is included in Annex 5.

**Table 7.1-1** Reported emissions / removals, calculation methods and types of emission factors for the LULUCF sector (DOM= dead organic matter, SOM= soil organic matter)

CRF	Source	Stock change reported	Emission reported	Methods	Emission factors
5.A	Forest land ( <i>remaining, converted</i> ) - living biomass, DOM and SOM (mineral and organic soils)	carbon / CO <sub>2</sub>		Tier 3, Tier 2	CS
5.B	Cropland ( <i>remaining, converted</i> ) - living biomass, DOM and SOM (mineral and organic soils)	carbon / CO <sub>2</sub>		Tier 3, Tier 2, Tier 1, D	CS, D
5.C	Grassland ( <i>remaining, converted</i> ) - living biomass, DOM and SOM (mineral and organic soils)	carbon / CO <sub>2</sub>		Tier 3, Tier 2, Tier 1	CS, D
5.D	Wetlands ( <i>converted</i> ) - Peat extraction areas - living biomass, DOM and SOM - Regressed peatlands - SOM - Inland waters - living biomass, SOM	carbon / CO <sub>2</sub>		Tier 3, Tier 2  Tier 2  Tier 3, Tier 1	CS  CS  CS, D
5.E	Settlements (converted) - living biomass, DOM and SOM	carbon / CO <sub>2</sub>		Tier 2	CS
5.G	Harvested wood products	carbon / CO <sub>2</sub>		Tier 3	CS
5(I)	Direct N <sub>2</sub> O emissions from fertilisation - Forest land		N <sub>2</sub> O	Tier 1	D
5(II)	Non-CO <sub>2</sub> emissions from the drainage of soils - Wetlands (peat extraction areas) <sup>1</sup> - Inland waters - Drained organic forest soils		CH <sub>4</sub> , N <sub>2</sub> O  CH <sub>4</sub> N <sub>2</sub> O	Tier 2  Tier 1 Tier 2	CS  D CS
5(III)	Non-CO <sub>2</sub> emissions from disturbances associated with land use conversion to cropland		N <sub>2</sub> O	Tier 1	CS, D
5(IV)	CO <sub>2</sub> emissions from agricultural lime application - Cropland <sup>2</sup>		CO <sub>2</sub>	D	D
5(V)	Biomass burning - Forest land		CO <sub>2</sub> , CH <sub>4</sub> , NO <sub>2</sub> , NO <sub>x</sub> , CO	Tier 2	D

<sup>1</sup> N<sub>2</sub>O emissions from agricultural soils are reported under the Agriculture sector.

<sup>2</sup> Also includes liming on grasslands.

The LULUCF sector has been a net sink for CO<sub>2</sub> during the whole time series. Forest land has been a net sink, whereas the other land-use categories have comprised net sources. The level, trend and the inter-annual variability in the sink for the whole LULUCF sector are determined by the forest land sink (Figure 7.1-1).

In 2012, the estimated net sink in living biomass on forest land was -38.3 Tg CO<sub>2</sub>. The soil organic matter (SOM) pool and the dead organic matter (DOM) pool in mineral forest soils together comprised a sink for -7.8 Tg CO<sub>2</sub>. In organic forest soils those carbon pools amounted to emissions of 7.7 Tg. Minor emission sources in the forest land category included N fertilisation on forest land (0.015 Tg CO<sub>2</sub> eq.) and biomass burning (0.001 Tg CO<sub>2</sub> eq.).

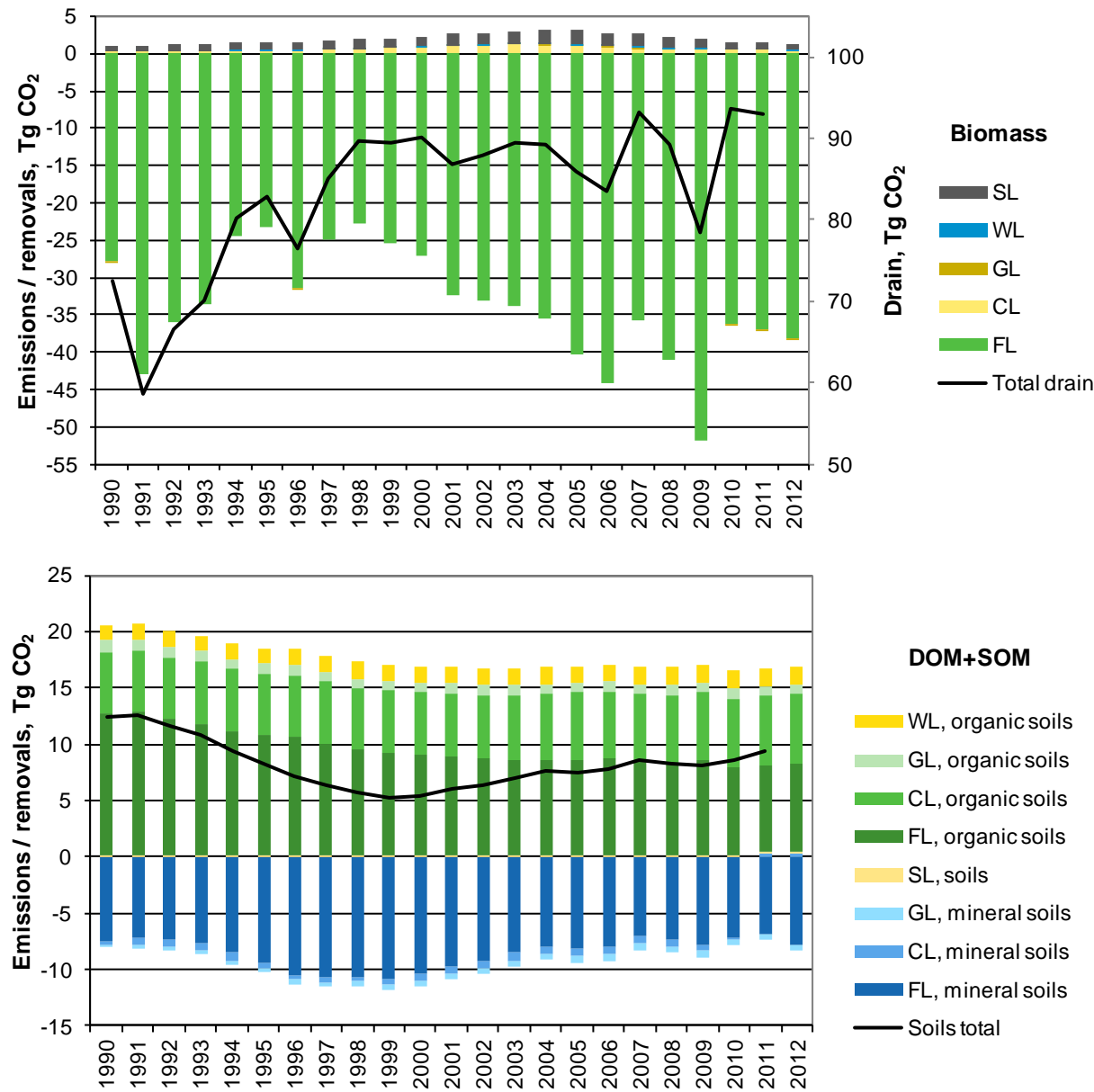
The high fluctuation in net biomass removals in the forest land category during the period 1990-2012 was mainly caused by the changes in the international market of forest industry products, which affected the amount of domestic commercial roundwood fellings. Another factor affecting the increasing removals trend in forest land is the increase in the annual volume increment. It rose from 77.7 million m<sup>3</sup> at the beginning of the 1990s to its present level of 104 million m<sup>3</sup> (Finnish Statistical Yearbook of Forestry 2013).

In the cropland category mineral soils were a source of 0.3 Tg CO<sub>2</sub> and organic soils were a source of 6.2 Tg CO<sub>2</sub> in 2012. Woody living biomass on cropland was only a minor source of CO<sub>2</sub>. In addition, emissions from liming in agricultural soils made up approximately 0.2 Tg CO<sub>2</sub> in 2012. Mineral soils in the grassland category were a sink for -0.5 Tg CO<sub>2</sub> and organic soils a source of 0.9 Tg CO<sub>2</sub> in 2012 (Table 7.1-2, Figure 7.1-2).

In 2012, emissions in the Wetland category were a source of 1.9 Tg CO<sub>2</sub> eq., of which emissions from peat extraction were 97%. The rest of the emissions come from subcategories Land converted to Inland waters and Forest Land regressed to Wetlands.

Emissions from Settlements were in 2012 a source of 0.9 Tg CO<sub>2</sub> eq. These emissions consist of biomass and deadwood loss due to conversion and emissions from litter and soil organic matter after conversion.

In 2012, harvested wood products constituted a carbon source of 1.3 Tg CO<sub>2</sub> eq. in Finland. This is due to diminished consumption of both solid wood products and paper products during recent years.



**Figure 7.1-2** Emissions (positive sign) and removals (negative sign) from biomass (upper) and from soils (soil and dead organic matter) (lower) in different land-use classes, Tg CO<sub>2</sub>. (FL = Forest land, CL=Cropland, GL=Grassland, SL= Settlements, WL=Wetland)

**Table 7.1-2** Greenhouse gas emissions and removals from the LULUCF sector (Tg CO<sub>2</sub> eq.) (positive figures indicate emissions, negative removals)

Tg CO <sub>2</sub> eq.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>Forest land <sup>1</sup></b>	<b>-21.8</b>	<b>-36.3</b>	<b>-30.2</b>	<b>-28.5</b>	<b>-21.0</b>	<b>-21.0</b>	<b>-30.3</b>	<b>-24.7</b>	<b>-23.1</b>	<b>-26.1</b>	<b>-27.6</b>	<b>-32.2</b>	<b>-32.8</b>	<b>-32.8</b>	<b>-34.1</b>	<b>-38.9</b>	<b>-42.5</b>	<b>-33.5</b>	<b>-39.4</b>	<b>-50.3</b>	<b>-34.7</b>	<b>-35.1</b>	<b>-37.2</b>
Biomass, mineral soils	-16.9	-29.1	-23.0	-20.5	-12.3	-10.8	-17.3	-11.4	-9.3	-11.1	-12.2	-16.6	-17.1	-17.5	-19.0	-23.0	-26.2	-19.1	-24.5	-33.7	-20.6	-21.1	-22.2
Biomass, organic soils	-11.1	-14.0	-13.2	-13.2	-12.4	-12.5	-14.3	-13.8	-13.7	-14.5	-15.1	-15.9	-16.2	-16.5	-16.8	-17.4	-18.0	-16.7	-16.8	-18.3	-15.9	-15.9	-16.2
DOM+SOM, mineral soils	-7.6	-7.2	-7.3	-7.7	-8.6	-9.5	-10.5	-10.7	-10.7	-10.9	-10.5	-9.8	-9.2	-8.5	-7.9	-8.2	-8.0	-7.1	-7.4	-7.9	-7.2	-6.9	-7.8
DOM+SOM, organic soils	12.5	12.7	12.1	11.7	11.1	10.6	10.5	9.9	9.3	9.1	8.9	8.8	8.6	8.4	8.4	8.5	8.5	8.2	8.1	8.3	7.7	7.7	7.7
<b>Cropland <sup>2</sup></b>	<b>5.3</b>	<b>4.9</b>	<b>4.9</b>	<b>5.0</b>	<b>5.0</b>	<b>5.3</b>	<b>5.3</b>	<b>5.4</b>	<b>5.5</b>	<b>5.5</b>	<b>5.7</b>	<b>5.8</b>	<b>6.0</b>	<b>6.1</b>	<b>6.2</b>	<b>6.1</b>	<b>6.1</b>	<b>6.0</b>	<b>6.0</b>	<b>6.0</b>	<b>6.2</b>	<b>6.7</b>	<b>6.7</b>
Biomass	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.4	0.5	0.6	0.8	0.9	1.0	1.1	1.0	0.9	0.7	0.5	0.4	0.4	0.3	0.3	0.2
DOM+SOM, mineral soils	-0.2	-0.7	-0.7	-0.7	-0.7	-0.4	-0.5	-0.5	-0.5	-0.6	-0.6	-0.6	-0.7	-0.7	-0.7	-0.7	-0.6	-0.6	-0.5	-0.5	-0.2	0.2	0.3
DOM+SOM, organic soils	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.6	5.7	5.8	5.9	5.9	6.0	6.1	6.1	6.1	6.1	6.2	6.2
<b>Grassland</b>	<b>0.8</b>	<b>0.7</b>	<b>0.7</b>	<b>0.6</b>	<b>0.6</b>	<b>0.6</b>	<b>0.5</b>	<b>0.5</b>	<b>0.5</b>	<b>0.5</b>	<b>0.5</b>	<b>0.5</b>	<b>0.5</b>	<b>0.4</b>	<b>0.5</b>	<b>0.5</b>	<b>0.4</b>	<b>0.4</b>	<b>0.4</b>	<b>0.3</b>	<b>0.3</b>	<b>0.3</b>	<b>0.3</b>
DOM+SOM, mineral soils	-0.3	-0.3	-0.3	-0.3	-0.3	-0.3	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.4	-0.5	-0.5	-0.6	-0.6	-0.6	-0.6	-0.6	-0.5	-0.5	-0.5
DOM+SOM, organic soils	1.0	1.0	1.0	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
<b>Wetlands</b>	<b>1.4</b>	<b>1.5</b>	<b>1.5</b>	<b>1.5</b>	<b>1.6</b>	<b>1.6</b>	<b>1.6</b>	<b>1.6</b>	<b>1.6</b>	<b>1.7</b>	<b>1.7</b>	<b>1.7</b>	<b>1.7</b>	<b>1.7</b>	<b>1.7</b>	<b>1.8</b>	<b>1.8</b>	<b>1.9</b>	<b>1.9</b>	<b>2.0</b>	<b>1.9</b>	<b>2.0</b>	<b>1.9</b>
Biomass	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.1
DOM+SOM, organic soils <sup>3</sup>	1.4	1.4	1.4	1.5	1.5	1.5	1.5	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.7	1.7	1.8	1.8	1.8	1.8
<b>Settlement</b>	<b>0.9</b>	<b>1.0</b>	<b>1.0</b>	<b>1.1</b>	<b>1.2</b>	<b>1.2</b>	<b>1.2</b>	<b>1.4</b>	<b>1.4</b>	<b>1.5</b>	<b>1.5</b>	<b>1.7</b>	<b>1.7</b>	<b>1.7</b>	<b>2.0</b>	<b>2.0</b>	<b>1.9</b>	<b>1.8</b>	<b>1.7</b>	<b>1.4</b>	<b>1.2</b>	<b>1.1</b>	<b>0.9</b>
Biomass	0.8	0.8	0.9	0.9	1.0	1.0	1.1	1.2	1.3	1.3	1.3	1.5	1.5	1.6	1.8	1.8	1.7	1.6	1.5	1.2	1.0	0.9	0.7
DOM+SOM	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.16	0.16	0.16	0.16	0.17	0.17	0.17	0.18	0.19	0.19	0.19	0.19	0.19	0.18	0.18	0.17
<b>N fertilisation on forest land</b>	<b>0.027</b>	<b>0.020</b>	<b>0.009</b>	<b>0.003</b>	<b>0.011</b>	<b>0.007</b>	<b>0.008</b>	<b>0.013</b>	<b>0.013</b>	<b>0.010</b>	<b>0.010</b>	<b>0.011</b>	<b>0.011</b>	<b>0.011</b>	<b>0.012</b>	<b>0.011</b>	<b>0.018</b>	<b>0.017</b>	<b>0.035</b>	<b>0.025</b>	<b>0.023</b>	<b>0.021</b>	<b>0.015</b>
<b>Drainage (non-CO<sub>2</sub> emissions)</b>	<b>1.26</b>	<b>1.26</b>	<b>1.27</b>	<b>1.28</b>	<b>1.28</b>	<b>1.29</b>	<b>1.29</b>	<b>1.30</b>	<b>1.31</b>	<b>1.31</b>	<b>1.31</b>	<b>1.32</b>	<b>1.32</b>	<b>1.32</b>	<b>1.32</b>	<b>1.33</b>	<b>1.33</b>	<b>1.33</b>	<b>1.34</b>	<b>1.34</b>	<b>1.35</b>	<b>1.35</b>	<b>1.35</b>
N <sub>2</sub> O from drained org. forest soils	1.14	1.15	1.15	1.16	1.16	1.16	1.17	1.17	1.17	1.18	1.18	1.18	1.18	1.18	1.18	1.19	1.19	1.19	1.19	1.19	1.19	1.20	1.20
N <sub>2</sub> O and CH <sub>4</sub> emissions from the drained wetlands	0.12	0.12	0.12	0.12	0.12	0.13	0.13	0.13	0.13	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.14	0.15	0.15	0.15	0.16	0.16
<b>Disturbance from land-use conv. to cropland (N<sub>2</sub>O)</b>	<b>0.007</b>	<b>0.007</b>	<b>0.007</b>	<b>0.006</b>	<b>0.006</b>	<b>0.006</b>	<b>0.006</b>	<b>0.006</b>	<b>0.006</b>	<b>0.007</b>	<b>0.007</b>	<b>0.008</b>	<b>0.008</b>	<b>0.008</b>	<b>0.009</b>	<b>0.009</b>	<b>0.009</b>	<b>0.010</b>	<b>0.011</b>	<b>0.011</b>	<b>0.011</b>	<b>0.012</b>	<b>0.012</b>
<b>Liming</b>	<b>0.62</b>	<b>0.43</b>	<b>0.27</b>	<b>0.45</b>	<b>0.45</b>	<b>0.39</b>	<b>0.45</b>	<b>0.47</b>	<b>0.43</b>	<b>0.43</b>	<b>0.33</b>	<b>0.39</b>	<b>0.42</b>	<b>0.28</b>	<b>0.25</b>	<b>0.26</b>	<b>0.30</b>	<b>0.25</b>	<b>0.29</b>	<b>0.31</b>	<b>0.25</b>	<b>0.18</b>	<b>0.19</b>
<b>Biomass burning on forest land</b>	<b>0.008</b>	<b>0.004</b>	<b>0.012</b>	<b>0.001</b>	<b>0.009</b>	<b>0.007</b>	<b>0.005</b>	<b>0.012</b>	<b>0.002</b>	<b>0.007</b>	<b>0.004</b>	<b>0.004</b>	<b>0.008</b>	<b>0.008</b>	<b>0.004</b>	<b>0.006</b>	<b>0.016</b>	<b>0.006</b>	<b>0.009</b>	<b>0.006</b>	<b>0.006</b>	<b>0.007</b>	<b>0.001</b>
<b>Harvested wood products</b>	<b>-0.9</b>	<b>0.3</b>	<b>-0.2</b>	<b>-0.1</b>	<b>-0.8</b>	<b>-0.9</b>	<b>-1.0</b>	<b>-2.1</b>	<b>-1.8</b>	<b>-2.0</b>	<b>-1.3</b>	<b>-0.3</b>	<b>-0.4</b>	<b>-0.9</b>	<b>-0.8</b>	<b>-0.3</b>	<b>-0.5</b>	<b>-1.2</b>	<b>0.1</b>	<b>1.6</b>	<b>0.6</b>	<b>0.7</b>	<b>1.3</b>
<b>Total CO<sub>2</sub> eq.</b>	<b>-13.7</b>	<b>-27.4</b>	<b>-22.0</b>	<b>-19.9</b>	<b>-13.0</b>	<b>-12.8</b>	<b>-22.2</b>	<b>-17.4</b>	<b>-15.3</b>	<b>-18.5</b>	<b>-19.2</b>	<b>-22.4</b>	<b>-22.9</b>	<b>-23.4</b>	<b>-24.3</b>	<b>-28.6</b>	<b>-32.5</b>	<b>-24.3</b>	<b>-29.0</b>	<b>-38.8</b>	<b>-24.1</b>	<b>-24.1</b>	<b>-25.9</b>

<sup>1</sup> Excludes emissions from biomass burning and N<sub>2</sub>O emissions from drained organic soils and N fertilisation<sup>2</sup> Excludes CO<sub>2</sub> emissions from liming and N<sub>2</sub>O emissions from disturbance associated with land-use conversion to cropland<sup>3</sup> Includes emissions from peat extraction areas

### *7.1.2 Information on the approaches used for representing land areas and on the land-use data used for the inventory preparation*

The area estimates for the land-use categories are based on the National Forest Inventories (NFI) carried out by the Finnish Forest Research Institute (Metla). The NFI is a sampling-based forest inventory system. Sample plots are located in systematic clusters and the ratio of temporary and permanent clusters is 3:1. The field measurements are carried out in five-year cycles and each year 20% of the plots are measured. The most recent inventories are NFI10 (2004-2008) and the NFI11 (2009-2013). Older NFI data were used to compute estimates for land-use changes before 1990, which information is needed for the estimation of carbon stock changes in soil. More detailed information on NFI is provided in Appendix 7a .

The information on Finland's official total land area and inland water area is applied for area estimates. The method, how official areas were employed for area estimation is described briefly in Appendix\_7a. Official areas are published annually by the National Land Survey of Finland, which is responsible for Finland's cadastral system and general mapping assignment. In this submission, the reference date for official area data is 1 January 2009 (Land Survey of Finland 1.1.2009). The official area can change time to time due to ongoing remapping with more advanced mapping methods. To avoid recalculations because of small changes, the decision to use the same official area for consecutive submissions was made. At any rate, if significant changes occur, the new official land area will be used. The steering group for the greenhouse gas inventory for the LULUCF sector in Metla and the advisory board for the greenhouse gas inventory set by the Statistics Finland will decide up on the change.

The grounds for the use of NFI data for the area estimations in the GHG inventory are: i) NFI is the only data source which covers the whole country and all land-use types, ii) NFI data cover the whole time span needed for inventory's time series, iii) NFI definitions and measurements of important variables relative to GHG inventory have been unchangeable, iv) NFI provides data on land use, land-use changes, soils and tree biomass on different land use, v) NFI is a continuous system which provides data also for recent years.

The proportions of land-use categories were calculated from NFI sample plot data. The official total land area was multiplied by the proportions of land-use categories resulting in areas of land-use categories in hectares. Areas were calculated separately for South and North Finland in sampling density regions (Figure 1\_App\_7a), as well as separately for land areas and inland waters. This method gives each sample plot a specific representativeness in hectares. The sampling pattern is denser in the southern part of the country. All the areas of different land-use categories as well as the areas of land use conversions are derived from the plot data, see Appendix 7a. The sum of individual land-use categories is equal to the official land area or inland water area of Finland.

The primary task was to constitute the six IPCC land-use categories according to Finnish circumstances. This is described in the next Section 7.1.4. Secondly, the employed NFI sample plot and stand level data were classified to the six IPCC land-use categories. The area estimates for land-use categories were computed separately for South and North Finland but final results are reported at the country level (Figure 7.1-3). A 20-year period is used for converted lands. The areas of land-use categories and subcategories were subdivided into mineral and organic soils, and organic forest soils further into drained and undrained lands. The principle for the area estimation is provided in detail in Appendix\_7a.

NFI data do not provide information to separate over 5 years old grazing lands and grasslands from other cultivated agricultural lands, which are classified as croplands in the GHG inventory. These areas were obtained from the Yearbook of Farm Statistics and from the Matilda database of the Information Centre of the Ministry of Agriculture and Forestry. This was quite small area (approximately 30,000 ha) and was reduced from the estimated cropland area and added to grassland area.

The NFI data were used to estimate the areas of land-use categories and land-use changes. A full record of NFI data comprises of five years measurements, which is the complete data of an inventory cycle. Due to this characteristics of the NFI, a full dataset is available only for years until 2007. The incomplete data of the measurement years after 2007 were not used to estimate the areas of land-use categories. Instead, to provide

a full dataset also for the latest years, land-use information of the NFI sample plots data was updated by means of aerial photo interpretation to the end of 2012. There were also other data sources for the updating, i.e., Landsat images and land parcel register for croplands.

The annual areas of land-use changes in 1990-2012 were based on a five-year moving average method, which was presented in the submission 2012. The five-year moving averages were used to decrease the effect of sampling error. For a more detailed description of the area computations and the estimation of the annual land-use changes, see Appendix\_7b.

Information on land-use changes before 1990 is needed for the estimation of carbon stock changes in soil. Therefore, the areas of land-use changes were estimated also for 1970-1989 by employing NFI7-NFI9 data. The average annual areas of land-use changes were estimated for the mean years of the inventories based on land-use changes for the ten years prior to the field measurements. The mean years of the inventories applied in the area calculations were computed from an average measurement year minus five years because of the ten-year period of land-use changes. In South Finland, the mean years of the inventories in NFI8 and NFI9 were 1984 and 1993, respectively. In North Finland, the mean years for NFI7, NFI8 and NFI9 were 1977, 1988 and 1996, respectively. The areas that were converted from one category to another between the inventories' mean years were interpolated (for the years 1970-1989).

The information on areas of the mineral and organic soils is needed for the estimation of carbon stock changes and non-CO<sub>2</sub> emissions from soils. The areas were derived from the NFI data and the georeferenced soil database. The Finnish soil database includes a soil map at a scale of 1:250 000 and properties of the soil (Lilja et al. 2006; Lilja et al. 2009). The database was utilised for those NFI sample plots that did not have information on the soil type (croplands and part of the grasslands). In the database, polygons smaller than 6.25 ha were merged with adjacent larger polygons. The soil database was produced by Agrifood Research Finland (MTT), the Finnish Forest Research Institute (Metla) and the Geological Survey of Finland (GTK).

### *7.1.3 Land-use definitions and the classification systems used and their correspondence to the LULUCF*

The land areas used in the inventory reporting are consistent with the land-use categories given in the GPG LULUCF 2003. The nationally classified NFI plots are re-classified as IPCC land-use categories according to the recommendation given by a working group on a follow-up system for land use and land-use changes in Finland (Ministry of Agriculture and Forestry 2005:5).

#### *National application of IPCC land-use categories in the Finnish inventory*

**Forest land.** The FAO FRA2005 definition is applied, except the requirement of the minimum area of 0.5 ha. A forest is a land with a tree crown cover (or equivalent stocking level) of more than 10%. The trees should be able to reach a minimum height of 5 m at maturity in situ. Young natural stands and all plantations established for forestry purposes that have yet to reach a crown density of 10% or a tree height of 5 m are included under the category of forest land, as are the areas normally forming a part of the forest area that are temporarily unstocked as a result of human intervention or natural causes but which are expected to revert to forest land. A minimum area of 0.25 ha for a forest stand is applied in South Finland and 0.5 ha in North Finland. (See Appendix\_7a for how South and North Finland are defined.) For linear formations, a minimum width of 20 m is applied. Parks and yards are excluded, regardless of whether they would meet the forest land definition (FRA 2010). The FAO forest land covers the nationally defined productive forest land, part of the poorly productive forest land and forest roads. Note that the definition for forest land used under the UNFCCC reporting differs from that used for Kyoto Protocol reporting. Finland prefers to report to the UNFCCC all forest land under the forest land category. All forests are considered managed land.

**Cropland.** The area of cropland comprises the area defined as arable crops, grass (< 5 years), set-aside, permanent horticultural crops, greenhouses and kitchen gardens. All croplands are considered managed land.

**Grassland.** Grassland includes the area of grass ( $\geq 5$  years), ditches associated with agricultural land, areas of bioenergy plants and abandoned arable land. In this context, abandoned arable land refers to fields that are no longer used for agricultural production and where natural reforestation is possible or is already taking place. All grasslands are considered managed land.

**Wetlands.** Wetlands include peat extraction areas and peatlands that do not fulfil the definition of forest land, cropland, grassland or settlements. Inland waters, which comprise reservoirs and natural lakes and rivers, are included in wetlands. Peat extraction areas, lands converted from other land use to wetlands as well wetlands underwent change in land management are considered managed lands.

**Settlements.** Settlements comprise of the combined area of NFI built-up land, power supply lines and roads, which include roads and railroads, ditches and open side areas close to these. This category also includes airports, parks, yards, farm roads and barns. Settlements are considered managed land.

**Other land.** Other land includes mineral soils on nationally defined, poorly productive forest land, which do not fulfil the threshold values of crown cover or minimum tree height for forest land. In addition, unproductive lands on mineral soils are included. Typical sites include rocky lands and treeless mountain areas. Only the total area of other land is reported. All other land is considered unmanaged land.

The areas of IPCC land-use categories are given in Table 7.1-3 where the total land area refers to Finland's official land area. The total area is the official area of Finland including inland waters.



**Figure 7.1-3** The partitioning of the country to South Finland (pale grey) and North Finland (dark grey)



**Table 7.1-3** The areas of IPCC land-use categories (1 000 ha). The last row shows the uncertainties, which are twice the relative standard errors, in area estimates due to sampling

Year	Forestland	Cropland	Grassland	Peat Extraction*	Peat Land**	Settlements	Otherland	Total land area	Inland waters	CRF Total area	Wetlands***
1990	22 187	2 454	283	82	2 923	1 224	1 239	30 392	3 450	33 842	6 455
1991	22 193	2 450	277	83	2 920	1 229	1 239	30 392	3 451	33 842	6 454
1992	22 198	2 446	271	84	2 918	1 235	1 238	30 392	3 451	33 842	6 453
1993	22 201	2 442	267	86	2 915	1 242	1 238	30 391	3 451	33 842	6 452
1994	22 204	2 438	262	87	2 913	1 249	1 238	30 391	3 451	33 842	6 451
1995	22 205	2 434	258	90	2 910	1 256	1 238	30 391	3 451	33 842	6 450
1996	22 206	2 427	258	91	2 907	1 264	1 238	30 391	3 451	33 842	6 449
1997	22 203	2 420	260	93	2 904	1 273	1 238	30 391	3 451	33 842	6 448
1998	22 200	2 417	258	95	2 900	1 283	1 238	30 391	3 451	33 842	6 447
1999	22 194	2 416	257	97	2 897	1 293	1 237	30 391	3 451	33 842	6 445
2000	22 185	2 412	261	98	2 895	1 302	1 237	30 391	3 451	33 842	6 444
2001	22 172	2 416	259	99	2 893	1 314	1 237	30 391	3 452	33 842	6 444
2002	22 158	2 420	260	99	2 891	1 325	1 237	30 390	3 452	33 842	6 443
2003	22 141	2 426	261	99	2 889	1 337	1 237	30 390	3 452	33 842	6 441
2004	22 122	2 430	262	99	2 888	1 350	1 237	30 390	3 452	33 842	6 440
2005	22 104	2 430	268	100	2 886	1 364	1 237	30 390	3 453	33 842	6 439
2006	22 087	2 431	272	101	2 885	1 377	1 237	30 390	3 453	33 842	6 439
2007	22 071	2 433	270	104	2 884	1 390	1 237	30 390	3 453	33 842	6 440
2008	22 058	2 435	269	106	2 883	1 401	1 237	30 390	3 453	33 842	6 442
2009	22 047	2 435	270	109	2 882	1 411	1 237	30 389	3 453	33 842	6 444
2010	22 038	2 436	268	110	2 881	1 419	1 237	30 389	3 453	33 842	6 444
2011	22 030	2 438	267	111	2 880	1 425	1 237	30 389	3 454	33 842	6 445
2012	22 024	2 439	267	111	2 879	1 431	1 237	30 388	3 454	33 842	6 445
	0.8	4.2	8.2	29.8	4.8	5.6	24.2	-	-	-	-

\*From CRFReporter PeatExtraction: FL--&gt;WL + OL--&gt;WL

\*\* Wetlands = CRFWetlands - Inland Waters --&gt; Peatland = Wetlands - PeatExtraction

\*\*\* Total area LULUCF 5.D Wetlands

The transition areas between all possible land-use categories were calculated using NFI field data (Table 7.1-4) including both temporary and permanent NFI10 and NFI11 sample plots. In NFI there are approximately 15,000 plots measured each year. Land use changes are assessed in the field but plots are checked for undetected changes by utilizing other NFI variables (such as stand age), and auxiliary data as old maps, satellite images, thematic maps and aerial photographs (See Appendix\_11a). The land-use changes found in the interpretation were confirmed with aerial photographs. The aerial photographs were from the year 1990, when available, and otherwise from the years 1987-1995. The aerial photographs included low and high-altitude black-and-white images and false-colour images. The satellite images were from the years 1987-1994 and the thematic maps from multi-source NFI8 data based on these satellite images. If old aerial images taken in the years 1987-1995 were not available, these plots were checked from aerial images taken in the years 1996-2000 or from paper maps (125 plots). Aerial images were needed for approximately 950 sample plots resulting 190 observed land-use changes from images. Furthermore there were 5,800 plots where land use change was observed in the field. The NFI data were complemented by the findings of image interpretation. The image interpretation is done once for each plot, hence in the next submission only the new data are checked. In the updating of the NFI data to the end of 2012, aerial images from years 2008-2013 were utilized together with satellite images from years 2011-2012 and other relevant spatial data.

The uncertainties for the areas were calculated separately for lands remaining in the same land use and lands converted to other land use. For reporting non-CO<sub>2</sub> emissions, the uncertainties were also calculated for areas of drained organic forest soils (section 7.8).

**Table 7.1-4** The land-use change matrix for IPCC land-use categories from 31.12.1992 to 31.12.2012 (1 000 ha) together with percent uncertainty twice the relative sampling error

Final	Initial							Total (Final)
	Forest land	Cropland	Grassland	Wetlands	Settlements	Other land	Inland waters	
Forest land	21 893 (0.8%)	37 (15.6%)	58 (13.4%)	19 (24.8%)	17 (26.2%)	1 (115.4%)	0	22 024
Cropland	86 (17%)	2 323 (4.4%)	16 (51.8%)	13 (55.4%)	1 (0%)	0	0	2 439
Grassland	14 (36.4%)	63 (22.8%)	183 (10.2%)	7 (80%)	1 (141.4%)	0	0	267
Wetlands	30 (39%)	1 (141.4%)	2 (98.4%)	2 958 (4.8%)	1 (200%)	0	0	2 991
Settlements	175 (10.8%)	23 (35.2%)	13 (38.6%)	3 (107.2%)	1 215 (5.6%)	1 (100%)	0	1 431
Other land	0	0	0	0	1 (155.8%)	1 236 (24.4%)	0	1 237
Inland waters	0	0	1 (115.8%)	3 (115.6%)	0	0	3 450 (0%)	3 454
Total (initial)	22 198	2 446	271	3 002	1 235	1 238	3 451	33 842
NET change	-174	-7	-5	-11	195	-1	4	0

\* Areas of peat extraction remaining and converted to peat extraction are included in wetlands. However, peat extraction fields are reported as converted areas and placed in CRF table 5.D 2.5. Other land converted to wetlands/peat extraction. In addition to those areas, cropland (0.765 kha) and grassland (0.965 kha) converted to peat extraction are placed in CRF table 5.D 2.5. Conversion area from FL to WL includes here regressed peatlands and peat extraction fields converted from forest land).

#### Recalculation of areas for the land-use categories

The land-use areas were recalculated due to new data, updating of NFI data and error corrections in calculations. In this submission, the area estimates for the latest five years were calculated from the updated NFI data and there were also new NFI data available. The effect of the changes is shown in Table 7.1-5. In the year 2011, a decrease in the area of Settlements and increase in the area of Forest land is mainly due to the new data and updated NFI.

**Table 7.1-5** The difference due to recalculation in the areas of the land-use categories between the 2013 and 2014 submissions (1 000 ha)

	Areas in Submission 2013		Areas in Submission 2014		Difference in areas 2014–2013	
	Year 1990	Year 2011	Year 1990	Year 2011	Year 1990	Year 2011
Forest land	22 188	22 017	22 187	22 030	-1	13
Cropland	2 453	2 441	2 454	2 438	1	-3
Grassland	282	264	283	267	1	3
Wetlands	3 001	2 993	3 005	2 991	4	-2
Settlements	1 230	1 439	1 224	1 425	-6	-14
Other land	1 239	1 237	1 239	1 237	0	0
Inland waters	3 450	3 453	3 450	3 454	0	1

### 7.1.4 Key Categories

The key categories in the LULUCF sector in 2012 are summarised in Table 7.1-6.

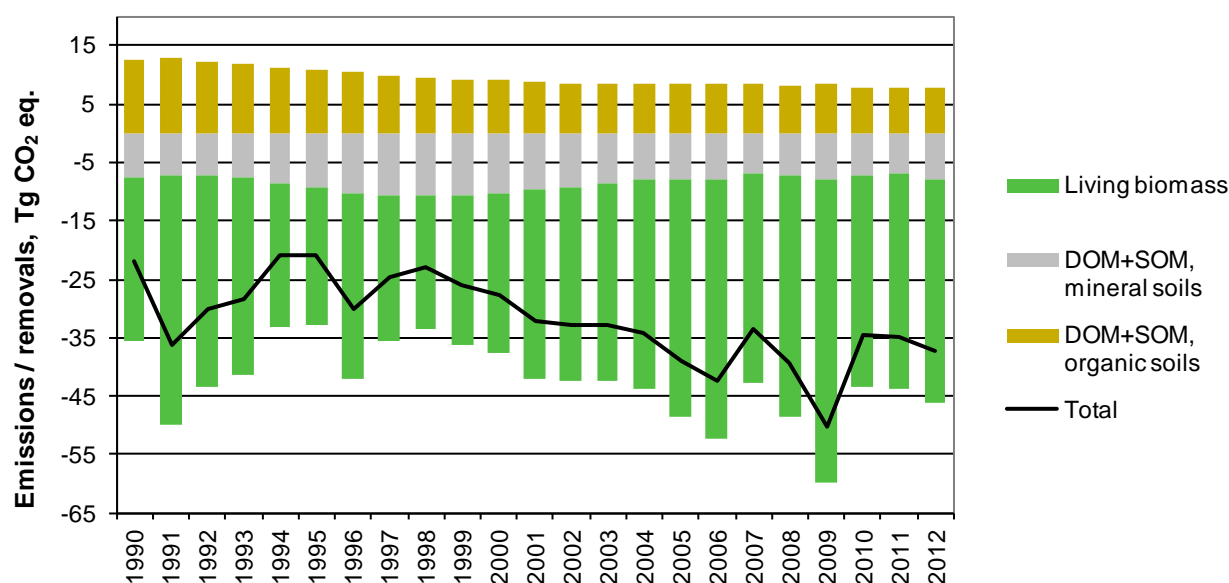
**Table 7.1-6** Key categories in the LULUCF sector (CRF 5) in 2012 (quantitative method used: Tier 2)

IPCC source category	Gas	Identification criteria
5.A.1. Forest Land remaining Forest Land	CO <sub>2</sub>	L, T
5.A.2. Land converted to Forest Land	CO <sub>2</sub>	L, T
5.B.1. Cropland remaining Cropland	CO <sub>2</sub>	L, T
5.B.2. Land converted to Cropland	CO <sub>2</sub>	L, T
5.C.1. Grassland remaining Grassland	CO <sub>2</sub>	L, T
5.C.2. Land converted to Grassland	CO <sub>2</sub>	L, T
5.D.2. Land converted to Wetlands	CO <sub>2</sub>	L, T
5.E.2. Land converted to Settlements	CO <sub>2</sub>	L, T
5.G. Other (Harvested Wood Products)	CO <sub>2</sub>	L, T
5.II. Non-CO <sub>2</sub> emissions from drainage of soils and wetlands	N <sub>2</sub> O	L, T

## 7.2 Forest land (CRF 5.A)

### 7.2.1 Source category description

The net removals from forest land were -38.4 Tg CO<sub>2</sub> in 2012. The net sink is 67% higher than 1990. Emissions and removals derived from carbon stock changes on forest land are reported under this category. Other emissions caused by forestry activities, such as N<sub>2</sub>O emissions from fertilisation (CRF 5(I)), N<sub>2</sub>O emissions from drainage (CRF 5(II)) and emissions from biomass burning (CRF 5(IV)), are presented in the proper sections.



**Figure 7.2-1** Emissions (positive sign) and removals (negative sign) in forest land

This source category includes CO<sub>2</sub> emissions resulting from changes in carbon stock in living biomass, litter and dead wood (DOM) and soil organic matter (SOM) in Forest land remaining as Forest land (CRF 5.A 1) and Land converted to Forest land (CRF 5.A 2).

Forest land constitutes 72% of Finland's land area, or 22 million ha. Finland is characterized by a high proportion of peatlands (27%), of which 73% have been drained. The main tree species are Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*), Silver birch (*Betula pendula*) and Downy birch (*Betula pubescens*). These four species constitute approximately 95% of the volume and annual increment of growing stock. All of the forest land area is considered managed, including commercially managed forests and protected forest areas.

The most important quantity of the total sink in forest land is the net removals in tree biomass: -38.3 Tg CO<sub>2</sub>. Mineral soils (DOM+SOM) were also a net sink for 7.8 Tg CO<sub>2</sub>, whereas organic soils (DOM+SOM) were a net source of 7.7 Tg CO<sub>2</sub>. The living biomass and mineral soils have been a sink during the whole time series whereas the organic soils have been a source of CO<sub>2</sub> emissions (Table 7.1-2). Removals in mineral soils have varied moderately during the reported period. The drainage causes the CO<sub>2</sub> emissions on organic soils (peatlands) due to the oxidation of organic matter. Poorly productive lands were drained in the 1960's and 1970's to amend the site conditions for trees to grow. The effect of increased tree growth increased the litter input for the soil and it can be seen in the time series as a declining trend in the emissions of organic soils.

The CO<sub>2</sub> removals in tree biomass have increased from 27.9 Tg CO<sub>2</sub> in 1990 to 38.3 Tg CO<sub>2</sub> in 2012. The development of the two components, the annual increment of the growing stock and the drain of the growing stock, determines the trend of the sink. The inter-annual fluctuation in the sink is very much determined by the volume of roundwood removals, which constitutes the main part of the drain (Table 7.2-2). Other components are the harvest residues and the natural mortality of trees. The international market situation in

the forest industry affects the variation in roundwood removals. The domestic wood volume has corresponded to about 76% of the wood procurement of the forest industries during this millennium. The cuttings were at a low level in the first half of the 1990's, reaching their lowest level of 44.6 million m<sup>3</sup> in 1991. In the second half of the decade, they increased considerably; the drain reached a level of 70 million m<sup>3</sup> at the end of the decade. Although wood consumption increased in 2006, the total drain still decreased by 3%. Imported roundwood and the use of reserve roundwood compensated for the domestic commercial roundwood fellings. The situation changed in 2007; the total drain amounted to 73 million m<sup>3</sup> and the roundwood was purchased from domestic roundwood markets. The low cutting level at the beginning of the 1990's and in the mid-2000's can be seen as a high CO<sub>2</sub> sink in the biomass (Figure 7.2-1). In 2007, commercial roundwood fellings were at an exceptionally high level, being 58 million m<sup>3</sup>. The increase in fellings compared to the earlier year was 14% (Finnish Statistical Yearbook of Forestry 2013). Due to the slow domestic roundwood markets, the commercial roundwood removals in 2009 were 41 million m<sup>3</sup>, which was 20% less than in the previous year. The global economic downturn had a considerable negative effect on the demand for forest-based industry products in 2009. In addition, there was a large existing store of roundwood in Finland, which was imported in 2008 from Russia (Finnish Statistical Yearbook of Forestry 2010). The global recession in 2009 has caused activity to decrease noticeably in some of the forest industry's key client sectors, such as the construction, packaging and print industries. According to the Finnish Forest Industry, construction volumes collapsed both in the larger EU countries as well as in Finland, and this slashed export and domestic demand for sawn timber and other wood products in 2009. Thus, the decreased roundwood removals in 2009 were the main reason for the increase of 35% in the sinks in 2009 compared to the year 2008.

In 2010, forest industry production recovered. The wood product industry's production rebounded closer to its normal level when demand increased both domestically and in the export markets. Also, pulp and paper demand recovered (Finnish Forest Industries Federation). Thus, roundwood fellings in Finland increased in 2010 to almost their normal level. In 2010, commercial fellings totalled 52 million m<sup>3</sup>, which is almost one fourth more than in the previous year. Increased fellings mainly resulted in a decrease in biomass C stock sinks compared to the previous year.

In 2012, the growth of the Finnish national economy was at a modest rate. The total drain was 70 million m<sup>3</sup> of which the commercial roundwood removals were 52 million m<sup>3</sup> that is about at the same level as in previous year. (Finnish Statistical Yearbook of Forestry 2013).

The annual increment of the growing stock has increased almost steadily during the period 1990-2012. It rose from 77.7 million m<sup>3</sup> in the 8<sup>th</sup> National forest inventory (measured 1986-1994) to 86.7 million m<sup>3</sup> in the 9<sup>th</sup> inventory (measured 1996-2003) and increased by 14% from the NFI9 to the NFI10 (99.5 million m<sup>3</sup>). According to the NFI11 the latest estimate for the annual increment is 104 million m<sup>3</sup> (Finnish Statistical Yearbook of Forestry 2013). The effective forest management activities in the 1960's and 1970's and the sustainable forest management since then can be seen as a reason for the increased growth in forests. Due to the intensive silvicultural practices, the age-class distribution has changed and nowadays the proportion of young, under 40-year-old forests is higher than in the 1960's. Not only have the areas changed, but also the mean growing stock volume and the mean volume increment were higher in all age classes in the NFI9 data compared to the NFI7 data (1977-1982) (Tomppo et al. 2011). The mean growing stock volume has still been increasing, it was 92 m<sup>3</sup> per ha according to the NFI8 and 112 m<sup>3</sup> per ha in 2012 according to NFI11. The increased volume growth has compensated for the emissions caused by the higher cutting volumes. However, the higher level of the cuttings has increased the annual production of the dead organic matter, particularly when the level of the cuttings rose in the mid-1990's. The presented volume estimates, growing stock volumes, volume increments and volume removals are defined as tree stem volume with bark from above the stump to the top of the tree, excluding branches (Tomppo et al. 2011).

Forest management activities can also be seen as a reason for the increased CO<sub>2</sub> sink of the mineral soil. In the organic soils, there are two main factors for the variations in emissions and sink in the period 1990-2012: 1) due to the drainage, the non-forested sites have been transferred to forest land, and thereby this explains the slight increase in the area of the drained organic soils; and 2) an increase in the growing stock on organic soils. The first factor has slightly increased the total emissions caused by peat decomposition. The second factor has increased the removal in drained peatlands by increasing fine- and coarse root litter production.

The reduction in emissions is due to the fact that peat decomposition is assumed constant while litter input to the soil increases as the biomass increases.

## 7.2.2 Definitions

### Forest land

The definition of forest land is described in Section 7.1.3. This definition is compatible with the forest land definition reported to the FAO (Food and Agriculture Organization of the United Nations). According to the Global Forest Resources Assessments Country report (FRA2005), Finland has reported using a minimum area of 0.5 ha for forest land. At any rate, the Country report includes an additional note: *“Information generated from NFI database. The FRA2005 definition is ‘Land spanning more than 0.5 hectares...’. Finland uses a minimum area of ‘more than 0.25 ha...’ and does not consider the width of the area. It is only defined that the shape of forest land is such that it can be considered forestry land”* (FRA2005). The area of forest land was estimated based on the NFI data (see Section 7.1.2).

For the category forest land remaining as forest land, the lands have been forest land for at least 20 years; other forest lands are reported under the category land converted to forest land.

### Carbon pools

The following carbon stock changes are reported: the estimates for the above- and below-ground biomass of the growing stock and the combined estimates for litter, dead wood and soil organic matter. In this report, DOM refers to litter and dead wood and SOM to soil organic matter, and the reported DOM and SOM are aggregated under the heading mineral soils. Carbon stock changes are reported separately for mineral and organic forest soils. For drained organic forest soils, the litter pool is assumed to be in a steady state.

#### *Living biomass*

Tree biomass is the dry weight of living trees with a height of at least 1.35 m, i.e. those trees that are measured in NFIs, including the stem wood, stem bark, living and dead branches, cones, needles/foilage, stump, and roots down to a minimum diameter of 1cm (Repola 2008, Repola 2009, Appendix\_7c).

The default factor 0.5 was used to convert the whole tree biomass increment/drain to carbon uptake/loss, and  $CO_2$  emissions/removals = (carbon uptake by tree growth - carbon loss due to drain) \* 44/12

The biomass of other vegetation includes the biomass of ground vegetation, which consists of moss-, lichen-, shrub- and dwarf shrub vegetation. This carbon pool is not included in the living biomass, but it is included when the litter input to the soil is estimated.

#### *Dead wood*

This carbon pool includes tree stems that are left in the forest to decay. This pool originates from the natural mortality of the trees and from wastewood from logging. The minimum diameter is 10 cm. On mineral soils, this carbon pool is reported as a combined estimate for dead wood, litter and soil organic matter pools. These are provided as aggregated pools due to the modelling framework. On drained organic forest soils, the pools are also reported as an aggregated estimate.

#### *Litter*

This carbon pool includes both above-ground and below-ground litter, which originates from trees and ground vegetation. Litter consists of dead foliage, leaves, branches, bark, coarse roots, stumps and fine roots. On mineral soils, this carbon pool is reported as a combined estimate for dead wood, litter and soil organic matter pools. These are provided as aggregated pools due to the modelling framework. On drained organic forest soils, this pool is assumed to be in a steady state (i.e. no change).

### *Soil organic matter*

Soil organic matter is built by the decomposed litter that has accumulated in soils. Yasso07 estimates soil carbon stocks and their changes to a depth of one metre (Appendix\_7f). On mineral soils, this carbon pool is reported as a combined estimate for dead wood, litter and soil organic matter pools. These are provided as aggregated pools due to the modelling framework. On drained organic forest soils, the carbon stock change of SOM is estimated based on the below-ground litter input and peat decomposition.

Soil is considered organic if the soil type is peat. Peatlands are defined in the same way as in the NFI; a site is classified as peatland if the organic layer is peat or if more than 75% of the ground vegetation consists of peatland vegetation. Otherwise, the soil is considered mineral. The applied definition gives a slightly larger area for organic soil than the IPCC definition.

## **7.2.3 Methodological issues**

### **7.2.3.1 Forest land remaining Forest land (CRF 5.A 1)**

#### *Activity data*

Land use area calculations are described in detail in Section 7.1.2. The areas of forest land remaining as forest land were computed by subtracting the converted areas from the forest land area for each year. Furthermore, the total area of forest land remaining as forest land on organic soils was divided into undrained and drained soils and the drained soils further into five site types based on the fertility of the soil (Table 7.2-1). The proportional distribution of site types on the organic soils of forest land was estimated by using data from different inventories (NFI7-NFI11). The areas were calculated as a product of these proportions and the area of forest land on mineral or organic soils. The areas for the years between the inventories were interpolated.

**Table 7.2-1** Areas of organic soils (peatlands) of forest land remaining forest land by site type (1 000 ha)

Year	Undrained	Herb-rich type (Rhtkg)	Vaccinium		Dwarf shrub type (Vatkg)	Cladina type (Jätkg)
			myrtillus type (Mtkg)	vitis-idaea type (Ptkg)		
1990	1 750	694	1 143	1 493	855	8
1991	1 738	688	1 149	1 508	849	11
1992	1 726	683	1 155	1 522	843	14
1993	1 714	677	1 161	1 537	837	17
1994	1 702	672	1 167	1 552	831	20
1995	1 689	666	1 173	1 566	825	23
1996	1 677	660	1 179	1 580	819	27
1997	1 665	655	1 184	1 595	813	30
1998	1 652	649	1 190	1 609	807	33
1999	1 645	647	1 191	1 618	803	35
2000	1 638	644	1 192	1 626	799	37
2001	1 630	642	1 194	1 635	795	39
2002	1 616	646	1 185	1 635	809	39
2003	1 603	651	1 176	1 636	823	40
2004	1 589	655	1 167	1 636	837	40
2005	1 576	660	1 158	1 636	851	41
2006	1 562	664	1 149	1 636	865	42
2007	1 549	669	1 140	1 637	879	42
2008	1 536	673	1 131	1 638	893	43
2009	1 524	678	1 123	1 639	907	44
2010	1 512	683	1 115	1 641	922	44
2011	1 500	688	1 107	1 643	937	45
2012	1 488	694	1 099	1 645	952	46

### Carbon stock changes in living biomass

The estimation of change in the carbon stock in the living tree biomass is consistent with Method I (the so-called default method) in the GPG LULUCF 2003, which requires that the biomass carbon loss be subtracted from the biomass carbon increment for the reporting year (IPCC 2003, Eq 3.22, p. 3.24).

### Annual increase in carbon stocks due to biomass growth

The annual biomass increments of living trees on forest land remaining as forest land were estimated as the differences between the increments in all of the forest land (Appendix\_7e) and those in land converted to forest land (Section 7.2.3.2). The annual increments for all of the forest land, in turn, were linearly interpolated from the estimates based on four national forest inventories (NFI8-NFI11) (see Appendix\_7a). These estimates,  $\Delta C_{G,NFI,sp,soil,region}$ , were computed separately for the above- and below-ground biomass increment by tree species group (sp = pine, spruce, broadleaved), soil type (mineral, organic), and region (South Finland, North Finland) using the following equation:

$$\Delta C_{G,NFI,sp,soil,region} = I_{V,NFI,sp,soil,region} \bullet BCEF_{G,NFI,c,sp,soil,region} \bullet CF,$$

where subscript G refers to growth and V to stem volume (as in GPG LULUCF 2003), and subscript c is included to index the two biomass compartments (above-ground and below-ground).  $I_V$  is the total increment of stem volume ( $m^3$ ) estimated using the standard NFI procedures (see, e.g., Tomppo et al. 2011), and the biomass conversion and expansion factors for the increment  $BCEF_G$  were computed (for both above- and below-ground biomass) separately for each NFI as the ratio of appropriately weighted mean biomass

increments and mean stem volume increments over the NFI sample trees belonging to the respective strata (Appendix\_7d). A default value of 0.5 was used for the carbon fraction CF.

The estimation of increments was based on tree-level measurements at five-year increments in the breast-height diameter (DBH) and in the height of the trees and on Finnish tree-level biomass models (Appendix\_7c), which enabled an estimation of the biomass five years before the inventory, in addition to the current biomass. The differences divided by five served as the estimates of annual biomass increments.

Each estimate,  $\Delta C_{G,NFI,sp,soil,region}$ , was allocated to the appropriately weighted mean of the mid-points for the five-year period of increment measurements, and the 30 June values of a linear interpolation between the estimates were reported as annual increments. The trend in total increment has been increasing for the whole period 1990-2007 (Appendix\_7e), but in order to avoid overestimation, the years after the NFI11 mean date were extrapolated as a constant equal to the NFI11 result.

### Annual decrease in carbon stocks due to biomass loss

The biomass loss in living trees in forest land remaining as forest land was estimated as the difference between the estimated biomass of the total drain and the sum of the estimated biomass losses due to forest land being converted to other land uses (see Sections 7.3.2.2, 7.4.2.2, 7.5.2.2, 7.6.2.2).

Drain is the decrease in the growing stock due to fellings and unrecovered natural losses. Fellings consist of commercial and other roundwood removals and harvesting losses. The annual statistics on *commercial removals* are based on the information provided by sampled roundwood purchasers and by Metsähallitus. The sample for removal statistics covers more than 90% of the roundwood purchasers and is, therefore, considered very reliable. Since 2000 commercial removals have been at the rate of 41-58 million m<sup>3</sup> annually (Finnish Statistical Yearbook of Forestry 2012).

The non-commercial roundwood removals refer to logs for contract sawing and the fuelwood used in dwellings. The Finnish Forest Research Institute has investigated the volumes of contract sawing and fuelwood in 10-year intervals. The estimate for contract sawing in 2012 is 0.3 million m<sup>3</sup> of logs and for fuelwood 5.4 million m<sup>3</sup> of logs. For the latter, the standard error is 4.9%. Accordingly, the roundwood removals in total have recently ranged from 47 to 62 million m<sup>3</sup>.

Part of the stems is left on the ground during fellings and, therefore, Finnish Forest Research Institute investigated those *harvesting losses*, including those from silvicultural measures, during 1966-1971. The results were presented as percentages of the total felled stemwood volumes (Mikkola 1972). Previously, annual harvesting losses have been approximately 4-6 million m<sup>3</sup> and fellings 39-69 million m<sup>3</sup>/a in total, (Finnish Statistical Yearbook of Forestry 2012), while since 2004 the estimate of harvesting losses was updated and during 2012, the amount of harvesting losses was 8.1 million m<sup>3</sup>.

The volume of *unrecovered natural losses* was estimated by the NFI based on the follow-up assessment of 3,000 permanent sample plots measured in 1985 and 1995. The estimated unrecovered natural losses were 2.8 million m<sup>3</sup>/a. The most recent estimate, 4.9 million m<sup>3</sup>/a, for the volume of *unrecovered natural losses* is based on the NFI9 and NFI10 measurements of permanent sample plots. These NFI-based estimates of unrecovered natural losses are included in the statistics on the total drain. Recently, the total drain has been 60-73 million m<sup>3</sup>/a.

This information on removals, fellings and drain is available for pine, spruce and broadleaved trees by the Forestry Centre regions and concerns total volumes by the three tree species groups. Carbon stock changes are reported in mineral and organic soils, but there is no information on the distribution of cutting removals according to the soil type. The following procedure was applied to estimate the distribution.

The annual drain of the growing stock without the natural drain component (i.e. stem removals and the residual stem parts in cuttings) was estimated for the Forestry Centre regions by tree species group and separately for intermediate fellings and regeneration fellings as well as for mineral soils and organic soils. These values were estimated for 1990-2012. The growing stock drain is published in the Finnish Statistical Yearbook of Forestry (2013). First, the natural drain component estimated for the 9<sup>th</sup> NFI was subtracted from the growing stock drain. This component does not include the natural drain removed in the cuttings.



Then, the drain in forest land remaining forest land was estimated as the difference between the estimate of the total drain and the sum of the estimated drain due to forest land being converted to other land uses.

The drain for the growing stock was divided into strata of mineral and organic soils and into intermediate and regeneration fellings by applying the yearly areas treated with fellings (Finnish Statistical Yearbook of Forestry 2012), the NFI10 estimates of the proportions of felling types on mineral and organic soils, and the NFI9 estimates of average removals in intermediate and regeneration fellings.

1. The annual felling areas were divided into mineral and organic soils and, within them, into intermediate and regeneration fellings by applying the proportions calculated from the NFI9 data by the Forestry Centre regions.
2. The mean volumes of removals in regeneration fellings were estimated from the NFI field plots, where regeneration was suggested for the next five years, while the removals in intermediate fellings were estimated from recently treated (0-5 years) forest stands and the removal was estimated to have been 25% of the original growing stock.
3. The total removals by strata were calculated by multiplying the strata areas (1) by the average removals by tree species (2). The proportions of removals in strata by tree species were used to divide the drain of the growing stock (without natural removals) into the particular strata (Table 7.2-2, Appendix\_7e).

As in the case of the increment, the drain of the growing stock is computed for the combined national productive forest land and poorly productive forest land. The forests belonging to this set but not to FAO forest land are very poorly productive forests, almost never treated with cuttings and in that sense in balance, i.e., the natural mortality of the trees is the same as the increment of the trees. This means that the increment minus drain is approximately zero and does not affect the CO<sub>2</sub> balance of the growing stock.

**Table 7.2-2** The drain by tree species groups (abbreviation decid. means broadleaved trees) in category forest land remaining forest land (million m<sup>3</sup>/a)

	Mineral soils			Organic soils			Total
	pine	spruce	decid.	pine	spruce	decid.	
1990	17.9	19.2	8.7	2.8	2.8	3.0	54.4
1991	13.7	16.1	7.1	2.2	2.3	2.4	43.8
1992	16.6	17.9	7.8	2.6	2.6	2.7	50.0
1993	17.2	19.1	8.2	2.7	2.7	2.8	52.7
1994	19.5	23.3	8.5	3.0	3.3	2.8	60.5
1995	20.3	23.4	9.2	3.1	3.3	3.0	62.4
1996	19.2	21.6	8.3	3.0	3.0	2.7	57.7
1997	20.9	24.9	9.0	3.2	3.5	2.9	64.4
1998	22.9	24.9	9.9	3.6	3.4	3.1	67.9
1999	22.8	25.1	9.8	3.6	3.4	3.1	67.8
2000	23.1	25.3	9.7	3.6	3.5	3.1	68.2
2001	22.4	23.7	9.7	3.5	3.3	3.1	65.7
2002	22.9	24.0	9.7	3.5	3.3	3.2	66.6
2003	23.7	23.9	9.9	3.6	3.3	3.2	67.7
2004	23.3	24.2	9.8	3.6	3.4	3.2	67.5
2005	22.3	22.8	9.9	3.4	3.2	3.3	64.9
2006	22.4	21.5	9.8	3.4	3.0	3.2	63.2
2007	25.8	23.7	10.6	3.9	3.3	3.5	70.9
2008	24.5	19.5	12.3	3.9	2.8	4.1	67.1
2009	19.0	16.4	13.3	3.0	2.3	4.2	58.2
2010	23.9	20.3	14.7	3.8	2.8	4.7	70.2
2011	23.8	20.0	14.7	3.8	2.8	4.7	69.8
2012	23.8	19.8	14.2	3.8	2.8	4.5	68.9

The stem volumes of the drain were converted to whole tree biomasses and those of the tree compartments using expansion factors estimated on the basis of the data from the permanent sample plots established in NF19 (1996-2003) and remeasured in NF10 (2004-2008). Separate expansion factors were computed for the fellings and for the unrecovered natural losses as the ratios of biomass stocks and stem volume stocks estimated from the NF19 measurements for those trees in the permanent plots that were harvested or had died between the inventories (Appendix\_7d). The same factors were applied for the whole series of drain volumes.

### *Carbon stock changes in dead wood, litter and soil organic matter*

#### **Mineral soils**

The methodology for estimating carbon stock changes in soil, litter and dead wood on mineral soils builds on the research by Liski et al. (2006). This method combines forest inventory data, biomass models, litter turnover rates and the dynamic soil carbon model. For forest land remaining as forest land, the Yasso07 model (Tuomi et al. 2011b) was applied. For a more detailed description of the Yasso07 model, see Appendix\_7f. The use of the Yasso07 model represents a continuation of the former model version, Yasso. The Yasso07 model is used for GHG reporting because there are no other existing methods to model estimates or produce estimates from measured soil data for country-specific carbon stock changes in mineral forest soils. The advantage of Yasso07 is the model's ability to produce uncertainty estimates for carbon stock changes. The model has been verified and reported in several scientific articles (Tuomi et al. 2008, 2009, 2011a, 2011b).

An aggregated estimate of the litter, dead wood and soil organic matter (DOM+SOM) was provided in the reporting because the Yasso07 soil carbon model estimates carbon stock change for the total of the above-mentioned components. The Yasso07 model has been defined to estimate carbon stock change to a depth of 1 metre. The division of the model estimate into soil carbon pools (SOM and DOM) is artificial, and therefore an aggregated estimate has been provided.

The aggregated estimate of carbon stock changes in DOM+SOM was driven by tree- and ground vegetation litter production and was estimated using the Yasso07 soil model, which has been developed for applications concerning the decomposition of various litter types and soils. The description of the processes and the model are available in Appendix\_7f. The Yasso07 simulations were made separately for the mineral soils of South and North Finland.

Before soil carbon stock change simulations, preliminary preparations had to be done involving three steps:

- i) Estimating the litter input data from trees, ground vegetation and drain and dividing them into three different decomposition compartments
  - non-woody litter (e.g. fine roots, foliage and ground vegetation)
  - fine woody litter (e.g. branches and woody roots)
  - coarse woody litter (e.g. dead wood, stumps and cutting waste)
- ii) Estimating weather parameters for South and North Finland
- iii) Estimating the initial values of the model state variables based on the NFI6 data (1971–1976) (sc. spin-up runs to obtain a steady state for the model)

The annual litter input of the model originated from the living trees, ground vegetation, harvesting residues and unrecovered natural losses. Litter production from living trees was estimated using the biomass compartments of living trees and litter production rate coefficients. Biomass compartments were calculated from NFI data using Finnish tree-level biomass models (Appendix\_7c). The method was similar to that for estimating the “annual increase in carbon stocks due to biomass growth” in the section on “carbon stock changes in living biomass”, except that current volumes and biomasses were used instead of the increments. Fine root biomass was estimated using coefficients that describe the relation between root and leaf biomass (Helmisaari et al. 2007).

The litter input has been estimated since the 6th National Forest Inventory (NFI6). Harvesting and drain statistics were also used to estimate the litter input of these components. Harvesting residues consist of foliage, branches, waste wood and stumps, while litter from living trees and from natural mortality consists of all the biomass components of trees. The increase in the energy wood use since 2000 was also taken into account by deducting the amounts of harvesting residues used for energy production (Finnish Statistical Yearbook of Forestry 2012). The volumes of the harvesting residues and unrecovered natural losses were converted to biomass using the expansion factors provided in Appendix\_7d; their derivation is explained at the end of the subsection “Annual decrease in carbon stocks due to biomass loss” in the section “Carbon stock changes in living biomass”. For the ground vegetation of the mineral soils, the biomass was estimated with the use of 3,000 permanent sample plots described by Mäkipää and Heikkinen (2003). The models of Muukkonen et al. (2006) were applied to estimate the biomass of shrubs, herbs and grasses and mosses separately for mineral soils in South and North Finland. The litter input of the ground vegetation was estimated using litter turnover rates presented by Liski et al. (2006).

The litter production from each tree biomass compartment was calculated using litter production rate coefficients (Table 7.2-3) as follows:

$$litter_i = r_i * W_i,$$

where  $r_i$  is the litter production rate of compartment  $i$  and  $W_i$  is the biomass of compartment  $i$  (kg). In mineral soils, litter production from the ground vegetation was assessed based on the vegetation coverage measurements of the NFI and biomass models (Muukkonen et al. 2006) (Table 7.2-4).

**Table 7.2-3** Litter production rates of the biomass compartments of trees (Lehtonen et al. 2004, Muukkonen and Lehtonen 2004, Starr et al. 2005, Liski et al. 2006). The litter production rate for pine needles in drained organic soils is based on measurements (Penttilä, unpublished data)

Tree species	Needles	Branches	Bark of stems	Bark of stumps	Roots >2mm	Fine roots
pine, south	0.245	0.02	0.0052	0.0029	0.0184	0.85
pine, north	0.154	0.02	0.0052	0.0029	0.0184	0.85
pine, drained peatlands	0.33	0.02	0.0052	0.0029	0.0184	0.85
spruce, south	0.1	0.0125	0.0027	0	0.0125	0.85
spruce, north	0.05	0.0125	0.0027	0	0.0125	0.85
deciduous, south	0.79	0.0135	0.0029	0.0001	0.0135	0.85
deciduous, north	0.79	0.0135	0.0029	0.0001	0.0135	0.85

**Table 7.2-4** Litter production of ground vegetation on drained organic soils and on mineral soils ( $\text{g C m}^{-2} \text{a}^{-1}$ ) (Laiho et al. 2003, Muukkonen et al. 2006)

Species group	Above ground	Below ground	Area	Soil
Shrubs	5.0	56.8	Finland	Drained organic
Herbs and grasses	13.1	53.7	Finland	Drained organic
Mosses	101.2		Finland	Drained organic
Total, South Finland	50.6	-	South Finland	Mineral soils
Total, North Finland	66.6	-	North Finland	Mineral soils

The weather data applied in the model runs were obtained from data provided by the Finnish Meteorological Institute (FMI). The daily weather data since 1961 were provided with a 10\*10 km grid covering all of Finland. The 10th National Forest Inventory data were thereafter used to estimate the "forest weather" of South and North Finland. The daily weather data were obtained from each grid point classified as forest according to the FAO definition. The mean annual weather data used with the Yasso07 model were estimated for South and North Finland for the period 1971-2012. The Yasso07 model requires an annual mean temperature, annual precipitation and temperature amplitude [ $0.5 * (\text{minimum monthly mean} - \text{maximum monthly mean})$ ] as an input.

The model initialisation was done using NFI6 data from 1971-1974 in South Finland and from 1975-1976 in North Finland. The average annual litter input of trees, ground vegetation, loggings and natural mortality from those periods were given to the Yasso07 model. The model used the given litter and mean weather data for 1961-1990 as the steady state. Earlier research has shown that approximately ten years of simulation since spin-up is enough to cancel out the effect of the spin-up level (Peltoniemi et al. 2006). Stock changes in forest soil carbon were reported as five-year moving averages. Model predictions provide an aggregate for the carbon stock change of dead wood, litter and soil organic matter.

The soil carbon stock change simulations based on litter input, weather data and the Yasso07 model resulted in emission factors for the mineral soils of the forest land remaining as forest land (see Appendix\_7g).

### Organic soils

Organic forest soils (peatlands) are defined according to the NFI:

- a site is classified as peatland, if the organic layer is peat or if more than 75% of the ground vegetation consists of peatland vegetation.

A description of the decomposition of peat is a significant part of estimating carbon stock changes in the organic forest soils in Finland, and these decomposition estimates were made using emission coefficients (heterotrophic soil respiration). The estimation for the emissions and removals on organic soils was done as follows:

$$\text{change in DOM+SOM} = \text{change in DW} + \text{below-ground litter input} - \text{emission from soil},$$

where DW refers to dead wood measured by the NFI9 and NFI10 field data. Below-ground litter input is based on the modelling of NFI data, while soil emissions have been measured by different site types. The modelling of the below-ground litter input is based on biomass estimates and on litter turnover rates and follows same the principles as litter modelling for mineral soils. The above-ground litter pool of drained organic forest soils were assumed to be in a steady state. The carbon stock change of dead wood on drained organic soils was based on the measurements for the NFI9 and NFI10 field data.

Carbon stock changes in organic soils were assessed only in the drained peatlands, while the carbon stock changes of soils in undrained peatlands were assumed to be in a steady state (equal to zero).

The decomposition of peat was estimated by multiplying the site-type-specific emission values (Minkkinen et al. 2007) (Table 7.2-5) by the corresponding area estimates provided by the NFI (Table 7.2-1).

The litter input of the trees on organic drained soils was based on the NFI measurements and biomass modelling of the corresponding NFI data. The biomass estimation is described in the section above. Below-ground litter inputs consisted of the annual litter production from the roots of trees, shrubs and graminoids and the roots of trees subjected to cuttings or natural losses. Similarly as in mineral soils, the below-ground litter production from trees was estimated as a product of the biomass estimate and turnover rate (Table 7.2-3). The annual below-ground litter production from ground vegetation was estimated according to Laiho et al. (2003) (Table 7.2-4). Stem volume estimates of dead wood on drained organic soils were based on the NFI9 and NFI10 plots and were converted to carbon by applying wood density and carbon content estimates by decomposition classes (see Mäkinen et al. 2006).

**Table 7.2-5** Carbon emissions ( $\text{g C m}^{-2} \text{a}^{-1}$ ) due to heterotrophic soil respiration from drained organic soils (peatlands) (Minkkinen et al. 2007). For the names of site types, see: (Laine 1989). Finnish abbreviations of the names are given in parenthesis

Name of site type group	Average emission	stdev
Herb-rich type (Rhtkg)	425.7	25.7
<i>Vaccinium myrtillus</i> type (Mtkg)	312.1	20.2
<i>Vaccinium vitis-idaea</i> type (Ptkg)	242.3	15.6
Dwarf shrub type (Vatkg)	218.9	15.4
<i>Cladina</i> type (Jätkg)	185.2	9.1

The estimated carbon stock changes in soils are presented annually for forest land remaining as forest land, separately for South and North Finland and by fertility type in Appendix\_7g.

### 7.2.3.2 Lands converted to forest land (CRF 5.A.2)

#### Activity data

Land use area calculations are described in detail in Sections 7.1.2 and 7.2.3.1 and in Appendix\_7b. The total area of forest land on mineral and organic soils and the area converted to forest land between 1990 and 2012 were computed using NFI10 and NFI11 data. Land use conversions before 1990 were estimated using NFI7-NFI11 data (Sections 7.1.2). The area of lands converted to forest land during each year between 1990 and 2012 is a cumulative sum of the converted areas over a 20-year period. The areas of drained organic soils by site types and undrained soils are derived in the same way as the area of lands converted to forest land.

The land-use categories from which areas have converted to forest land are cropland, grassland, wetlands, settlements and other land. Wetlands were further divided into lands converted from former peat extraction areas and undrained peatlands, which have been converted to forest due to drainage. Former settlements are a diverse group of lands. Areas belonging to this group include, for example, large forested gravel pits, forested roads and old abandoned dwelling places, especially in North Finland.

### Carbon stock changes in living biomass

The carbon stock change in living biomass of trees was estimated according to the Tier 2 method in the GPG LULUCF 2003 (Eq 3.2.25, p.3.53). The net mean annual increase per area unit due to tree growth was estimated separately for forest land converted from each of the other land-use categories (Table 7.2-6). For forest land converted from cropland, wetlands (in this context are peat extraction areas), or settlements, the tree biomass before and immediately after the conversion was assumed to be zero. The net mean annual increment after conversion was estimated as an average of current stocks per area unit divided by the number of years since the conversion (Table 7.2-7). For forest land converted from grassland or wetlands (drained peatlands), the assumption of initial zero biomass is not justified, and the net mean increment (Table 7.2-8) was estimated using similar methods as described in Section 7.2.3.1/Annual increase in carbon stocks due to biomass growth for all of the forest land. In both cases the mean increments were computed for the NFI11 sample plots belonging to the relevant converted categories and the same mean increments were applied throughout the entire time series.

The annual increase in carbon stocks was then obtained by multiplying the net mean increments by the annual area estimates of the converted categories. The losses in carbon stock in the living biomass of trees were not estimated separately because the method used gives an estimate of the average net-growth of the growing stock. This method does not exclude any cutting removals from the reporting since all cutting removals are included and reported in the category forest land remaining as forest land.

The loss in carbon stock due to the removal of annual non-woody crops from conversion of cropland to forest land was 4 t C/ha, which is a national value of mean crop biomasses based on yields. The subtraction was done in the year of the conversion. Similar subtractions were not done for the other conversion types, because it was assumed the initial vegetation will not be removed during the conversion.

**Table 7.2-6** Reported conversion types in category lands converted to forest land

Original land-use		Soil type	Drainage	Biomass before conversion
Cropland		mineral	yes	no
		organic	yes	no
Grassland		mineral	no/yes	yes
		organic	no/yes	yes
Wetlands	peat extraction	organic	yes	no
	peatland	organic	yes	yes
Settlements				no

**Table 7.2-7** Mean annual biomass increment (Mg/ha) in Forest land converted from Cropland, Peat extraction areas and Settlements (initial tree biomass assumed to be zero)

Conversion from	Tree species-soil type	Biomass increment
Cropland	Broadleaved-mineral	0.605
Cropland	Pine-mineral	0.325
Cropland	Spruce-mineral	0.239
Cropland	Broadleaved-organic	1.838
Cropland	Pine-organic	0.628
Cropland	Spruce-organic	0.649
Peat Extraction	Broadleaved-organic	2.791
Peat Extraction	Pine-organic	0.216
Settlements	Broadleaved-mineral	0.783
Settlements	Pine-mineral	0.954
Settlements	Spruce-mineral	0.434

**Table 7.2-8** Mean annual biomass increment (Mg/ha) in Forest land converted from Grassland and Wetland (initial biomass not equal to zero)

Conversion from	Tree species-soil type	Biomass increment
Grassland	Broadleaved-mineral	0.858
Grassland	Pine-mineral	0.118
Grassland	Spruce-mineral	0.114
Grassland	Broadleaved-organic	0.686
Grassland	Pine-organic	0.085
Grassland	Spruce-organic	0.192
Wetland	Broadleaved-organic	0.179
Wetland	Pine-organic	0.685

### *Carbon stock changes in dead wood, litter and soil organic matter*

#### **Mineral soils**

The Yasso07 soil carbon model (Tuomi et al. 2011b) was applied for the lands converted to forest land (see Appendix\_7f). The Yasso07 model was developed and tested against soil carbon measurements on afforestation and reforestation sites in a HILPE project and it was found that the model worked well against the measurements (Karhu et al. 2011). The HILPE project developed the estimation method of carbon stock changes for afforested/reforested croplands and for croplands that formerly had been forest land. Also the paper by Rantakari et al. (2012) resulted that estimated soil carbon stock changes by Yasso07 matched well with soil carbon stock measurements from Biosoil data of Finland.

For mineral soils, an aggregated estimate of the litter, dead wood and soil organic matter (SOM) was provided due to the fact that the Yasso07 soil carbon model estimates carbon stock change for the total of the above-mentioned components (DOM+SOM). The division of soil carbon pools from those models into SOM and DOM is artificial.

Before simulations, preliminary preparations were made using three steps:

- i) estimating the litter input data from trees and ground vegetation and dividing them into two different decomposition compartments
  - non-woody litter
  - fine woody litter (mean size 2 cm)
- ii) estimating the chemical properties of the litter (acid-, water-, ethanol- and non-soluble compounds) and weather data (mean temperature, amplitude and precipitation)
- iii) estimating the initial values of the model state variables (Table 7.2-9).

The annual mean temperature, precipitation and amplitudes ( $0.5 \times (\text{minimum monthly mean} - \text{maximum monthly mean})$ ) were estimated for South and North Finland (see a more detailed description of weather data derivation under the section on mineral soils above). The response of the soil carbon and litter stocks to the land-use change were estimated using the Yasso07 model and the average weather for the years 1971-2012 derived from the NFI10 plots.

The carbon stock estimates of the previous land use before conversion were estimated by applying the Yasso07 model with typical agricultural litter input provided by MTT Agrifood Research Finland. For both the cropland and grassland model, runs with Yasso07 were made with typical cultivation practices to estimate carbon stocks (Table 7.2-9). Carbon input from agricultural crops was estimated based on mean crop yields from agricultural statistics and harvest indices from the existing Nordic literature. The chemical quality of the wheat and barley litter was measured by fractionating it into the compound soluble in ethanol (E), water (W), hydrolysable with acid (A) and a non soluble- non hydrolysable residue (N) (Berg et al. 1991). For rye and oats, an average of these values was used because all these cereals have a rather similar chemical quality. The quality of grass litter was estimated based on Van Soest extractions (Jensen et al.

2005) that were transformed to correspond to the proximate carbon fractions (EWAN) with the regression models of Ryan et al (1990). The Yasso07 soil model was driven using mean weather data from the years 1971-2012. For unvegetated settlements the starting value of soil carbon was assumed to be equal to zero.

**Table 7.2-9** The carbon stocks of mineral agricultural soils and settlements (tons of carbon per ha) before land-use change for South Finland (SF) and North Finland (NF) divided into acid (A), water (W), ethanol (E), non-solubles (N) and humus compartments (tons C per ha).

Original land use	A	W	E	N	humus	total
Cropland SF	3.91	0.49	0.51	5.3	44.31	54.52
Cropland NF	4.86	0.61	0.64	6.6	36.76	49.48
Grassland SF	6.73	1.15	1.23	6.31	45	60.42
Grassland NF	8.38	1.43	1.53	7.86	37.45	56.65
Settlements	-	-	-	-	-	0

For lands converted to forest land, the litter input given in the model consisted of tree and ground vegetation litter. The tree litter estimation after land-use change was based on the corresponding NFI plots and then mean biomass of the NFI10 plots were used. The tree biomass estimation is described in the section above. This estimation was done separately for forested croplands, grasslands and settlements. The same biomass turnover rates were applied here as for forest land remaining as forest land. The average ground vegetation litter was also applied as an input during the simulations. The Yasso07 model runs were made for 20 years to estimate the response of the soil carbon to the land-use change. For settlements converted to forest land, only unvegetated settlements were simulated using the Yasso07 model. The soils of vegetated settlements (gardens, greenhouses, etc) were assumed to be in a steady state during conversion to forest land.

Annually estimated carbon stock changes in soils are presented for land converted to forest land and separately for South and North Finland in Appendix\_7g.

### Organic soils

The emission estimation of organic lands converted to forest land followed the estimation principles of organic forests remaining as forests, where emission factors by fertility have been applied with the modelled below-ground litter input (see organic soils under Section 7.2.3.1 Forest land remaining Forest land). The below-ground litter input of the trees was derived from the biomass estimates of the corresponding NFI data; for the ground vegetation average estimates of below-ground litter were used. The biomass estimation is described in the section above.

The difference between below-ground litter input and emissions was estimated for the period of 20 years after conversion and the annual average was used in the calculation.

**Table 7.2-10** The emissions of the original land use on organic soils converted to forests (tons C per ha)

Original land use	Assumed previous emissions of CO <sub>2</sub> (tons C per ha)	Source
Cropland	4.9	MTT Agrifood Research Finland
Grassland	3.2	(Maljanen et al. 2007)
Peat extraction sites	2.6	(Alm et al. 2007)
Wetlands	Depending on the fertility, see Table 7.2-5.	(Minkinen et al. 2007)

For organic lands converted to forests, previous emissions were obtained mainly from MTT Agrifood (Table 7.2-10). Those emission factors were in line with the reporting for the emissions from organic grasslands and croplands. Annually estimated carbon stock changes in soils are presented for land converted to forest land and separately for South and North Finland in Appendix\_7g.



## 7.2.4 Uncertainty and time series' consistency

### 7.2.4.1 Uncertainty of carbon stock changes in living biomass

The uncertainty due to NFI sampling in the estimates of biomass increment was assessed on the basis of four years' data from NFI11 (2009-12) using the standard approach of the Finnish NFI. As explained in Section 7.2.3.1, the total biomass increment was estimated as a sum of stratum-specific increments

$$I_{B,sp,soil,region} = I_{V,sp,soil,region} \bullet BCEF_{G,sp,soil,region}$$

where  $I_V$  is the stem volume increment and  $BCEF_G$  the biomass conversion and expansion factor for growth. Their sampling uncertainties, and the propagation of these uncertainties for the total biomass increment are reported in Table 7.2-11.

**Table 7.2-11** Sampling uncertainties, twice the relative standard errors, for NFI11 estimates of biomass increment in living trees,  $U(I_B) = \sqrt{U(I_V)^2 + U(BCEF)^2}$

Region	Soil	Tree species	Volume inc., $I_V$ million m <sup>3</sup> /a	$U(I_V)$ , %	BCEF	$U(BCEF)$ , %	Biomass inc., $I_B$ Tg/a	$U(I_B)$ , %
south	mineral	pine	22.19	2.7	0.572	0.4	12.693	2.7
		spruce	22.571	3.2	0.681	0.7	15.371	3.3
		deciduous	13.982	3.5	0.805	0.6	11.256	3.6
	organic	pine	6.452	3.5	0.587	0.5	3.787	3.5
		spruce	4.259	6.1	0.711	1.5	3.028	6.3
		deciduous	3.896	5.4	0.813	1.4	3.167	5.6
north	mineral	pine	13.059	6.5	0.613	0.5	8.005	6.5
		spruce	3.8	8.2	0.8	1.6	3.04	8.4
		deciduous	3.644	9.2	0.961	1.9	3.502	9.4
	organic	pine	5.63	4.3	0.62	0.5	3.491	4.3
		spruce	1.988	9.9	0.812	2	1.614	10.1
		deciduous	2.878	6.9	0.807	1.3	2.323	7
Total, using Equation 5.2.2 in GPG LULUCF 2003							71.277	1.5

The uncertainty due to NFI sampling in the expansion factors for fellings was also assessed by region, soil and species and propagated into the sampling uncertainty in the total biomass of fellings as reported in Table 7.2-12.

**Table 7.2-12** Sampling uncertainties, twice the relative standard errors, for the biomass loss due to fellings in 2012

Region	Soil	Tree species	Volume mill.m <sup>3</sup>	BCEF	Biomass Tg	U(biomass), %
south	mineral	pine	16.028	0.622	9.970	1.2
		spruce	17.200	0.729	12.538	1.4
		deciduous	11.099	0.845	9.379	10.1
	organic	pine	2.327	0.629	1.464	1.9
		spruce	2.177	0.777	1.692	4.7
		deciduous	2.570	0.876	2.251	7.1
north	mineral	pine	6.672	0.633	4.223	2.7
		spruce	1.421	0.811	1.153	4.8
		deciduous	1.765	0.907	1.600	11.7
	organic	pine	1.028	0.644	0.662	3.4
		spruce	0.370	0.851	0.315	6.4
		deciduous	1.528	0.857	1.309	4.0
Total, using Equation 5.2.2 in GPG LULUCF 2003					46.556	2.2

In addition to sampling uncertainty in the expansion factors, biomass estimate of fellings is influenced by the uncertainty in the felling volume. Assuming 5% uncertainty in the annual statistics on commercial removals yields 5.5% total sampling uncertainty for fellings. The sampling uncertainty, 14.7%, in the total biomass of unrecovered natural losses, 4.38 Tg/a, was estimated in the same way as demonstrated for fellings in Table 7.2-12. Propagation of sampling uncertainty for the net change in living biomass is reported in Table 7.2-13.

**Table 7.2-13** Sampling uncertainties, twice the relative standard errors, for the net change in living biomass in 2012

Source	Biomass change, Tg	Uncertainty, %
Increment	71.277	1.5
Fellings	-46.556	5.5
Natural losses	-4.380	14.7
Net change (GPG 2000, eq. 6.3)	20.181	14.8

Biomass conversion and expansion factors (BCEF) are also influenced by uncertainty due to uncertain parameter values of the biomass models, which were assessed with methods presented by Ståhl et al. (2014) on the basis of the simplest model versions with only tree species, diameter and height as explanatory variables (Appendix\_7h). The resulting estimates of model uncertainty are reported in Table 7.2-14.

**Table 7.2-14** Model uncertainties based on permanent sample plots, twice the relative standard errors, for net change in living biomass in 2012

Tree species	Biomass change, Tg	Uncertainty, %
pine	10.157	2.9
spruce	4.606	7.2
deciduous	1.462	41.9
Total	16.225	4.7

The total uncertainty in biomass change, including

- sampling uncertainty in volume increment based on NFI,
- assumed uncertainty, 5%, in annual statistics on commercial timber removals,
- NFI sampling uncertainty in all BCEF estimates, and
- biomass model parameter uncertainty in the net change,

computed from Table 7.2-13 and Table 7.2-13 is 15.9%.

#### 7.2.4.2 Uncertainty for Carbon stock changes in dead wood, litter and soil organic matter

Uncertainty estimation for mineral soils is described in Appendix 7i, yielding 46.8% uncertainty for the 2012 in South Finland, 26.2% uncertainty in North Finland, and 24.1% uncertainty for the net change in the whole country.

Further, the uncertainty in estimating the decomposition of peat on drained organic soils, based on the standard deviation of the emission coefficients reported by Minkkinen et al. (2007) (see Table 7.2-5), was added to the total variance estimate, yielding a 150% uncertainty for carbon stock change in organic soils in the year 2012.

#### 7.2.4.3 Combined uncertainty for carbon stock changes in forest land remaining forest land

The uncertainty estimates reported in Sections 7.2.4.1 and 7.2.4.2 are combined in Table 7.2-15.

**Table 7.2-15** Uncertainties, twice the relative standard errors, for carbon stock changes in forest land remaining forest land in 2012

Component	Change, Gg C	Uncertainty, %
Tree biomass	10 456	15.9
Mineral soils	2 139	24.1
Organic soils	-2 123	150
Total	10 472	34.6

#### 7.2.4.4 Uncertainty of carbon stock changes in land converted to forest land

The propagation of uncertainty for 2010 carbon stock changes on lands converted to forest land is reported in Table 7.2-16. Uncertainty due to sampling in the area estimates was estimated by the standard NFI methods. Assessments of uncertainty in the mean increment of living tree biomass and in the soil emission factors are based on expert judgement. The method will be further developed along the lines of Sections 7.2.4.1-7.2.4.3.

**Table 7.2-16** Uncertainties, twice the relative standard errors, for carbon stock changes in land converted to forest land in 2012

Component	Area, 1000 ha	Emission factor, Mg C/ha	Changes in carbon stock, Gg C	Uncertainty, %		
				Area	EF	Combined
Tree biomass	130.824	0.846	9.4	110.64	20	22.1
Mineral soils	84.883	-0.099	16	-8.38	60	62.1
Organic soils	45.941	-1.782	20	-81.89	90	92.2
Total				20.37		390.5

#### 7.2.4.5 Time series' consistency

Forest land area, tree biomass and the growth of the tree biomass were estimated using NFI data. The time series for the area of forest land was estimated using the NFI10 and NFI11 data. The entire time series for 1990-2012 was calculated from these data. Therefore, possible inconsistencies due to a different sample design or different classification between inventories were avoided. The latest NFI data were also used for area estimates because it was not possible to apply the FAO definition of a forest consistently to older data. Tree biomass and the growth of the biomass were estimated from data based on four NFIs. No inconsistencies can be expected between the inventories due to the use of the same methods and tree measurement techniques.

The time series consistency of the carbon stock change in mineral soils is ensured by using NFI data in a consistent way to estimate litter inputs. This means that the same biomass models and litter turnover rates are applied throughout the time series. This also applies to drained organic soils where emissions and litter inputs have been estimated with consistent methods since 1990.

### 7.2.5 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6.

The Finnish Forest Research Institute (Metla) has set up a management team to guide and supervise the reporting of emissions and removals for the LULUCF sector, which are part of Metla's responsibility. The members have a broad expertise in using the measurements and methodology to estimate carbon stock changes and greenhouse gases. All changes in methods, activity data and emissions or other factors and parameters are discussed and approved by the management team before they are introduced to the advisory board (see Section 1.6.1). Representatives from Statistics Finland and Agrifood Research Finland are invited to the meetings. The management team meets 2-4 times per year. After meeting small amendments, clarifications and additions were made in the NIR.

QA/QC related issues are discussed together with the inventory unit and other expert organisations in the inventory working group meetings (3-7 meetings per year) and at the bilateral quality meeting between Metla and the inventory unit once a year.

The quality control procedures specified in the GPG LULUCF 2003 Table 5.5.1 were followed for all calculations.

Tier 2 QC procedures:

- NFI is the only data source that covers all land-use categories. Forest and forest land areas were compared to the forest areas reported to the FAO. Calculated areas for land-use changes were compared to available statistics (see Chapter 11).

- We had a aim to improve to the reliability of area estimates for the 2014 submission, specially due to the KP reporting. Land-use changes are rare events and the transition areas are usually small in Finland. The question was, how to update the status of land-use category of the NFI sample plots to the end of 2012. A research project was launched in 2012 and ended in 2013. The aim was to update the land-use category of all NFI sample plots employed for GHG inventory. The project was funded by the Ministry of Environment. In the project, geographic information on land, land use, buildings, roads, land-use planning etc. were used to check and update the land-use of each sample plot. The NFI sample plots measured 2008-2011 were included in the process whose total number was about 70 000. Finally, 5501 sample plots were checked more detailed. The work enabled to compute areas from a full NFI dataset also for reporting years 2008-2012, and hence the uncertainty of the land-use changes was decreased.
- For every sample plot in the NFI data, the IPCC land-use category was determined. This prevents double counting. By summing up all the sample plots, it was assured that all plots have an IPCC land-use category (no missing data).
- The areas of all land-use categories were estimated by Metla to prevent double counting or omissions of land areas. MTT use the same areas of cropland and grassland for the agriculture sector.
- During the calculation procedure, the areas were summed up to check that all sample plots were included in the calculation: the areas of all the land-use categories and subcategories add up to the total land area in Finland.
- Areas of land-use changes were compared to the statistics (Table 11.3-2 and 11.3-3).
- The reporting covers the whole of Finland, since the NFI has been carried out throughout the country.
- All relevant carbon pools are included in forest land reporting. The excluded trees, those with a height less than 1.3 m, are not a significant part of the living biomass pool. Their proportion of the volume of growing stock is less than 1%, which is about the same as their proportion of the total biomass.
- NFI data were used for area and biomass estimation. The NFI is a sampling based inventory. The sampling method is reported in reviewed articles and books (Tomppo 2006, Heikkinen 2006, Tomppo et al. 1998, Tomppo et al. 2001).
- The aerial photos, satellite images and other material used to assess land-use changes for NFI sample plots and the applied procedure were documented.
- The biomass models implemented in this submission are published in reviewed articles (Repola 2008, Repola 2009). The development work took two years and the results were compared to calculations done using the previous Karjalainen and Kellomäki conversion factors. The biomass estimates were compared to the biomass estimates calculated using Marklund's models (Marklund 1988).
- The Yasso07 model was compared against repeated soil carbon measurements (BioSoil data and SLU soil inventory data). It was found the Yasso07 model agreed with repeated soil carbon measurements, but noting that both, model and measurements had substantial uncertainties (Rantakari et al. 2012 and Ortiz et al. 2003) (see also <http://www.metla.fi/ghg/yasso07-en.htm>).
- The Yasso07 model has been tested on afforestation, reforestation and deforestation sites by Metla and MTT in the HILPE project. The results from this comparison of the model results to the soil carbon measurements indicate the model performs adequately (Karhu et al. 2011).
- The following three program tools have been implemented to support GHG inventory reporting: 1) CRFTool program automates and provides error free transfer of inventory results to CRF Reporter. 2) check-ghg-inventory program reads and compares the results of two consecutive inventory years and reports those time series that differ more than given percentage in any one year. 3) ghg-to-do program reads the results of two consecutive inventory years and reports those times series that have been calculated for the previous year but not (yet) for the current year and vice versa.

The data based on forest statistics were produced by the Finnish Forest Research Institute, Forest Information Service. Data descriptions are available (in Finnish), including the applied definitions, methods of data compilation, reliability and comparability (<http://www.metla.fi/metinfo/tilasto/hakkuut/>, <http://www.metla.fi/metinfo/tilasto/metsienhoito/>).

### 7.2.6 Source-specific recalculations, including changes made in response to the review process

The recalculation of forest land is described in detail in Section 7.1.3. Due to the recalculation of forest land areas, the carbon stock changes in the biomass, DOM and SOM pools were also recalculated. The effects of recalculations are shown in Table 7.2-17.

NFI11 data for 2012 became available also for tree biomass estimation. This implied changes in the interpolated values for all the years after the mean measurement date of NFI10 which is year 2006 for biomass stock and after the mean date for the five-year increment measurement period (approximately from 2004 onwards) for the tree biomass increment.

**Table 7.2-17** Implication of recalculations made in Forest land category to the emission level in 1990 and 2012 (Gg CO<sub>2</sub> eq.)

	Submission 2013	Submission 2014	Difference	Submission 2013	Submission 2014	Difference
	1990			2011		
FL remaining FL						
Biomass	-27 774	-27 508	266	-37 095	-36 588	507
Mineral soil	-7 747	-7 691	56	-6 291	-6 950	-659
Organic soil	12 081	12 088	7	7 234	7 381	147
Total	-23 440	-23 111	329	-36 152	-36 157	-5
Lands converted to FL						
Biomass	-166	-430	-264	-227	-441	-214
Mineral soil	150	112	-37	48	33	-15
Organic soil	505	449	-56	343	291	-52
Total	488	131	-358	164	-117	-281

The weather data used with the Yasso simulations were updated to include data for the latest inventory year.

### 7.2.7 Source-specific planned improvements

The validation of the Yasso07 soil carbon model will be continued. A new project has started in 2012, in which the model based estimates will be compared against the measured soil and litter data. Duration of the project is two years.

The work to improve tree biomass removal estimates has started at Metla in 2011. The aim is to have better estimates for the allocation of cutting removals to the mineral and organic forest lands, as well for lands converted to and from forest land. The plan was to implement the results in this submission, but due to changes in the tasks of the responsible research group in 2013 it was not possible to finish the work. The study will continue and the results will be implemented when ready during the second commitment period of the Kyoto Protocol.

## 7.3 Cropland (CRF 5.B)

### 7.3.1 Source category description

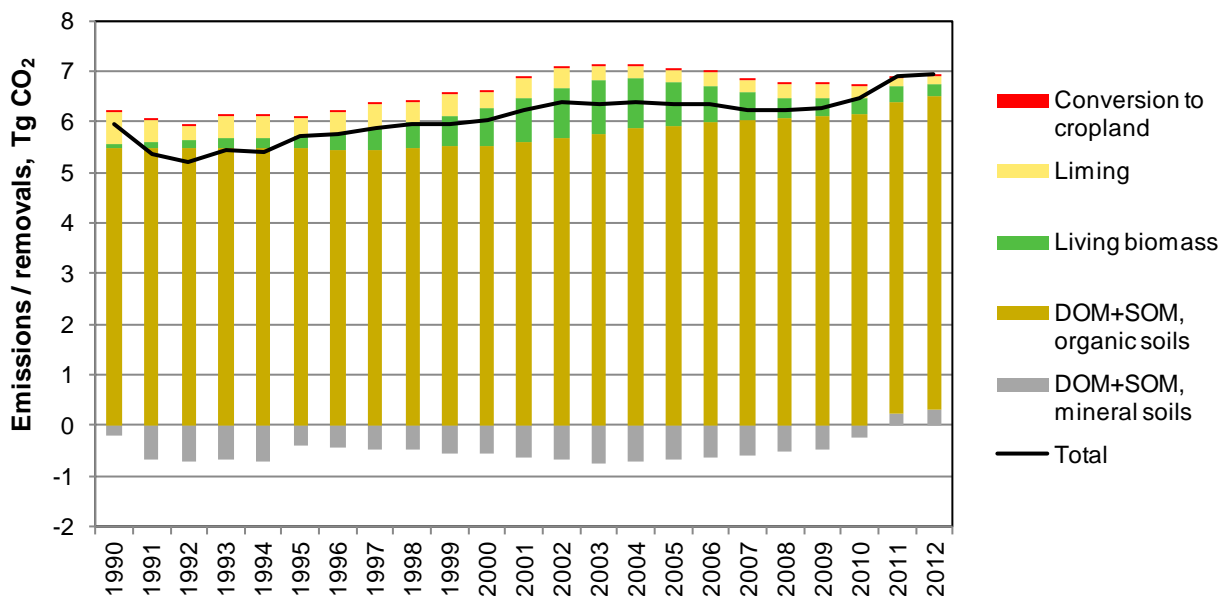
The total net emissions from croplands were 6.0 Tg CO<sub>2</sub> eq. in 1990 and 6.9 Tg CO<sub>2</sub> eq. in 2012. The CO<sub>2</sub> emissions from cultivated organic soils, mineral soils and liming were 6.2, 0.3 and 0.2 Tg, respectively. The carbon stock change in living biomass was 0.2 Tg in 2012.

The cropland source category includes carbon stock changes in soils (both mineral and organic) and living biomass reported as CO<sub>2</sub> emissions as well as CO<sub>2</sub> emissions from liming and N<sub>2</sub>O emissions from mineral soil conversion to cropland. Nitrous oxide emissions from fertilization of croplands are not reported as part of the cropland category but under the category of agriculture (4.D Agricultural soils).

The area of cropland comprises of the area used for arable crops, grass ( $\leq$  five years), permanent horticultural crops, greenhouses, kitchen gardens and set-aside. The area of cropland is divided into land remaining cropland and areas converted to cropland. The area data are obtained from NFI (see Section 7.1.2).

The amount of CO<sub>2</sub> emitted from soils is affected, for example, by the type and amount of organic material input, disturbance, soil properties and climatic variables (IPCC, 1997). Soils may act as sources of or sinks for CO<sub>2</sub> depending on the conditions. Agricultural practices and lime application affect the amount of CO<sub>2</sub> released from croplands.

Croplands have been a net source of CO<sub>2</sub> since 1990. The mineral soils have mainly been a sink for CO<sub>2</sub>, but the magnitude of the sink varies according to the area and management of the soils. The organic soils have been an increasing source of CO<sub>2</sub> due to their increased area. Emissions from liming have decreased slightly as the usage of lime has declined. The changes in living biomass vary according to the activities in clearance of forest to new fields (Figure 7.3-1).



**Figure 7.3-1** Emissions and removals in cropland, Tg CO<sub>2</sub>

## 7.3.2 Methodological issues

### 7.3.2.1 Cropland remaining cropland

#### Activity data

The area estimates for cropland remaining as cropland were obtained from the NFI data (Table 7.1-3). The distribution of the whole area to mineral and organic soils is based on the NFI and soil database data. The percentage distribution of different mineral soil types is estimated so that the proportion of sandy soils is 64% and that of the high-activity soils is 36% (Table 7.3-1). The estimate for the proportion of sandy and high-activity soils is based on the data on the soil type distribution of the soil fertility samples taken from farms in the years 1998-2002 and analysed in the largest laboratories performing such analyses in Finland. Low-activity soils, as defined by the GPG LULUCF 2003, are not found in Finland (Yli-Halla et al. 2000). The area estimate of no-till agriculture before 2005 is based on expert judgement (Mikkola et al. 2005), as is the area of reduced tillage for the whole time series (Smith et al. 2004). From 2005 onwards, the statistics on the no-till area are available from the Information Centre of the Ministry of Agriculture and Forestry. In the category of full tillage, the area is divided into medium input and high input so that the area of organic farming found in the statistics of the Ministry of Agriculture and Forestry is considered to be the area receiving high input.

The area estimate for cultivated organic soils was derived in the manner described in Section 7.1.2. The proportions of grass and other crops grown on organic soils were obtained from the agricultural statistics for the years 1995 and 2008 and the values for the other years were derived by linear interpolation and extrapolation. Organic soils are determined to be those soils containing more than 20% organic matter in the top 20 cm layer of the soil and thus the definition corresponds to the guidelines of the IPCC.

**Table 7.3-1** Distribution of areas of soil types, management and input on mineral cropland remaining as cropland (1 000 ha) (Yearbook of Farm Statistics; Mikkola et al. 2005)

	1990	1995	2000	2005	2010	2012
<b>Sandy soils</b>	<b>1 343</b>	<b>1 337</b>	<b>1 322</b>	<b>1 315</b>	<b>1 314</b>	<b>1 312</b>
Crops	1 240	1 211	1 219	1 179	1 140	1 161
Full tillage	1 097	1 032	980	865	762	767
Medium input	1 093	1 010	914	807	705	705
High input	3	22	66	58	57	62
Reduced tillage	143	179	215	250	286	301
No-till	1	0	25	64	91	94
Fallow	103	126	102	136	173	151
<b>High activity soils</b>	<b>751</b>	<b>747</b>	<b>737</b>	<b>730</b>	<b>725</b>	<b>723</b>
Crops	693	676	680	655	629	640
Full tillage	612	576	546	480	421	423
Medium input	611	564	510	448	389	388
High input	1.8	12	37	32	32	34
Reduced tillage	80	100	120	139	158	166
No-till	0.3	0	14	35	50	52
Fallow	58	70	57	76	96	83
<b>Organic soils</b>	<b>283</b>	<b>283</b>	<b>281</b>	<b>282</b>	<b>286</b>	<b>287</b>

#### Carbon stock changes in biomass

The biomass of apple trees and currants are taken into account when calculating the carbon stock change in the living biomass. The method corresponds to the Tier 2 method of the IPCC (IPCC 2003). The annual carbon stock change is determined as the difference between biomass accumulation due to growth and its loss as removals of old plants. The emissions are also allocated to cropland remaining as cropland in cases in which cropland was converted to other land-use categories. This is done using the following equation:



$$\Delta C C C C_{LB} = \sum_i (C_{ai} - C_{di})$$

$$B_{hi} = d_i * w_i * Frac_{Dm} * Frac_C$$

$$G_i = B_{hi} / H_{ci}$$

$$C_{ai} = A_i * G_i$$

$$C_{di} = A_{ci} * B_{hi}$$

where

i denotes the plant species (currants, dwarfish apple trees, vigorously growing apple trees)

$\Delta C C C C_{LB}$  = Annual change in carbon stocks in the living biomass, tonnes C/a

$C_{ai}$  = Carbon accumulation in a year

$C_{di}$  = Carbon decline in a year

$B_{hi}$  = Above-ground biomass carbon stock at harvest, tonnes C/a

$d_i$  = Density of growing plants

$w_i$  = Weight of an average single plant

$Frac_{Dm}$  = Dry matter content of the above-ground biomass

$Frac_C$  = Carbon fraction

$G_i$  = Biomass accumulation rate, tonnes C/ha/a

$H_{ci}$  = Harvest cycle, a

$A_i$  = Area of growing plants

$A_{ci}$  = Size of cleared area (plants removed).

The parameters used for determining the carbon stock changes in the living biomass for apple trees and currants are presented in Table 7.3-2. Apple trees were divided into vigorously growing and dwarfish trees and the typical average values for apple trees and black, red, green or white currant bushes were estimated. The background information (e.g. density, mature weight, dry matter) for the coefficients in Table 7.3-2 was obtained from national experts (Source: Tahvonen, MTT Agrifood Research Finland, pers.comm., and Tanska, Horticulture Union, pers.comm.). The division value (50% of trees are dwarfish) for the year 2007 is an estimate from an inquiry made by the Information Centre of the Ministry of Agriculture and Forestry, which has been inter/extrapolated for the years 1998-2008 and extrapolated since that. The dwarfish trees began to come to the market in 1997.

**Table 7.3-2** National coefficients for living apple trees and currants (cropland remaining as cropland)

	Aboveground biomass carbon stock at harvest (t C/ha)	Harvest cycle (a)	Biomass accumulation rate (t C/ha/a)	Biomass carbon loss (t C/ha)
Vigorously-growing apple trees	18	35	0.514	18
Dwarfish apple trees	21	18	1.167	21
Currants	4.0	17	0.236	4.02

The Information Centre of the Ministry of Agriculture and Forestry collects data for the area on apple trees and currants (Table 7.3-3).

**Table 7.3-3** Areas of apple trees and currants, ha

	Vigorously-growing apple trees	Dwarfish apple trees	Currants
1990	380	0	1 407
1991	361	0	1 598
1992	348	0	1 550
1993	354	0	1 534
1994	377	0	1 497
1995	419	0	1 535
1996	437	0	1 723
1997	447	0	1 772
1998	446	18	1 793
1999	446	33	1 867
2000	457	49	1 976
2001	464	67	2 259
2002	473	87	2 373
2003	486	110	2 451
2004	487	133	2 485
2005	489	157	2 443
2006	462	173	2 342
2007	453	196	2 264
2008	447	221	2 190
2009	418	235	2 097
2010	415	264	2 007
2011	389	279	1 920
2012	369	299	1 813

### *Carbon stock changes in soil*

#### **Mineral soils**

The calculation of CO<sub>2</sub> emissions from the mineral soils of cropland remaining as cropland is based on changes in the carbon stocks resulting from changes in land-use and management activities over a period of 20 years according to the Tier 1 method (IPCC 2003). The reference carbon stock values for each soil type are multiplied by the IPCC default management and input factors for each soil and land-use type. The change in carbon stocks between the inventory year and 20 years before the inventory year is calculated for each soil type, land-use, management and input category. Changes in the carbon stocks of all soil and land-use categories are summed up to gain the net carbon stock change for mineral soils. CO<sub>2</sub> emissions for each inventory year are calculated by multiplying the carbon stock change during a 20-year time period by -1 and the coefficient 44/12 and dividing this by 20.

The default carbon stock change factors (IPCC 2003) for a temperate wet climate were used for estimating the effect of land use, management and input on carbon stock changes in mineral cropland soils (Table 7.3-4).

**Table 7.3-4** Carbon stock change factors used in calculating CO<sub>2</sub> emissions from cropland remaining as cropland (Source: IPCC, 2003)

	C stock (t/ha)	F <sub>LU</sub> <sup>a</sup>	F <sub>MG</sub> <sup>b</sup>	F <sub>I</sub> <sup>c</sup>
<b>Sandy soils</b>				
Crops				
Full tillage				
Medium input	71	0.71	1.0	1.0
High input	71	0.71	1.0	1.38
Reduced tillage				
No-till	71	0.71	1.09	1.0
Fallow	71	0.82	1.0	1.0
<b>High activity soils</b>				
Crops				
Full tillage				
Medium input	95	0.71	1.0	1.0
High input	95	0.71	1.0	1.38
Reduced tillage				
No-till	95	0.71	1.09	1.0
Fallow	95	0.82	1.0	1.0

<sup>a</sup>Stock change factor for land use or land-use change type.

<sup>b</sup>Stock change factor for management regime

<sup>c</sup>Stock change factor for input of organic matter

### Organic soils

Emissions from organic soils are calculated using the following equation (IPCC 2003):

$$\Delta C_{ccOrganic} = A * EF$$

where  $\Delta C_{ccOrganic}$  = Annual CO<sub>2</sub> emissions from cultivated organic soils in cropland/grassland

A = Land area (ha)

EF = Emission factor (t C ha<sup>-1</sup> a<sup>-1</sup>).

The amount of carbon released is converted to CO<sub>2</sub> by multiplying it by 44/12.

For calculating CO<sub>2</sub> emissions from cropland remaining as cropland on organic soils, national emission factors are used for organic soils under grass or other crops (Table 7.3-5).

**Table 7.3-5** Emission factors used for calculating CO<sub>2</sub> emissions from cropland on organic soils

Emission source	EF (t C/ha/a)	Reference
Grass	4.1	Maljanen et al. (2007)
Other crops	5.7	Maljanen et al. (2007)

### 7.3.2.2 Land converted to cropland

#### Activity data

Areas and proportions of mineral and organic soils in the class of land converted to cropland (Table 7.3-6) were estimated using the NFI data together with the soil database as described in Section 7.1.2.

**Table 7.3-6** Areas of land converted to cropland by soil type (1 000 ha).

Converted from	Soil type	1990	1995	2000	2005	2010	2012
Forest land	mineral	49	43	43	51	49	50
	organic	22	18	20	31	35	36
Grassland	mineral	0.74	1.1	3.2	6.4	11	13
	organic	0.07	0.33	0.44	1.1	2.0	2.7
Wetland	mineral <sup>a</sup>	NO	NO	NO	NO	NO	NO
	organic	4.1	4.6	6.0	13	14	13
Settlements	mineral	NO	NO	NO	NO	0.44	1.0
	organic	NO	NO	NO	NO	NO	NO
Other land	mineral	NO	NO	NO	NO	NO	NO
	organic	NO	NO	NO	NO	NO	NO

<sup>a</sup>former peat harvesting areas that were converted to mineral soils as the peat was removed

#### Changes in biomass and dead organic matter

The removal of biomass from forest land converted to cropland was estimated using the products of the annual converted areas and the mean living tree biomass over all forests, excluding the most xeric sites, which were considered unsuitable for conversion to cropland (Appendix\_7e). The removal of biomass after the conversion of grassland to cropland was 8.5 t C/ha (IPCC 2003). An increase in the carbon stock during the first year after the conversion from forest land or grassland to cropland was 4 t C/ha which is a national value of mean crop biomasses based on yields.

The removal of deadwood from forest land converted to cropland was estimated using the products of the annual converted areas and the mean deadwood carbon stock. The mean deadwood carbon stocks were estimated separately for South and North Finland but only for organic soils since they are included in the estimate of soil C in mineral soils (see Appendix\_7j).

**Table 7.3-7** Carbon stock change in living biomass and DOM (Gg C) in forest land converted to cropland

	Soil	1990	1995	2000	2005	2010	2012
Living biomass	mineral	-19	-57	-127	-143	-55	-40
	organic	-3.2	-10	-78	-93	-36	-26
DOM	organic	-0.12	-0.21	-1.12	-1.38	-0.47	-0.32

#### Carbon stock changes in soil

Carbon stock changes in forest land converted to cropland on mineral soils were estimated using the Yasso07 model (Appendix\_7f), which has been found to simulate C stock changes well in cases when forest is cleared to cropland (Karhu et al. 2011). The results of the simulation of forest soil carbon stocks were used as the initial state values and they represent the typical forest soil carbon stocks for South and North Finland (Table 7.3-8). The carbon input values were derived from the average yields for a typical crop rotation together with data on the carbon fractions (Karhu et al. 2011). Annually estimated carbon stock changes in soils are presented as the range and average for forest lands converted to cropland and separately for South and North Finland in Table 7.3-9.

**Table 7.3-8** Initial C stock of forest and the C input as crop residues divided in fractions for the Yasso07 model simulations of forest land converted to cropland

Parameter	C stock in the initial state (t/ha)		Input <sup>a</sup> (t C/ha)
	South Finland	North Finland	
Total C	67	53	1.86
Acid soluble	9.5	7.2	0.69
Water soluble	1.0	0.8	0.44
Ethanol soluble	1.1	0.9	0.12
Non-soluble	11	7.7	0.61
Humus	45	37	-

<sup>a</sup> The average annual input of a crop rotation

**Table 7.3-9** Estimated carbon stock changes of soil organic matter and dead organic matter in mineral forest soils converted to cropland (20 years after conversion)

Carbon stock change (t C/ha)	Activity	Soil type	Area	Min	Max	Mean
DOM+SOM	FL to CL	Mineral	South	-1.41	0.07	-0.42
DOM+SOM	FL to CL	Mineral	North	-0.34	0.02	-0.09

Carbon stock changes in grassland converted to cropland on mineral soils were calculated using the Tier 1 method for calculating the carbon stocks before and after the land use change (IPCC 2003). The difference in the carbon stocks divided by 20 was reported as the annual stock change. The average annual change per hectare is 1.2 t C. The emissions from organic forest soils or grassland soils converted to cropland were calculated using the mean emission factor for the cultivation of grass or other crops on organic soils (4.9 t C/ha).

### 7.3.2.3 CO<sub>2</sub> emissions from liming

The emissions from the liming of agricultural soils are mainly reported under cropland remaining as cropland, but a minor part is reported under grassland. Forest lands are not limed in Finland. The emissions from liming have been calculated using the IPCC method described in the GPG LULUCF 2003. Limestone (CaCO<sub>3</sub>), dolomite (MgCa(CO<sub>3</sub>)<sub>2</sub>) and briquette lime were included. The amount of lime sold annually is multiplied by the specific emission factor for each lime type in order to estimate the amount of carbon in each compound. The high water content (33%) of briquette lime (waste material from sugar factories) is taken into account in the calculations. Carbon is converted to CO<sub>2</sub> by multiplying it by 44/12.

The IPCC default emission factors are used for calculating CO<sub>2</sub> emissions from agricultural lime application. The emission factors are 0.12 for limestone and 0.13 for dolomite and 0.12 for briquette lime (IPCC 2003).

The amount of lime sold annually has been used as activity data. The amount of lime on cropland is the annual total minus the amount that was allocated to grassland based on the area of improved grassland (Table 7.3-10). The data have been taken from the Yearbook of Farm Statistics together with some additional data from the lime producers. The emissions from limestone and briquette lime have been combined in the CRF table for limestone since they have the same emission factor.

**Table 7.3-10** The amount of lime sold annually (1,000 t/year)

	Cropland Limestone+ briquette lime	Dolomite	Grassland Limestone	Dolomite	Total
1990	624	707	7	7	1 345
1991	426	498	7	7	938
1992	428	163	7	7	606
1993	700	280	7	7	995
1994	702	279	7	7	996
1995	603	238	8	8	856
1996	705	283	9	9	1 006
1997	729	287	11	11	1 037
1998	665	263	11	11	949
1999	667	264	11	11	952
2000	503	195	13	13	723
2001	611	240	13	13	876
2002	652	258	13	13	937
2003	425	163	14	14	616
2004	386	144	14	14	559
2005	404	150	17	17	588
2006	453	174	18	18	662
2007	374	144	17	17	552
2008	437	173	16	16	642
2009	472	187	17	17	692
2010	368	143	17	17	544
2011	273	101	16	16	406
2012	289	110	16	16	431

### 7.3.3 *Uncertainty and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

Total uncertainty in cropland remaining cropland was  $\pm 79\%$  and in land converted to cropland  $\pm 72\%$ .

The area estimates in the cropland category are mainly based on the national forest inventory. Since the time series were estimated using the NFI10 data, any possible inconsistency due to a different sample design or different classification between inventories was avoided. However, there are subdivisions based on expert judgement, such as areas under reduced tillage and no-till agriculture but the effects of these on the net carbon stock change in the whole category is of minor importance.

Since the calculation method for cropland remaining as cropland is Tier 1 while the method for the area of forest land converted to cropland is Tier 3, the calculation is not totally consistent.

#### 7.3.3.1 *CO<sub>2</sub> emissions from liming*

The uncertainty in activity data for liming is estimated at  $\pm 20\%$  based on expert judgement. The uncertainty estimate for the emission factor is negatively skewed ( $-20$  to  $+3\%$ ) because more than 100% of the carbon cannot be released, but the amount can be smaller.

The amount of lime sold annually has been received from the same sources for the whole time series thus the time series can be considered consistent. However, because the estimation of the amount of lime applied annually to agricultural soils is based on sales statistics, and not on the amounts applied, it causes some additional uncertainty in this emission source category.

### *7.3.4 Source-specific QA/QC and verification*

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6. The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives in LULUCF. The bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert. The comments received about QA from the reviews of the inventory are taken into account when developing the inventory.

The QA/QC plan for the LULUCF category (cropland, grassland) includes the QC measures based on the IPCC (IPCC 2000, Table 8.1, p. 8.8-8.9). These measures are implemented every year during the inventory. Potential errors and inconsistencies are documented and corrections are made if necessary. The files and documents used in preparing the inventory are archived annually and back-up copies are made daily.

The area estimate for cropland from the NFI data was compared with the estimate from the field register in 2010 and they were found to be nearly equal. The suitability of the Yasso07 model for simulating carbon stock changes in forest land converted to cropland was investigated in a project. The results showed that Yasso07 could be used to simulate C stock changes in forest land converted to cropland. The results were published as a peer-reviewed article (Karhu et al. 2011); thus the verification of the method was done according to the Tier 2 QA methodology.

### *7.3.5 Source-specific recalculations including changes made in response to the review process*

To increase the accuracy of the emission estimates, the time series of the areas were updated (see Section 7.1.3) and all soil and biomass emissions were recalculated.

### *7.3.6 Source-specific planned improvements*

The suitability of the Yasso07 model for estimating carbon stock changes in agricultural soils will be investigated in an ongoing project.

The work to improve tree biomass removal estimates has started at Metla in 2011. The aim is to have better estimates for the allocation of cutting removals to the mineral and organic forest lands, as well for lands converted to and from forest land. The plan was to implement the results in this submission, but due to changes in the tasks of the responsible research group in 2013 it was not possible to Finnish the work. The study will continue and the results will be implemented when ready during the second commitment period of the Kyoto Protocol.

## 7.4 Grassland (CRF 5.C)

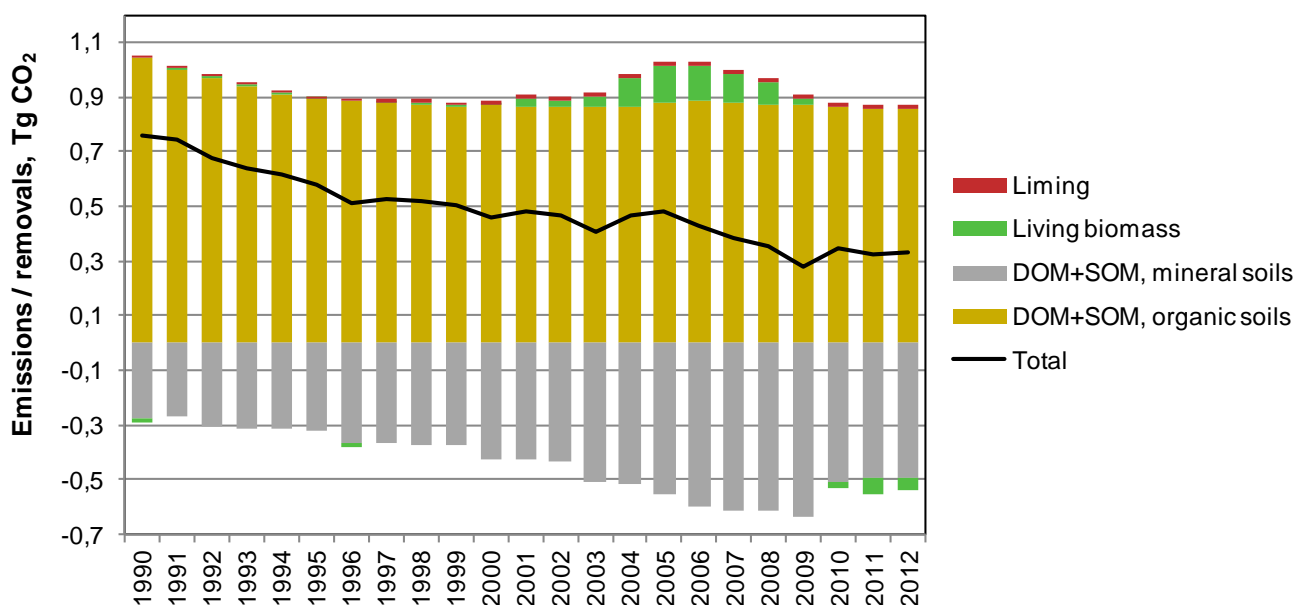
### 7.4.1 Source category description

Carbon stock changes in organic and mineral grassland are reported under the grassland category. The emissions of organic soils on grasslands were 0.9 Tg CO<sub>2</sub> in 2012 and the sink for mineral soils was 0.5 Tg CO<sub>2</sub>. The sink of living biomass were 47 Gg CO<sub>2</sub>. CO<sub>2</sub> emissions from liming were 15 Gg. The net emissions from grasslands were 0.3 Tg CO<sub>2</sub> in 2012.

In Finland, there are no large grazing land areas or permanent grasslands. The area of grassland consists mostly of abandoned fields that are slowly gaining tree biomass and turning to forest soils. The grassland category comprises grasslands and meadows more than five years old together with the abandoned agricultural areas that have not turned into forest land yet (FAO forest definition). The area is divided between grasslands remaining as grasslands and land converted to grasslands.

The amount of CO<sub>2</sub> emitted from soils is the result of changes in the carbon stocks of the soils. The soil carbon balance is affected by, for example, the type and amount of organic matter input, disturbance, soil properties and climatic variables (IPCC 1997). The soils may act as a source of or sink for CO<sub>2</sub> depending on the conditions.

The emissions from grasslands on organic soils have decreased since 1990 (Figure 7.4-1). The reason for the decrease is that some grassland have been converted to cropland. The sink of mineral soil has increased due to the increase of the proportion of improved grassland. The trend in biomass varies according to clearance of new grassland from forest.



**Figure 7.4-1** Emissions and removals in grassland, Tg CO<sub>2</sub>



## 7.4.2 Methodological issues

### 7.4.2.1 Grassland remaining grassland

#### Activity data

The area estimate for grasslands was derived from the NFI data in the manner described in Section 7.1.2. The division of grassland remaining as grassland into high-activity and sandy soils is done according to the description in Section 7.3: Cropland. The area was also divided between nominally managed and improved grassland (Table 7.4-1).

**Table 7.4-1** Distribution of areas of soil types and management on grassland remaining as grassland (1 000 ha)

	1990	1995	2000	2005	2010	2012
Sandy soils						
Nominally managed	65	64	60	61	64	64
Improved	8.7	10	16	21	21	20
High activity soils						
Nominally managed	36	36	34	34	36	36
Improved	5	5	9	12	12	12
Organic soils	71	59	56	55	53	51
<b>Total</b>	<b>186</b>	<b>174</b>	<b>175</b>	<b>183</b>	<b>186</b>	<b>183</b>

#### Carbon stock changes in soils

##### Mineral soils

CO<sub>2</sub> emissions from grassland remaining as grassland on mineral soils are calculated using the methods described in Chapter 3 of the GPG 2000 for Land Use, Land-Use Change and Forestry (Equation 3.4.9B in IPCC 2003). The methodology used corresponds to the Tier 1-level method of the GPG LULUCF 2003. Carbon stocks are estimated for each soil type category of the mineral soils in the inventory year and 20 years prior to that. The default carbon stocks for grasslands are multiplied by the stock change factor for each soil type. Changes in the carbon stocks of all soil types are summed up to gain the net carbon stock change for mineral soils. The sum of the stock changes in each category is multiplied by -1 and divided by 20 to obtain the annual emission that is reported.

IPCC default carbon stocks for high activity and sandy grassland soils for a wet temperate climate were used together with the default carbon stock change factors for nominally managed and improved grassland (Table 7.4-2).

**Table 7.4-2** Carbon stocks and stock change factors used in calculating CO<sub>2</sub> emissions from grassland remaining as grassland (Source: IPCC 2003)

	C stock (t/ha)	F <sub>LU</sub> <sup>a</sup>	F <sub>MG</sub> <sup>b</sup>	F <sub>I</sub> <sup>c</sup>
<b>Sandy soils</b>				
Nominally managed	71	1	1	1
Improved	71	1	1.14	1
<b>High activity soils</b>				
Nominally managed	95	1	1	1
Improved	95	1	1.14	1

<sup>a</sup>Stock change factor for land use or land-use change type.

<sup>b</sup>Stock change factor for management regime

<sup>c</sup>Stock change factor for input of organic matter

## Organic soils

Organic soils are determined to be as those soils containing more than 20% organic matter in the top 20 cm layer of the soils and thus defined according to the IPCC methodology.

Emissions from organic soils are calculated using the following equation (IPCC 2003):

$$\Delta C_{ccOrganic} = A * EF$$

where  $\Delta C_{ccOrganic}$  = Annual CO<sub>2</sub> emissions from cultivated organic soils

A = Land area (ha)

EF = Emission factor (t C ha<sup>-1</sup> a<sup>-1</sup>): Maljanen et al. 2007).

The amount of carbon released is converted to CO<sub>2</sub> by multiplying it by 44/12.

### 7.4.2.2 Land converted to grassland

#### Activity data

The area estimate for grasslands was derived from the NFI data in the manner described in Section 7.1.2. The division of grassland remaining as grassland into high-activity and sandy soils is done according to the description in Section 7.3: Cropland. The area estimates for land converted to grassland divided by the soil type are presented in Table 7.4-3.

**Table 7.4-3** Areas of land converted to grassland by soil type (1,000 ha)

Converted from	Soil type	1990	1995	2000	2005	2010	2012
Forest land	mineral	8	8	8	10	11	10
	organic	NO	NO	1	2	3	4
Cropland	mineral	72	59	58	54	49	50
	organic	18	17	17	16	13	13
Wetland	mineral	NO	NO	NO	NO	NO	NO
	organic	NO	NO	NO	1	3	3
Settlements	mineral	NO	NO	NO	1	NO	NO
	organic	NO	NO	NO	NO	NO	NO
Other land	mineral	NO	NO	NO	NO	NO	NO

#### Carbon stock changes in biomass and dead organic matter

The removal of biomass in the area of forest land converted to grassland was estimated using the products of the annual converted areas and the mean living tree biomass for all the forests, excluding most xeric sites, which were considered unsuitable for conversion to grassland (Appendix 7e). The removal of cropland biomass when converted to grassland was 4 t C/ha. An increase in the carbon stock for the first year after the conversion was estimated using the Tier 1 methodology. The amount of carbon added as crop biomass was 8.5 t C/ha, as suggested in Table 3.4.9 of the GPG LULUCF 2003. The gain in tree biomass on abandoned fields, which represents a small sink of carbon, was not estimated due to lack of data.

The removal of deadwood in forest land converted to grassland was estimated using the products of the annual converted areas and the mean deadwood carbon stock. The mean deadwood carbon stocks were estimated separately for South and North Finland for organic soils (see Appendix\_7j). In mineral soils, DOM is included in the estimate of soil carbon.

**Table 7.4-4** Changes in biomass and DOM (Gg C) in forest land converted to grassland

	1990	1995	2000	2005	2010	2011
Living biomass	-16	-18	-18	-55	-9.5	-4.0
DOM	NO	-0.04	-0.04	-0.21	-0.05	-0.08

Carbon stock changes in forest land converted to grassland on mineral soils were estimated using the Yasso07 model (Appendix\_7f). The results for the simulation of forest soil carbon stocks were used as the initial state values and they represent the typical forest soil carbon stocks for South and North Finland (Table 7.4-5). The carbon input values were derived from the average yields of agricultural grasses together with data on the carbon fractions (Karhu et al. 2011). Annually estimated carbon stock changes in soils are presented as a range and average for forest lands converted to grassland and separately for South and North Finland in Table 7.4-6.

**Table 7.4-5** Initial C stock of forest and the C input as crop residues divided into fractions for the Yasso07 model simulations of forest land converted to grassland

Parameter	C stock in the initial state (t/ha)		Input <sup>a</sup> (t/ha)
	South Finland	North Finland	
Total C	67	53	4.33
Acid soluble	9.5	7.2	1.81
Water soluble	1.0	0.8	1.87
Ethanol soluble	1.1	0.9	0.32
Non-soluble	11	7.7	0.33
Humus	45	37	-

<sup>a</sup> The annual input of agricultural grass species

**Table 7.4-6** Estimated carbon stock changes (t C/ha) in soil organic matter and dead organic matter for mineral forest soils converted to grassland (20 years after conversion)

Carbon stock change (t C/ha)	Activity	Soil type	Area	Min	Max	Mean
DOM+SOM	FL to GL	Mineral	South	-0.38	-0.04	-0.16
DOM+SOM	FL to GL	Mineral	North	0.05	1.14	0.23

Carbon stock changes in cropland converted to grassland on mineral soils were calculated using the Tier 1 method (IPCC 2003). The carbon stocks before and after the land use change were determined using the average carbon stocks for sandy and high-activity soils together with the carbon stock change factors for tilled cropland with medium input (Table 7.3-4) and nominally managed grassland (Table 7.4-2). The annual stock change per hectare was calculated based on the difference in the carbon stocks of cropland and grassland divided by 20. The converted area (ha) was multiplied by the annual carbon stock change (1.2 t C/ha) to obtain the total annual C stock change.

#### 7.4.2.3 CO<sub>2</sub> emissions from liming

The emissions from liming have been calculated using the IPCC method described in the GPG LULUCF 2003. The amount of lime sold annually is multiplied by the specific emission factor for each lime type in order to estimate the amount of carbon in each compound. Carbon is converted to CO<sub>2</sub> by multiplying it by 44/12.

IPCC default emission factors are used for calculating the CO<sub>2</sub> emissions from resulting agricultural lime application. The emission factors are 0.12 for limestone and 0.13 for dolomite (IPCC 2003).

The grassland area consists mostly of abandoned fields that are not limed. Liming has been allocated to the area of fields that have had grass cover for more than five years, not to abandoned fields. An annual amount of 1000 t/ha was assumed a default level of liming for these soils (5 t every 5 years) (Table 7.3-10). The emissions were divided between limestone and dolomite (50:50).

### *7.4.3 Uncertainty and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

Total uncertainty in grassland remaining grassland was  $\pm 202\%$  and in land converted to grassland  $\pm 3455\%$ .

The time series for the emissions from grasslands is consistent. However, since the calculation method for grassland remaining as grassland is Tier 1 while the method for the area of forest land converted to grassland is Tier 3 the calculation is not totally consistent.

### *7.4.4 Source-specific QA/QC and verification*

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6. The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives in LULUCF. The bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert.

The QA/QC plan for the LULUCF category (cropland, grassland) includes the QC measures based on the IPCC (IPCC 2000, Table 8.1, p. 8.8-8.9). These measures are implemented every year during the inventory. Potential errors and inconsistencies are documented and corrections are made if necessary. The files and documents used in preparing of the inventory are archived annually and back-up copies are made daily.

The comments received from the reviews of the inventory are taken into account in developing the inventory.

A research project for verifying the use of the Yasso07 model for calculating the carbon stock changes in the case of grassland is currently ongoing. The results of the project will be published as a peer-reviewed article; thus the verification can be considered a Tier 2 QA process.

### *7.4.5 Source-specific recalculations, including changes made in response to the review process*

To increase the accuracy of the emission estimates, the time series of areas were updated (see Section 7.1.3) and all emissions from soils were recalculated.

### *7.4.6 Source-specific planned improvements*

The possibility to use the Yasso07 model for estimating carbon stock changes in grassland remaining grassland will be examined in an ongoing project.

The work to improve tree biomass removal estimates has started at Metla in 2011. The aim is to have better estimates for the allocation of cutting removals to the mineral and organic forest lands, as well for lands converted to and from forest land. The plan was to implement the results in this submission, but due to changes in the tasks of the responsible research group in 2013 it was not possible to Finnish the work. The study will continue and the results will be implemented when ready during the second commitment period of the Kyoto Protocol.

## 7.5 Wetlands (CRF 5.D)

### 7.5.1 Source category description

According to the GPG LULUCF 2003, wetlands include land that is covered or saturated by water for all or part of the year and that does not fall into the forest land, cropland, grassland or settlement categories (IPCC 2003). Wetlands are reported on in the sub-categories wetlands remaining as wetlands (CRF 5.D 1) and lands converted to wetlands (CRF 5.D 2).

Wetlands remaining wetlands are divided to managed and unmanaged part. The unmanaged part consists of natural lakes and rivers, and peatlands that do not fulfil the definition of forest land. These peatlands are for the most part undrained and thus can be considered unmanaged. The subgroups belonging to the managed wetlands are reservoirs. No emissions are estimated on wetlands remaining wetlands because the method for estimating the emissions from wetlands remaining as wetlands is given in Appendix 3a.3 and, therefore, reporting on them is not mandatory (IPCC 2003). All areas converted to Wetlands are considered managed.

The category Forest land converted to Wetlands (CRF 5.D.2.1) is divided into three subcategories according to type of conversion: Inland waters, Peat extraction and Regressed. The total CO<sub>2</sub> emissions from forest land converted to wetlands were 0.5 Tg CO<sub>2</sub> in 2012. The category Other land converted to Wetlands (CRF 5.D.2.5) is divided into two subcategories: Inland waters and Peat extraction. Inland waters under this category include lands converted to Inland waters from all other land uses than forest land. Peat extraction under this category includes land converted to peat extraction from all other land uses than forest, and land remaining in peat extraction. The total CO<sub>2</sub> emissions from these lands were 1.3 Tg CO<sub>2</sub> in 2012.

N<sub>2</sub>O and CH<sub>4</sub> emissions from wetlands are reported in category CRF 5 (II). However, the description of the method and activity data for all three gases are given in this section. The emissions from peat extraction fields comprise the emissions from the area of active and temporarily set-aside peat extraction fields and abandoned, non-vegetated peat extraction areas. Emissions from peat combustion are calculated under the energy sector. The CH<sub>4</sub> emissions from lands converted to inland waters consist of diffusive emissions during ice-free period.

When forest land is converted to peat extraction or to inland waters the carbon stock change in the living tree biomass is reported under the forest land converted to wetlands category (CRF 5.D 2.1).

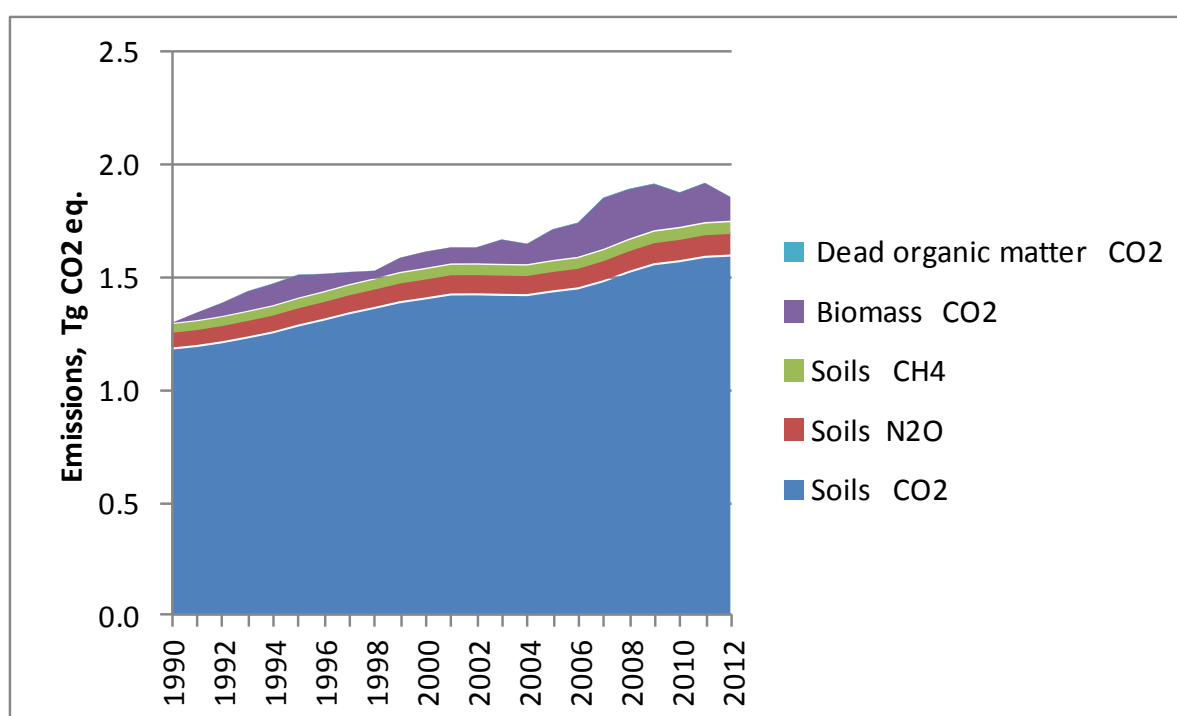
The total emissions from lands converted to peat extraction and the lands remaining in peat extraction were 1.86 Tg CO<sub>2</sub> eq. in 2012. The total emissions including the emissions from regressed peatlands and land converted to inland waters were 1.91 Tg CO<sub>2</sub> eq. in 2012 (see Figure 7.5-1 and Table 7.5-1)

**Table 7.5-1** Greenhouse gas emissions from lands converted to Wetlands in 2012 (Gg CO<sub>2</sub> eq.)

	Biomass	Dead wood	CO <sub>2</sub>	Soil CH <sub>4</sub>	N <sub>2</sub> O	Total*
Peat extraction areas						
Converted from Forest land	105	1	331	11	21	469
Converted from Other land use	NO	NO	1 266	41	79	1 387
Peatlands						
Regressed from Forest land	NO	NO	44	-	-	44
Inland waters						
Converted from Forest land	NA,NO	NA,NO	1	2	-	2
Converted from Other land use	NA	NA	5	3	-	8
<b>Total</b>	<b>105</b>	<b>1</b>	<b>1 647</b>	<b>57</b>	<b>100</b>	<b>1 910</b>

NA and NO refer to CRF notation keys: no emission in inventory year

\* Results are presented as integral numbers. Total sums coincide those in CRF.



**Figure 7.5-1** Emissions from wetland, Tg CO<sub>2</sub> eq.

## 7.5.2 Methodological issues

### 7.5.2.1 Wetlands remaining Wetlands

#### *Activity data*

The areas of wetlands remaining wetlands were calculated from NFI9-NFI11 data; the method is described in detail in Section 7.1.2. Wetlands remaining wetlands is divided into three subcategories: Inland waters, managed and unmanaged. Inland waters include all natural lakes and rivers, and remaining reservoirs. Managed subcategory consists of abandoned peat extraction fields that have developed to wetlands. Unmanaged subcategory consists mainly of undrained peatlands not fulfilling the definition of forest land.

#### *Carbon stock changes in living biomass*

A method for estimating the emissions from wetlands remaining as wetlands is given in Appendix 3a.3 and, therefore, reporting on them is not mandatory (IPCC 2003). Currently there is not sufficient information available to prepare reliable estimates for this category.

#### *Carbon stock changes in dead wood, litter and soil organic matter*

A method for estimating the emissions from wetlands remaining as wetlands is given in Appendix 3a.3 and, therefore, reporting on them is not mandatory (IPCC 2003). Currently there is not sufficient information available to prepare reliable estimates for this category.

### 7.5.2.2 Lands converted to Wetlands

#### *Activity data*

The areas of lands converted to wetlands were calculated from NFI9-NFI11 data; the method is described in detail in Section 7.1.2.

Annual peat extraction areas are computed using NFI data. The areas were estimated for three regions: south boreal, middle boreal and north boreal regions. This regional area information was computed by combining

NFI plot data with a vegetation zone data. The vegetation zone data (different boreal zones) were obtained from the Finnish Environment Institute (2010).

The category Forest land converted to Wetlands is divided into three subcategories according to type of conversion: Inland waters, Peat extraction and Regressed. Inland waters include forest land converted to reservoirs. Regressed category consists of forest lands that have converted to wetlands. This can happen for example due to rise in the water level, which slows down the growth of the trees even leading to losses in tree biomass so that the definition of forest land is no longer fulfilled. The category Other land converted to Wetlands is divided into two subcategories: Inland waters and Peat extraction. Inland waters under this category include lands converted to Inland waters from all other land uses than forest land. Peat extraction under this category includes land converted to peat extraction from all other land uses than forest, and land remaining in peat extraction.

### *Forest land converted to wetlands*

This category consists of organic forest land that has regressed to wetlands (CRF 5.D.2.1).

#### *Carbon stock changes in living biomass*

When forest land regresses to wetlands, the biomass is not removed, but it no longer fulfils the definition for forest land. The biomass is assumed in steady state, so that gains equal removals.

#### *Carbon stock changes in dead wood, litter and soil organic matter*

Emissions from these soils were reported by applying the emission factors shown in (Table 7.5-2).

**Table 7.5-2** Estimated carbon stock changes of soil organic matter and dead organic matter in organic forest soils converted to Wetlands (peat extraction or peatlands), tons C per ha

Carbon stock change (tons C per ha)	Activity	Soil type	Area	Emission factor
DOM+SOM	FL to WL (peat extraction)	Organic	South boreal	-3.99
DOM+SOM	FL to WL (peat extraction)	Organic	Middle boreal	-3.89
DOM+SOM	FL to WL (peat extraction)	Organic	North Boreal	-3.62
SOM+litter	FL to WL (peatlands)	Organic	Finland	-1.85

### *Lands converted to inland waters*

Emissions from land converted to inland waters were reported separately for Forest land converted to inland waters (CRF 5.D.2.1) and Other land converted to inland waters (CRF 5.D.2.5). Other land converted to inland waters contains all conversion classes except conversion from Forest land. Emissions from removal of tree biomass and from soils due to land-use conversion were estimated. Gases reported are CO<sub>2</sub> and CH<sub>4</sub>.

#### *Carbon stock changes in living biomass*

It was assumed that during conversion to inland water, all tree biomass is removed. The amount of emissions due to losses in tree biomass when forest land is converted to inland water was estimated as the product of the annual converted areas and the current mean biomass for all forests. Mean biomasses applied are listed in Appendix\_7e.

#### *Carbon stock changes in dead wood, litter and soil organic matter*

Method applied for CO<sub>2</sub> is the 2006 IPCC Guidelines Level 1 method presented in 2006 IPCC Guidelines (IPCC 2006, Appendix 2). Level 1 method includes only the diffusive emissions during the ice-free period. Diffusive emissions related to ice-cover period are assumed to be zero. Emissions were assumed to be limited to the first 10 years which is the default assumption of the method.. Emission factor applied for CO<sub>2</sub>

is the median IPCC default for Polar/Boreal wet climate:  $11.8 \text{ kg CO}_2 \text{ ha}^{-1} \text{ day}^{-1}$  (IPCC 2006, Table 2A.2, p. Ap2.6). Length of ice-free period was assumed to be 180 days.

#### *Non-CO<sub>2</sub> emissions*

CH<sub>4</sub> emissions were estimated with Tier 1 method of the 2006 IPCC Guidelines (IPCC 2006, Appendix 3). Tier 1 method includes only the diffusive emissions during ice-free period. Emissions during the ice-cover period are assumed to be zero. Emission factor applied for CH<sub>4</sub> is the median IPCC default for Polar/Boreal wet climate:  $0.086 \text{ kg CH}_4 \text{ ha}^{-1} \text{ day}^{-1}$  (IPCC 2006, Table 3A.2, p. Ap3.5). Length of ice-free period was assumed to be 180 days.

#### *Lands converted to peat extraction*

##### *Carbon stock changes in living biomass*

The loss in tree biomass due to the conversion of forest land into peat extraction was estimated as the product of the converted area and the current mean living tree biomass for all forest land suitable for peat extraction, i.e. forest land where the organic layer consists mainly of peat and is thicker than 150 cm. Mean biomasses of land converted from forest land to other land uses are provided in Appendix\_7e.

##### *Carbon stock changes in dead wood, litter and soil organic matter*

The emissions from the deadwood carbon pool due to land-use change were estimated by applying emission factors. More details about these emission factors are provided in Appendix\_7j.

The emissions from peat extraction sites were calculated by multiplying the area estimates by the national emission factors. Emissions from stockpiles and ditches are included in the inventory. In the process of peat extraction, a part of the litter from the forest land converted to the wetland is used to construct a stable ground for peat stockpiles and thus emissions of this part of the litter are included in the emissions measured from the stockpiles of harvested peat. The rest of the litter is mixed with peat during the extraction and its emissions are included in the emissions from the energy sector.

The CO<sub>2</sub> emission factor describing the changes in the soil organic matter due to the oxidation of peat in the aerobic layer on the land during peat extraction is based on recent research (Alm et al. 2007).

Carbon dioxide emissions from the soil are in proportion to the soil surface layer temperature and soil moisture. Therefore, a statistical relationship between CO<sub>2</sub> evolution with soil temperature at a depth of 5 cm and the position of the water table was established. It is assumed that the sites studied represent the behaviour of similar sites elsewhere in Finland, but the summertime (snow-less period) CO<sub>2</sub> emission controlled by temperature and soil moisture regimes are typical for the location. Based on that assumption, regional weather-dependent emission factors were generated. The regional weather patterns were obtained from long-term (30-year) weather statistics, and the daily and hourly temperatures were generated using a weather simulator that corresponded to the measured long-term average monthly temperatures. Wintertime (snow-covered period) gas emissions were calculated using the averages of the observed values. The soil moisture was accounted for by computing the CO<sub>2</sub> emissions for several static summertime water table values separately in order to find reasonable extreme values (close to the minimum and maximum) for the emissions integrated over the course of the year.

Emission factors for CO<sub>2</sub> were computed for 11 locations (weather stations) in Finland. The locations were pooled into climatic zones and the corresponding summertime CO<sub>2</sub> emissions averaged for the entire zone. Three zones were defined: north boreal, middle boreal and south boreal. Separate CO<sub>2</sub> emission factors are provided for the north boreal, middle boreal and south boreal vegetation zones (water table 40 cm) (Table 7.5-3).

The data from measurements used in the estimation of the emission factors are still very sparse and will be improved when new data become available.



The emission factors for stockpiles and ditches are based on national measurements (Nykänen et al. 1996; Alm et al. 2007). It was assumed that 70% of stockpiles exist for all of June, July and August (92 days), while they are used for energy production between September and April (and therefore the estimated average wintertime existence of a stockpile is four months, being 122 days). To ensure energy security, approximately 30% of stockpiles are kept year round (365 days), and originating emissions were estimated accordingly. Daily estimates of CO<sub>2</sub> fluxes for stockpiles during a summer day were 83, whereas for a winter day they were 139. Summertime flux rates were used for the period between May and August, while wintertime estimates were applied to the period between September and April.

**Table 7.5-3** Emission factors used in calculating of emissions from peat extraction sites (kg CO<sub>2</sub> eq./ha/year). (Nykänen et al. 1996, Alm et al. 2007)

Source of flux	Share of area	CO <sub>2</sub> emissions			CH <sub>4</sub> emissions			N <sub>2</sub> O emissions		
		South Boreal	Middle Boreal	North Boreal	South Boreal	Middle Boreal	North Boreal	South Boreal	Middle Boreal	North Boreal
<b>Stockpiles</b>	2%	293 955	293 955	293 955	6 275	6 275	6 275	910	910	910
<b>Ditches</b>	7%	90	90	90	3 724	3 724	3 724	1	1	1
<b>Production</b>	91%	9 860	9 460	8 400	105	105	105	961	961	961
<b>Total emissions</b>	<b>100%</b>	<b>14 615</b>	<b>14 250</b>	<b>13 282</b>	<b>468</b>	<b>468</b>	<b>468</b>	<b>895</b>	<b>895</b>	<b>895</b>

### 7.5.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents the assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

The uncertainty associated with the peat extraction area stems from several different sources. The most important source of uncertainty is associated with CO<sub>2</sub>; by volume CO<sub>2</sub> is the most important GHG species emitted from the extraction areas. For CO<sub>2</sub> emission dynamics, the effects of summertime (May-October) temperatures and moisture are important (Alm et al. 2007). The present emission factors do not account for the effect of moisture variation, because no moisture monitoring exists. However, the contribution of inter-annual variations in temperatures was assessed via weather simulations based on statistics from the reference period 1961-1990. The simulated temperatures were used in regression transfer models to estimate the contribution of long-term weather variations in CO<sub>2</sub> emissions. The standard deviation of the simulated fluxes varied from 6% to 8% for the cumulative summertime emissions. The SD of CO<sub>2</sub> emissions measured in wintertime was approximately 10%. The fluxes in CH<sub>4</sub> and N<sub>2</sub>O vary in a complex way and the range of observations around the mean was skewed. Therefore, the uncertainties cannot be estimated simply by combining the variances. If the uncertainty for summertime CO<sub>2</sub> emissions is estimated using 2SD (±12-16%), the contribution of winter CO<sub>2</sub> and non-CO<sub>2</sub> emissions (CH<sub>4</sub>, N<sub>2</sub>O) with lower emission rates can be expertly deemed to increase the level of uncertainty to ±25% CO<sub>2</sub> equivalents. On rare occasions, the CO<sub>2</sub> emissions from the extraction field could rise by about 200% (Alm et al. 2007); however, most of the available data support the present lower emission factors.

Uncertainty due to sampling in the area of peat extraction was estimated by the standard method of Finnish NFI (Table 7.1-3). Applicable data is currently not available for assessing the uncertainty in the estimated loss of tree biomass due to conversion of forest land into peat extraction; expert judgement 100% was used.

The area estimations are based on NFI data and the total areas of the peat extraction fields are consistent for the entire time series (1990-2012) because they were computed using the same NFI data. Land conversions before 1990 were interpolated using NFI9-NFI11 data.

Tree biomass is estimated using data from four NFIs. There should not be any inconsistencies between the inventories because the same methods and tree measurement techniques were used. The CO<sub>2</sub> and CH<sub>4</sub> emissions from flooded land and from lands converted to flooded land were estimated with IPCC (2006) default emission factor values and the uncertainty of those were estimated to be one order of magnitude, i.e. 100%.

### 7.5.4 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6.

The Finnish Forest Research Institute (Metla) has set up a management team to guide and supervise the reporting of emissions and removals for the LULUCF sector, which are part of Metla's responsibility. The members have a broad expertise in using the measurements and methodology to estimate carbon stock changes and greenhouse gases. All changes in methods, activity data and emissions or other factors and parameters are discussed and approved by the management team before they are introduced to the advisory board (see Section 1.6.1). Representatives from Statistics Finland and Agrifood Research Finland are invited to the meetings. The management team meets 2-4 times per year.

QA/QC related issues are discussed together with the inventory unit and other expert organisations in the inventory working group meetings (3-7 meetings per year) and at the bilateral quality meeting between Metla and the inventory unit once a year.

The quality control procedures specified in the GPG LULUCF 2003 Table 5.5.1 were followed. In particular, the land areas were critically compared to the statistical ones and the causes for the differences between the two data sources were identified.

The NFI peat extraction areas were compared to statistical areas (Table 7.5-4). At the end of the time series, the areas estimated using NFI plot data were substantially greater than those estimated using statistics. This is because of the small number of NFI field plots available for the last years, since the NFI inventory cycle is 5 years. Area estimates for the years 2007 onwards will improve when there are more NFI data available. The statistical areas for the annual peat extraction areas were acquired from the Association of Finnish Peat Industry (1990-1995) and from the VAHTI system from 1996 onwards. Since the data from the VAHTI system do not cover all peat extraction areas, it was complemented and evaluated by the Thule Institute (Mäenpää and Jutila 2008).

The following three program tools have been implemented to support GHG inventory reporting: 1) CRFTool program automates and provides error free transfer of inventory results to CRF Reporter. 2) check-ghg-inventory program reads and compares the results of two consecutive inventory years and reports those time series that differ more than given percentage in any one year. 3) ghg-to-do program reads the results of two consecutive inventory years and reports those times series that have been calculated for the previous year but not (yet) for the current year and vice versa.

**Table 7.5-4** Area of industrial peat extraction in Finland (1000 ha) compared to the statistics

Year	Forest land converted to peat extraction	Other land converted to peat extraction	Total	Area from statistics	Difference
1990	17.8	64.6	82.4	64.7	17.7
1991	17.3	65.9	83.2	66.0	17.2
1992	17.1	67.3	84.4	68.9	15.5
1993	17.2	68.6	85.9	70.3	15.6
1994	17.5	70.0	87.5	72.6	14.9
1995	17.8	71.8	89.6	73.8	15.8
1996	17.9	73.5	91.4	76.3	15.1
1997	17.7	75.8	93.4	78.8	14.6
1998	17.1	78.0	95.1	80.9	14.2
1999	16.8	80.1	96.9	82.0	14.9
2000	16.5	81.6	98.1	83.3	14.8
2001	16.1	83.2	99.3	83.5	15.8
2002	15.8	83.6	99.4	82.2	17.2
2003	15.7	83.5	99.3	82.1	17.2
2004	15.7	83.5	99.2	88.3	10.9
2005	16.2	84.1	100.3	87.2	13.1
2006	16.8	84.5	101.3	86.8	14.5
2007	18.2	85.4	103.5	85.3	18.2
2008	19.4	87.0	106.4	87.3	19.1
2009	20.4	88.4	108.8	85.1	23.7
2010	21.8	87.9	109.8	87.2	22.6
2011	22.9	88.2	111.1	83.7	27.4
2012	23.1	88.4	111.5	81.8	29.7

### 7.5.5 Source-specific recalculations

New area estimates were calculated as a result of new data, updating of NFI data and corrections (see Section 7.1.3). In addition, the emission estimates changed due to the recalculated land areas. This resulted in recalculations of the emissions from lands converted to Wetlands (Table 7.5-5).

**Table 7.5-5** Recalculations made in Wetlands category and their implications to the emission level in 1990 and 2011 (Gg CO<sub>2</sub>eq.)

	Submission 2013 1990	Submission 2014 1990	Difference	Submission 2013 2011	Submission 2014 2011	Difference
Peat extraction areas						
Converted from Forest land	256	256	0	641	505	-136
Converted from Other land use	861	927	67	1 293	1 263	-31
Peatlands						
Regressed from Forest land	118	118	0	47	45	-3
Inland waters						
Converted from Forest land	5	5	0	0	0	0
Converted from Other land use	4	4	0	1	4	3
Total	1 244	1 311		1 983	1 817	

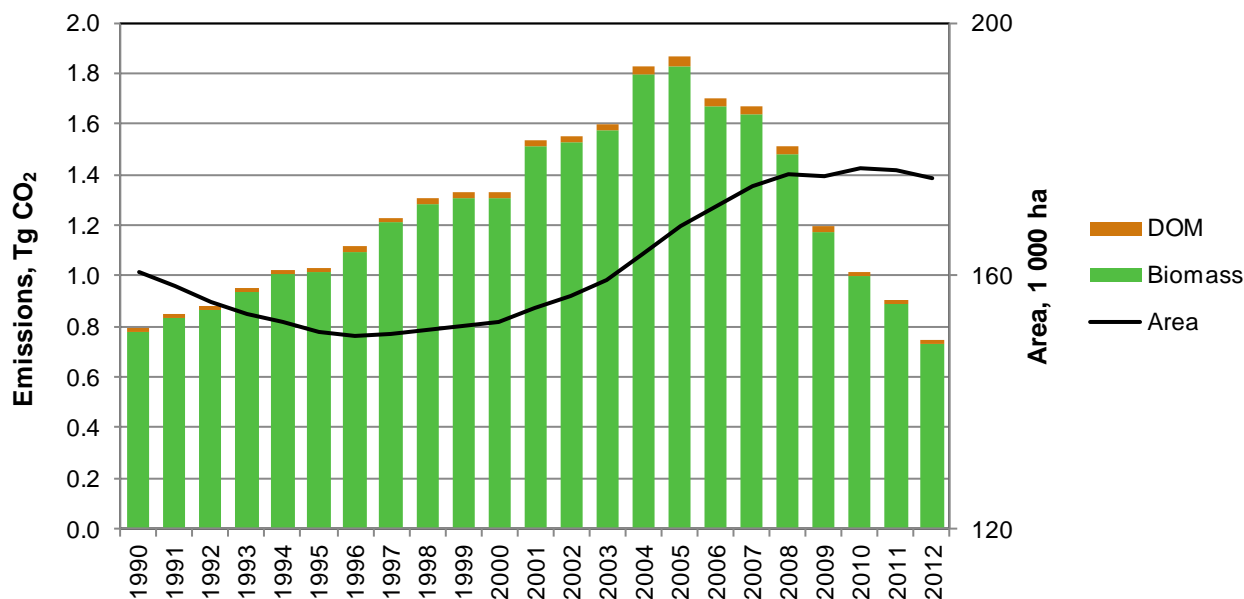
### *7.5.6 Source-specific planned improvements*

The work to improve tree biomass removal estimates has started at Metla in 2011. The aim is to have better estimates for the allocation of cutting removals to the mineral and organic forest lands, as well for lands converted to and from forest land. The plan was to implement the results in this submission, but due to changes in the tasks of the responsible research group in 2013 it was not possible to finish the work. The study will continue and the results will be implemented when ready during the second commitment period of the Kyoto Protocol.

## 7.6 Settlements (CRF 5.E)

### 7.6.1 Source category description

The areas of settlements comprise nationally defined built-up land, roads, railroads, gravel collection sites and power lines (see Section 7.1.3). Finland reports CO<sub>2</sub> emissions under Forest land converted to Settlements from biomass and deadwood loss due to conversion and emissions from litter and soil organic matter after conversion. Emissions from Forest land converted to Settlements were 0.9 Tg CO<sub>2</sub> in 2012 (Figure 7.6-1). During recent years there is a small declining trend in the emissions due to declining yearly areas converted from Forest land to Settlements. The 20-year conversion area is however still increasing. Emissions from deadwood and soil are small compared to emissions from biomass loss.



**Figure 7.6-1** Emissions (Tg CO<sub>2</sub>) of Forest land converted to Settlement

### 7.6.2 Methodological issues

#### 7.6.2.1 Settlements remaining Settlements

The areas of settlements remaining settlements were calculated from NFI9-NFI11 data. The method for estimating areas for land-use categories is described in Section 7.1.2.

A method for estimating the emissions from settlements remaining settlements is given in Appendix 3a.4 of the GPG LULUCF 2003 and, therefore, reporting on them is not mandatory. At the moment, there is not sufficient information available to prepare reliable estimates on this category addressed in the referred appendix.

#### 7.6.2.2 Land converted to Settlements

##### Activity data

The areas of settlements comprise nationally defined built-up land, traffic lines, gravel collection sites and power lines. The areas of lands converted to settlements were calculated from NFI9-NFI11 data. The method for estimating areas for land-use categories is described in Section 7.1.2. Forest land converted to built-up land was further subdivided by using a sample of aerial photographs. The idea of this subdivision was to improve estimation of carbon stock change of litter and soil organic matter due to land-use change. Forest land converted to built-up land was further divided into following classes:

1. Sealed- and gravel soils (21%)
2. Turfgrass and grassland type (28%)
3. Areas with forest cover (50%)
4. Open cliffs (1%)

### *Carbon stock changes in living biomass*

When forest land is converted to developed use, such as for infrastructure or urban areas, the trees are usually removed. The resulting emissions are reported based on the assumption that all of the trees are removed. If trees are left to grow in the settlement area, the gain in tree biomass is not reported. This is due to fact that currently we don't have enough data for this and the methodology is under development.

The amount of emissions due to losses in tree biomass when forest land is converted to settlements was estimated as the product of the annual converted areas and the current mean biomass for all mineral forest land (Appendix\_7e).

### *Carbon stock changes in dead wood, litter and soil organic matter*

The amount of emissions due to losses in deadwood when forest land is converted into settlements was estimated as the product of the annual converted areas and the emission factors (Appendix\_7j). The emissions for carbon stock change for litter and soil organic matter were estimated similarly with 2006 IPCC Guidelines Tier 2 methods. The estimation was done for following conversion classes:

1. Sealed- and gravel soils
2. Turfgrass and grassland type
3. Areas with forest cover
4. Open cliffs
5. Power and gas lines
6. Gravel collections sites.

For classes 1 and 6 it was assumed that 20% of the soil carbon stock (including litter and SOM) will be lost during the 20 years transition period. For class 2 (Forest land converted to grassland type) emissions were estimated with FL to GL emissions factors (See section 7.4.2.2). For Forest land converted to settlement types 3, 4 and 5 (e.g. summer cottage surroundings) 2006 IPCC Guidelines method for wooded settlements was used and it was assumed that there is no carbon stock change for litter- and soil organic carbon pools.

### *7.6.3 Uncertainty and time series' consistency*

Uncertainty due to sampling in the area of settlements was estimated by the standard method of Finnish NFI (Table 7.1-3). Applicable data is currently not available for assessing the uncertainty in the estimated loss of tree biomass due to conversion of forest land into settlements; expert judgement 100% was used.

The area estimations are based on NFI data. The NFI data cover all land-use categories, and the total areas of settlements and land converted to settlements are consistent for the entire time series (1990-2012) because they are computed using the same NFI data. Land conversions before 1990 are interpolated from NFI9-NFI11 data.

Tree biomass is estimated using data based on four NFIs. Any inconsistency cannot be expected between inventories due to the same methods and tree measurement techniques. The emission from litter and soil carbon lost due to land-use change from forest to settlements were estimated with IPCC (2006) default emission factor values and the uncertainty of those were estimated to be one order of magnitude, i.e. 100%.

### 7.6.4 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6.

The Finnish Forest Research Institute (Metla) has set up a management team to guide and supervise the reporting of emissions and removals for the LULUCF sector, which are part of Metla's responsibility. The members have a broad expertise in using the measurements and methodology to estimate carbon stock changes and greenhouse gases. All changes in methods, activity data and emissions or other factors and parameters are discussed and approved by the management team before they are introduced to the advisory board (see Section 1.6.1). Representatives from Statistics Finland and Agrifood Research Finland are invited to the meetings. The management team meets 2-4 times per year.

QA/QC related issues are discussed together with the inventory unit and other expert organisations in the inventory working group meetings (3-7 meetings per year) and at the bilateral quality meeting between Metla and the inventory unit once a year.

The following three program tools have been implemented to support GHG inventory reporting: 1) CRFTool program automates and provides error free transfer of inventory results to CRF Reporter. 2) check-ghg-inventory program reads and compares the results of two consecutive inventory years and reports those time series that differ more than given percentage in any one year. 3) ghg-to-do program reads the results of two consecutive inventory years and reports those times series that have been calculated for the previous year but not (yet) for the current year and vice versa.

The quality control procedures specified in the GPG LULUCF 2003 Table 5.5.1 were followed.

### 7.6.5 Source-specific recalculations

New area estimates were calculated due to new data, updating of NFI data and error corrections (see Section 7.1.3). This resulted in recalculations for the whole time series (Table 7.6-1)

**Table 7.6-1** The difference in the emissions from Forest land converted to Settlements due to recalculation between 2013 and 2014 submissions (Gg CO<sub>2</sub>). This number does not include emissions from litter and soil organic matter that are reported for the first time in this submission

Year	2013 submission	2014 submission	Difference
1990	929	929	-0.1
2011	1 523	1 069	-454

### 7.6.6 Source-specific planned improvements

The work to improve tree biomass removal estimates has started at Metla in 2011. The aim is to have better estimates for the allocation of cutting removals to the mineral and organic forest lands, as well for lands converted to and from forest land. The plan was to implement the results in this submission, but due to changes in the tasks of the responsible research group in 2013 it was not possible to Finnish the work. The study will continue and the results will be implemented when ready during the second commitment period of the Kyoto Protocol.

## *7.7 Other land (CRF 5.F)*

### *7.7.1 Source category description*

Other land includes the part of the mineral soils of nationally defined, poorly productive forest land, which do not fulfil the threshold values for forest land and barren mineral soils of unproductive land (see Appendix\_7a). Other lands are considered unmanaged land. The method for estimating the areas of other lands is provided in Section 7.1.2.

Parties do not have to prepare estimates for the categories contained in Appendices 3a.2, 3a.3 and 3a.4 of the GPG LULUCF 2003.



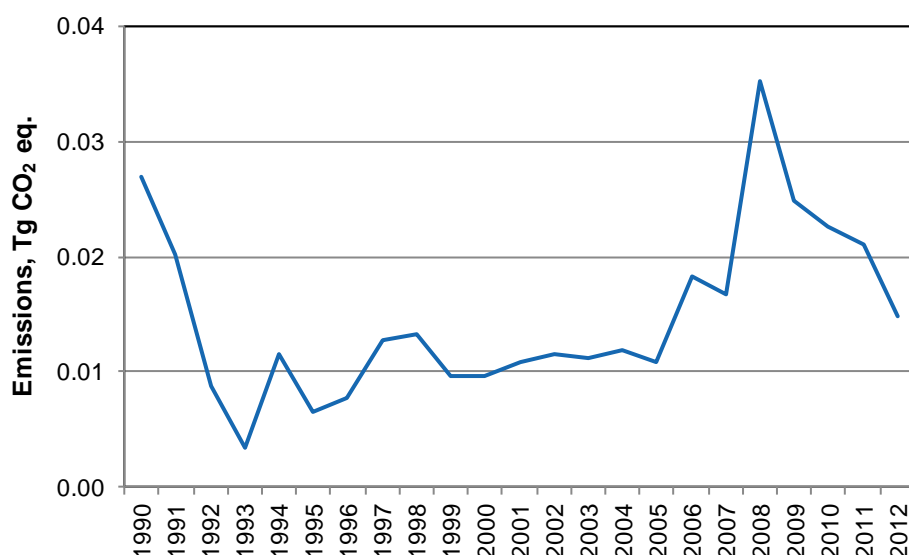
## 7.8 Non-CO<sub>2</sub> emissions

### 7.8.1 Direct N<sub>2</sub>O emissions from fertilisation (CRF 5 (I))

#### 7.8.1.1 Source category description

This source category covers direct nitrous oxide emissions from forest fertilisation (CRF 5 (I)) (Figure 7.8-1). There are two types of forest fertilisation: growth and forest vitality fertilisations. Nitrogen fertilisers are mainly used to increase growth. There are fertilisers that are only applied to forests and fertilisers like saltpetre and urea, which are used in both agriculture and forestry. The amount of these two fertilisers used in forestry is based on the sales statistics. This category includes N<sub>2</sub>O emissions from fertiliser applications on both forest land remaining as forest land and land converted to forest land.

N<sub>2</sub>O emissions from forest fertilisation were declining in the beginning of the 1990's, but from 1993 increased until 2008. During recent years the emissions have been declining again, still being at quite high level compared to the average of the time series. In 2012 the emissions from forest N<sub>2</sub>O fertilisation were 0.015 Tg CO<sub>2</sub> eq.



**Figure 7.8-1** N<sub>2</sub>O emissions from forest fertilisation (Tg CO<sub>2</sub> eq.)

#### 7.8.1.2 Methodological issues

##### Methods

The IPCC default method (Tier 1) is used to estimate N<sub>2</sub>O emissions from forest fertilisation (IPCC 2003). Equation 3.2.18 is applied using country-specific activity data and the IPCC default emission factor.

##### Emission factors and other parameters

The default emission factor of 1.25% is used (IPCC 2003).

##### Activity data

The amount of nitrogen for forest fertilisation is based on the annual sales statistics for forest fertilisers, from which the amount of nitrogen is derived (Table 7.8-1). Yara Suomi Oy, previously Kemira GrowHow Oy, produces the information. The company delivers almost 100% of fertilisers applied to forests.

**Table 7.8-1** The estimated amount of nitrogen (N) applied to forest land (1,000 kg/year) (Source: Yara Suomi Oy)

Year	N (1 000 kg/year)
1990	4 404
1991	3 324
1992	1 408
1993	565
1994	1 897
1995	1 066
1996	1 262
1997	2 063
1998	2 206
1999	1 564
2000	1 588
2001	1 800
2002	1 900
2003	1 850
2004	1 957
2005	1 800
2006	2 993
2007	2 742
2008	5 818
2009	4 073
2010	3 720
2011	3 482
2012	2 461

#### 7.8.1.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents the assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

The same uncertainty estimates for the activity data ( $\pm 10\%$ ) and the emission factors ( $-90$  to  $+380\%$ ) were used for estimating the uncertainties as are used in the agricultural sector.

At the beginning on the 1990's, the sales statistics for forest fertilisers were registered for each fertilising year (starting from the beginning of July), while the statistics for recent years only concern the calendar year. This inconsistency is considered as marginal because the fertilisers may not be used in the same year in which they are purchased.

#### 7.8.1.4 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6. The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives. The bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert.

##### General Quality Control procedures (Tier 1)

The quality control procedures specified in the GPG LULUCF 2003 Table 5.5.1 were followed and nitrogen fertiliser providers were interviewed. In addition, the nitrogen fertilisation quantities reported here were compared to the total number of areas fertilised annually obtained from statistics (Finnish Statistical Yearbook of Forestry 2012). It was confirmed that all of the data used in this section cover the whole land area of Finland.

The sales statistics for N fertilizers applied to forest land and agricultural lands were cross-checked. No discrepancy was found.

The following three program tools have been implemented to support GHG inventory reporting: 1) CRFTool program automates and provides error free transfer of inventory results to CRF Reporter. 2) check-ghg-inventory program reads and compares the results of two consecutive inventory years and reports those time series that differ more than given percentage in any one year. 3) ghg-to-do program reads the results of two consecutive inventory years and reports those times series that have been calculated for the previous year but not (yet) for the current year and vice versa.

#### 7.8.1.5 Source-specific recalculations

No recalculations have been carried out.

#### 7.8.1.6 Source-specific planned improvements

No planned improvements.

### 7.8.2 Non-CO<sub>2</sub> emissions from drainage of soils (CRF 5 (II))

#### 7.8.2.1 Source category description

Finland reports non-CO<sub>2</sub> emissions in the CRF Table 5 (II) that is, N<sub>2</sub>O and CH<sub>4</sub> emissions from peat extraction areas, CH<sub>4</sub> emissions from lands converted to inland waters and N<sub>2</sub>O emissions from drained organic forests soils (both, forest land remaining forest land and lands converted to forest land).

CO<sub>2</sub> emissions from peat extraction areas and lands converted to inland waters are reported in category 5.D Wetlands. Descriptions of the source category and methodological issues are provided in Section 7.5 Wetlands (CRF 5.D).

During 2012 N<sub>2</sub>O emissions from drained organic forest soils were 1.198 Tg CO<sub>2</sub> equivalents. This estimate includes emissions from both, forest land remaining forest land and those converted to forest lands.

#### 7.8.2.2 Methodological issues

Emission factors (based on Ojanen et al. 2010) for N<sub>2</sub>O emissions by soil fertility for drained organic forest lands have been given in a Table 7.8-2. Emission estimates for N<sub>2</sub>O from forest land remaining forest land and from lands converted to forest land have been given in Table 7.8-3. Emissions were estimated with Tier 2 methods by multiplying land areas of drained organic forest soils with emissions factors. The fertility classification was based on the one presented in the Table 7.2-1, but slightly modified to match emissions factors classes provided by Ojanen et al. 2010.

**Table 7.8-2** Emissions factors and their uncertainty for N<sub>2</sub>O emissions from drained forest lands, based on Ojanen et al. (2010)

Site type	EF	SE
	g N <sub>2</sub> O m <sup>-2</sup> a <sup>-1</sup>	g N <sub>2</sub> O m <sup>-2</sup> a <sup>-1</sup>
Rhtkg	1.85	0.065
Mtkgl	1.16	0.035
Mtkgll	1.67	0.072
Ptkgll	0.28	0.01
Ptkgll	0.71	0.016
Vatkg	0.29	0.007
JÄtkg	0.29	0.007

**Table 7.8-3** N<sub>2</sub>O emissions from drained forest lands (Gg CO<sub>2</sub> eq.)

Year	FL rem FL	FL converted to FL
1990	1 119	22
1991	1 122	24
1992	1 126	25
1993	1 129	26
1994	1 132	27
1995	1 135	28
1996	1 138	29
1997	1 141	29
1998	1 144	30
1999	1 145	30
2000	1 147	30
2001	1 148	30
2002	1 150	30
2003	1 153	29
2004	1 156	28
2005	1 158	28
2006	1 161	27
2007	1 163	26
2008	1 166	25
2009	1 169	23
2010	1 173	21
2011	1 177	19
2012	1 180	17

#### 7.8.2.3 Uncertainty and time series' consistency

The uncertainties for emission factors were reported in Table 7.8-2, while uncertainties of land areas were estimated as described in the section 7.1.3. The total uncertainty was propagated according to GPG LULUCF 2003 guidance chapter 5. It was assumed that the uncertainties between site types were independent from each other. The total uncertainty of the N<sub>2</sub>O emissions from forest land was  $\pm 30\%$ .

#### 7.8.2.4 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6. The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives. The bilateral quality meeting, which function as Tier 1 QA audit, is held annually between the inventory unit and the sectoral expert.

The following three program tools have been implemented to support GHG inventory reporting: 1) CRFTool program automates and provides error free transfer of inventory results to CRF Reporter. 2) check-ghg-inventory program reads and compares the results of two consecutive inventory years and reports those time series that differ more than given percentage in any one year. 3) ghg-to-do program reads the results of two consecutive inventory years and reports those times series that have been calculated for the previous year but not (yet) for the current year and vice versa.

#### 7.8.2.5 Source-specific recalculations

N<sub>2</sub>O emissions of this source-category were reported first time. There are no recalculations.

### 7.8.2.6 Source-specific planned improvements

There are no planned improvements.

## 7.8.3 N<sub>2</sub>O emissions from disturbance associated to land use conversion to cropland (CRF 5 (III))

### 7.8.3.1 Source category description

Emissions of N<sub>2</sub>O following the conversion of forest land and grassland into cropland are reported under this category. In 2012, the emissions from forest land converted into cropland were 0.019 Gg and those from grassland converted into cropland were 0.021 Gg. There has been an increasing trend in the levels of these emissions since the amount of converted area has increased between the years 1990 and 2012.

### 7.8.3.2 Methodological issues

#### Methods

The N<sub>2</sub>O emissions from forest land and grassland converted into cropland were calculated according to equations 3.3.14 and 3.3.15 of the GPG LULUCF 2003:

$$N_2O_{\text{net-min}} - N = EF_1 * N_{\text{net-min}}$$

where

$N_2O_{\text{net-min}} - N$  = additional emissions arising from the land use change, kg N<sub>2</sub>O-N a<sup>-1</sup>

$EF_1$  = IPCC default EF, 0.0125 kg N<sub>2</sub>O-N/kg N

$N_{\text{net-min}}$  = N released annually by net soil organic matter mineralization, kg N a<sup>-1</sup>

$$N_{\text{net-min}} = \Delta C * 1 / \text{C:N ratio}$$

where

$\Delta C$  = carbon loss from soil as a result of conversion, kg C a<sup>-1</sup>

C:N ratio = ratio of C to N in soil organic matter, kg C/kg N

#### Emission factors and other parameters

The IPCC default emission factor of 1.25% is used (IPCC 2003). In the case of forest land converted into cropland, a national value for the C:N ratio was used. Based on published data for the C:N ratio of the humus layer (Hilli et al. 2008) and unpublished data for the C:N ratio of the 0-20 cm layer of the mineral soil (Karhu et al. 2011), a value of 21.4 was obtained. For grassland converted into cropland, a default C:N ratio of 15 was used.

#### Activity data

The area estimate was obtained as described in Section 7.1.2. The reduction of the C stock due to conversion was determined as described in Section 7.3.2.2.

### 7.8.3.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents the assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

The time series is consistent.

#### *7.8.3.4 Source-specific QA/QC and verification*

The quality control procedures specified in the GPG LULUCF 2003 Table 5.5.1 were followed.

#### *7.8.3.5 Source-specific recalculations*

The whole time series was recalculated as the result of updated time series for the area data (see Section 7.1.3). An error was corrected in the calculation of N<sub>2</sub>O emissions from disturbance. It was earlier calculated only for the first year of clearance but now it was extended to the period of 20 years.

#### *7.8.3.6 Source-specific planned improvements*

No improvements are planned at the moment.

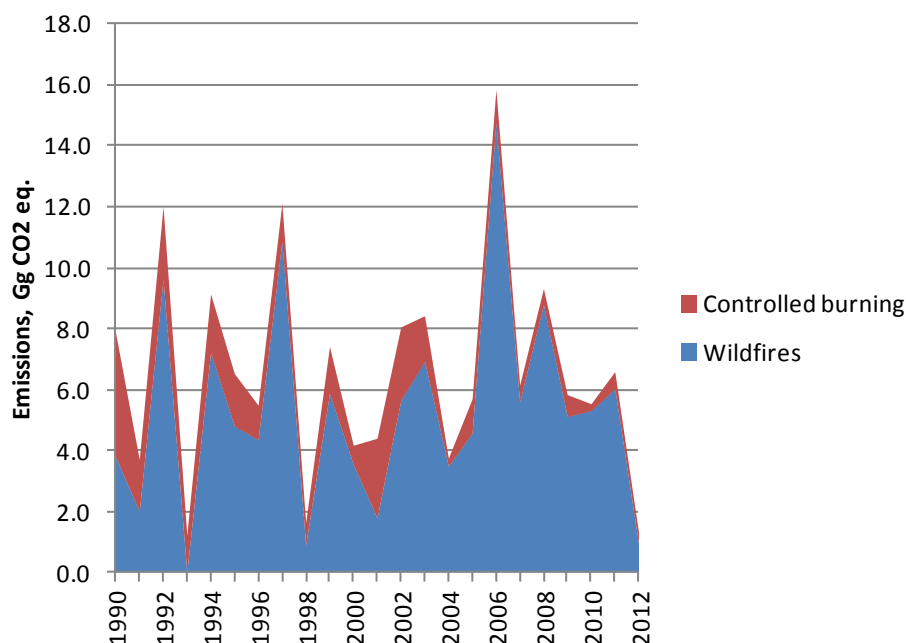
### *7.8.4 CO<sub>2</sub> emissions from agricultural lime application (CRF 5 (IV))*

CO<sub>2</sub> emissions from agricultural lime application are described under category CRF 5(B): Cropland, which is discussed in Section 7.3; they are also described as part of category CRF 5 (C): Grassland, which is discussed in Section 7.4.

### *7.8.5 Biomass burning (CRF 5 (V))*

#### *7.8.5.1 Source category description*

This source category includes greenhouse gas emissions (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O) and other air emissions (NO<sub>x</sub> and CO) from biomass burning on forest land comprising wildfires and controlled burnings (Figure 7.8-2). Restoration burnings carried out to increase biodiversity are excluded from this report. The area statistics on wildfires are compiled by the Ministry of the Interior and they are based on information given by rescue authorities. These areas vary highly between years due to high weather condition dependency of the controlled burning and wildfires. In the statistics all wildfires are classified as forest fires and for this reason it is not possible to separate wildfires on wetlands from fires on forest land. When classifying land area by IPCC land-use category, forest fires can occur on forest land, wetlands and other land. All wildfires are reported under category 5.A 1: Forest land remaining as forest land. In the KP-LULUCF reporting wildfires are allocated to AR and FM areas because the NFI data showed that in the years 2008-2010 wildfires also occurred on AR areas. The mean biomasses correspond with the mean biomasses applied in the KP-LULUCF reporting.



**Figure 7.8-2** Emissions from biomass burning (Gg CO<sub>2</sub> eq.)

CO<sub>2</sub> emissions are only reported for wildfires. CO<sub>2</sub> emissions from cutting residues are reported under carbon stock changes in dead organic matter (litter) and, to avoid double counting, those emissions are excluded here.

#### 7.8.5.2 Methodological issues

##### *Methods*

The default IPCC method was applied using national activity data and IPCC default emission factors. Equation 3.2.9 was used to estimate the annual losses of carbon and Equation 3.2.19 was used to estimate the non-CO<sub>2</sub> emissions from carbon released (IPCC, 2003).

##### Wildfires

The mean biomasses of the growing stock on forest land by tree species groups were estimated from the NFI8, NFI9 and NFI10 data (See the methods described in Section 7.2). The mean burning biomasses on AR lands were calculated as the mean biomass of the growing stock weighted with the area of each AR category on AR land areas in the NFI10.

The biomass of the understorey was added to the total biomass. The used biomass of the field layer was 782 kg ha<sup>-1</sup> and the bottom layer was 1,534 kg ha<sup>-1</sup> (Muukkonen et al. 2006). The estimated average biomass per hectare of burned area has been approximately 60 tonnes. The combustion efficiency is based on expert judgement<sup>11</sup> and it was assumed that 7.5% (±2.5%) of the tree biomass, 20% (±10%) of the field layer biomass and 12.5% (±7.5%) of the bottom layer biomass would burn. Separate combustion efficiencies for AR areas were not available and the combustion efficiencies of forest land were used. The IPCC default carbon fraction (50%), emission ratios and N/C ratio were used.

The emissions are slightly overestimated because wildfires also include fires on treeless wetlands, even though they are not included when calculating the mean volumes used for estimating the biomass that is

<sup>11</sup> Ilkka Vanha-Majamaa (Finnish Forest Research Institute) and Timo Heikkilä (Ministry of the Interior), 2007

burned. The activity data came from statistics compiled for the burned area and they are annually published in the Finnish Statistical Yearbook of Forestry.

### Controlled burning

Controlled burning refers to post-logging burning of harvest residues (prescribed burning). It is assumed that prescribed burnings are carried out only on forest land and on mineral soils. The mean volume of the growing stock on these sites was estimated based on NFI data for mature stands. The estimates were made separately for South and North Finland.

The volume of cutting residues was calculated by multiplying the mean volume by the dry crown mass. The used crown mass (kg) per mean volume (m<sup>3</sup>) after the final cut of the mature stand was as follows (Hakkila 1991):

	<u>South Finland</u>	<u>North Finland</u>
Scots pine	82.1	107.4
Norway spruce	164.4	217.5
Broad-leaved trees	82.8	120.1

The used biomass for the bottom layer was 1,935 kg ha<sup>-1</sup> and for the field layer it was 770 kg ha<sup>-1</sup> (Muukkonen et al. 2006). It was assumed, according to expert judgement,<sup>12</sup> that 25% (±5%) of the tree biomass, 20% (±10%) of the field layer biomass and 12.5% (±7.5%) of the bottom layer biomass would burn. The IPCC default carbon fraction (50%), emission ratios and N/C ratio were used.

The activity data came from statistics compiled for the burned area and they are annually published in the Finnish Statistical Yearbook of Forestry.

### *Emission factors and other parameters*

Default emission factors from the GPG LULUCF 2003 (Table 3A.1.15, p. 3.185) were applied, namely 0.012 for CH<sub>4</sub>, 0.007 for N<sub>2</sub>O, 0.121 for NO<sub>x</sub> and 0.06 for CO. For the N/C ratio, the IPCC default value of 0.01 was also used.

### *Activity data*

The time series of the burned area are based on the areas of prescribed burnings and wildfires published annually in the Finnish Statistical Yearbook of Forestry (Table 7.8-4). The information source for the area of wildfires is the Ministry of the Interior.

The NFI10 data showed that there were forest fires on the AR areas during the years 2008-2010, but NFI data were not suitable for estimating the areas for that purpose. Therefore, the area of wildfires on AR lands was calculated using the share of AR land area out of the total forest area and allocating the total wildfire areas accordingly. The AR areas burned are as follows: 2008: 8 ha, 2009: 4 ha, 2010: 5 ha.

The area of prescribed burnings comes from the information compiled by the forestry organisations and companies that carry out prescribed burnings. The statistics are compiled by the Finnish Forest Research Institute.

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<sup>12</sup> Ilkka Vanha-Majamaa (Finnish Forest Research Institute) and Timo Heikkilä (Ministry of the Interior), 2007



**Table 7.8-4** Burned forest area (ha)

Year	Wildfires		Controlled burning	
	South	North	South	North
1990	335	99	1 497	2 257
1991	174	52	961	484
1992	834	247	1 203	844
1993	0	0	749	214
1994	605	180	767	901
1995	406	120	864	531
1996	362	76	607	289
1997	983	163	636	377
1998	114	17	297	325
1999	546	64	601	721
2000	244	17	391	81
2001	127	47	909	1 376
2002	399	184	1 044	966
2003	392	272	442	901
2004	292	59	150	66
2005	342	147	359	706
2006	1 067	528	330	702
2007	437	133	275	202
2008	778	47	295	139
2009	372	159	216	475
2010	418	101	147	27
2011	454	135	127	445
2012	74	15	154	178

### 7.8.5.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents the assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

Based on expert judgement, uncertainty in the activity data (area) for biomass burning is estimated at  $\pm 10\%$ . Uncertainty concerning combustion efficiencies is 10%. The uncertainties in emission factors ( $\pm 70\%$ ) are based on the GPG LULUCF 2003.

The Ministry of the Interior compiles the area statistics on wildfires and they are based on information provided by rescue authorities. The time series of activity data is consistent.

### 7.8.5.4 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6. The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives. The bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert. Also emissions of this category were estimated with two separate softwares, namely R and excel.

#### General QC procedures (Tier 1)

The quality control procedures specified in the GPG LULUCF 2003 Table 5.5.1 were followed. The possibility of emission/removal estimates overlapping with other sources has been checked. Land areas with

wildfires and controlled burning were reviewed using the latest statistics (Finnish Statistical Yearbook of Forestry 2010). It was confirmed that all of the data used in this section cover the whole land area of Finland.

The following three program tools have been implemented to support GHG inventory reporting: 1) CRFTool program automates and provides error free transfer of inventory results to CRF Reporter. 2) check-ghg-inventory program reads and compares the results of two consecutive inventory years and reports those time series that differ more than given percentage in any one year. 3) ghg-to-do program reads the results of two consecutive inventory years and reports those times series that have been calculated for the previous year but not (yet) for the current year and vice versa.

#### *7.8.5.5 Source-specific recalculations*

The FM and AR area data were updated and allocation of wildfires on AR and FM area changed in the years 2008-2010. This resulted in marginal recalculations of less than 0.1% for the emissions of biomass burning.

#### *7.8.5.6 Source-specific planned improvements*

There are no planned improvements.

## 7.9 Harvested Wood Products (CRF 5.G)

### 7.9.1 Source category description

In 2012, harvested wood products were a carbon source of 1.3 Tg CO<sub>2</sub> in Finland.

The harvested wood products (HWP) category basically includes the carbon balance of all wood products in use in Finland. The carbon balance has been calculated using the Stock Change Approach (SCA). HWP are divided into solid wood products (sawnwood, wood-based panels and round timber in long-term use, e.g. poles) and paper products (paper and paperboard). The balance is converted into Gg CO<sub>2</sub>; the emissions are reported as positive numbers and the removal as negative numbers. The changes in roundwood stocks and their carbon balance are not taken into account in the reporting. Furniture and wooden packages are also excluded from the estimate, but fittings are included. The carbon balance of HWP in solid waste disposal sites is also excluded from the estimate. As the SCA is used in the reporting, the only variable to be estimated is Variable 1A, which is described in the 2006 IPCC Guidelines (IPCC 2006, Table 12.1, p. 12.8; in this report, see Table 7.9-2). Variable 1B is not needed because of the exclusion of solid waste disposal sites from HWP reporting. The other variables in the table, which are required in reporting when using the other approaches, are on the side estimated by the HWP worksheet accompanying the 2006 IPCC Guidelines, but they are not needed in the Finnish reporting. See Table 7.9-2.

In accordance with the 2006 IPCC Guidelines, the emissions of non-CO<sub>2</sub> greenhouse gases from HWP are reported under other sectors such as energy.

The estimated changes in carbon stocks in wood products are shown in Table 7.9-1. According to the estimate, wood products have been a sink for CO<sub>2</sub> except in 1991 and in 2008-2012. It can be noted that the annual carbon balance of wood products varies substantially. The major reason for this is the first-order decay pattern in the HWP worksheet (for the algorithm of the model, see Pingoud et al. 2006): The real consumption of wood products (i.e. the input flow of the HWP pool in the model) varies notably on an annual basis, whereas the decay estimated by the model is directly proportional to the HWP pool, which does not vary as much annually. As a result of the estimated total HWP balance during periods when consumption is low, the HWP pool becomes a source of CO<sub>2</sub>. In the early 1990s, there was a deep economic recession in Finland (see Chapter 2). Activities in the construction sector declined, including the consumption of wood products, which can be seen as an emission from HWP in 1991. Similarly, the diminished consumption of both solid wood products and paper products during recent years is shown as an emission in 2008-2012.

**Table 7.9-1** Estimated net emissions and removals of harvested wood products by category, CO<sub>2</sub> (Gg)

Year	Solid wood products	Paper products	Total
1990	-809	-136	-946
1991	279	28	307
1992	-153	-71	-225
1993	139	-233	-93
1994	-525	-232	-756
1995	-296	-574	-870
1996	-383	-665	-1 048
1997	-1 483	-639	-2 122
1998	-1 584	-182	-1 766
1999	-1 887	-152	-2 038
2000	-908	-359	-1 267
2001	-445	130	-315
2002	-856	419	-437
2003	-1 199	309	-889
2004	-989	157	-832
2005	-511	170	-340
2006	-521	70	-451
2007	-1 291	81	-1 210
2008	135	-15	120
2009	1 058	555	1 613
2010	258	364	623
2011	376	300	677
2012	960	327	1 287

## 7.9.2 Methodological issues

### 7.9.2.1 Methods

The emission/removal from harvested wood products is estimated by the stock change approach and, further, only HWP in use are considered. The emission/removal from HWP at solid waste disposal sites is excluded from the reporting. Thus, the only HWP variable needed when estimating the emission/removal is variable 1A (Table 7.9-2), with the reported emission being  $= -44/12 * \Delta \mathbf{CHWPIU}_{DC}$  (given in Gg CO<sub>2</sub>/a).

The method used when estimating the emission/removal from harvested wood products is a country-specific Tier 3 method (Method D), which is described briefly in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The method is a combination of the First Order Decay method (IPCC 2006, p.12.16) (flux methods) and a direct inventory of harvested wood products (Method A, IPCC 2006, p. 12.15):

- 1) The carbon stock of *solid wood products* in Finland has been estimated at five-year intervals based on building stock and other statistics. The stock in the other, non-inventory years is then estimated by first fitting the HWP worksheet accompanying the 2006 IPCC Guidelines to the direct inventories and then using the fitted HWP worksheet to estimate the carbon stock and its annual change in other years. The HWP model was thus used as an interpolation/extrapolation tool for the direct stock inventories.

- 2) The carbon stock in *paper products* and its annual change is estimated straightforwardly using the HWP worksheet with default parameters. This part of the estimation is thus a Tier 1 level method.

The sum of the estimated annual stock change in *solid wood products* and *paper products* in use is the HWP variable 1A (Table 7.9-2).

**Table 7.9-2** The HWP variables associated with HWP reporting. When applying the stock-change approach for HWP in use, only the variable 1A has to be estimated (IPCC 2006, Table 12.1)

Variable definition	Variable names HWP in “products in use”	HWP in SWDS
Annual change in carbon stock in a) HWP in use and b) in HWP in solid waste disposal sites in the reporting country, this wood carbon that came from <u>domestic consumption</u> of products, <b><math>\Delta\text{CHWP}_{\text{DC}} = \Delta\text{CHWPIU}_{\text{DC}} + \Delta\text{CHWP SWDS}_{\text{DC}}</math></b>	Variable 1A <b><math>\Delta\text{CHWPIU}_{\text{DC}}</math></b>	Variable 1B <b><math>\Delta\text{CHWPSWDS}_{\text{DC}}</math></b>
Annual change in carbon stock in a) HWP in use, and b) in HWP in solid waste disposal sites where the wood in the products came from <u>domestic harvest</u> - trees harvested in the reporting country, this includes exported HWP to other countries, <b><math>\Delta\text{CHWP}_{\text{DH}} = \Delta\text{CHWPIU}_{\text{DH}} + \Delta\text{CHWP SWDS}_{\text{DH}}</math></b>	Variable 2A <b><math>\Delta\text{CHWPIU}_{\text{DH}}</math></b>	Variable 2B <b><math>\Delta\text{CHWPSWDS}_{\text{DH}}</math></b>
Carbon in annual imports of HWP coming into the reporting country, including all wood-based material - roundwood, solidwood products, paper, pulp and recovered paper	$P_{\text{IM}}$	
Carbon in annual exports of HWP leaving the reporting country, including all wood-based material - roundwood, solidwood products, paper, pulp and recovered paper	$P_{\text{EX}}$	
Carbon in the annual harvest of roundwood for products - wood removed from harvest sites in the reporting country including fuel wood	$H$	

The estimation method is described in detail in the following section.

#### The stock inventory

The method for performing direct stock inventories of harvested wood products in use in Finland is described in Appendix\_7k. Inventories of the carbon stock in wood products have been performed earlier for the years 1980, 1990, 1995 and 2000 (Pingoud and Perälä 2000; Pingoud et al. 2001; Pingoud et al. 2003). For the Finnish greenhouse gas inventory, a new stock inventory was performed for the year 2005. The inventories for the years 1995, 2000 and 2005 are relatively comprehensive – they include all construction wood and wood products in fittings – and were utilized to estimate the carbon balance in HWP. Paper products are excluded from these inventories. The earlier inventories from 1980 and 1990 were not used because they were incomplete; they only included the housing stock.

#### Using the stock inventory results to fit the HWP worksheet model

The HWP worksheet (IPCC 2006) is a tool for estimating the annual development of carbon balance in HWP – using any of the alternative HWP approaches. The carbon stock in the model consists of two components: 1) solid wood products and 2) paper products, both of which have different half-lives. The basic algorithm for estimating the carbon stock in wood products and its change over time is described in the next equations.

Starting with  $i=1900$  and continuing to the present year, use the following calculation:

$$C(i+1) = e^{-k} * C(i) + \left[ \frac{(1 - e^{-k})}{k} \right] * \text{Inflow}(i)$$

$$\Delta C(i) = C(i+1) - C(i)$$

with  $C(1900) = 0.0$ .

Note: for an explanation of the technique used in the first equations for estimating first-order decay, see Pingoud and Wagner (2006).

The variables in the equations have the following values:

$i$  = year

$C(i)$  = the carbon stock of the HWP pool at the beginning of the year  $i$ , Gg C

$k$  = decay constant of first-order decay given in units,  $a^{-1}$  ( $k = \ln(2) / HL$ , where  $HL$  is the half-life of the HWP pool in years. A half-life is the number of years it takes to lose one-half of the material currently in the pool.)

$Inflow(i)$  = the inflow to the HWP pool during year  $i$ , Gg C  $a^{-1}$

$\Delta C(i)$  = carbon stock change of the HWP pool during year  $i$ , Gg C  $a^{-1}$

The stock change approach was applied in the HWP inventory for Finland. This means that the HWP stocks under consideration are the domestic ones, i.e. those within national boundaries. The inflow to the domestic solid wood and paper product pools in the HWP model is the annual apparent consumption (=production+imports-exports) of solid wood products and paper products converted to carbon flows. These inflows are estimated based on activity data (production in Finland, imports and exports; the time series can be downloaded from the FAO databases, and they are identical to the Finnish national statistics) and the carbon conversion factors of the different products. The calculations of solid wood and paper using the HWP model differ from each other in how the emission factor (half-life) is estimated:

- 1) Solid wood products: No default values for emission factors in the HWP worksheet model were used. Instead, the factors were chosen so that the model results could be fitted to the direct stock inventories for solid wood stocks. The direct inventories provided an estimate of the solid-wood product stock in the years 1995, 2000, and 2005. The first order decay model combined with the above inventories was applied to estimate the *annual* stock change from 1990 to 2006. The worksheet was first fitted to the inventory results so that the model gave exactly the same carbon stock of solid wood products for the years 1995, 2000, and 2005 as the inventories. This could be done by adjusting the half-life of the solid wood products in the worksheet. To obtain an exact fit with the inventories, a slight modification has to be made to the original worksheet, which enables a varying half-life for solid wood. Three half-life parameters were used: a half-life from 1900 to 1995, a half-life from 1995 to 2000 and a half-life from 2000 to 2006. With the fitted model, the carbon stock of solid wood products for all the years between 1990 and 2006 (not only those years of direct stock inventories: 1995, 2000 and 2005) could then be estimated as well as the annual change in their carbon stock.
- 2) Paper products: As there are no country-specific methods applicable for estimating paper stocks, the default emission factor given in the 2006 IPCC Guidelines in the HWP worksheet was applied when estimating the paper stock and its annual change.

The total carbon balance of HWP was then estimated as a sum of the carbon stock change of the two components.

#### 7.9.2.2 Emission factors and other parameters

In the Finnish case, the basic inflows were estimated based on the activity data downloaded from the FAO databases and the default conversion factors (IPCC 2006, Table 12.4). The emission factor, i.e. the half-life of paper products, was assumed the default value: the default value equals two years (IPCC 2006, Table 12.2). For solid wood products, the half-life was chosen so that a fit with the inventory of solid wood products in Finland could be obtained.

### Emission factors

For paper products the default half-life equal to two years (IPCC 2006, Table 12.2) was used.

For solid wood products, a modification was made to the original IPCC model, as mentioned above. The three half-life parameters were chosen so that the model could be fitted to the results from the direct inventory of solid wood products. The fitted parameters are as follows:

Half-life 1900-1995: 14.8 years

Half-life 1995-2000: 16.0 years

Half-life 2000-2012: 10.5 years

From the above parameters, it can be seen that in the 2000s an essentially lower half-life in the IPCC model gave the best fit for the inventory of solid wood products. The major reason for this is the increasing export of secondary wood products in the 2000s (A-L. Perälä, personal communication, Oct 2007). An increasing share of primary solid wood products, such as sawn wood and wood-based panels, consumed in Finland have been exported as pre-fabricated houses, windows, doors, furniture, etc. However, the HWP model provided by the IPCC only uses the consumed primary products as activity data and cannot take into account the above-mentioned indirect export. The influence of this export flux can only be described by a more rapid decay, i.e. a shorter half-life, in the model.

### Other parameters

In addition, the IPCC model needs the estimated annual rate of increase for industrial roundwood production as an input parameter for the period 1900 to 1961. For this period there are no activity data in the FAO database (FAOSTAT). The default value for Europe, 0.0151, was chosen (IPCC 2006, Table 12.3). The model also uses factors to convert the product m<sup>3</sup> and tonne values of the activity data to carbon tonnes. The default values (IPCC 2006) were used.

The data needed in the direct stock inventory are described in Appendix\_7k.

#### 7.9.2.3 Activity data

The HWP model of the IPCC requires activity data since 1961, i.e. production data and import and export data for HWP, which can be downloaded from the FAO statistical databases (FAOSTAT). The previous activity data for the years 1900-1960, which were also needed in the model calculations, are approximated by assuming that the consumption correlates with the average annual increase in industrial roundwood production in Europe during that particular period (IPCC 2006, Table 12.3). The time series until the year 2012 are available in the FAO Forestry database (FAO 2012). The data in the FAOSTAT database are the same as the national data.

#### 7.9.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents the assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

- The estimated emissions and removals from HWP are a sum of two components: solid wood products and paper products. The emission/removal estimate for solid wood products is based on direct inventories of the construction wood stock, which have been performed for the base years 1995, 2000 and 2005. The overall accuracy of these stock inventories was estimated to be  $\pm 11\%$  (see Appendix\_7k).
- Because of the features of the first-order decay model (see 7.8.1), the *annual* emission/removal estimates for the solid wood products are more uncertain than the estimated accuracy of the stock inventories. The individual years can be over- or underestimated, but the estimate for the above five-year periods is as accurate as the stock inventories. The accuracy of the inventory made in 2005 is estimated to be  $\pm 11\%$  (for more details, see Appendix\_7k).

- The emission/removal estimate for paper products could not be verified against any direct inventories and is thereby much more uncertain. Only the default parameters provided by Pingoud et al. (2006) could be used in the HWP worksheet. The default half-life of two years in Table 12.2 (Pingoud et al. 2006, p. 12.17) is estimated to be too long for the average consumption of paper in Finland. According to the estimate, paper products would contribute to approximately 15% of the total removal due to HWP during the period 1990-2012. Decreasing the half-life of paper from two years to 0.5 years would decrease the removal due to paper products by 84%, but this would only decrease the *total* removal due to HWP during 1990-2012 by less than 12%. This could be the uncertainty bound downwards that could be added to uncertainty bound of the direct stock inventories
- Some solid wood product stocks are excluded from the estimate: roundwood stocks, furniture and packages:
  - The roundwood stocks vary more by season than by year, with the summer stocks in general being higher than the winter stocks (Finnish Statistical Yearbook of Forestry 2008). Since the year 1990, the stocks have varied between 17 Mm<sup>3</sup> and 6 Mm<sup>3</sup>, which corresponds to approximately 3.4 Mt C and 1.2 Mt C. In addition, there has been a declining trend in the roundwood stocks: the winter stocks (of 31 December) have declined from 12.7 Mm<sup>3</sup> (1990) to 7.7 Mm<sup>3</sup> (2007), i.e. by 5.0 Mm<sup>3</sup> or approximately 1.0 Mt C, which on an annual basis would mean an additional emission of approximately 0.06 Mt C/a, or 220 Gg CO<sub>2</sub>/a.
  - The wood furniture stock is most likely an order of magnitude smaller than that of construction wood. The same likely applies to the carbon stock change in furniture.
  - Packages constitute a short-term HWP stock, and their change was assumed to have a minor influence on the HWP balance.
- A major carbon stock not included in the reporting is HWP in solid waste disposal sites. This stock is decaying very slowly, if not at all, in anaerobic conditions. According to EU legislation, disposal of organic wastes at solid waste disposal sites is no longer permitted. Consequently, the former accumulation of HWP into disposal sites has also been strongly reduced. Thus, the annual removal has most likely been declining in the 2000s. It can be presumed that the HWP in solid waste disposal sites would currently represent only a small removal.
- Some systematic errors in the emission/removal estimates could be caused by uncertain values for the conversion factors (e.g. the carbon content in m<sup>3</sup> of a wood product). In this HWP reporting, the default conversion factors given in the IPCC 2006 Guidelines were used because more detailed information was not available for the reporting. The uncertainty range from this is of the order of  $\pm 10\%$  in the inventory of construction wood.
- The Finnish reporting is based on the stock-change approach, but the IPCC model also estimates the emissions/removals using the other approaches. The uncertainties of the Tier 3 method when applied to the different approaches could be characterised as follows: 1) when using the SCA, the uncertainty is much lower than when using the other approaches. The most important solid wood stock and its change could be estimated from direct country specific statistics and then by fitting the worksheet model to these stock inventories; 2) in the Atmospheric Flow Approach (AFA), significant uncertainties would have been involved with the trade flows of secondary products, which are a component of Variables 3 and 4 in Table 7.9-2. There are no statistics available for estimating the amount of wood in production or the trade flows of secondary wood products; only monetary values are available; 3) the Tier 3 method cannot be applied to the Production Approach (PA) because it is not possible to make any direct inventories of solid wood stocks for the export markets. However, the emission/removal of HWP can be estimated very roughly by assuming that the exported wood products have a similar lifecycle as those consumed within Finland.

The rough uncertainty bound of the HWP emissions/removals for 1990-2012 could be, on the basis of the discussion above, of the order of  $\pm 25\%$ .



### 7.9.4 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6. The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives. The bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert.

Here the outline of the 2006 IPCC Guidelines, Vol. 4, Chapter 12, p. 12.23 (IPCC 2006) is followed:

1. The country data have been checked. The best activity data (regarding variable 1A) are available at the FAO database (FAOSTAT). Data for 2005 and 2010 were changed in the FAOSTAT database, and new updated data were applied for the 2013 submission.
2. There is some uncertainty regarding the conversion factors (densities, etc.). The exact Finnish mix of wood products (e.g. panel products) was not used in determining the factors. As an approximation, the default parameters given in Table 12.4 (IPCC 2006) were used.
3. Disposal of HWP into solid waste disposal sites was not considered in the reporting study, and this kind of crosschecking was not applied.
4. A modified HWP worksheet model based on the worksheet of the 2006 IPCC Guidelines (IPCC 2006) was fitted by adjusting the half-life of solid wood products to match the real inventory data for solid wood products.

These inventory data are believed to be the most reliable data regarding the solid wood product stock in Finland and the emissions/removals from this stock during the five-year periods between the sequential inventories. A similar fitting procedure could not be applied to paper products, but their contribution to the HWP emissions/removals is much less than that of solid wood products.

The following three program tools have been implemented to support GHG inventory reporting: 1) CRFTool program automates and provides error free transfer of inventory results to CRF Reporter. 2) check-ghg-inventory program reads and compares the results of two consecutive inventory years and reports those time series that differ more than given percentage in any one year. 3) ghg-to-do program reads the results of two consecutive inventory years and reports those times series that have been calculated for the previous year but not (yet) for the current year and vice versa.

### 7.9.5 Source-specific recalculations

The estimates for year 2011 were recalculated due to the updated FAOSTAT values.

**Table 7.9-3** The difference in the emissions from harvested wood products between the 2013 and 2014 submissions (Gg CO<sub>2</sub>)

Year	2013 submission	2014 submission	Difference
2011	650	677	26.4

### 7.9.6 Source-specific planned improvements

The estimation of carbon stock changes in the HWP pool will be developed to meet the requirements of the decision 2/CMP.7 for the second commitment period of the Kyoto Protocol.

## Appendix\_7a

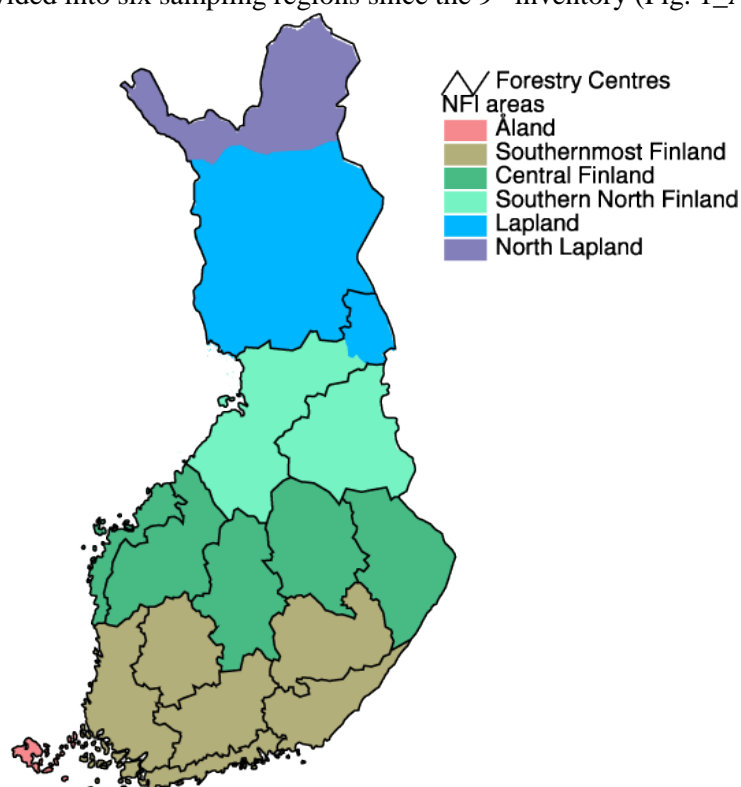
### National forest inventory

The National Forest Inventory (NFI) is a sampling-based forest inventory system. The sampling design has been fitted to the variability of land-use classes and the variation in the structure of the growing stock in different parts of Finland. The 11<sup>th</sup> inventory was launched in 2009 and the field measurements were completed in 2013. Table 1\_App\_7a lists the NFI data and the field measurement years of each inventory used to estimate areas and/or carbon stock changes for the greenhouse gas inventory.

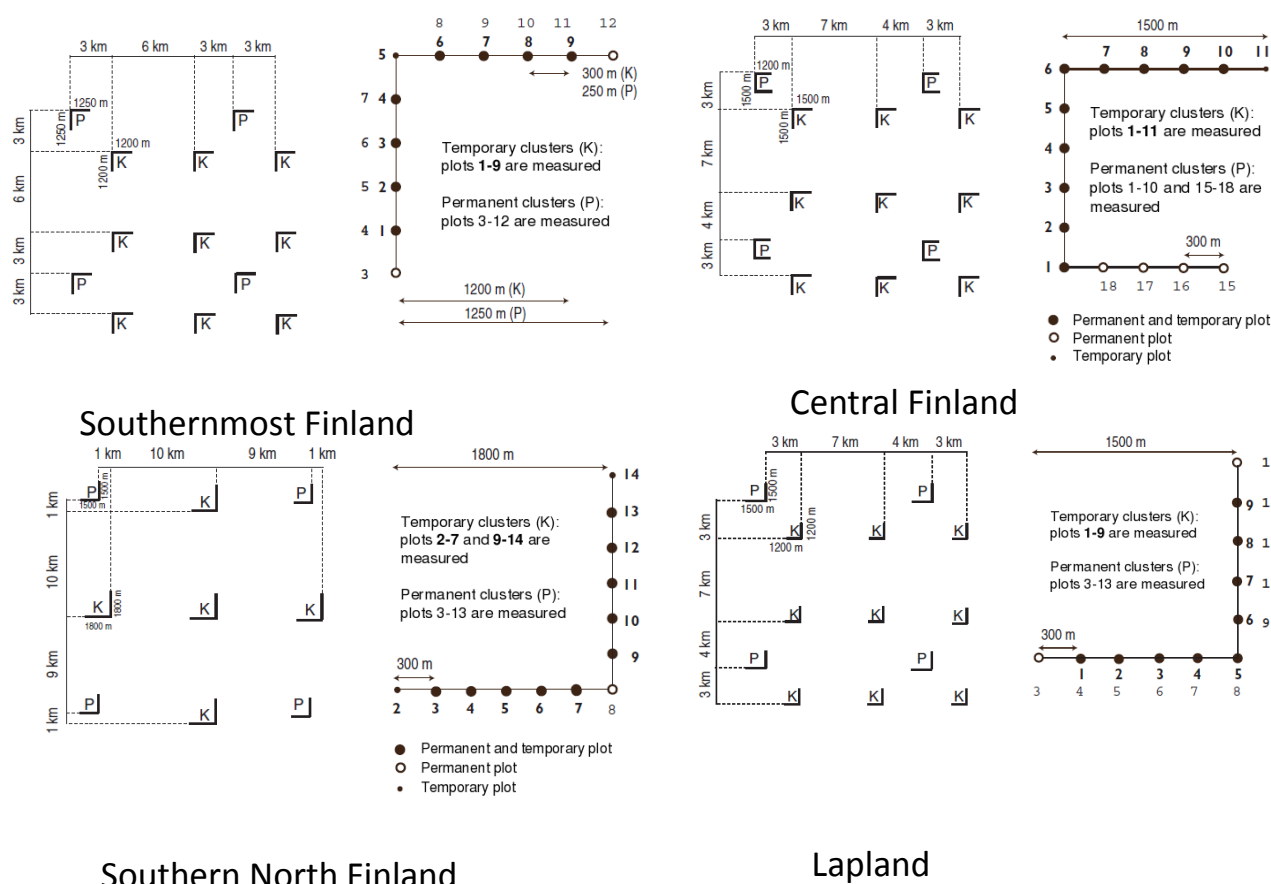
**Table 1\_App\_7a.** The areas of national land classes in the whole country in the 6<sup>th</sup> to 11<sup>th</sup> National Forest Inventories. The land total areas correspond the official land area provided by the National Land Survey of Finland at the time period of each inventory

Inventory		Field measurement years	Forest land	Poorly productive forest land	Unproductive land	Forest roads, depots, etc.	Forestry land total	Other land	Total land area
						1 000 ha			
6 <sup>th</sup>	NFI6	1971-1976	19 738	3 583	3 371	86	26 778	3 772	30 550
7 <sup>th</sup>	NFI7	1977-1984	20 065	3 157	3 049	103	26 374	4 096	30 470
8 <sup>th</sup>	NFI8	1986-1994	20 074	2 983	3 093	151	26 301	4 159	30 460
9 <sup>th</sup>	NFI9	1996-2003	20 338	2 670	3 156	154	26 317	4 130	30 447
10 <sup>th</sup>	NFI10	2004-2008	20 085	2 735	3 259	184	26 263	4 151	30 415
11 <sup>th</sup>	NFI11	2009-2012	20 312	2 448	3 218	197	26 174	4 215	30 389

NFI is a systematic cluster sampling. The distance between clusters, the shape of a cluster, the number of field plots in a cluster and the distance between the plots within a cluster vary in different parts of the country according to the spatial variation of the forests and the density of the road network. Finland has been divided into six sampling regions since the 9<sup>th</sup> inventory (Fig. 1\_App\_7a, Fig. 2\_App\_7a).



**Figure 1\_App\_7a.** Six sampling regions (NFI areas) and the boundaries of the regional units of the Public Services at the Finnish Forestry Centres



**Figure 2\_App\_7a** Sampling design by sampling regions in NFI11

On the sample plots, tree- and stand-level information is assessed and measured. Stand-level variables describe, for example, the forest site, the growing stock, the health of the forest and previous and proposed cuttings. The most important site description variables for the GHG inventory are the land-use class, for which both national and FAO definitions are applied, and the site class and soil type, which separate the mineral soils from the organic soils. In addition, the conversions between land-use classes are assessed for past 20 years or since 1990, the conversion year is also assessed by observing the plot surroundings in the field. The trees that will be measured on the sample plots, the so-called tally trees, are sampled using an angle gauge (relascope). A tally tree should be at least 1.3 m tall with a minimum diameter 0 cm at a height of 1.3 metres. The measured variables are the tree species, the diameter at breast height, the quality class and the crown story class. The height, the diameter at 6 m, the thickness of the bark and the annual increment for the diameter and height over the course of five years are measured using the sample trees and these variables are applied in volume and biomass estimations together with the stand variables.

The main task of the NFI is to produce forest resource information, such as Forest land area, volume of the growing stock and the annual increment for the growing stock. Based on the field data, reliable forest statistics are calculated for the whole country and for large areas of over 200,000 hectares.

The total area of Finland is divided into ten national land classes:

*Forest land:* stocked or temporarily unstocked land with the potential capacity to produce a mean annual increment of at least 1 m<sup>3</sup>/ha of stem wood over bark during a prescribed rotation under the most favourable stock conditions. Parks and yards are excluded.

*Poorly productive forest land:* stocked or temporarily unstocked land with potential capacity to produce a mean annual increment of 0.10-0.99 m<sup>3</sup>/ha of stem wood over bark. Parks and yards are excluded.

*Unproductive land:* either naturally treeless land or land that has the potential capacity to produce a mean annual increment of less than 0.1 m<sup>3</sup>/ha of stem wood over bark.

*Other forestry land:* Forestry roads, forest depots and camp lots, small gravel and peat soil pits and game fields within forestry land.

*Agricultural land:* arable land and other land needed for agriculture and agro-buildings except for farmhouses.

*Build-up land:* urban areas, buildings, farmhouses, factory areas, large peat extraction areas and gravel pits.

*Land required by transport infrastructure. Land under power lines.*

*Inland water bodies:* rivers, ponds, lakes and reservoirs.

*Salt water.*

The area estimation is based on the total land area of the calculation region and on the number of centre points of sample plots falling in the stratum of interest (Tomppo et al. 2011). The official land area applied is produced by the National Land Survey of Finland. The area estimate of a land stratum is the number of the plot centres in the stratum divided by the total number of plot centres on land and multiplied by the total land area:

$$A_s = \frac{N_s}{N} A, \quad (1)$$

where  $A_s$  is the area estimate of stratum  $s$ ,  $N_s$  is the number of centre points in the stratum,  $N$  is the number of centre points on land, and  $A$  is the land area of the calculation unit (e.g. as the regions in Figure 1\_App\_7a). The same method is applied for area estimates of inland waters.

More information about Finnish NFI is available on the following website:  
<http://www.metla.fi/ohjelma/vmi/info-en.htm>

## Appendix\_7b

### *Estimation of land-use changes for the years 1990–2012*

Areas of land-use and land-use change are calculated from NFI data. An inventory cycle takes 5 years in NFI, and therefore NFI from 5 years is needed for a full dataset. This means that NFI data with a full sampling density was available for reporting of the years 1990-2007 and figures of the years after that based on updated NFI data. Land-use information of the NFI plots was updated to the end of 2012 by means of remote sensing where aerial photos, Landsat images and other relevant spatial data were utilised.

Land-use changes and the year of transition are assessed in the NFI. The data were applied for the years preceding the field measurements, for example NFI data from measurement years 2005-2009 were applied for computing areas of land-use changes from 1990 to 2004. Areas of land-use changes for 2008-2012 are based on NFI data from the same years and updating of the data.

The areas were computed as follows:

- annual areas of land-use changes for the whole time series 1990-2012
- areas on land-use categories for the basic year, 2002. The selection of basic year is related to data and method
- areas of land-use categories for the other years, 1990-2001 and 2003-2012. This is done by rolling backward and forward from the 2002 areas using land-use change data

#### **Annual areas of land-use changes**

The moving average method was applied to provide annual estimates of land-use changes for the years 1990-2012. The method was used to decrease the sampling error caused by a small number of those sample plots where land-use change has occurred in one specific year.

In the calculation procedure areas of land-use changes were calculated for each year 1990-2011 at first. These are called as “raw estimates”, calculated directly from NFI. The five-year moving average method is applied for “raw estimates” and areas of land-use change in each year were divided by 5 and spread for 5 adjacent years, e.g. change areas in 1999 are divided equally for years 1997-2001. Modifications were needed for the years 1990-1991 in order to avoid including changes that took place before 1990 and for the years 2010-2012 because the latest available raw estimate was for the year 2011. Raw estimate for 2012 was not used because of there were aerial photographs available only for approximately 30 % of the plots and the interpretation based more on coarse resolution spatial data.

The computation of raw estimates and moving average are introduced more closely below.

#### **Raw estimates**

The raw estimates,  $x_t$ , for the areas of a specific type of land-use change in years  $t = 1990, 1991, \dots, 2004$  were computed, separately for South Finland and North Finland, from NFI sample plots measured in years 2005-9 according to equation:

$$x_t = \sum_{i \in c_t} a_i,$$

where set  $c_t$  contains those plots of SF/NF, where the given type of change has been recorded for year  $t$ , and  $a_i$  is the area represented by sample plot  $i$ , i.e., the land area of the sampling density region to which plot  $i$  belongs divided by the number of 2005-9 plots on land within that region. Concerning latest years  $t = 2005, 2006, \dots, 2012$ , plots measured in year  $t$  were not used in the estimation of  $x_t$ , because some of year  $t$ 's changes in those plots may have occurred after the measurement, and the changes cannot be assumed uniformly distributed over the year. The latest years from 2005 onwards were reported by replacing older NFI data with new one, 2010 measurements were utilized for  $x_t$ ,  $t \geq 2005$ , 2011 measurements for  $x_t$ ,  $t \geq$

2006 and 2012 measurements for  $x_t$ ,  $t \geq 2007$ . They were not used for the earlier years' changes a) because five year's data was considered sufficient and b) in order to avoid the need to re-calculate the whole time series. Hence, for  $t = 2005, 2006, \dots, 2011$ ,

$$x_t = \sum_{i \in c_t} a_{it},$$

where set  $c_t$  contains those plots of SF/NF measured during years  $t + 1, \dots, 2012$ , where the given type of change has been recorded for year  $t$ , and  $a_{it}$  is the area represented by sample plot  $i$  in estimates for year  $t$ , i.e., the land area of the sampling density region to which plot  $i$  belongs divided by the number of those plots on land within that region that were measured in years  $t + 1, \dots, 2012$ .

### Moving averages

The final estimates,  $y_t$  for years  $t = 1992, 1993, \dots, 2009$  were computed as simple moving averages,

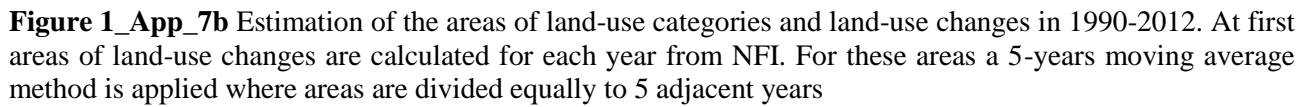
$$y_t = \frac{1}{5} \sum_{s=t-2}^{t+2} x_s,$$

and those for the remaining years near the end-points of the  $x_t$  series as weighted averages,

$$\begin{aligned} y_{1990} &= \frac{2}{5}x_{1990} + \frac{2}{5}x_{1991} + \frac{1}{5}x_{1992} \\ y_{1991} &= \frac{2}{5}x_{1990} + \frac{1}{5}x_{1991} + \frac{1}{5}x_{1992} + \frac{1}{5}x_{1993} \\ y_{2010} &= \frac{1}{5}x_{2008} + \frac{1}{5}x_{2009} + \frac{1}{5}x_{2010} + \frac{2}{5}x_{2011} \\ y_{2011} &= \frac{1}{5}x_{2009} + \frac{2}{5}x_{2010} + \frac{2}{5}x_{2011} \\ y_{2012} &= \frac{2}{5}x_{2010} + \frac{3}{5}x_{2011} \end{aligned}$$

### Annual areas of land-use classes

Land-use areas were estimated for the beginning of the time series from NFI 2005-2009 data at first. Land-use change areas for years 2005-2012 were computed by utilising newer NFI data and because of 5-years moving average, they affect change estimates back to year 2003. Therefore 2002 was used as a fixed point in area calculations for land-use categories. The estimates for land-use class areas for years 2003-2012 were computed based on the 2002 area estimates and the annual change estimates  $y_t$  (Fig. 1\_App\_7b).



## Appendix\_7c

### *Biomass models used in estimating the biomass increment and stock*

The applied models are represented in Table 1\_App\_7c. Repola's Model 1 is based on the tree diameter at breast height ( $d$ ) [cm] (or  $2+1.25*d = dk$  [cm]) and tree height ( $h$ ) [m]. Model 2 contains, in addition to the diameter and the height, the tree age at breast height ( $t_{13}$ ), the length of the living crown ( $cl$ ) [m] and the crown ration ( $cr$ ). The diameter/age is shortened to  $d_a$  [cm]. Model 3 is based on the previously mentioned variables and bark thickness ( $bt$ ) [cm] as well as the radial increment during the last five years ( $i_5$ ) [cm], or, for Scots Pine, the cross-sectional area increment at breast height during the last five years ( $i_{g5}$ ) [cm<sup>2</sup>]. Repola's density model for stem wood is based on diameter, diameter/age and average temperature sum ( $dd$ ). For estimating the biomass increment, the above-ground biomass is calculated as Repola 2009 above-ground – (Repola 2009 stem wood+Repola 2009 stem bark) + Repola 2007 stem wood density \* volume. The stem-wood model is thus replaced with the more accurate stem-wood density model. Marklund's model for needles is used for estimating the biomass of the fine roots of pine and spruce trees (Marklund 1988). The ratios of fine root quantity to modelled needle masses were based on the work by Helmisaari et al. (2007).



**Table 1\_App\_7c** Biomass models used in estimating the of biomass increment and stock**Scots pine (*Pinus sylvestris*)**

	<b>Biomass compartment</b>	<b>Biomass function</b>	<b>Reference</b>	<b>Applied in</b>
<b>Repola multivariate models</b>				
Model 1	stem wood	$\exp(-3.721+8.103*dk/(dk+14)+5.066*h/(h+12)+(0.002+0.009)/2)$	Repola 2009 (4)	inc
	stem bark	$\exp(-4.548+7.997*dk/(dk+12)+0.357*\log(h)+(0.015+0.061)/2)$	Repola 2009 (5)	inc, stock
	living branches	$\exp(-6.162+15.075*dk/(dk+12)-2.618*h/(h+12)+(0.041+0.089)/2)$	Repola 2009 (6)	stock
	needles	$\exp(-6.303+14.472*dk/(dk+6)-3.976*h/(h+1)+(0.109+0.118)/2)$	Repola 2009 (7)	stock
	dead branches	$0.911*\exp(-5.201+10.574*dk/(dk+16))$	Repola 2009 (8)	stock
	stump	$\exp(-6.753+12.681*dk/(dk+12)+(0.010+0.044)/2)$	Repola 2009 (10)	inc, stock
	roots	$\exp(-5.550+13.408*dk/(dk+15)+0.079/2)$	Repola 2009 (11)	inc, stock
	above-ground	$\exp(-3.198+9.547*dk/(dk+12)+3.241*h/(h+20)+(0.009+0.010)/2)$	Repola 2009 (9)	inc
Model 2	stem wood	$\exp(-4.018+8.358*dk/(dk+14)+4.646*h/(h+10)+0.041*\log(t_{13})+(0.001+0.008)/2)$	Repola 2009 (A1)	inc
	stem bark	$\exp(-4.695+8.727*dk/(dk+12)+0.228*\log(h)+(0.014+0.057)/2)$	Repola 2009 (A2)	inc, stock
	living branches	$\exp(-5.166+13.085*dk/(dk+12)-5.189*h/(h+8)+1.110*\log(cl)+(0.020+0.063)/2)$	Repola 2009 (A3)	stock
	needles	$\exp(-1.748+14.824*dk/(dk+4)-12.684*h/(h+1)+1.209*\log(cl)+(0.032+0.093)/2)$	Repola 2009 (A4)	stock
	dead branches	$0.913*\exp(-5.318+10.771*dk/(dk+16))$	Repola 2009 (A5)	stock
	above-ground	$\exp(-3.416+9.555*dk/(dk+12)+3.592*h/(h+24)+0.395*cr+(0.008+0.009)/2)$	Repola 2009 (A6)	inc
Model 3	stem wood	$\exp(-4.590+8.520*dk/(dk+9)+5.013*h/(h+16)+0.002*t_{13}+0.002*i_{g5}+(0.001+0.008)/2)$	Repola 2009 (A13)	inc
	stem bark	$\exp(-5.565+9.691*dk/(dk+8)-0.444*d_a+0.068*bt+(0.008+0.058)/2)$	Repola 2009 (A14)	inc, stock
	living branches	$\exp(-4.833+13.126*dk/(dk+10)-4.808*h/(h+4)+0.098*\log(i_{g5})+0.727*\log(cl)+(0.018+0.059)/2)$	Repola 2009 (A15)	stock
	needles	$\exp(-2.209+9.347*dk/(dk+6)-6.364*h/(h+1)+0.309*\log(i_{g5})+0.611*\log(cl)+(0.027+0.082)/2)$	Repola 2009 (A16)	stock
	dead branches	$0.918*\exp(-5.798+17.82*dk/(dk+16)-0.738*\log(cl)-0.461*\log(i_{g5})-0.017*t_{13})$	Repola 2009 (A17)	stock
	above-ground	$\exp(-3.529+9.337*dk/(dk+12)+3.265*h/(h+18)+0.124*i_s+0.001*t_{13}-0.006*bt+(0.003+0.009)/2)$	Repola 2009 (A18)	inc
<b>Repola density model</b>				
	stem wood density	$378.39-78.829*d_a+0.039*dd$	Repola 2007 (52)	inc, stock
<b>Marklund model for needles (estimation of fine roots)</b>				
	needles	$\exp(12.1095*d/(d+7)+0.0413*h-1.565*\log(h)-3.4781)$	Marklund 1988 (T-18)	stock

**Norway spruce (*Picea abies*)**

	<b>Biomass compartment</b>	<b>Biomass function</b>	<b>Reference</b>	<b>Applied in</b>
Repola multivariate models				
Model 1	stem wood	$\exp(-3.555+8.042*dk/(dk+14)+0.869*\log(h)+0.015*h+(0.009+0.009)/2)$	Repola 2009 (12)	inc
	stem bark	$\exp(-4.548+9.448*dk/(dk+18)+0.436*\log(h)+(0.023+0.041)/2)$	Repola 2009 (13)	inc, stock
	living branches	$\exp(-4.214+14.508*dk/(dk+13)-3.277*h/(h+5)+(0.039+0.081)/2)$	Repola 2009 (14)	stock
	needles	$\exp(-2.994+12.251*dk/(dk+10)-3.415*h/(h+1)+(0.107+0.089)/2)$	Repola 2009 (15)	stock
	dead branches	$1.343*\exp(-4.850+7.702*dk/(dk+18)+0.513*\log(h))$	Repola 2009 (16)	stock
	stump	$\exp(-3.964+11.730*dk/(dk+26)+(0.065+0.058)/2)$	Repola 2009 (18)	inc, stock
	roots	$\exp(-2.294+10.646*dk/(dk+24)+(0.105+0.114)/2)$	Repola 2009 (19)	inc, stock
	above-ground	$\exp(-1.808+9.482*dk/(dk+20)+0.469*\log(h)+(0.006+0.013)/2)$	Repola 2009 (17)	inc
Model 2	stem wood	$\exp(-4.000+8.881*dk/(dk+12)+0.728*\log(h)+0.022*h-0.273*d_a+(0.003+0.008)/2)$	Repola 2009 (A7)	inc
	stem bark	$\exp(-4.437+10.071*dk/(dk+18)+0.261*\log(h)+(0.019+0.039)/2)$	Repola 2009 (A8)	inc, stock
	living branches	$\exp(-3.023+12.017*dk/(dk+14)-5.722*h/(h+5)+1.033*\log(cl)+(0.017+0.068)/2)$	Repola 2009 (A9)	stock
	needles	$\exp(-0.085+15.222*dk/(dk+4)-14.446*h/(h+1)+1.273*\log(cl)+(0.028+0.087)/2)$	Repola 2009 (A10)	stock
	dead branches	$1.208*\exp(-5.317+6.384*dk/(dk+18)+0.982*\log(h))$	Repola 2009 (A11)	stock
	above-ground	$\exp(-2.141+9.074*dk/(dk+20)+0.570*\log(h)+0.403*cr+(0.006+0.013)/2)$	Repola 2009 (A12)	inc
Model 3	stem wood	$\exp(-3.950+8.534*dk/(dk+12)+0.743*\log(h)+0.022*h+0.001*t_{13}-0.071*i_5+(0.003+0.008)/2)$	Repola 2009 (A19)	inc
	stem bark	$\exp(-4.626+9.638*dk/(dk+16)+0.266*\log(h)+0.084*bt+(0.013+0.042)/2)$	Repola 2009 (A20)	inc, stock
	living branches	$\exp(-3.950+12.014*dk/(dk+18)-1.296*h/(h+2)+1.528*cr-0.461*d_a+0.112*i_5+(0.011+0.067)/2)$	Repola 2009 (A21)	stock
	needles	$\exp(-4.258+9.200*dk/(dk+12)+0.967*cr+0.287*\log(i_5)+(0.022+0.068)/2)$	Repola 2009 (A22)	stock
	dead branches	$1.091*\exp(-0.140+11.293*dk/(dk+14)+3.058*\log(cr)-7.014*cr-0.189*\log(i_5))$	Repola 2009 (A23)	stock
	above-ground	$\exp(-2.037+9.146*dk/(dk+20)+0.543*\log(h)+0.296*cr+(0.007+0.013)/2)$	Repola 2009 (A24)	inc
Repola density model				
	stem wood density	$442.03-0.904*dk-82.695*d_a$	Repola 2007 (53)	inc, stock
Marklund model for needles (estimation of fine roots)				
	needles	$\exp(9.7809*d/(d+12)-0.4873*\log(h)-1.8551)$	Marklund 1988 (G-16)	stock

**Broadleaved trees**

	<b>Biomass compartment</b>	<b>Biomass function</b>	<b>Reference</b>	<b>Applied in</b>
Repola multivariate models				
Model 1	stem wood	$\exp(-4.879+9.651*dk/(dk+12)+1.012*\log(h)+(0.00263+0.00544)/2)$	Repola 2008 (7)	inc
	stem bark	$\exp(-5.401+10.061*dk/(dk+12)+2.657*h/(h+20)+(0.01043+0.04443)/2)$	Repola 2008 (8)	inc,stock
	living branches	$\exp(-4.152+15.874*dk/(dk+16)-4.407*h/(h+10)+(0.02733+0.07662)/2)$	Repola 2008 (9)	stock
	foliage	$\exp(-29.556+33.372*dk/(dk+2)+(0.077)/2)$	Repola 2008 (12)	inc,stock
	dead branches	$2.073*\exp(-8.335+12.402*d/(d+16))$	Repola 2008 (10)	stock
	stump	$\exp(-3.574+11.304*dk/(dk+26)+(0.02154+0.04542)/2)$	Repola 2008 (13)	stock
	roots	$\exp(-3.223+6.497*dk/(dk+22)+1.033*\log(h)+(0.048+0.02677)/2)$	Repola 2008 (14)	stock
	above-ground	$\exp(-3.654+10.582*dk/(dk+12)+3.018*h/(h+22)+(0.00068+0.00727)/2) + \text{foliage}$	Repola 2008 (11)	inc
	below-ground	$\exp(-2.726+7.652*dk/(dk+24)+0.799*\log(h)+(0.02623+0.02152)/2)$	Repola 2008 (15)	inc
Model 2	stem wood	$\exp(-4.886+9.965*dk/(dk+12)+0.966*\log(h)-0.135*d_a+(0.00160+0.00537)/2)$	Repola 2008 (A1)	inc
	stem bark	$\exp(-5.433+10.121*dk/(dk+12)+2.647*h/(h+20)+(0.01059+0.04419)/2)$	Repola 2008 (A2)	inc,stock
	living branches	$\exp(-5.067+14.614*dk/(dk+12)-5.074*h/(h+12)+0.092*cl+(0.01508+0.05663)/2)$	Repola 2008 (A3)	stock
	foliage	$\exp(-20.856+22.320*dk/(dk+2)+2.819*cr+(0.01082+0.04355)/2)$	Repola 2008 (A6)	inc,stock
	dead branches	$2.149*\exp(-7.996+11.824*d/(d+16))$	Repola 2008 (A4)	stock
	above-ground	$\exp(-3.659+10.588*dk/(dk+12)+2.996*h/(h+22)+0.0006*t_{13}+(0.00049+0.00711)/2) + \text{foliage}$	Repola 2008 (A5)	inc
Model 3	stem wood	$\exp(-4.915+9.984*dk/(dk+12)+0.981*\log(h)-0.180*d_a+(0.0014+0.00534)/2)$	Repola 2008 (A7)	inc
	stem bark	$\exp(-5.304+8.498*dk/(dk+8)+3.380*h/(h+22)+0.382*\log(bt)+(0.01135+0.03508)/2)$	Repola 2008 (A8)	inc,stock
	living branches	$\exp(-5.918+12.867*dk/(dk+10)-3.573*h/(h+10)+0.238*\log(i_5*10.)+0.095*cl+0.007*t_{13}+(0.01171+0.043)/2)$	Repola 2008 (A9)	stock
	dead branches	$1.788*\exp(-16.113+37.902*dk/(dk+6)-17.342*h/(h+10)-0.063*t_{13}-0.166*i_5*10)$	Repola 2008 (A10)	stock
	above-ground	$\exp(-3.713+10.616*dk/(dk+12)+3.235*h/(h+22)+0.007*i_5*10.-0.214*(dk/t_{13})+(0.00673)/2) + \text{foliage}$	Repola 2008 (A11)	inc
Repola density model				
	stem wood density	$431.43 + 28.054 * \log(dk) - 52.203 * d_a$	Repola 2007 (54)	inc, stock

## Appendix\_7d

### Expansion factors

**Table 1\_App\_7d** Expansion factors applied to convert the stem volumes of stock as well as the increment and drain into whole tree biomass (Mg/ m<sup>3</sup>). The expansion factors of the stock and increment are estimated separately from the living trees measured in the four NFIs

Tree species group	Region	Soil	Biomass compartment	Living biomass								Fellings	Unrecovered natural losses
				Stock				Increment				NF110	NF110
				NFI8	NFI9	NFI10	NFI11	NFI8	NFI9	NFI10	NFI11		
				1986-1995	1996-2003	2004-2008	2009-2012	1986-1995	1996-2003	2004-2008	2009-2012	2004-2008	2004-2008
Pine	south	mineral	above-ground	0.508	0.504	0.498	0.494	0.495	0.488	0.477	0.472	0.489	0.518
			below-ground	0.13	0.129	0.125	0.124	0.112	0.106	0.103	0.1	0.122	0.119
		organic	above-ground	0.531	0.521	0.511	0.506	0.516	0.503	0.488	0.484	0.498	0.502
			below-ground	0.133	0.133	0.129	0.129	0.116	0.11	0.104	0.103	0.125	0.113
	north	mineral	above-ground	0.531	0.526	0.524	0.519	0.538	0.508	0.503	0.497	0.502	0.487
			below-ground	0.143	0.145	0.142	0.141	0.135	0.122	0.12	0.116	0.13	0.138
		organic	above-ground	0.558	0.549	0.541	0.533	0.555	0.526	0.522	0.508	0.512	0.518
			below-ground	0.144	0.143	0.139	0.138	0.139	0.119	0.117	0.112	0.13	0.139
Spruce	south	mineral	above-ground	0.563	0.553	0.551	0.55	0.544	0.539	0.532	0.533	0.541	0.564
			below-ground	0.166	0.166	0.164	0.165	0.148	0.147	0.145	0.148	0.16	0.187
		organic	above-ground	0.585	0.581	0.585	0.582	0.563	0.571	0.572	0.557	0.564	0.616
			below-ground	0.177	0.18	0.181	0.179	0.152	0.159	0.164	0.154	0.179	0.219
	north	mineral	above-ground	0.635	0.642	0.641	0.634	0.656	0.628	0.626	0.618	0.594	0.596
			below-ground	0.213	0.217	0.216	0.211	0.199	0.184	0.185	0.182	0.187	0.227
		organic	above-ground	0.666	0.669	0.672	0.667	0.627	0.646	0.649	0.628	0.624	0.725
			below-ground	0.236	0.232	0.233	0.23	0.18	0.189	0.198	0.184	0.199	0.303
Broadleaved trees	south	mineral	above-ground	0.626	0.621	0.616	0.615	0.608	0.608	0.597	0.599	0.607	0.605
			below-ground	0.2	0.204	0.201	0.197	0.21	0.227	0.209	0.206	0.222	0.283
		organic	above-ground	0.626	0.619	0.613	0.613	0.613	0.607	0.602	0.603	0.606	0.604
			below-ground	0.218	0.214	0.207	0.205	0.21	0.213	0.214	0.21	0.25	0.326

Tree species group	Region	Soil	Biomass compartment	Living biomass								Fellings	Unrecovered natural losses
				Stock				Increment				NF110	NF110
				NFI8	NFI9	NFI10	NFI11	NFI8	NFI9	NFI10	NFI11		
				1986-1995	1996-2003	2004-2008	2009-2012	1986-1995	1996-2003	2004-2008	2009-2012	2004-2008	2004-2008
	north	mineral	above-ground	0.671	0.679	0.673	0.668	0.718	0.648	0.624	0.653	0.632	0.633
			below-ground	0.234	0.243	0.238	0.235	0.402	0.281	0.251	0.308	0.259	0.246
		organic	above-ground	0.658	0.653	0.648	0.646	0.638	0.627	0.601	0.606	0.634	0.619
			below-ground	0.24	0.241	0.225	0.225	0.213	0.241	0.199	0.201	0.217	0.244

## Appendix\_7e

*Biomass increment of living trees, biomass of the drain and mean biomasses in lands converted from Forest land to other land uses*

**Table 1\_App\_7e** Biomass increment of living trees (Tg/a) on forest land mineral soils

Mineral soils													
Year	South Finland						North Finland						Total
	Above-ground			Below-ground			Above-ground			Below-ground			
	Pine	Spruce	Broadleaved	Pine	Spruce	Broadleaved	Pine	Spruce	Broadleaved	Pine	Spruce	Broadleaved	
1990	8.58	11.05	5.86	1.91	3.01	2.10	4.16	1.57	1.49	1.05	0.47	0.84	42.08
1991	8.60	10.93	5.95	1.91	2.98	2.15	4.33	1.60	1.57	1.08	0.48	0.86	42.43
1992	8.62	10.82	6.04	1.90	2.95	2.20	4.50	1.63	1.64	1.12	0.49	0.87	42.77
1993	8.64	10.70	6.13	1.90	2.92	2.24	4.67	1.67	1.71	1.16	0.50	0.88	43.12
1994	8.67	10.59	6.21	1.90	2.89	2.29	4.85	1.70	1.78	1.19	0.51	0.89	43.46
1995	8.69	10.47	6.30	1.90	2.86	2.34	5.02	1.73	1.85	1.23	0.52	0.90	43.80
1996	8.81	10.45	6.43	1.92	2.85	2.39	5.19	1.76	1.92	1.27	0.52	0.91	44.43
1997	9.04	10.51	6.60	1.97	2.87	2.43	5.36	1.80	1.99	1.30	0.53	0.92	45.34
1998	9.27	10.58	6.77	2.01	2.89	2.47	5.54	1.83	2.07	1.34	0.54	0.93	46.25
1999	9.50	10.65	6.95	2.06	2.91	2.51	5.71	1.86	2.14	1.38	0.55	0.94	47.15
2000	9.74	10.72	7.12	2.10	2.93	2.56	5.89	1.90	2.19	1.41	0.56	0.94	48.05
2001	9.97	10.79	7.29	2.15	2.94	2.60	6.08	1.95	2.15	1.46	0.57	0.91	48.86
2002	10.20	10.85	7.46	2.20	2.96	2.64	6.28	2.01	2.10	1.51	0.59	0.88	49.68
2003	10.43	10.92	7.63	2.24	2.98	2.68	6.48	2.06	2.06	1.55	0.61	0.84	50.49
2004	10.51	11.09	7.79	2.25	3.04	2.72	6.67	2.11	2.03	1.59	0.62	0.82	51.25
2005	10.50	11.33	7.94	2.25	3.11	2.76	6.62	2.17	2.11	1.58	0.64	0.89	51.90
2006	10.49	11.57	8.09	2.24	3.19	2.80	6.58	2.22	2.19	1.56	0.66	0.96	52.55
2007	10.48	11.81	8.24	2.23	3.27	2.84	6.54	2.28	2.27	1.54	0.67	1.03	53.20
2008	10.47	12.03	8.38	2.22	3.35	2.88	6.50	2.33	2.35	1.52	0.69	1.10	53.83
2009	10.47	12.03	8.38	2.22	3.35	2.88	6.48	2.35	2.38	1.52	0.69	1.12	53.88
2010	10.47	12.03	8.38	2.22	3.35	2.88	6.48	2.35	2.38	1.52	0.69	1.12	53.88
2011	10.47	12.03	8.38	2.22	3.35	2.88	6.48	2.35	2.38	1.52	0.69	1.12	53.88
2012	10.47	12.03	8.38	2.22	3.35	2.88	6.48	2.35	2.38	1.52	0.69	1.12	53.88

**Table 2\_App\_7e** Biomass increment of living trees (Tg/a) on forest land organic soils

Organic soils													
Year	South Finland						North Finland						Total
	Above-ground			Below-ground			Above-ground			Below-ground			
	Pine	Spruce	Broadleaved	Pine	Spruce	Broadleaved	Pine	Spruce	Broadleaved	Pine	Spruce	Broadleaved	
1990	2.73	1.92	2.21	0.61	0.53	0.76	1.48	0.46	1.09	0.37	0.13	0.36	12.65
1991	2.73	1.94	2.19	0.61	0.53	0.76	1.59	0.51	1.14	0.39	0.15	0.39	12.93
1992	2.74	1.96	2.18	0.6	0.54	0.76	1.69	0.55	1.2	0.41	0.16	0.42	13.21
1993	2.74	1.99	2.16	0.6	0.55	0.75	1.79	0.6	1.25	0.43	0.17	0.44	13.49
1994	2.74	2.01	2.15	0.6	0.56	0.75	1.9	0.65	1.3	0.45	0.19	0.47	13.77
1995	2.75	2.03	2.14	0.6	0.57	0.75	2	0.7	1.36	0.47	0.2	0.5	14.05
1996	2.78	2.06	2.14	0.61	0.58	0.75	2.1	0.74	1.41	0.49	0.22	0.52	14.4
1997	2.84	2.1	2.15	0.62	0.59	0.76	2.21	0.79	1.46	0.51	0.23	0.55	14.8
1998	2.9	2.14	2.16	0.63	0.6	0.76	2.31	0.84	1.52	0.53	0.24	0.57	15.21
1999	2.96	2.18	2.17	0.64	0.62	0.77	2.41	0.89	1.57	0.55	0.26	0.6	15.61
2000	3.02	2.21	2.18	0.65	0.63	0.77	2.51	0.93	1.59	0.57	0.27	0.6	15.95
2001	3.08	2.25	2.2	0.66	0.64	0.78	2.59	0.98	1.57	0.59	0.29	0.58	16.22
2002	3.15	2.29	2.21	0.67	0.65	0.78	2.68	1.03	1.56	0.6	0.31	0.55	16.49
2003	3.21	2.33	2.22	0.68	0.67	0.79	2.76	1.08	1.54	0.62	0.33	0.53	16.76
2004	3.21	2.34	2.24	0.68	0.67	0.8	2.84	1.14	1.52	0.64	0.35	0.51	16.94
2005	3.19	2.35	2.27	0.68	0.67	0.8	2.85	1.16	1.58	0.64	0.35	0.52	17.06
2006	3.16	2.36	2.3	0.68	0.66	0.81	2.85	1.19	1.63	0.64	0.36	0.54	17.17
2007	3.14	2.37	2.33	0.67	0.66	0.81	2.86	1.22	1.69	0.63	0.36	0.56	17.29
2008	3.12	2.37	2.35	0.67	0.66	0.82	2.86	1.25	1.74	0.63	0.37	0.58	17.41
2009	3.12	2.37	2.35	0.67	0.66	0.82	2.86	1.25	1.74	0.63	0.37	0.58	17.41
2010	3.12	2.37	2.35	0.67	0.66	0.82	2.86	1.25	1.74	0.63	0.37	0.58	17.41
2011	3.12	2.37	2.35	0.67	0.66	0.82	2.86	1.25	1.74	0.63	0.37	0.58	17.41
2012	3.12	2.37	2.35	0.67	0.66	0.82	2.86	1.25	1.74	0.63	0.37	0.58	17.41

**Table 3\_App\_7e** The drain (Tg/a) on forest land remaining as forest land mineral soils

Mineral soils													
Year	South Finland						North Finland						Total
	Above-ground			Below-ground			Above-ground			Below-ground			
	Pine	Spruce	Broadleaved	Pine	Spruce	Broadleaved	Pine	Spruce	Broadleaved	Pine	Spruce	Broadleaved	
1990	6.37	9.51	4.44	1.56	2.68	1.58	2.59	1.55	1.05	0.67	0.47	0.41	32.88
1991	4.84	7.99	3.61	1.18	2.25	1.29	2.03	1.29	0.84	0.52	0.39	0.33	26.56
1992	5.91	9	3.9	1.45	2.53	1.39	2.37	1.29	0.99	0.61	0.39	0.39	30.22
1993	6.03	9.67	4.21	1.48	2.72	1.5	2.56	1.35	0.97	0.66	0.41	0.38	31.94
1994	6.9	11.86	4.4	1.69	3.33	1.57	2.88	1.55	0.96	0.74	0.47	0.38	36.73
1995	7.25	11.98	4.81	1.78	3.37	1.71	2.93	1.48	0.99	0.76	0.45	0.39	37.90
1996	6.7	11.17	4.34	1.64	3.14	1.55	2.92	1.23	0.87	0.75	0.37	0.34	35.02
1997	7.35	12.95	4.74	1.8	3.64	1.69	3.12	1.33	0.92	0.81	0.41	0.36	39.12
1998	8.01	12.96	5.17	1.96	3.65	1.85	3.47	1.32	1.06	0.9	0.41	0.41	41.17
1999	7.78	13.16	5.05	1.9	3.7	1.81	3.61	1.23	1.11	0.93	0.38	0.43	41.09
2000	7.88	13.17	5	1.93	3.7	1.79	3.69	1.34	1.1	0.95	0.42	0.43	41.40
2001	7.53	12.22	4.94	1.84	3.44	1.77	3.69	1.42	1.13	0.95	0.44	0.44	39.81
2002	7.78	12.42	4.94	1.9	3.5	1.77	3.67	1.38	1.16	0.95	0.43	0.45	40.35
2003	8.03	12.2	5.07	1.96	3.43	1.82	3.82	1.52	1.19	0.99	0.47	0.46	40.96
2004	7.78	12.3	5	1.9	3.46	1.79	3.88	1.63	1.18	1.01	0.5	0.46	40.89
2005	7.33	11.57	5.03	1.79	3.26	1.8	3.81	1.56	1.22	0.99	0.48	0.48	39.32
2006	7.62	10.97	4.96	1.87	3.09	1.78	3.57	1.37	1.19	0.93	0.43	0.46	38.24
2007	8.75	12.09	5.42	2.14	3.4	1.94	4.15	1.56	1.27	1.08	0.48	0.5	42.78
2008	8.13	9.74	6.08	1.99	2.75	2.19	4.15	1.53	1.7	1.08	0.48	0.66	40.48
2009	6.39	8.32	6.8	1.56	2.35	2.44	3.11	1.16	1.57	0.81	0.37	0.61	35.49
2010	8.1	10.29	7.57	1.98	2.9	2.72	3.86	1.43	1.69	1	0.45	0.66	42.65
2011	8.06	10.07	7.53	1.97	2.84	2.7	3.87	1.46	1.72	1.01	0.46	0.67	42.36
2012	8.2	10.03	7.25	2	2.83	2.6	3.73	1.38	1.7	0.97	0.44	0.66	41.79



**Table 4\_App\_7e** The drain (Tg/a) on forest land remaining forest land organic soils

Organic soils													
Year	South Finland						North Finland						Total
	Above-ground			Below-ground			Above-ground			Below-ground			
	Pine	Spruce	Broadleaved	Pine	Spruce	Broadleaved	Pine	Spruce	Broadleaved	Pine	Spruce	Broadleaved	
1990	0.99	1.3	1.07	0.25	0.39	0.43	0.43	0.41	0.8	0.11	0.13	0.27	6.58
1991	0.75	1.09	0.88	0.19	0.33	0.35	0.34	0.34	0.63	0.09	0.11	0.21	5.31
1992	0.91	1.23	0.94	0.23	0.37	0.38	0.39	0.34	0.75	0.1	0.11	0.25	6.00
1993	0.93	1.32	1.01	0.23	0.4	0.41	0.42	0.35	0.74	0.11	0.11	0.25	6.28
1994	1.05	1.61	1.06	0.26	0.48	0.43	0.47	0.41	0.73	0.12	0.13	0.25	7.00
1995	1.11	1.62	1.15	0.27	0.49	0.46	0.48	0.39	0.75	0.12	0.12	0.26	7.22
1996	1.02	1.51	1.04	0.25	0.45	0.42	0.48	0.32	0.66	0.12	0.1	0.22	6.59
1997	1.12	1.75	1.13	0.28	0.52	0.46	0.51	0.35	0.7	0.13	0.11	0.24	7.30
1998	1.23	1.75	1.25	0.31	0.53	0.51	0.59	0.34	0.73	0.15	0.11	0.25	7.75
1999	1.19	1.78	1.22	0.3	0.53	0.5	0.61	0.31	0.77	0.16	0.1	0.26	7.73
2000	1.2	1.77	1.2	0.3	0.53	0.49	0.62	0.34	0.76	0.16	0.11	0.26	7.74
2001	1.15	1.65	1.19	0.29	0.5	0.48	0.61	0.36	0.79	0.16	0.12	0.27	7.57
2002	1.19	1.68	1.2	0.3	0.5	0.49	0.6	0.34	0.8	0.15	0.11	0.27	7.63
2003	1.22	1.65	1.23	0.3	0.5	0.5	0.63	0.38	0.81	0.16	0.12	0.27	7.77
2004	1.19	1.66	1.21	0.29	0.5	0.49	0.64	0.41	0.81	0.16	0.13	0.28	7.77
2005	1.12	1.57	1.22	0.28	0.47	0.5	0.63	0.39	0.85	0.16	0.13	0.29	7.61
2006	1.16	1.48	1.2	0.29	0.45	0.49	0.59	0.34	0.82	0.15	0.11	0.28	7.36
2007	1.31	1.63	1.3	0.32	0.49	0.53	0.69	0.4	0.9	0.18	0.13	0.3	8.18
2008	1.24	1.32	1.49	0.31	0.4	0.61	0.73	0.37	1.12	0.19	0.12	0.38	8.28
2009	0.97	1.13	1.65	0.24	0.34	0.67	0.57	0.27	1	0.15	0.09	0.34	7.42
2010	1.24	1.39	1.83	0.31	0.42	0.75	0.69	0.34	1.11	0.18	0.12	0.38	8.76
2011	1.22	1.36	1.82	0.3	0.41	0.74	0.7	0.36	1.14	0.18	0.12	0.39	8.74
2012	1.25	1.35	1.75	0.31	0.41	0.72	0.68	0.33	1.12	0.17	0.11	0.38	8.58

**Table 5\_App\_7e** Mean biomasses in lands converted from Forest land to other land uses in South Finland (Mg/ha)

Deforestation Tree species	Cropland mineral			Cropland organic			Grassland mineral			Grassland organic			Peat extraction			Settlements			Water		
	pine	spruce	broadl.	pine	spruce	broadl.	pine	spruce	broadl.	pine	spruce	broadl.	pine	spruce	broadl.	pine	spruce	broadl.	pine	spruce	broadl.
1990	27	45.7	17	22.1	28.1	24.3	27	45.7	17	22.1	28.1	24.3	32.4	8.7	12.2	27.1	43.3	16.3	21.9	22.6	20
1991	27.4	45.4	17.4	22.8	28.3	24.5	27.4	45.4	17.4	22.8	28.3	24.5	32.4	8.7	12.2	27.4	43.1	16.6	22.6	22.7	20.1
1992	27.7	45.2	17.7	23.5	28.6	24.7	27.7	45.2	17.7	23.5	28.6	24.7	32.4	8.7	12.2	27.7	42.9	16.9	23.3	22.9	20.3
1993	28	44.9	18	24.1	28.8	24.9	28	44.9	18	24.1	28.8	24.9	32.4	8.7	12.2	28.1	42.7	17.3	24	23	20.4
1994	28.4	44.7	18.4	24.8	29.1	25.2	28.4	44.7	18.4	24.8	29.1	25.2	32.4	8.7	12.2	28.4	42.5	17.6	24.7	23.2	20.6
1995	28.7	44.4	18.7	25.5	29.3	25.4	28.7	44.4	18.7	25.5	29.3	25.4	32.4	8.7	12.2	28.8	42.3	17.9	25.4	23.3	20.7
1996	29.1	44.2	19	26.2	29.6	25.6	29.1	44.2	19	26.2	29.6	25.6	32.4	8.7	12.2	29.1	42.1	18.2	26.1	23.4	20.9
1997	29.4	43.9	19.3	26.8	29.8	25.8	29.4	43.9	19.3	26.8	29.8	25.8	32.4	8.7	12.2	29.4	41.9	18.6	26.9	23.6	21
1998	29.8	43.7	19.7	27.5	30	26	29.8	43.7	19.7	27.5	30	26	32.4	8.7	12.2	29.8	41.7	18.9	27.6	23.7	21.2
1999	30.1	43.3	20	28.1	30.1	26.4	30.1	43.3	20	28.1	30.1	26.4	32.6	8.8	12.4	30.1	41.4	19.2	28.2	23.8	21.4
2000	30.4	43	20.3	28.7	30.1	26.8	30.4	43	20.3	28.7	30.1	26.8	33.1	9	12.7	30.4	41.1	19.5	28.8	23.7	21.7
2001	30.6	42.6	20.7	29.4	30.1	27.2	30.6	42.6	20.7	29.4	30.1	27.2	33.7	9.3	13	30.7	40.7	19.8	29.5	23.6	22
2002	30.9	42.2	21	30	30.1	27.6	30.9	42.2	21	30	30.1	27.6	34.2	9.5	13.3	31	40.3	20.1	30.1	23.6	22.2
2003	31.2	41.9	21.3	30.6	30.1	28.1	31.2	41.9	21.3	30.6	30.1	28.1	34.7	9.7	13.6	31.2	40	20.5	30.7	23.5	22.5
2004	31.5	41.5	21.6	31.2	30.1	28.5	31.5	41.5	21.6	31.2	30.1	28.5	35.3	10	14	31.5	39.6	20.8	31.3	23.5	22.8
2005	31.8	41.1	22	31.8	30.1	28.9	31.8	41.1	22	31.8	30.1	28.9	35.8	10.2	14.3	31.8	39.3	21.1	31.9	23.4	23.1
2006	32	40.8	22.3	32.4	30.1	29.3	32	40.8	22.3	32.4	30.1	29.3	36.4	10.5	14.6	32.1	38.9	21.4	32.5	23.4	23.4
2007	32.3	40.7	22.6	32.8	30.3	29.7	32.3	40.7	22.6	32.8	30.3	29.7	37	10.7	14.8	32.3	38.8	21.7	33.1	23.5	23.7
2008	32.4	40.9	22.8	33.2	30.6	29.9	32.4	40.9	22.8	33.2	30.6	29.9	37.7	10.8	15	32.5	39.1	21.9	33.5	23.8	23.9
2009	32.6	41.1	23.1	33.5	31	30.2	32.6	41.1	23.1	33.5	31	30.2	38.4	11	15.1	32.6	39.3	22.2	33.9	24.1	24.2
2010	32.8	41.4	23.3	33.9	31.4	30.5	32.8	41.4	23.3	33.9	31.4	30.5	39.1	11.1	15.3	32.8	39.6	22.4	34.3	24.4	24.4
2011	32.9	41.6	23.6	34.2	31.7	30.8	32.9	41.6	23.6	34.2	31.7	30.8	39.8	11.2	15.4	32.9	39.9	22.7	34.7	24.7	24.7
2012	32.9	41.6	23.6	34.2	31.8	30.8	32.9	41.6	23.6	34.2	31.8	30.8	39.9	11.2	15.4	32.9	39.9	22.7	34.7	24.7	24.7

**Table 5\_App\_7e** Mean biomasses in lands converted from Forest land to other land uses in North Finland (Mg/ha)

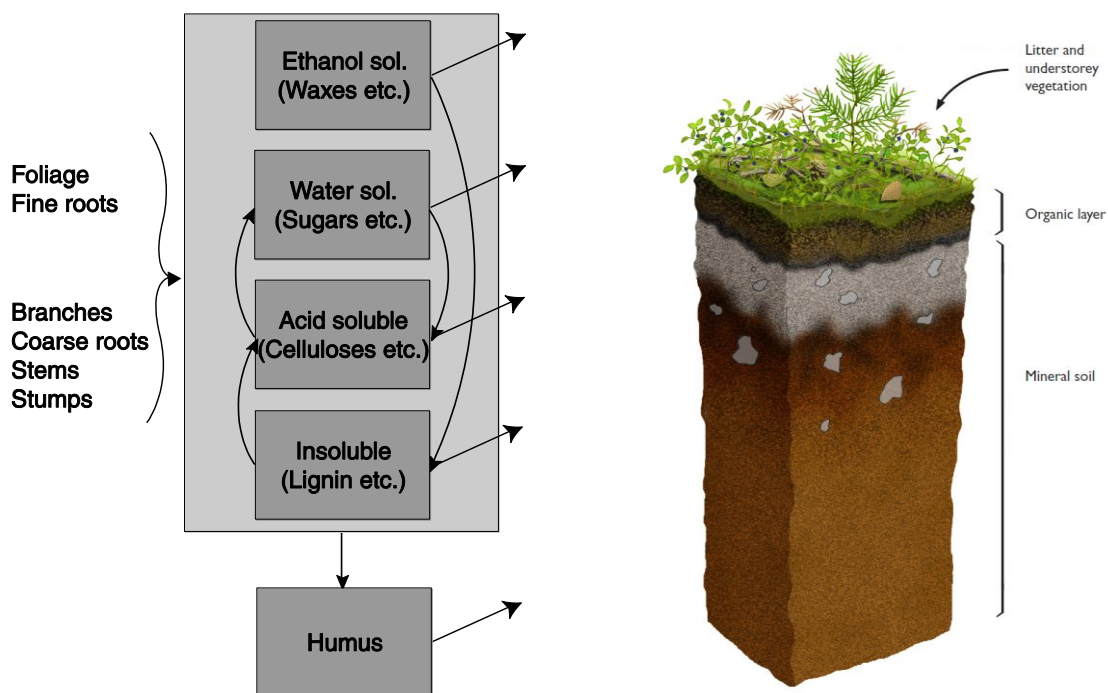
Deforestation	Cropland mineral			Cropland organic			Grassland mineral			North Finland Grassland organic			Peat extraction			Settlements			Water			
	Tree species	pine	spruce	broadl.	pine	spruce	broadl.	pine	spruce	broadl.	pine	spruce	broadl.	pine	spruce	broadl.	pine	spruce	broadl.	pine	spruce	broadl.
1990		25.7	13.8	8.5	14.9	8.9	13.1	25.7	13.8	8.5	14.9	8.9	13.1	17.1	3.3	8.2	24.2	12.1	8	15	7.5	11
1991		25.8	13.8	8.6	15.1	9	13.3	25.8	13.8	8.6	15.1	9	13.3	17.1	3.3	8.2	24.3	12.1	8.2	15.2	7.6	11.2
1992		25.9	13.8	8.7	15.4	9.2	13.4	25.9	13.8	8.7	15.4	9.2	13.4	17.1	3.3	8.2	24.4	12.1	8.3	15.4	7.7	11.3
1993		26	13.8	8.9	15.6	9.3	13.6	26	13.8	8.9	15.6	9.3	13.6	17.1	3.3	8.2	24.5	12.1	8.4	15.6	7.9	11.5
1994		26.1	13.8	9	15.8	9.4	13.7	26.1	13.8	9	15.8	9.4	13.7	17.1	3.3	8.2	24.6	12.1	8.5	15.8	8	11.7
1995		26.2	13.8	9.1	16.1	9.6	13.9	26.2	13.8	9.1	16.1	9.6	13.9	17.1	3.3	8.2	24.7	12.1	8.7	16	8.1	11.9
1996		26.4	13.7	9.2	16.3	9.7	14.1	26.4	13.7	9.2	16.3	9.7	14.1	17.1	3.3	8.2	24.8	12.1	8.8	16.2	8.3	12
1997		26.5	13.7	9.3	16.5	9.9	14.2	26.5	13.7	9.3	16.5	9.9	14.2	17.1	3.3	8.2	24.9	12.2	8.9	16.4	8.4	12.2
1998		26.6	13.7	9.4	16.8	10	14.4	26.6	13.7	9.4	16.8	10	14.4	17.1	3.3	8.2	25	12.2	9.1	16.6	8.5	12.4
1999		26.7	13.7	9.5	17	10.2	14.6	26.7	13.7	9.5	17	10.2	14.6	17.1	3.3	8.2	25.1	12.2	9.2	16.7	8.7	12.6
2000		26.8	13.7	9.6	17.2	10.3	14.7	26.8	13.7	9.6	17.2	10.3	14.7	17.1	3.3	8.2	25.2	12.2	9.3	16.9	8.8	12.7
2001		26.9	13.7	9.7	17.5	10.4	14.9	26.9	13.7	9.7	17.5	10.4	14.9	17.1	3.3	8.2	25.3	12.2	9.5	17.1	8.9	12.9
2002		27	13.7	9.8	17.7	10.6	15	27	13.7	9.8	17.7	10.6	15	17.1	3.3	8.2	25.5	12.2	9.6	17.3	9.1	13.1
2003		27.2	13.7	10	18.1	10.8	15.3	27.2	13.7	10	18.1	10.8	15.3	17.4	3.5	8.3	25.6	12.3	9.7	17.8	9.3	13.4
2004		27.8	13.9	10.1	18.8	11.3	15.8	27.8	13.9	10.1	18.8	11.3	15.8	18	3.7	8.6	26.2	12.4	9.8	18.5	9.6	13.7
2005		28.4	14	10.2	19.4	11.7	16.3	28.4	14	10.2	19.4	11.7	16.3	18.6	4	8.9	26.8	12.5	9.9	19.2	9.9	14
2006		29	14.2	10.3	20.1	12.1	16.7	29	14.2	10.3	20.1	12.1	16.7	19.2	4.2	9.2	27.4	12.6	10	20	10.2	14.4
2007		29.4	14.3	10.5	20.8	12.5	17.2	29.4	14.3	10.5	20.8	12.5	17.2	19.7	4.5	9.5	27.8	12.8	10.2	20.7	10.5	14.7
2008		29.6	14.5	10.7	21.1	12.8	17.5	29.6	14.5	10.7	21.1	12.8	17.5	19.7	4.6	9.8	28	12.9	10.4	21.1	10.7	14.8
2009		29.8	14.7	11	21.5	13.1	17.7	29.8	14.7	11	21.5	13.1	17.7	19.6	4.6	10.2	28.3	13.1	10.6	21.4	10.9	15
2010		30	14.9	11.3	21.9	13.5	18	30	14.9	11.3	21.9	13.5	18	19.5	4.7	10.6	28.5	13.3	10.8	21.8	11.1	15.1
2011		30.2	15	11.5	22.3	13.8	18.2	30.2	15	11.5	22.3	13.8	18.2	19.3	4.8	11	28.8	13.5	11.1	22.2	11.3	15.2
2012		30.3	15.1	11.6	22.3	13.8	18.3	30.3	15.1	11.6	22.3	13.8	18.3	19.3	4.8	11.1	28.9	13.5	11.1	22.2	11.3	15.2

## Appendix\_7f

### Description of the Yasso07 soil carbon model

The Yasso07 model describes the decomposition of organic matter (Tuomi et al. 2011b). The model is driven by the litter quantity, litter quality, temperature and precipitation. The model structure (Figure 1\_App\_7f) constitutes five state variables: water solubles (W), ethanol solubles (E), acid hydrolysables (A), compounds that are neither soluble nor hydrolysable (N) and a humus (H) fraction. The arrows indicate the transfer of litter into the system, the transfer between state variables and also the transfer from the soil system to the atmosphere as CO<sub>2</sub> respiration.

The Yasso07 model is based on the litter bag, wood decomposition and soil carbon measurements. These measurements have been used to calibrate the model using MCMC techniques (Tuomi et al. 2011b). The Yasso07 soil carbon model has been calibrated against the soil carbon measurements, which include the soil organic matter to a depth of 1 metre.



**Figure 1\_App\_7f** The structure of the Yasso07 soil carbon model (left) and an illustration of the soil profile (right)

The decomposition sensitivity of the organic matter has been described in the Yasso07 model by a Gaussian function, where the temperature and precipitation affect the decomposition modifier  $k$  (see Tuomi et al. 2008 and 2009). The  $k$  is defined as follows:

$$k_i(C) = \alpha_i \exp(\beta_1 T + \beta_2 T^2) (1 - \exp[\gamma P_a]) ,$$

where  $T$  is the temperature (Celsius) and  $P_a$  is the annual precipitation and  $\alpha_i$ ,  $\beta_1$ ,  $\beta_2$  and  $\gamma$  the parameters (Table 1\_App\_7f and Figure 2\_App\_7f). When the Yasso07 model is applied at an annual time resolution, it requires a mean annual temperature, annual precipitation and temperature amplitude [ $0.5 \times (\text{minimum monthly mean} - \text{maximum monthly mean})$ ] as input.

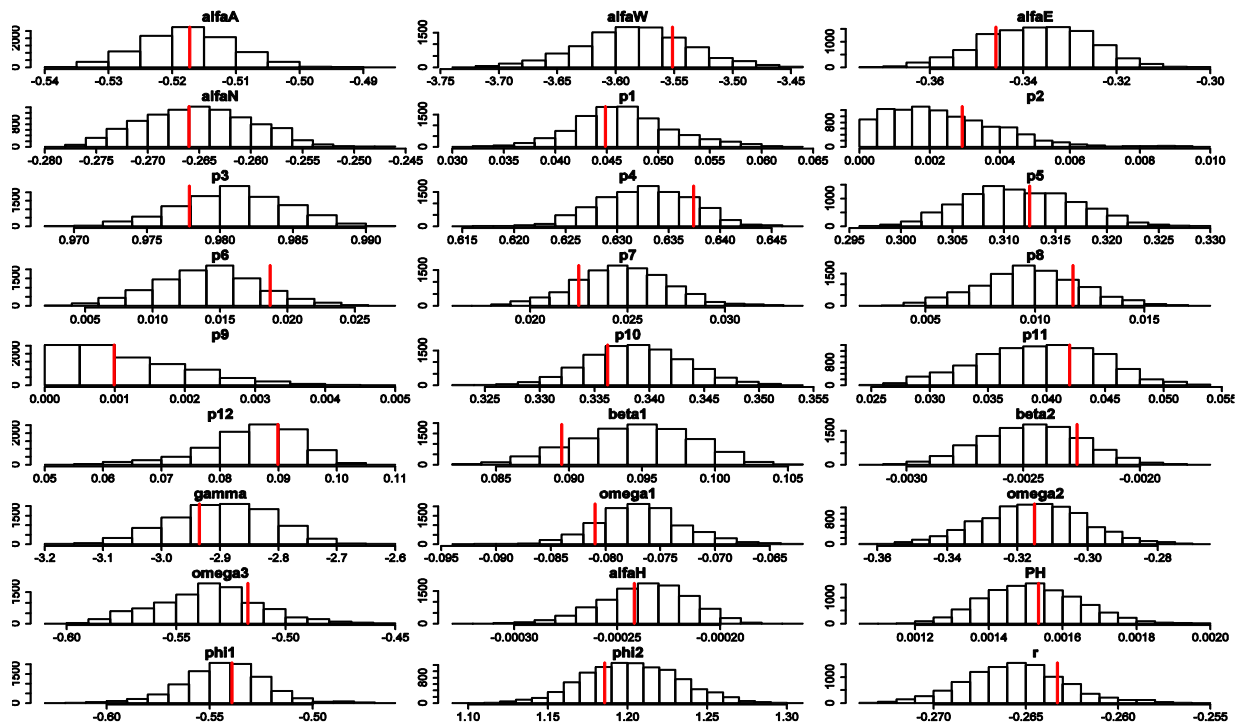
In the Yasso07 model the size of woody material also affects the decomposition rate (Tuomi et al. 2011a). The size-dependent coefficient  $h_s(d)$  multiplies the decomposition factors and, therefore, slows the decomposition of woody material. The size-dependent coefficient  $h_s(d)$  has been defined using the following equation:

$$h_s(d) = \min \{(1 + \phi_1 d + \phi_2 d^2)^r, 1\},$$

where  $\phi_1$ ,  $\phi_2$  and  $r$  are the parameters (Table 1\_App\_7f and Figure 2\_App\_7f). The equation results in a value of one when  $d$  approaches a small value.

**Table 1\_App\_7f** Parameter values and their uncertainty used in the Yasso07 model simulations for mineral forest soils. Scandinavian parameter set, see Rantakari et al. (2012) for details. See also Figure 2\_App\_7f

Parameter	Value	Unit	Meaning
aA	-0.517	a <sup>-1</sup>	decomposition rate of A
aW	-3.552	a <sup>-1</sup>	decomposition rate of W
aE	-0.346	a <sup>-1</sup>	decomposition rate of E
aN	-0.266	a <sup>-1</sup>	decomposition rate of N
p1	0.0449	.	mass flow from W to A
p2	0.0029	.	mass flow from E to A
p3	0.978	.	mass flow from N to A
p4	0.637	.	mass flow from A to W
p5	0.312	.	mass flow from E to W
p6	0.0187	.	mass flow from N to W
p7	0.0225	.	mass flow from A to E
p8	0.0117	.	mass flow from W to E
p9	0.001	.	mass flow from N to E
p10	0.336	.	mass flow from A to N
p11	0.042	.	mass flow from W to N
p12	0.0899	.	mass flow from E to N
b1	0.0895	C <sup>-1</sup>	temperature dependence parameter
b2	-0.0023	C <sup>-2</sup>	temperature dependence parameter
y	-2.94	m <sup>-1</sup>	precipitation dependence parameter
$\omega_1$	-0.081	a <sup>-1</sup> m <sup>-1</sup>	precipitation induced leaching (Europe)
pH	0.0015	10 <sup>-3</sup>	mass flow from A,W,E,N to humus
aH	-0.00024	10 <sup>-3</sup> a <sup>-1</sup>	humus decomposition coefficient
roo1	-0.539	cm <sup>-1</sup>	size dependence parameter
roo2	1.186	cm <sup>-2</sup>	size dependence parameter
r	-0.263	.	size dependence parameter



**Figure 2\_App\_7f** Probability distributions of the Yasso07 model parameters (Scandinavia 22.12.2011), applied to mineral forest soils. The vertical line indicates the location of the maximum posterior estimates

## Appendix\_7g

*Applied emission factors for forest land remaining forest land, for land converted to forest land and for forest land converted to wetlands.*

**Table 1\_App\_7g** The aggregated annual emission factors for soil organic matter (SOM) and dead organic matter (DOM) for forest land remaining forest land. Emission factors are listed separately for South and North Finland and by fertility type for drained peatlands, tonnes C per ha (negative numbers represent a loss of carbon)

Year	Mineral soils SF	Mineral soils NF	Rhtkg SF	Mtkg SF	Ptkg SF	Vatkg SF	Jatkg SF	Rhtkg NF	Mtkg NF	Ptkg NF	Vatkg NF	Jatkg NF
1990	0.14	0.12	-2.01	-0.87	-0.18	0.06	0.40	-2.36	-1.23	-0.53	-0.30	0.04
1991	0.13	0.11	-2.03	-0.89	-0.19	0.04	0.38	-2.36	-1.23	-0.53	-0.30	0.04
1992	0.14	0.11	-1.99	-0.85	-0.15	0.08	0.42	-2.33	-1.19	-0.49	-0.26	0.08
1993	0.15	0.11	-1.95	-0.82	-0.12	0.11	0.45	-2.30	-1.17	-0.47	-0.24	0.10
1994	0.17	0.11	-1.90	-0.77	-0.07	0.16	0.50	-2.27	-1.14	-0.44	-0.21	0.13
1995	0.20	0.12	-1.87	-0.74	-0.04	0.19	0.53	-2.25	-1.12	-0.42	-0.18	0.15
1996	0.22	0.13	-1.87	-0.74	-0.04	0.20	0.53	-2.24	-1.10	-0.41	-0.17	0.16
1997	0.23	0.13	-1.82	-0.69	0.01	0.24	0.58	-2.21	-1.08	-0.38	-0.14	0.19
1998	0.22	0.14	-1.78	-0.64	0.05	0.29	0.62	-2.19	-1.05	-0.35	-0.12	0.22
1999	0.22	0.15	-1.77	-0.64	0.06	0.30	0.63	-2.16	-1.03	-0.33	-0.09	0.24
2000	0.20	0.15	-1.77	-0.64	0.06	0.29	0.63	-2.14	-1.00	-0.30	-0.07	0.27
2001	0.18	0.16	-1.78	-0.65	0.05	0.29	0.62	-2.11	-0.98	-0.28	-0.04	0.29
2002	0.16	0.16	-1.78	-0.64	0.06	0.29	0.63	-2.09	-0.95	-0.25	-0.02	0.32
2003	0.14	0.16	-1.77	-0.64	0.06	0.29	0.63	-2.08	-0.94	-0.24	-0.01	0.33
2004	0.12	0.16	-1.77	-0.64	0.06	0.29	0.63	-2.08	-0.94	-0.24	-0.01	0.33
2005	0.13	0.16	-1.78	-0.65	0.05	0.29	0.62	-2.08	-0.94	-0.24	-0.01	0.33
2006	0.12	0.17	-1.78	-0.65	0.05	0.28	0.62	-2.08	-0.95	-0.25	-0.02	0.32
2007	0.09	0.16	-1.76	-0.62	0.07	0.31	0.64	-2.07	-0.93	-0.24	0.00	0.33
2008	0.10	0.16	-1.77	-0.64	0.06	0.29	0.63	-2.05	-0.91	-0.21	0.02	0.36
2009	0.12	0.16	-1.79	-0.66	0.04	0.28	0.61	-2.06	-0.92	-0.22	0.01	0.35
2010	0.10	0.15	-1.75	-0.61	0.08	0.32	0.65	-2.03	-0.89	-0.19	0.04	0.38
2011	0.10	0.14	-1.76	-0.62	0.08	0.31	0.65	-2.01	-0.88	-0.18	0.06	0.39
2012	0.13	0.15	-1.76	-0.62	0.07	0.31	0.65	-2.02	-0.89	-0.19	0.05	0.38

**Table 2\_App\_7g** The aggregated annual emission factors for soil organic matter (SOM) and dead organic matter (DOM) stock change on lands converted to forest land on mineral soils and on drained organic soils, tonnes C per ha (minus is a loss of carbon)

Time since conversion	Cropland mineral SF	Cropland mineral NF	Grassland mineral SF	Grassland mineral NF	Settlement mineral SF	Settlement mineral NF	Cropland organic	Grassland organic	Peat extraction
1	-1.06	-0.94	-2.13	-2.11	0.47	0.63	-3.72	-1.74	-1.43
2	-0.84	-0.75	-1.39	-1.38	0.43	0.57	-3.65	-1.74	-1.38
3	-0.69	-0.63	-1.11	-1.13	0.42	0.55	-3.58	-1.74	-1.34
4	-0.56	-0.53	-0.92	-0.95	0.42	0.55	-3.51	-1.74	-1.29
5	-0.44	-0.43	-0.77	-0.82	0.42	0.55	-3.44	-1.74	-1.24
6	-0.35	-0.35	-0.65	-0.71	0.43	0.55	-3.37	-1.74	-1.20
7	-0.26	-0.27	-0.55	-0.62	0.44	0.55	-3.30	-1.74	-1.15
8	-0.19	-0.20	-0.47	-0.54	0.44	0.56	-3.23	-1.74	-1.10
9	-0.12	-0.14	-0.41	-0.48	0.45	0.56	-3.16	-1.74	-1.05
10	-0.07	-0.08	-0.35	-0.42	0.46	0.57	-3.09	-1.74	-1.01
11	-0.02	-0.03	-0.30	-0.37	0.46	0.57	-3.02	-1.74	-0.96
12	0.02	0.01	-0.26	-0.33	0.47	0.58	-2.95	-1.74	-0.91
13	0.06	0.05	-0.23	-0.29	0.47	0.58	-2.88	-1.74	-0.86
14	0.09	0.09	-0.20	-0.26	0.48	0.59	-2.81	-1.74	-0.82
15	0.12	0.12	-0.17	-0.23	0.48	0.59	-2.74	-1.74	-0.77
16	0.14	0.14	-0.15	-0.20	0.48	0.59	-2.67	-1.74	-0.72
17	0.16	0.17	-0.13	-0.18	0.49	0.60	-2.60	-1.74	-0.68
18	0.18	0.19	-0.11	-0.16	0.49	0.60	-2.53	-1.74	-0.63
19	0.20	0.21	-0.10	-0.14	0.49	0.60	-2.46	-1.74	-0.58
20	0.21	0.23	-0.09	-0.13	0.49	0.61	-2.39	-1.74	-0.53

**Table 3\_App\_7g** The applied emission factors for soil organic matter (SOM) emissions on drained organic soils that have been converted from forest to wetlands, tonnes of carbon eq. per ha

Regressed forest lands [CO <sub>2</sub> ]	FL to peat extraction [CO <sub>2</sub> ] south boreal	FL to peat extraction [CO <sub>2</sub> ] middle boreal	FL to peat extraction [CO <sub>2</sub> ] north boreal	FL to peat extraction [CH <sub>4</sub> ]	FL to peat extraction [N <sub>2</sub> O]
1.85	3.99	3.89	3.62	0.13	0.24



## Appendix\_7h

### Assessment of parameter uncertainty in tree biomass models

For this submission, the uncertainty in the estimates of biomass stocks and their increment in living trees was assessed based on the simplest versions of biomass models, in which the explanatory variables were tree species, approximate stump diameter,  $d$ , and tree height,  $h$ . For single trees, the biomass predictions from these models are of the form

(A7h.1)

$$\hat{y} = \exp(\alpha_0 + \alpha_1 d + \alpha_2 h),$$

where  $\alpha_i$ 's are parameters that are specific to each tree species group (pines, spruces, deciduous species) and to each biomass component. Following Ståhl et al (2014), the uncertainty in biomass prediction (A7h.1) due to uncertainty in parameter values was approximated using

$$\text{Var}(\hat{y}) \approx \sum_{i=1}^2 \sum_{j=1}^2 \alpha_i \alpha_j \hat{y}^2 \text{Cov}(\alpha_i, \alpha_j).$$

The parameter uncertainty in a mean biomass estimate over  $m$  trees of the same species was obtained through

$$\text{Var}\left(\frac{1}{m} \sum_{k=1}^m \hat{y}_k\right) \approx \sum_{i=1}^2 \sum_{j=1}^2 \left(\frac{1}{m} \sum_{k=1}^m \alpha_i \hat{y}_k\right) \left(\frac{1}{m} \sum_{k=1}^m \alpha_j \hat{y}_k\right) \text{Cov}(\alpha_i, \alpha_j).$$

In particular, this implies that the parameter uncertainty in mean stock over  $m$  trees of the same species with equal diameters and heights is equal to the parameter uncertainty in single-tree prediction, which makes sense, because the same parameter values with the same error in them are applied in each prediction.

## Appendix\_7i

### Estimating the uncertainty of mineral soils of Finland

#### Uncertainty of the litter input of living trees

Uncertainty in the estimated biomass stocks of the different components (foliage, branches, stem, stump and roots) was assessed in the same way as for the biomass increment (Section 7.2.4.1, Table 1\_App\_7i)

**Table 1\_App\_7i** Uncertainties in the estimates of biomass stocks on mineral soils based on NFI11 (2009-2010)

Tree species	Region	Sampling uncertainty, %					Parameter uncertainty, %				
		stem	branches	foliage	stump	roots	stem	branches	needles/ foliage	stump	roots
pine	south	2	2	2	2	2	2	7	10	12	12
	north	5	4	4	4	4	2	7	10	11	11
spruce	south	3	3	3	3	3	3	7	10	25	32
	north	12	8	9	9	9	3	8	10	24	30
deciduous	south	3	4	3	4	3	2	9	15	12	16
	north	14	9	11	14	13	3	14	22	15	25

Parameter uncertainty of fine roots was assumed similar to that of foliage, because the amount of fine roots was estimated as a ratio between estimated leaf mass and fine roots, based on models of Marklund (1988) and ratios of Helmisaari et al. (2007).

The uncertainties of litter turnover rates (i.e. reciprocal of life span) for each biomass component were based on the work by Peltoniemi et al. (2006). The turnover rates were assumed to be independent between components.

#### Uncertainty of the litter input of understorey vegetation

Litter production from ground vegetation was assessed through vegetation coverage measurements of the Finnish NFI, cover to biomass models and with turnover rates. The litter input of the ground vegetation, such as shrubs, herbs and grasses, and mosses, of both South and North Finland were estimated with data of 3000 permanent sample plots, described with higher detail by Mäkipää and Heikkinen (2003), the biomass models (Muukkonen and Mäkipää 2006, Muukkonen et al. 2006) and the litter turnover rates from Liski et al. (2006).

The litter input of understorey was simulated for each sample plot defined as forest land and on mineral soil. The uncertainty of biomass model estimates were included by utilizing parameter uncertainties and variance-covariance matrices (Muukkonen et al. 2006). It was assumed that the coefficient of variation of litter turnover rate was 10% for each vegetation group (bryophytes, lichens, dwarf shrubs and herbs & grasses).

#### Uncertainty of the litter input of loggings and natural mortality

The uncertainty in the litter input from harvesting residues and natural mortality was assessed as described for the total drain in Section 7.2.4.1. Uncertainties of biomass estimates for the different components are given in Tables 2\_App\_7i and 3\_App\_7i.

**Table 2\_App\_7i** Combined sampling and parameter uncertainties, %, in the biomass of fellings

Tree species	Region	stem	branches	foliage	stump	roots
pine	south	11	12	14	16	17
	north	13	14	17	18	17
spruce	south	10	12	13	29	36
	north	59	50	50	60	63
deciduous	south	18	21	26	27	29
	north	49	54	61	56	55

**Table 3\_App\_7i** Combined sampling and parameter uncertainties, %, in the biomass of natural mortality

Tree species	Region	stem	branches	foliage	stump	roots
pine	south	31	32	29	31	35
	north	47	58	76	55	47
spruce	south	31	31	32	38	42
	north	41	28	40	41	52
deciduous	south	41	43	54	51	58
	north	59	59	71	57	60

### Uncertainty of the Yasso07 model

The Yasso07 model has been estimated by the sc. Bayesian approach, where MCMC (Markov chain Monte Carlo) approach was used (Tuomi et al. 2011b). Yasso07 model consists of 24 parameters that define decomposition of acid-, water-, ethanol- and non-soluble compounds (Appendix 7f). These parameters define also transfers between different compounds, sensitivity of decomposition to temperature and precipitation, humus decomposition and the impact of size to decomposition of the woody material.

The MCMC method was used to sample parameter space and this produced a sample of parameter combinations that were used to simulate the impact of model parameter uncertainty to the soil carbon stock change estimate.

### The simulation of uncertainty

The Monte Carlo simulation methods were applied when the uncertainties of different sources were combined. Firstly, the uncertainty of biomass sampling error of living trees was simulated and consecutive NFIs were assumed to be independent between each other, while it was assumed that different biomass components of same inventory correlate fully (i.e. same random numbers were applied). Implementing the sampling error uncertainty separately allowed us to treat NFIs independently that introduced variation into mean biomass trends from 1970s to 2012. Secondly, the model errors and litter turnover uncertainties were simulated by the biomass components. Also uncertainties of natural mortality, harvesting residues and understorey vegetation were simulated. The uncertainties of biomass and litter input were assumed to be normally distributed.

The soil carbon model Yasso07 was run to steady state with first year litter input (1972 for South Finland and 1975 for North Finland). This simulation of steady state was done with maximum a *posteriori* point estimates of Yasso07 parameters. During the each realization of litter input time series the soil carbon stock change was simulated with different parameter combination, meaning that steady state and time series simulation were done independently with regard to Yasso07 parameters. The parameter combination of Yasso07 were same during the simulation of each realization ensuring the full autocorrelation between consecutive years due to soil model uncertainty. The use of parameter combinations took into account that some of probability density

functions (PDF) of parameters were non-normal and that some of the parameters were correlated between each other.

The uncertainty of the soil carbon stock change was obtained as a result of the Monte Carlo simulation. The uncertainty bounds were estimated from the PDF of the soil carbon stock change.

## Appendix\_7j

### *Emission factors for dead wood loss*

The carbon stock estimate of deadwood was based on NFI10 measurements, where the quantity of deadwood was mapped by decomposition classes. The density and carbon content estimates were based on the estimates presented by Mäkinen et al. (2006) (Table 1\_App\_7j).

**Table 1\_App\_7j** Emission factors for dead wood loss due to deforestation (Mg C/ha)

Region	Soil	Emission factor
south	mineral	0.530
	organic	0.388
north	mineral	1.280
	organic	0.515

## Appendix\_7k

### *A direct carbon inventory of wooden materials in Finnish construction in 2005*

#### *Introduction*

In this document, the method for performing a direct carbon stock inventory of wood products in use in Finland is described. The procedure for estimating the carbon stock for the year 2005 is presented in detail, but a similar procedure has been used in earlier stock inventories. The method is country-specific and based on national statistics.

Inventories of the building stock were carried out previously in the years 1980, 1990, 1995 and 2000 (Pingoud et al. 2001 and 2003). Since 1995, these inventories include an estimate of the complete wood product stock, including the wood used, for example, in bridges, poles, buildings without permits, etc. (but not paper). The objective of the subsequent inventories is to create a time series that can be used to estimate the yearly change in carbon stocks in Finland. This report includes, in addition to the 2005 inventory, an update of the 2000 inventory and the time series of inventories for the years 1995, 2000 and 2005. The time series of inventories are presented in Tables 2\_App\_7k and 3\_App\_7k. These numbers were utilised, together with the HWP worksheet from the 2006 IPCC Guidelines (IPCC 2006), to estimate the time series for the carbon balance in harvested wood products from 1990 to 2006.

The use of wooden materials in Finnish building construction is common compared with many other European countries. Approximately 70% of sawn wood consumption in Finland was end-used in the construction area in 2005. This refers to the wood in new buildings, the renovation sector, windows, doors, kitchen equipment, the wood used in the civil engineering area and the equipment used in yards and gardens. In addition, furniture, packages and construction products (like wooden buildings, windows, doors, etc.) are produced for exports. These wood products are not included in the estimate. Further, the exported final products are not included in the FAO trade statistics, which causes a systematic error in the input data for the HWP worksheet model; this is discussed in more detail in the HWP inventory in Section 7.8.

The building stock in Finland is very well known, unlike in many other countries. The Population Register Centre maintains the building stock register and Statistics Finland publishes the building stock statistics. The VTT Business Intelligence Group has used the building stock statistics during the last decades and developed them further as part of a more detailed database; this database includes some additional building types.

The direct stock inventory of wood products has been compiled by VTT Senior Research Scientist Anna-Leena Perälä and Systems Specialist Harri Nuuttila.

#### *Methods*

The inventory of wooden materials in Finnish construction in 2005 is based on several data sources: 1) the building stock register, which is maintained by the Finnish Population Register Centre (VRK), and corresponding statistics collected by Statistics Finland (Statistics Finland 2006a); 2) the statistics on construction and housing (Statistics Finland 2006b); 3) the Construction and Housing Yearbook 2005 (Statistics Finland 2006c); and, 4) the VTT Business Intelligence Group's database. The statistics for the building stock include information on floor areas in different building types, which have been divided into 15 main categories (Statistics Finland 2006c).

The building-stock statistics do not include free-time residential buildings (holiday homes), which are an important sector of Finnish wooden construction. Also, different types of outbuildings and buildings used for agricultural production are not included in the official building stock statistics. Those building types have been included, however, in the new building registers for many years.

The statistics on construction and housing (Statistics Finland 2006b) include, for example, information on new building permits in 15 different categories. The statistics cover the construction of all new buildings and

extensions and the resulting stock of new dwellings. Building permits include information about the gross floor area (m<sup>2</sup>) and building volume (m<sup>3</sup>). In official Finnish building permits, information on bearing frame materials has been collected since 1952 and on main facade material since the beginning of the 1980s. During the last years, the amount of wood used in bearing construction and facades in new buildings has increased slightly.

The Land Use and Building Decree (Statutes of Finland 895 1999) defines when a building permit is required in Finland. There are no exactly defined national limits when a permit is needed for small buildings; practice vary by municipality. According to building statistics, approximately 87% of the municipalities have some limits on the number of outbuildings without a building permit. Furthermore, according to an inquiry, the area for which a permit is needed varies between 7 and 150 m<sup>2</sup> (Association of Finnish Local and Regional Authorities 2003). A typical small outbuilding without a fireplace and with an area of between 8 and 10 m<sup>2</sup> does not need a building permit in most municipalities. In agricultural areas, the limits are higher. The small outbuildings are typically wooden in Finland. In addition, only a notice-type planning permission for minor construction is required to build certain special structures, such as stands, platforms and sheds. This is not a building permit and is thus not included in the statistics on construction and housing.

The information from the above statistics, the results of specific enquiries and other information on construction are regularly combined by the VTT Business Intelligence Group to form a more detailed database on the Finnish building stock, new buildings, construction materials, working person-years and input-output analyses on how the construction field influences Finnish society. The database is more detailed than the official stock statistics. For example, more building types are included in the database than in the official statistics. The building stock part of the database and the new construction part are updated yearly nowadays. The database is used regularly in various assessments and prognoses concerning the Finnish construction industry. Most of these assessments are confidential and unpublished. The inventory of the wood product pool and its C content, which are considered in this study, is only one of the many applications of the above database.

Based on statistics and individual sample surveys in Finland, VTT has estimated for its stock database the average floor heights of each building type in each age class (i.e. decade of construction). Because the official statistics on building stock only include floor areas, these are converted into building volume using the average floor heights. In the database, buildings are divided into separate parts (bearing frames, facades, floors, roofs, etc.) and classified according to building type and age class. For each building type and age class, the use of different construction materials in separate parts of the buildings is estimated with the aid of sample surveys and information gathered from building permits. The estimate of wooden materials in permanent use is also based on estimates of material losses during construction. Technical changes and consumer trends have had an important impact on the materials used in Finnish buildings during recent decades.

The calculation of the carbon stock in wood products is based on the quantities of sawn wood, wood-based panel products and bearing logs (especially in the case of free-time residential buildings) in buildings and their carbon content. The major tree species, used as raw materials in the Finnish wood products industry, are spruce (*Picea abies*) and pine (*Pinus sylvestris*), whereas the average share of hardwood, mainly birch (*Betula sp.*), is just 5%; birch is predominantly used in the plywood industry. The volume of wooden products has been estimated according to the dry matter weight of the products per building-m<sup>3</sup> in each type and age class. The carbon content of the wood products was estimated to be 50% of their dry weight. The total carbon stock is calculated using the following formula:

$$C = \sum_{i,j} [A_{ij}(S_{ij} + P_{ij})],$$

where

C = total C reservoir of wooden materials in the building stock (t C),

A<sub>ij</sub> = building stock of building type i in age class j (building-m<sup>3</sup>)

S<sub>ij</sub> = amount of C in sawn wood and logs in building type i and age class j (t C / building-m<sup>3</sup>)

P<sub>ij</sub> = amount of C in wood-based panels in building type i and age class j (t C / building-m<sup>3</sup>)

and where age class j refers to the decade of its construction.

In addition to the Finnish building stock, the amounts of wood products and their carbon stock in gardens (e.g. fences and yard equipment) were approximated based on the specific amounts of each (sawn wood  $\text{m}^3/\text{building m}^3$ ) in different types of buildings. All building types have different quantities of sawn wood in their yard structures, the amounts of which were estimated from cost specifications for building construction in Finland.

The above carbon stock inventories were performed for the years 1980, 1990, 1995 and 2000. The inventories for the years 1980, 1990 and 1995 have been published previously (Pingoud et al. 2000 and 2001). The summary results of the 2000 inventory have been presented by Pingoud et al. (2003, p. 31). The inventory for 2005 was carried out in 2007, and the results (Figure 2\_App\_7k and 3\_App\_7k) – together with the summary results for the previous inventories (Figure 1\_App\_7k) – are presented at the end of this appendix.

The basis of this latest inventory (2005) was extended in the same way as in the 1995 and 2000 inventories and the inventory method applied was exactly the same. The stock of sawn wood in buildings not subject to building permits (for example, small buildings and some agricultural building types) was also included as well as the estimated quantities of wood used in civil engineering structures. The above buildings are not within the official statistics for the building stock. This extended stock is substantial, because in Finland there are many rural areas and much space is available to build many kinds of outbuildings. This estimate is based on statistics regarding production and the imports and exports of playhouses, small shelters and storehouses as well as on samples of their number and construction on building sites.

Sawn wood is also used in civil engineering: in bridges, docks, poles and piers. A rough approximation of wooden stock used in civil engineering was based on its estimated capital value in transportation networks, telecommunications networks and energy and water supply networks, as well as in other networks (VTT 2007). The amount of sawn wood ( $\text{m}^3$ ) per capital value (EUR) was approximated in these infrastructure sectors. Additional information can be obtained from some confidential reports by VTT regarding the end use of sawn wood and wood-based panels for the area of civil engineering area.

### *Carbon stock in Finnish building stock in 2005*

The carbon pool has been increasing during last decades. The C content of the dry matter weight of wood products has been 50% in all calculations. The cubic metres of wooden products have been changed first to dry weight and then to carbon stock. The dry density of sawn wood is assumed to be  $450 \text{ kg/m}^3$  and that of wood-based panels to be between 300 and  $700 \text{ kg/m}^3$ . The stock of wooden products includes the end use of products. Therefore, all residuals have been removed from the calculations. The carbon pool accounted for by sawn wood, logs and wood-based panels in the building stock and garden construction was 8.4 Mt C in 1980, 10.3 Mt C in 1990, 11 Mt C in 1995, 11.5 Mt C in 2000 and 12.3 Mt C in 2005 (Figure 1\_App\_7k). The total stock, including civil engineering and house construction, not subject to permission is given for the years 1995, 2000 and 2005. The estimated total carbon stock in 2005 was 18.6 Mt C. The average annual increase in building stock has been 0.15 Mt C/year during the years 1980 to 2005.

The total carbon stock used in construction (including construction with and without building permits and civil engineering) was estimated to be 18.6 Mt C in 2005 (Figure 2\_App\_7k). The most important carbon stock comes from detached houses. Important sectors also include small buildings, free-time residential buildings and agricultural and other separate buildings. Use of wood products in smaller buildings is more important than in big wooden buildings in Finland. However, there are good examples of new construction in Finland in which big buildings are built from wood-based materials. The totals from the area of civil engineering are also important for the carbon stock, but this area is divided into many products. Approximately 65% of the wooden stock of buildings have been constructed after 1970. It should also be noted that almost all of the timber used for construction until the year 2005 was grown in Finnish forests. In addition, a clear majority of sawn timber is exported.

In 2005, Finland had a building stock of 1.94 billion  $\text{m}^3$ . Approximately 42% of this stock consisted of housing, 21% of it consisted of industrial and storage buildings, 18% of it consisted of public and commercial buildings and 19% of it consisted of other buildings.



It is typical in Finland to construct wooden buildings. More than 30% of the construction wood used in the building sector is localised in detached houses (Figure 3\_App\_7k). Free-time residential buildings (holiday homes), agricultural buildings and other small buildings are also important C pools. Sawn-wood products form a much larger stock than wood-based panels. However, in Finland relatively little wood is currently used in public, commercial and industrial buildings. Apart from houses, the entire civil engineering sector is an important C pool in terms of sawn wood products, but the use of wooden products varies considerably in different sites.

### *Uncertainty and time series' consistency of calculations*

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of review and update of uncertainty analysis is included in Section 1.7.

The VTT Business Intelligence Group has used and developed building stock data during the last years in many public and private research commissions. There are still uncertainties in the estimates for the building stock, small buildings and civil engineering area.

The stock loss in buildings varies between 0.3% and 2%, depending on building type, with the average being approximately 1% (Heljo et al. 2005). The VTT Business Intelligence Group has also developed building stock analyses in many other research reports (Vainio et al. 2006), (Vainio et al. 2002) and (Perälä 2006).

The accuracy of the total inventory in 2005 appears to be of the order of  $\pm 11\%$ , because the use of treated wood is known based on production statistics, and the use of wooden materials in sectors outside construction is known as well (Table 1\_App\_7k). Uncertainty regarding the dwelling estimates vary between  $\pm 4\%$  and  $\pm 6\%$ , and in non-residential buildings the uncertainty is a bit higher. It is highest in the civil engineering area and for other uses of wood.

The building stock in Finland is very well known for different decades if we compare the situation to many other countries. Approximately 65% of the building stock has been built after 1970. The uncertainty in building stock is on the average of  $\pm 7\%$ . The building stock for earlier decades is more uncertain than the newer building stock. The dwelling stock is more accurate than industrial, agricultural and other building stocks.

**Table 1\_App\_7k** Uncertainty of building stock in 2005 in Finland. (VTT 2007)

	%
Dwellings	$\pm 4\% \dots \pm 6\%$
Non-residential	$\pm 6\% \dots \pm 9\%$
Civil eng. other	$\pm 11\% \dots \pm 20\%$
<b>Total building stock</b>	<b><math>\pm 11\%</math></b>

On the one hand, the estimate of the official building stock is more accurate than before; however, on the other hand, building control has made it easier to build small buildings without an official building permit, thereby decreasing the accuracy of the estimate, because this information is not collected as part of the official building statistics.

The age-distribution of the wood product stock (Figure 3\_App\_7k) refers to the construction year of the building. However, the present way of compiling statistics places an old house with new extensions into the age-class of an old building, even though, for example, the extension might be much larger than the original building. One building type can change to another building type during the course of its lifetime. For instance, what was once a single-family house can be now a storage building.

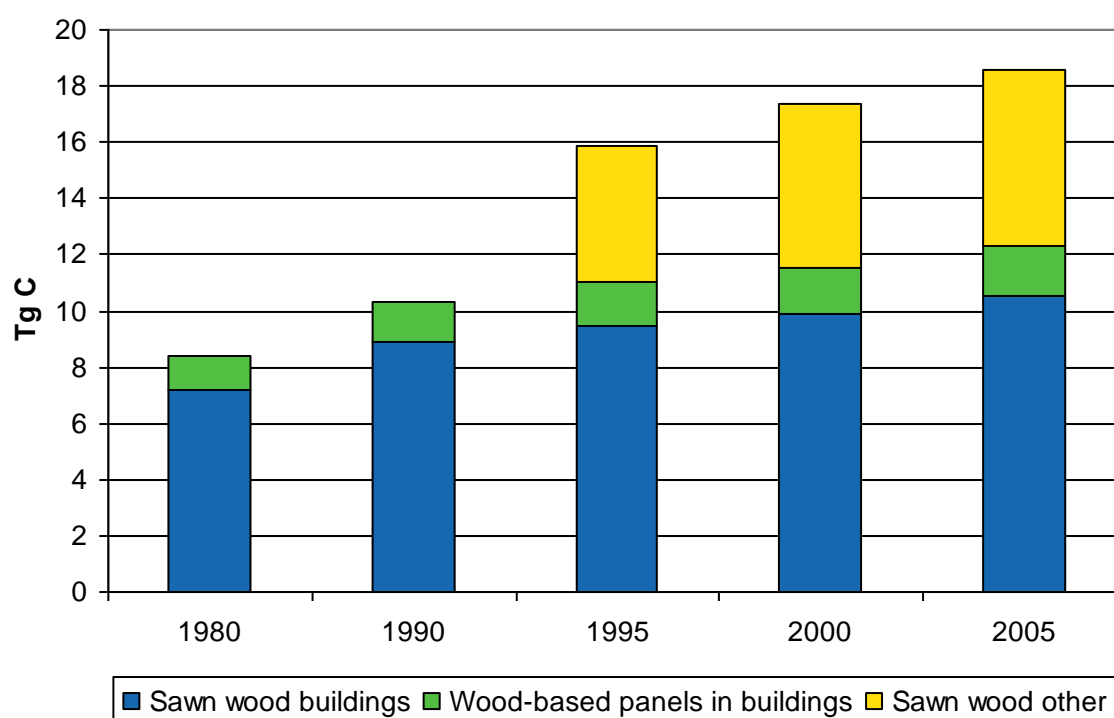
## Conclusions

The carbon stock of wood products used as part of the building stock and for other construction uses has increased during the years 2000-2005 by 0.21 Mt/year. That carbon stock has increased continuously during the last decades. There is still potential to increase the use of wood, but the competition with other materials is fierce. Also, building costs affect the decision makers and how they determine which material to use in dwellings and other buildings.

The building stock in 2005 is more accurate than in the earlier inventories. On the other hand, new small buildings do not always need building permits and they must be estimated separately.

Uncertainty in the calculations varies between  $\pm 4$  and  $\pm 20\%$  in different areas, being, on average,  $\pm 11\%$ . The calculations are more accurate for dwellings such as non-residential buildings. The uncertainty is highest in the civil engineering area and for small buildings.

More value-added wooden products like pre-fabricated houses, windows, doors, etc., are also produced in Finland. In cases when they are exported abroad, their carbon stock is not included in the inventory, because they are not situated in Finland.

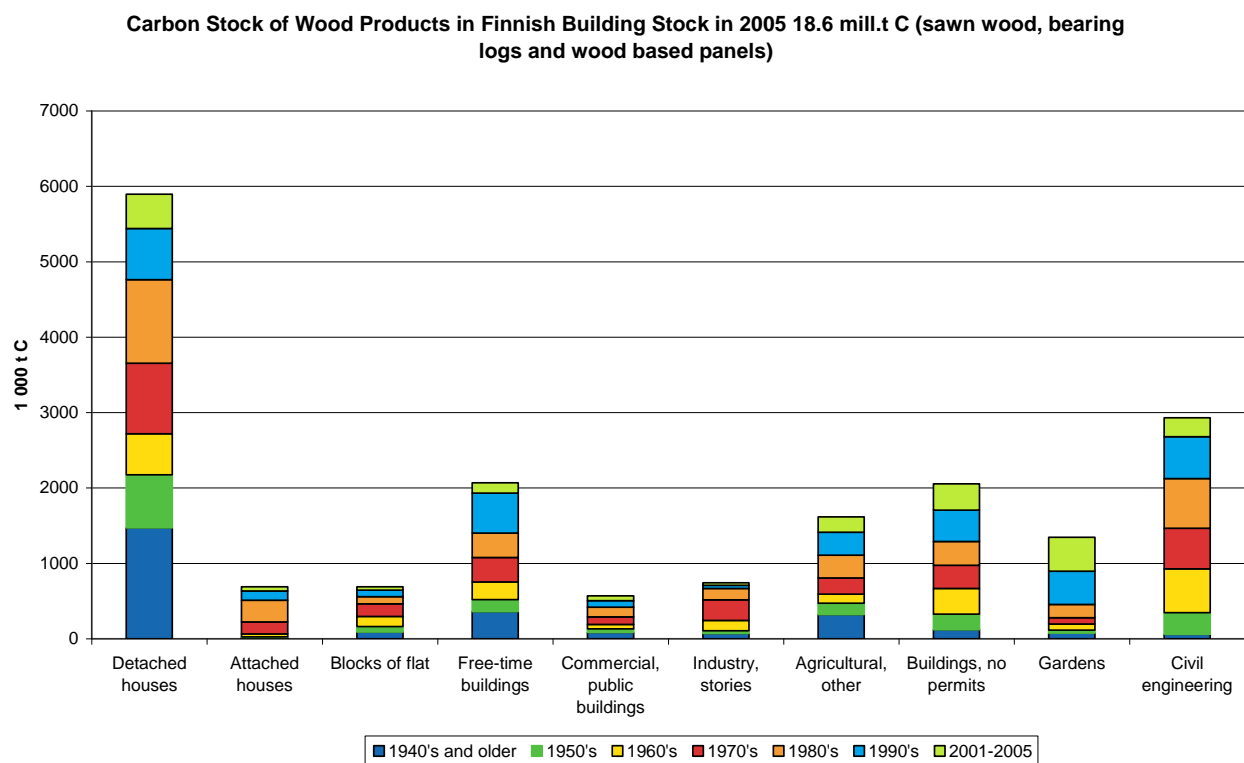


**Figure 1\_App\_7k** Carbon storage of wooden products in Finnish construction

**Table 2\_App\_7k** Carbon stock by building types in Finland in 2005 (1 000 Mg C)

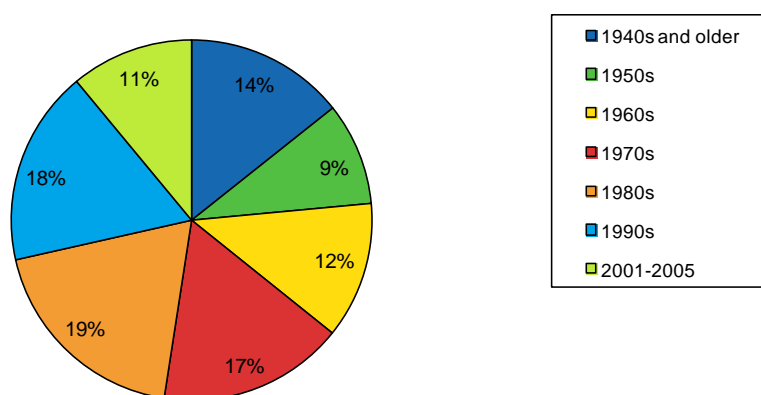
	1940's and older	1950's	1960's	1970's	1980's	1990's s	2001-2005
Detached houses	1470	704	546	934	1109	678	454
Attached houses	16	10	39	159	285	123	58
Blocks of flat	90	71	136	167	94	86	45
Free-time buildings	359	161	235	324	324	529	136
Commercial, public buildings	83	48	60	101	126	88	65
Industry, stories	71	34	138	272	151	42	34

	1940's and older	1950's	1960's	1970's	1980's	1990's s	2001- 2005
Agricultural, other	320	151	122	214	301	305	204
Buildings, no permits	120	208	340	308	315	415	350
Gardens	75	40	80	85	175	440	450
Civil engineering	57	288	582	538	660	555	250



**Figure 2\_App\_7k** Carbon stock by building types in Finland in 2005

**The Share of Carbon Stock by Decades in the Whole Finnish Buildings Stock in 2005 (18.6 mill.t C)**



**Figure 3\_App\_7k** Carbon stock in Finnish building stock by decades in 2005

**Table 3\_App\_7k** Time series of inventories for wood product stock in 1995, 2000 and 2005. Whole Wooden Material in Finnish Building Stock (sawn wood, bearing logs, wood-based panels, dry weight, 1,000 Mg C)

	2005								2000								1995							
	2001- 2005	1990' s	1980' s	1970' s	1960' s	1950' s	1940' s and older	Total	1990's	1980's	1970's	1960's	1950's	1940's and older	Total	1991- 1995	1980' s	1970' s	1960' s	1950' s	1940' s and older	Total		
Detached houses	909	1356	2217	1867	1092	1408	2939	11789	1562	2233	1691	1071	1536	2867	10960	882	2438	1737	1030	1313	2655	10054		
Attached houses	116	246	571	318	78	20	33	1381	291	550	293	68	20	39	1261	173	602	277	66	19	25	1162		
Blocks of flat	89	172	188	335	271	142	179	1377	174	182	344	249	131	177	1258	158	257	287	226	111	127	1165		
Free-time buildings	272	1057	647	648	469	321	719	4134	327	653	670	512	366	943	3472	313	693	708	473	396	610	3193		
Commercial, public buildings	130	175	253	202	121	96	165	1141	228	255	191	122	116	200	1112	189	345	140	92	85	139	990		
Industry, stories	69	84	302	544	277	68	142	1486	135	336	661	339	97	163	1732	24	132	238	131	42	31	598		
Agricultural, other Buildings, no permits	408	611	601	428	245	301	640	3233	842	683	471	220	239	761	3216	692	1056	607	346	366	533	3600		
Gardens	700	830	630	615	680	415	240	4110	992	630	630	720	450	270	3692	300	700	700	800	500	300	3300		
Civil engineering	900	880	350	170	160	80	150	2690	1000	360	180	180	100	180	2000	200	400	200	200	120	200	1320		
<b>Total</b>	4093	6521	7080	6203	4557	3426	5322	<b>37201</b>	6722	7383	6402	4837	3719	5740	<b>34803</b>	3874	8299	6309	4872	3692	4769	<b>31816</b>		
Total (%)	11	18	19	17	12	9	14	100	19	21	18	14	11	16	100	12	26	20	15	12	15	100		

**Table 4\_App\_7k** Time series of inventories for wood product stock in 1995, 2000 and 2005. Carbon Stock of Finnish Building Stock (1,000 Mg C).)

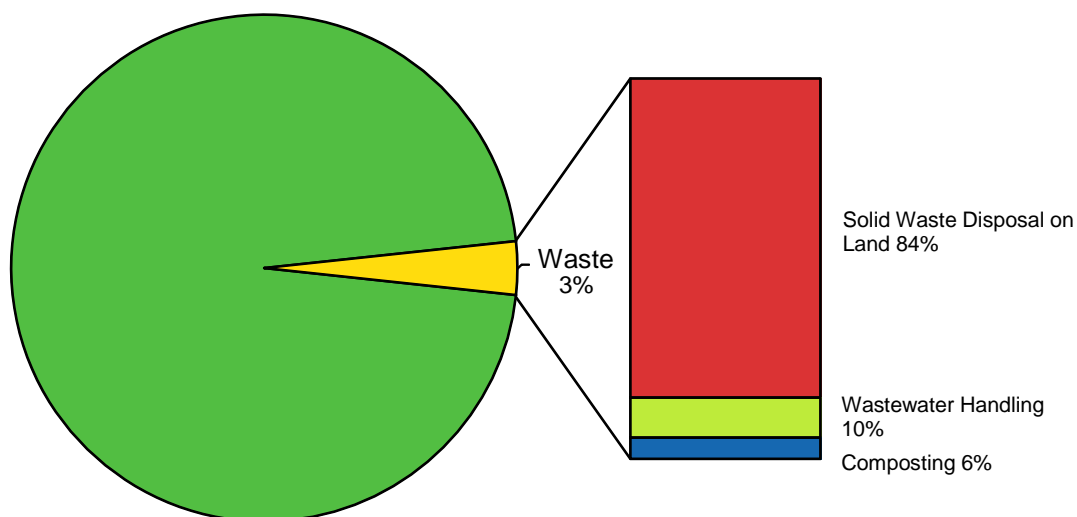
	2005							2000							1995							
	2001 - 2005	1990' s	1980' s	1970' s	1960' s	1950' s	1940' s and older	Total	1990' s	1980's	1970's	1960's	1950's	1940's and older	Total	1991- 1995	1980' s	1970' s	1960' s	1950' s	1940's and older	Total
Detached houses	454	678	1109	934	546	704	1470	5894	781	1117	846	535	768	1434	5480	441	1219	869	515	656	1327	5027
Attached houses	58	123	285	159	39	10	16	690	145	275	147	34	10	20	630	87	301	138	33	9	12	581
Blocks of flat	45	86	94	167	136	71	90	688	87	91	172	125	66	89	629	79	129	143	113	55	63	582
Free-time buildings	136	529	324	324	235	161	359	2067	164	326	335	256	183	472	1736	157	347	354	236	198	305	1597
Commercial, public buildings	65	88	126	101	60	48	83	571	114	127	96	61	58	100	556	94	172	70	46	43	70	495
Industry, stories	34	42	151	272	138	34	71	743	68	168	330	170	48	82	866	12	66	119	65	21	16	299
Agricultural, other Buildings, no permits	204	305	301	214	122	151	320	1617	421	342	236	110	120	381	1608	346	528	304	173	183	267	1800
Gardens	350	415	315	308	340	208	120	2055	496	315	315	360	225	135	1846	150	350	350	400	250	150	1650
Civil engineering	450	440	175	85	80	40	75	1345	500	180	90	90	50	90	1000	100	200	100	100	60	100	660
<b>Total</b>	2047	3260	3540	3101	2279	1713	2661	<b>18600</b>	3361	3691	3201	2418	1860	2870	<b>17401</b>	1937	4149	3155	2436	1846	2385	<b>15908</b>
Total (%)	11	18	19	17	12	9	14	100	19	21	18	14	11	16	100	12	26	20	15	12	15	100

## 8 WASTE (CRF 6)

### 8.1 Overview of the sector

Emissions from the waste sector were 2.1Tg CO<sub>2</sub> eq. in 2012. This was 3% of the total greenhouse gas emissions in Finland. Solid waste disposal on land (landfills and dumps) causes relatively large CH<sub>4</sub> emissions in Finland while emissions from wastewater handling and from composting are smaller (Figure 8.1-1). In the Finnish inventory emissions from the Waste Sector cover CH<sub>4</sub> emissions from solid waste disposal sites including solid municipal, industrial, construction and demolition wastes and municipal (domestic and commercial) and industrial sludges. In addition, the Waste Sector includes CH<sub>4</sub> emissions from municipal (domestic and commercial) and industrial wastewater handling plants and uncollected domestic wastewaters. N<sub>2</sub>O emissions are generated from nitrogen input of fish farming as well as domestic and industrial wastewaters discharged into waterways.

NMVOC emissions from solid waste disposal sites and wastewater handling as well as NMVOC, CH<sub>4</sub> and N<sub>2</sub>O emissions from composting are also estimated in the Finnish inventory. General assessment of completeness could be found in Section 1.8 and more detailed assessment is included in Annex 5.

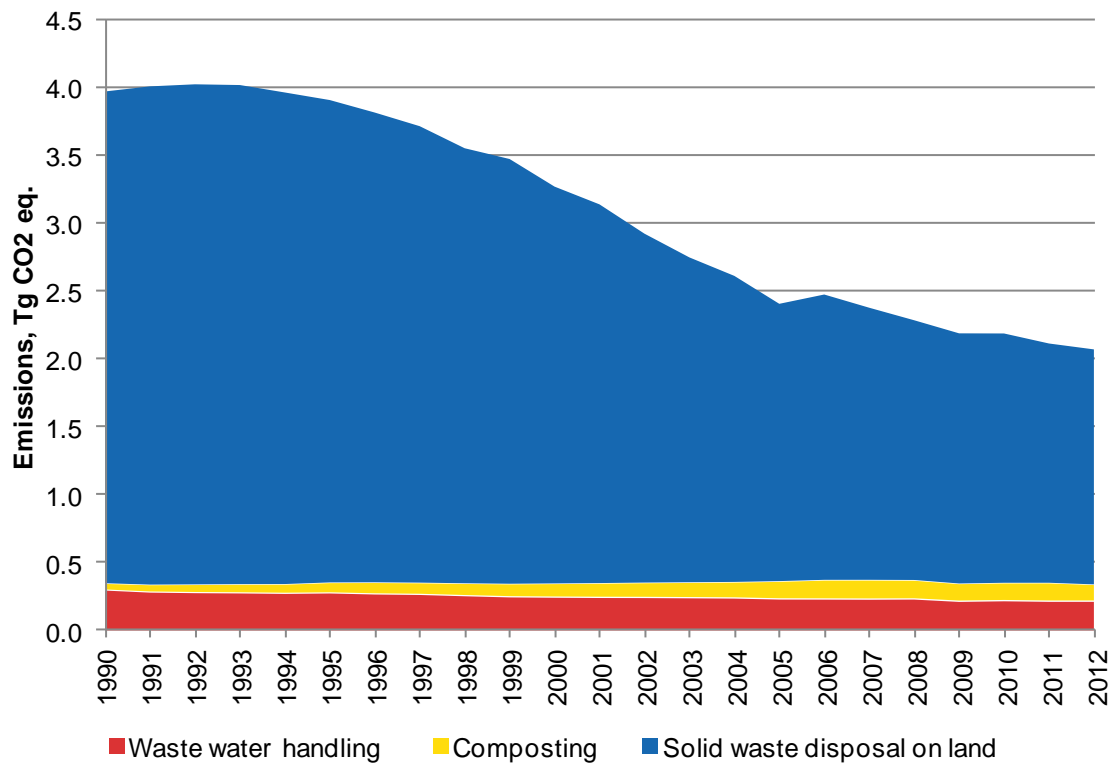


**Figure 8.1-1** Greenhouse gas emissions from the Waste Sector in 2012 compared with the total greenhouse gas emissions in Finland

CH<sub>4</sub> emissions from landfills are the most important greenhouse gas emissions in the waste sector. Solid waste disposal on land contributes over 84%, wastewater handling about 10% and composting 6% of this sector's total emissions. Since 1990 these emissions have decreased 48% (Figure 8.1-2). At the beginning of the 1990's, around 80% of the generated municipal waste was taken to solid waste disposal sites (landfills). After the implementation of the new Waste Act (1994) and the Landfill Directive (1999/31/EC) minimisation of waste generation, recycling and reuse of waste material, landfill gas recovery and alternative treatment methods to landfills have been endorsed. Similar developments have occurred in the treatment of industrial waste, and municipal and industrial sludges. While the emissions from solid waste disposal on land have decreased, the emissions from composting have increased until 2007. In addition, the increase of waste incineration has decreased the emissions from landfills from 2008 onwards. Implementation of landfill gas recovery has significant impact on emissions. The increase of emissions in 2006 followed from increased amount of waste landfilled and a low landfill gas recovery rate due to (temporary) technical problems in one important landfill gas recovery plant.

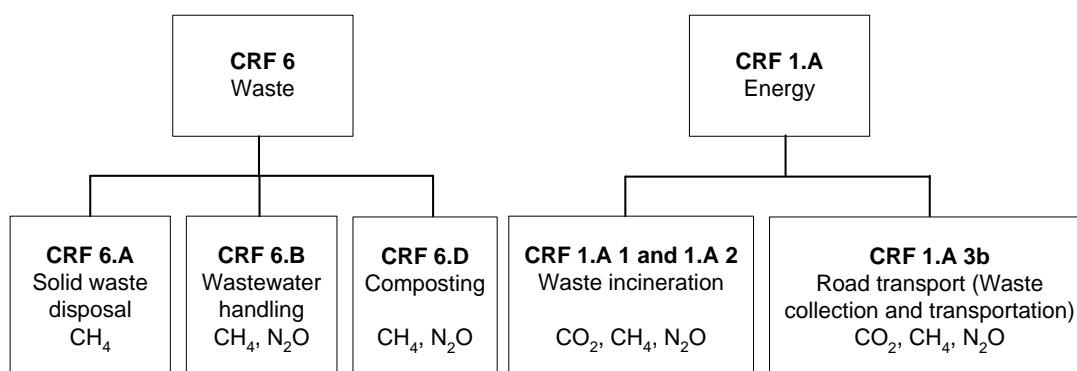
The treatment of municipal solid waste is divided into as follows in 2011 (Statistics Finland 2013):

- Landfilling 40%
- Composting and anaerobic digestion 13%
- Material recycling 22%
- Burning and incineration 25%



**Figure 8.1-2** Trend in the Waste Sector's emissions (Tg CO<sub>2</sub> eq.)

The emission trend in the Waste Sector by subcategory and gas is presented in Table 8.1-2.



**Figure 8.1-3** Emissions from waste handling and their reporting categories in the national greenhouse gas inventory

### *Key categories*

The key categories in the waste sector in 2012 are summarised in Table 8.1-1.

**Table 8.1-1** Key categories in Waste Sector (CRF 6) in 2012 (quantitative method used: Tier 2)

<b>IPCC source category</b>	<b>Gas</b>	<b>Identification criteria</b>
6.A. Solid Waste Disposal on Land	CH <sub>4</sub>	L, T
6.B.2. Domestic and Commercial Wastewater	N <sub>2</sub> O	L, T
6.B.3.a. Other (N input from Fish Farming)	N <sub>2</sub> O	T
6.B.3.b. Other (N input from Industrial Wastewater)	N <sub>2</sub> O	L, T
6.D. Other (Compost production)	CH <sub>4</sub>	T
6.D. Other (Compost production)	N <sub>2</sub> O	T



**Table 8.1-2** Emissions in the Waste Sector by source and gas (Tg CO<sub>2</sub> eq.)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>Solid waste disposal on land</b>	<b>3.64</b>	<b>3.68</b>	<b>3.70</b>	<b>3.69</b>	<b>3.63</b>	<b>3.57</b>	<b>3.47</b>	<b>3.37</b>	<b>3.22</b>	<b>3.14</b>	<b>2.93</b>	<b>2.80</b>	<b>2.58</b>	<b>2.40</b>	<b>2.26</b>	<b>2.05</b>	<b>2.11</b>	<b>2.01</b>	<b>1.92</b>	<b>1.85</b>	<b>1.84</b>	<b>1.77</b>	<b>1.74</b>
Methane	3.64	3.68	3.70	3.69	3.63	3.57	3.47	3.37	3.22	3.14	2.93	2.80	2.58	2.40	2.26	2.05	2.11	2.01	1.92	1.85	1.84	1.77	1.74
<b>Wastewater handling</b>	<b>0.30</b>	<b>0.28</b>	<b>0.28</b>	<b>0.28</b>	<b>0.27</b>	<b>0.28</b>	<b>0.27</b>	<b>0.26</b>	<b>0.25</b>	<b>0.25</b>	<b>0.24</b>	<b>0.24</b>	<b>0.24</b>	<b>0.24</b>	<b>0.24</b>	<b>0.23</b>	<b>0.23</b>	<b>0.23</b>	<b>0.23</b>	<b>0.21</b>	<b>0.22</b>	<b>0.21</b>	<b>0.21</b>
Methane	0.15	0.14	0.14	0.15	0.14	0.15	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.11
Nitrous oxide	0.14	0.14	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.10	0.10	0.10	0.10	0.09	0.10	0.10	0.10
<b>Composting</b>	<b>0.04</b>	<b>0.05</b>	<b>0.05</b>	<b>0.06</b>	<b>0.06</b>	<b>0.07</b>	<b>0.08</b>	<b>0.08</b>	<b>0.08</b>	<b>0.09</b>	<b>0.09</b>	<b>0.10</b>	<b>0.10</b>	<b>0.11</b>	<b>0.11</b>	<b>0.12</b>	<b>0.13</b>	<b>0.14</b>	<b>0.13</b>	<b>0.12</b>	<b>0.13</b>	<b>0.13</b>	<b>0.12</b>
Methane	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.07	0.07	0.07	0.06	0.06	0.06	0.06
Nitrous oxide	0.02	0.02	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.06	0.07	0.07	0.07	0.06	0.06	0.07	0.06
<b>Total</b>	<b>3.97</b>	<b>4.01</b>	<b>4.03</b>	<b>4.02</b>	<b>3.97</b>	<b>3.91</b>	<b>3.82</b>	<b>3.72</b>	<b>3.55</b>	<b>3.48</b>	<b>3.27</b>	<b>3.14</b>	<b>2.92</b>	<b>2.75</b>	<b>2.61</b>	<b>2.40</b>	<b>2.47</b>	<b>2.38</b>	<b>2.28</b>	<b>2.19</b>	<b>2.19</b>	<b>2.11</b>	<b>2.07</b>

## 8.2 Solid Waste Disposal on Land (CRF 6.A)

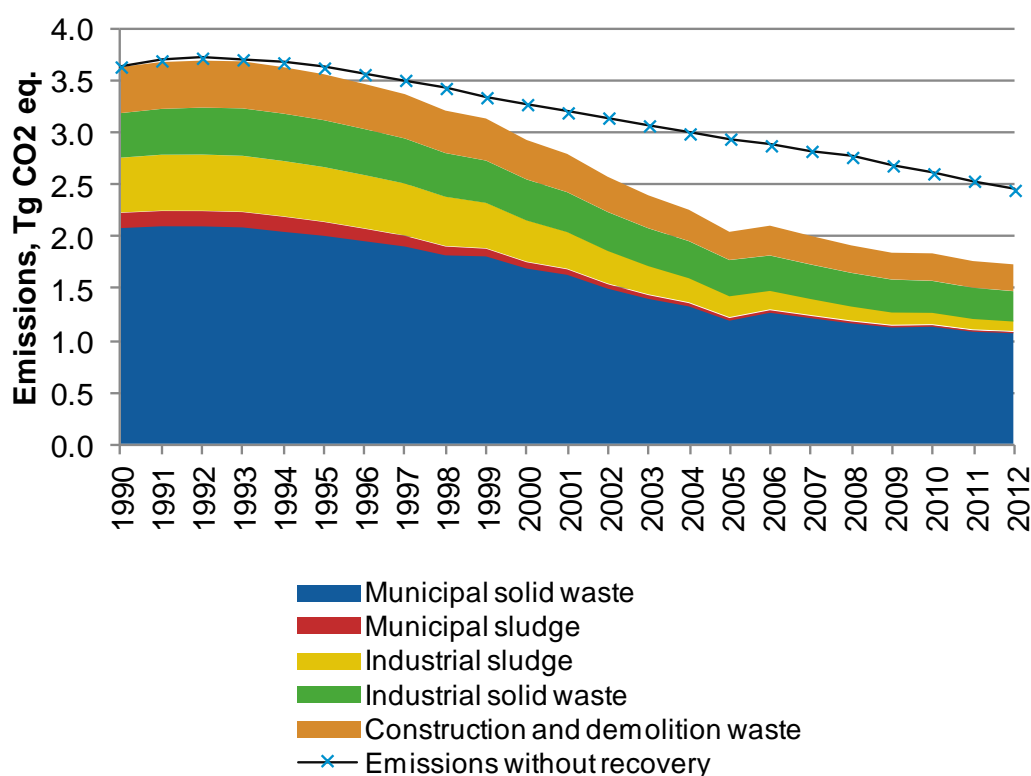
### 8.2.1 Source category description

The emission source includes CH<sub>4</sub> emissions from solid waste disposal sites from disposal of solid municipal, industrial, construction and demolition wastes, and municipal (domestic) and industrial sludges.

**Table 8.2-1** Reported emissions calculation methods and types of emission factors for the subcategory Solid Waste Disposal on Land in the Finnish inventory

CRF	Source	Emissions reported	Methods	Emission factors
6.A 1	Managed Waste Disposal on Land	CH <sub>4</sub>	Tier 2	CS, D
6.A 2	Unmanaged Waste Disposal Sites	IE, NO	NA	NA
6.A 3	Other		Tier 2	CS, D
	Construction and Demolition Waste	CH <sub>4</sub>		
	Industrial Solid Waste	CH <sub>4</sub>		
	Industrial Sludge (d.m.)	CH <sub>4</sub>		
	Municipal Sludge (d.m.)	CH <sub>4</sub>		

Emissions from solid waste disposal on land have decreased by 52% since 1990. The trend in CH<sub>4</sub> emissions from solid waste disposal on land is presented by subcategory in Figure 8.2-1 and Table 8.2-3.



**Figure 8.2-1** Methane emissions from solid waste disposal on land (Tg CO<sub>2</sub> eq.)

## 8.2.2 Methodological issues

### 8.2.2.1 Methods

Emissions from solid waste disposal on land have been calculated using the First Order Decay (FOD) method, which is the IPCC Tier 2 method given in the IPCC GPG 2000 (GPG 2000).

IPCC Equations 5.1 and 5.2 (GPG 2000) have been used as a basis for the calculations. Equation 5.1 has been slightly modified, so that the term  $MCF(x)$  (Methane correction factor in year  $x$ ) has been substituted by the term  $MCF(t)$  ( $t$  = year of inventory) in the calculation of the methane generation potential  $L_0(x)$ . Calculations are not made separately for each landfill but the total waste amount and the average common  $MCF$  value for each year have been used. It has been thought that the situation in year  $t$  defines the  $MCF$  to be used for the emissions caused by waste amounts landfilled in the previous years (and degraded later in year  $t$ ) as well. In Finland this is also valid for closed landfills (which have been unmanaged when used) because all the closed landfills have been covered at present. The modified equation can be seen in the Appendix\_8a at the end of Chapter 8.

### 8.2.2.2 Emission factors and other parameters

The parameters used in the calculation are mainly IPCC default values and IPCC 2006 values. Some country-specific emission parameters (factors) are used (Table 8.2-2). The choices of the parameters are in full agreement with the information and data ranges given in the GPG 2000.

**Table 8.2-2** Emission factors and parameters used in calculations (country-specific (CS) expert estimations or IPCC default values (D))

Factor/parameter	Value	Type of emission factor
DOC (Fraction of degradable organic carbon in municipal solid waste)	Between 0.172 and 0.186	D/CS Based on waste composition, varies in time series
DOCF (Fraction of DOC dissimilated)	0.5	CS
F (Fraction of methane in landfill gas)	0.5	D
OX (Oxidation factor)	0.1	CS
Methane generation rate constants; k1 = wastewater sludges, food waste k2 = wood waste, de-inking sludge k3 = paper waste, textile waste k4 = garden waste, napkins, fibre and coating sludges More detailed categories see Table 8.2-5.	k1 = 0.185 k2 = 0.03 k3 = 0.1 k4 = 0.06	D/CS IPCC 2006 Guidelines
MCF (Methane correction factor)	In 1990: 0.982 In 1991: 0.985 In 1992-1996: 0.988 In 1997-2001: 0.994 In 2002-2012: 1.0	D/CS; weighted mean value of the default values of 1 and of 0.4. Varies between the years, is 1 after 2002.

The historical development from 1948 to 1990 (until 1948 MCF is 0.4) of the methane correction factor is presented in Table 8.2-4. Between the years presented in the table MCF is linearly growing. The weighted mean values of the MCF presented in Table 8.2-4 are obtained respectively (e.g. the share of the waste amount under degradation is 0.99 from managed landfills and 0.01 from unmanaged shallows resulting to the weighted value of 0.994 in 1997-2001).

**Table 8.2-3** CH<sub>4</sub> emissions from solid waste disposal on land by subcategory (Tg CO<sub>2</sub> eq.)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Municipal solid waste	2.09	2.11	2.10	2.09	2.05	2.01	1.96	1.91	1.83	1.82	1.70	1.64	1.50	1.41	1.33	1.20	1.27	1.22	1.17	1.13	1.14	1.09	1.08
Municipal sludge	0.15	0.15	0.15	0.15	0.15	0.13	0.12	0.10	0.09	0.07	0.06	0.05	0.04	0.04	0.03	0.03	0.02	0.02	0.02	0.02	0.02	0.01	0.01
Industrial sludge	0.53	0.54	0.54	0.54	0.54	0.53	0.52	0.50	0.48	0.44	0.40	0.36	0.32	0.28	0.24	0.21	0.19	0.16	0.14	0.13	0.12	0.11	0.10
Industrial solid waste	0.43	0.44	0.45	0.45	0.45	0.45	0.44	0.43	0.42	0.41	0.39	0.38	0.37	0.36	0.36	0.35	0.34	0.33	0.32	0.32	0.31	0.30	0.29
Construction and demolition waste	0.44	0.45	0.45	0.45	0.45	0.44	0.43	0.43	0.41	0.40	0.38	0.37	0.34	0.32	0.30	0.27	0.29	0.27	0.26	0.26	0.26	0.25	0.26
<b>Total</b>	<b>3.64</b>	<b>3.68</b>	<b>3.70</b>	<b>3.69</b>	<b>3.63</b>	<b>3.57</b>	<b>3.47</b>	<b>3.37</b>	<b>3.22</b>	<b>3.14</b>	<b>2.93</b>	<b>2.80</b>	<b>2.58</b>	<b>2.40</b>	<b>2.26</b>	<b>2.05</b>	<b>2.11</b>	<b>2.01</b>	<b>1.92</b>	<b>1.85</b>	<b>1.84</b>	<b>1.77</b>	<b>1.74</b>

**Table 8.2-4** The historical development of MCF

	1948	1970	1983	1986	1990
<b>Weighted MCF</b>	0.4	0.796	0.952	0.97	0.982
<b>Share of managed (MCF=1) SWDS</b>	0	0.66	0.92	0.95	0.97

The use of other values than the IPCC default values is justified by international and national research. The IPCC default values generally overestimate the emissions and therefore a lower  $DOC_F$  value (0.5), based on the outcomes of expert meetings, have been chosen. This value is also consistent with the fact that the conditions at most Finnish landfills are not optimal for methane generation. For instance, many of the landfills are not so deep and the mean temperature has been found to be between 10-15°C (Väisänen 1997).  $OX$  is chosen to be 10% of the  $CH_4$  generated at landfills based on international research (e.g. Oonk & Boom 1995).

DOC fractions of different types of waste are based on the IPCC 2006 default values and national research data (Isännäinen 1994) and measurements made in industry (revised DOC value for de-inking sludges) (Huttunen 2008). For MSW IPCC 2006 default values of DOC fractions (wood 0.43, paper 0.4, napkins and textiles 0.24, food 0.15 and garden 0.2) are used and, in addition, the waste subgroup Other organic has the DOC fraction of 0.1. The DOC value of 0.5 is used for other municipal sludges from handling plants except for composted sludges the DOC value of 0 is used. The waste composition of MSW is presented in Table 8.2-6. The waste compositions and DOC values of construction and demolition waste (mixed) are based on research by VTT Technical Research Centre of Finland (Perälä & Nippala 1998) and expert estimate by Perälä (Perälä 2001).

**Table 8.2-5** The waste groups and the waste subgroups and the corresponding  $DOC$  and  $k$  values

Waste group and subgroups	DOC	k	Reference
<b>Solid municipal waste</b>			
Textiles	0.24	0.06	IPCC 2006
Food	0.15	0.185	IPCC 2006
Paper	0.4	0.06	IPCC 2006
Wood	0.43	0.03	IPCC 2006
Garden	0.2	0.1	IPCC 2006
Napkins	0.24	0.1	IPCC 2006
Mixed packaging	0.1	0.06	IPCC 2006
Other organic	0.1	0.1	Expert knowledge
<b>Municipal sludge (from dry matter)</b>			
Handling plants	0.5	0.185	Expert knowledge
Septic tanks	0.5	0.185	Expert knowledge
Sand separation	0.1	0.185	Expert knowledge
<b>Industrial sludge (from dry matter)</b>			
Pulp and paper (mainly wastewater sludges)	0.45	0.185	Isännäinen, 1994
Other industry (mainly wastewater sludges)	0.45	0.185	Expert knowledge
De-inking (pulp industry)	0.1	0.03	Huttunen, 2008
Fibre and coating (paper industry)	0.1	0.1	Expert knowledge
<b>Solid industrial waste</b>			
Textile	0.24	0.06	IPCC 2006
Food	0.15	0.185	IPCC 2006
Paper	0.4	0.06	IPCC 2006
Wood	0.43	0.03	IPCC 2006
Garden	0.2	0.1	IPCC 2006
De-inking reject	0.1	0.06	Expert knowledge
Oil	0.1	0.1	Expert knowledge
Green liquor sludge (from dry matter)	0.02	0.03	Expert knowledge
Mixed packaging and other organic (slowly)	0.1	0.06	Expert knowledge
Other organic (moderately degrading)	0.1	0.1	Expert knowledge

Waste group and subgroups	DOC	k	Reference
<b>Construction and demolition waste</b>			
Plastics	0		IPCC 2006
Other inert	0		IPCC 2006
Asphalt and tar	0.02	0.06	
Wood	0.43	0.03	IPCC 2006
Mixed (years 1997-1999)	0.0996	0.03	Perälä & Nippala, 1998
Mixed (years 2000-2012)	0.1384	0.03	Perälä, 2001
Total (years 1990-1996)	0.096-0.106	0.03	Calculated
Paper (packaging)	0.24	0.06	IPCC 2006
Textile (packaging)	0.43	0.06	IPCC 2006
Other (packaging)	0.1	0.06	
<b>Industrial and municipal inert waste</b>			
Plastics	0		IPCC 2006
Other combustible	0		IPCC 2006
Other non-combustible	0		IPCC 2006
Ash	0		IPCC 2006
Other sludges (mainly from inorganic processes)	0		IPCC 2006
<b>Other inert waste</b>			
Mine	0		IPCC 2006
Soil	0		IPCC 2006

The waste composition of solid municipal waste is calculated according to the estimated composition of generated municipal waste and separately collected waste fractions (top-down approach). Especially from paper and paperboard there is wide information on domestic consumption and recycling. However, in the years 2006-2012 there are unclear fluctuations in the paper and paperboard data and the composition of solid municipal waste is kept unchanged after 2008 until further information is achieved.

**Table 8.2-6** The estimated waste composition of solid municipal waste

Waste type	Composition of mixed MSW (%)						
	1990-1993	1994-1996	1997-1999	2000-2002	2003-2005	2006-2007	2008-2012
Paper and paperboard	14.9	18.3	21.3	16.5	18.5	22.7	20.8
Food	38.5	39.2	37.9	39.8	37.5	36.2	35.1
Garden	9.1	8.6	7.6	8.2	7.8	7.4	8.8
Plastics (inert)	5.9	6.2	6.5	6.4	7.1	7.3	7.9
Glass (inert)	1.6	1.2	1.1	1.2	1.5	0.8	0.5
Textiles	2.0	1.8	1.5	1.7	1.7	1.6	1.7
Napkins	2.5	3.1	3.3	3.5	3.8	3.6	2.9
Wood	6.1	3.7	3.0	3.4	3.2	2.6	2.2
Other – inert	15.8	14.6	14.4	15.6	16.0	15.0	16.8
Other – organic	3.6	3.4	3.4	3.7	2.9	2.8	3.3

**Table 8.2-7** DOC-values of municipal solid waste

	1990	1994	1997									2008
	-	-	-	2000	2001	2002	2003	2004	2005	2006	2007	-
	1993	1996	1999									2012
Mixed MSW	0.176	0.180	0.185	0.173	0.173	0.173	0.176	0.176	0.176	0.186	0.186	0.177
Total MSW	0.176	0.180	0.184	0.172	0.173	0.172	0.175	0.174	0.175	0.185	0.186	0.177

### 8.2.2.3 Activity data

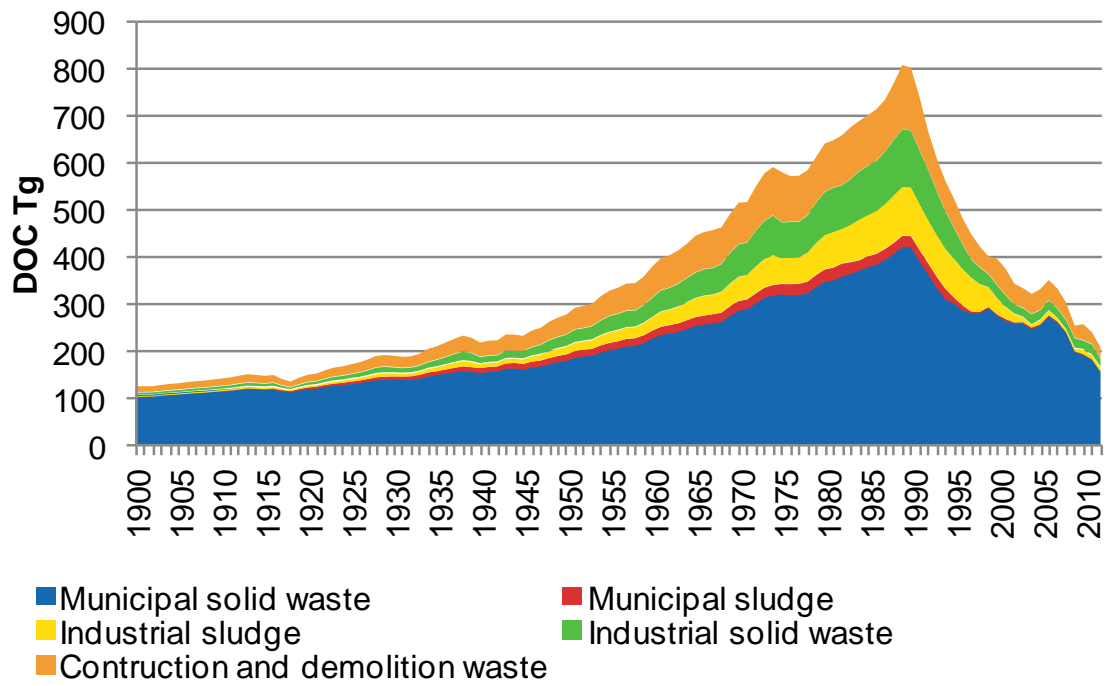
The activity data used in the calculation are taken from the VAHTI system (see Section 1.4 and Annex 2). It includes information on all landfills in Finland excluding Åland, which is estimated according to the population. The VAHTI contains data on the total amounts of waste taken to landfills from 1997 onwards. In the VAHTI the waste amounts are registered according to the EWC (European Waste Catalogue) classification (both EWC 1997 and EWC 2002). Sampling routines have been developed to convert the classification of the VAHTI system to the classification used in the emission estimations. Corresponding data (but with volume units and the waste classification is less detailed) for the years 1992-1996 were collected to the Landfill Registry of the Finnish Environment Institute. The activity data for municipal waste for the year 1990 are based on the estimates of the Advisory Board for Waste Management (1992) for municipal solid waste generation and treatment in Finland in 1989 with the correction of double counting in paper waste. The disposal data (amount and composition) at the beginning of the 1990's for industrial, construction and demolition waste are based on surveys and research by Statistics Finland (Isaksson 1993; Puolamaa et al. 1995), VTT Technical Research Centre of Finland (Perälä & Nippala 1998; Pipatti et al. 1996) and the National Board of Waters and the Environment (Karhu 1993). For base year activity data Isaksson (1993) and Pipatti et al. (1996) are used for construction and demolition waste, Karhu (1993) is used for industrial sludges and Puolamaa et al. (1995) is used for solid industrial waste.

The amount of landfilled waste in 1990-2012 is presented in Table 8.2-8. The corresponding DOC tonnes are given in Table 8.2-9. The waste composition of landfilled industrial solid waste is presented in Appendix\_8c and the DOC share of the landfilled industrial solid waste without inert industrial wastes is presented in Table 8.2-11. The Industrial solid waste category consist of several hundreds of EWC-codes (EWC principal groups 02-16 and 18-19) among others medical wastes. The composition of Industrial solid waste is presented according to the DOC and decay groups in Appendix\_8c. The quite large variation in the waste amounts of Industrial solid waste is due to the diverse reporting practices of some inert waste types to the VAHTI system.

The landfilled amounts of municipal solid waste have decreased clearly during last years because of energy use of wastes and this trend will continue in future, also. The variation in construction and demolition waste in the last years is due to the classification change made in 2010 inventory: The amount of rejects from wood waste handling has increased significantly in 2010-2012 due to the increased activity and especially due to the discharge of reject stocks to landfills. These rejects have been classified according to the origin of the wood waste since 2010 inventory. These EWC codes (191212 and 191211) were classified only as industrial waste in earlier inventories but the waste amounts were much smaller before 2010.

Estimated data on waste amounts before the year 1990 are based on the report of VTT (Tuhkanen 2002). In this report GDP has 30% weight and population has 70% weight for generated municipal solid waste. At the beginning of 1900's all the generated municipal solid waste was assumed to be landfilled and landfilling has linear development to 80% of the situation in the year 1990. Other waste groups develop according to the corresponding industrial or construction economical activities. The DOC tonnes of the five waste groups starting from the year 1900 are presented in Table 8.2-3.

Data on landfill gas recovery are obtained from the Finnish Biogas Plant Register (Huttunen and Kuittinen 2013) and presented in Table 8.2-10 and in Appendix\_8b (volume of collected gas by plant/site). The great increase in the amounts of recovered methane at the beginning of 2000 comes from the regulations of landfill gas recovery (Council of State Decree 861/1997 on Landfills).



**Figure 8.2-2** The DOC Tg of the five waste groups starting from the year 1900



**Table 8.2-8** Landfilled waste (1 000 t). (VAHTI system, Landfill Registry of the Finnish Environment Institute, Advisory Board for Waste Management 1992, Vahvelainen & Isaksson 1992, Isaksson 1993, Pipatti et al. 1996, Puolamaa et al. 1995, Perälä & Nippala 1998, Karhu 1993. Directly or indirectly interpolated values are presented in italics)

Waste group	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Municipal solid waste	2 400	2 230	2 070	1 909	1 725	1 682	1 599	1 535	1 528	1 586	1 602	1 542	1 507	1 488	1 423	1 462	1 485	1 411	1 358	1 128	1 095	1 033	885
Municipal sludge (d.m.)	47	48	48	47	46	25	21	7	6	5	6	8	6	6	6	6	5	4	4	3	3	2	3
Municipal sludge (wet m.)	498	504	510	505	501	298	212	84	71	67	70	79	66	63	58	53	51	39	27	26	22	23	22
Industrial sludge (d.m.)	337	318	299	285	268	260	248	229	182	140	118	97	65	42	29	48	44	32	15	18	26	27	32
Industrial sludge (wet m.)	1 193	1 129	1 065	999	935	881	790	695	606	559	550	329	209	198	127	161	144	119	49	55	82	78	96
Industrial solid waste	2 135	2 107	2 079	1 892	1 706	1 519	1 332	1 146	1 345	2 316	2 390	2 659	2 562	3 041	4 781	4 682	5 142	2 996	3 435	3 570	2 661	2 742	3 312
Constr. and demol. waste	1 262	1 110	781	667	639	637	567	540	438	415	454	457	377	401	373	390	353	336	331	229	342	240	241

**Table 8.2-9** Landfilled waste (1 000 DOC t)

Waste group	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Municipal solid waste	422	392	364	336	311	303	288	282	282	292	276	266	259	260	248	255	275	262	240	200	193	183	156
Municipal sludge	24	24	24	24	23	12	10	3	3	3	3	4	3	3	3	3	3	2	2	2	1	1	1
Industrial sludge	103	97	91	87	84	81	76	70	57	41	33	24	18	10	5	9	10	6	5	6	10	9	8
Industrial solid waste	121	115	108	94	80	66	52	38	35	27	27	25	19	18	21	19	20	19	19	20	17	21	17
Constr. and demol. waste	134	113	81	69	64	61	55	54	44	38	56	56	44	42	43	44	43	42	37	26	34	25	24

**Table 8.2-10** Landfill CH<sub>4</sub> recovery (Gg) and the number of operating CH<sub>4</sub> recovery plants (Huttunen and Kuittinen 2013)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Recovery (Gg)	0	0.54	1.10	0.75	1.96	2.84	4.30	6.34	10.16	9.58	16.24	18.83	26.93	31.83	34.76	42.51	36.64	38.73	40.28	39.82	36.46	36.60	33.93
Number	0	1	1	2	3	4	6	8	9	10	12	13	26	27	29	33	33	33	33	35	39	39	40

**Table 8.2-11** DOC share in landfilled Industrial solid waste without inert industrial wastes (-)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
DOC share (-)	0.189	0.187	0.185	0.177	0.167	0.154	0.138	0.117	0.104	0.089	0.104	0.090	0.082	0.070	0.073	0.071	0.069	0.065	0.060	0.068	0.064	0.073	0.068

### 8.2.3 *Uncertainty and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

The uncertainty in solid waste disposal is assessed by replacing the parameters of the FOD model with probability density functions describing the uncertainty. As a result of simulation, uncertainty in the emission estimate of CH<sub>4</sub> from landfills contained an uncertainty of around  $\pm 30\%$  in 2012. The correlation between uncertainties in emissions in 1990 and 2012 was 0.9 according to simulations. This correlation was also included in the KASPER model (model for the estimation of total uncertainty in the inventory).

In Finland, the historical waste amount is assessed starting from the year 1900. The uncertainties in historical activity data (estimated on the basis of different weighting of the population and GDP that are assumed to be good indicators of the amount of waste) are large but the amount of waste produced at the beginning of the 1900's was fairly small, thus reducing the significance of large uncertainties. The uncertainty estimates of the current amounts of waste are based on differences between different statistics and complemented with expert judgement.

In the case of municipal sludge, the uncertainties in both historical and current activity data are quite large. On the other hand, the amount of industrial waste can be fairly accurately estimated based on industrial production, and therefore these uncertainties are the smallest in historical years.

Parameters of the FOD model contain higher uncertainties than activity data. Uncertainties are mainly due to lack of knowledge of the waste degradation process. It is also unclear if the parameters of the model are suitable for Finnish conditions. The uncertainties in other calculation parameters of the FOD model are estimated using measurement data, IPCC default uncertainties and expert judgement.

In Finland, the amount of landfill gas recovered is obtained from the Finnish Biogas Plant Register, and this figure is considered accurate. An interesting note is that methane recovery describes the reduction of emissions compared with the situation where gas is emitted. In this case, the emission reduction is accurately known, though total emissions contain higher uncertainties.

The uncertainty estimate was performed by integrating the Monte Carlo simulation straight to the FOD model. Possible model error is also assumed to be covered by the uncertainty estimates of the model parameters. A detailed description of the uncertainty analysis has been presented in Monni & Syri (2003) and Monni (2004).

The time series' consistency of rejects from wood waste is imperfect considering the classification of these wastes. These rejects have been classified according to the origin (e.g. construction and demolition waste) of the wood waste since 2010 inventory. These EWC codes (191212 and 191211) were classified only as solid industrial waste in earlier inventories but the waste amounts were much smaller before 2010.

## 8.2.4 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6. The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives. The bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral experts. The common principles of the archiving guidelines of the waste sector are presented in Section 1.6.

### General (Tier 1) Quality Control (QC) procedures applied in category CRF 6.A.

The QA/QC plan for the waste sector includes the QC measures based on the GPG 2000, (Table 8.1) such as:

- Documentation on activity data and emission factors was crosschecked with the corresponding data on MS Access tables and calculation models.
- A sample of input data from each source category was crosschecked for transcription errors.
- Part of emission estimations (methane generation potential) was reproduced by mass balance model.
- Units and conversion factors were checked
- Database data relationships and data fields were checked. Database and data processing steps were documented.
- Consistency of DOC values in different groups (source categories) was checked.
- Data aggregation and transcription from lower reporting levels to higher levels were checked.

### Tier 2 QC for activity data

The MSW generation rate and the MSW disposal rate of the inventory were compared with the corresponding default values of the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 1997). In 1990 these values correspond to each other, but after that the values in the inventory have developed considerably lower. The decrease has been mainly due to the preparation and implementation of the new Waste Act in Finland in 1994. At the beginning of the 1990's, around 80% of the generated municipal waste was taken to solid waste disposal sites (landfills). After the implementation of the new Waste Act, minimisation of waste generation, recycling and reuse of waste material and alternative treatment methods to landfills have been endorsed. Similar developments have occurred in the treatment of industrial waste, and municipal and industrial sludges.

The VAHTI data were crosschecked with the data of previous years. The errors and faults discovered were corrected and documented. The most significant of them were checked either from the Regional Environment Centres or from the companies that manage the landfills in question.

The corrected activity data (from the Vahti database) of the landfilled municipal solid waste used in EU submission for the year 2012 has been delivered to Statistics Finland which compares this data with their own observations on the same initial data. The results from this QA procedure will be completed before the inventory is submitted to UNFCCC. The activity data of the landfilled municipal solid waste has been at the same level as the waste statistics delivered to Eurostat by Statistics Finland. The measurements of the landfill gas recovery of the largest solid waste disposal site in Finland has been studied more accurately (a visit on site) in 2010. The quite large yearly fluctuation in the landfill gas recovery was explained by capacity changes and by the results from quite dense leakage measurements in the SWDS. Also, the landfill gas concentration measurements and modelling results by Finnish Meteorological Institute supported the results of the recovery measurements.

### Tier 2 QC for emission factors

Country-specific emission factors were crosschecked and compared with IPCC default values. Emissions were also estimated with the IPCC default method and with the original IPCC calculation formula of the FOD method in the GPG 2000 (without the modification explained in Section 8.2.2).

### *8.2.5 Source-specific recalculations*

No recalculation has been made since the previous submission.

### *8.2.6 Source-specific planned improvements*

Specially, in the years 2006-2012 there are unclear fluctuations on the domestic consumption of paper and board. This data are under examination by Ministry of the Environment, also (concerning of EU directive reporting), but no justification for fluctuations have been found. Thus, the composition data of the previous period have been used in the inventory for the last years. The inspection work is carried on but clear results are uncertain.

A sample survey for construction and demolition waste was conducted in 2013 by Statistics Finland. The survey was sent to construction companies. Due to a low response rate the results didn't give enough new information about the composition of mixed construction and demolition waste for the revision of the waste composition. The need for new data on the composition of waste remains and new sources for the information will be studied.

The implementation of 2006 IPCC Guidelines are not expected to introduce major changes to the methodology and estimates. However, this will be evaluated for the 2015 submission.

## 8.3 Wastewater Handling (CRF 6.B)

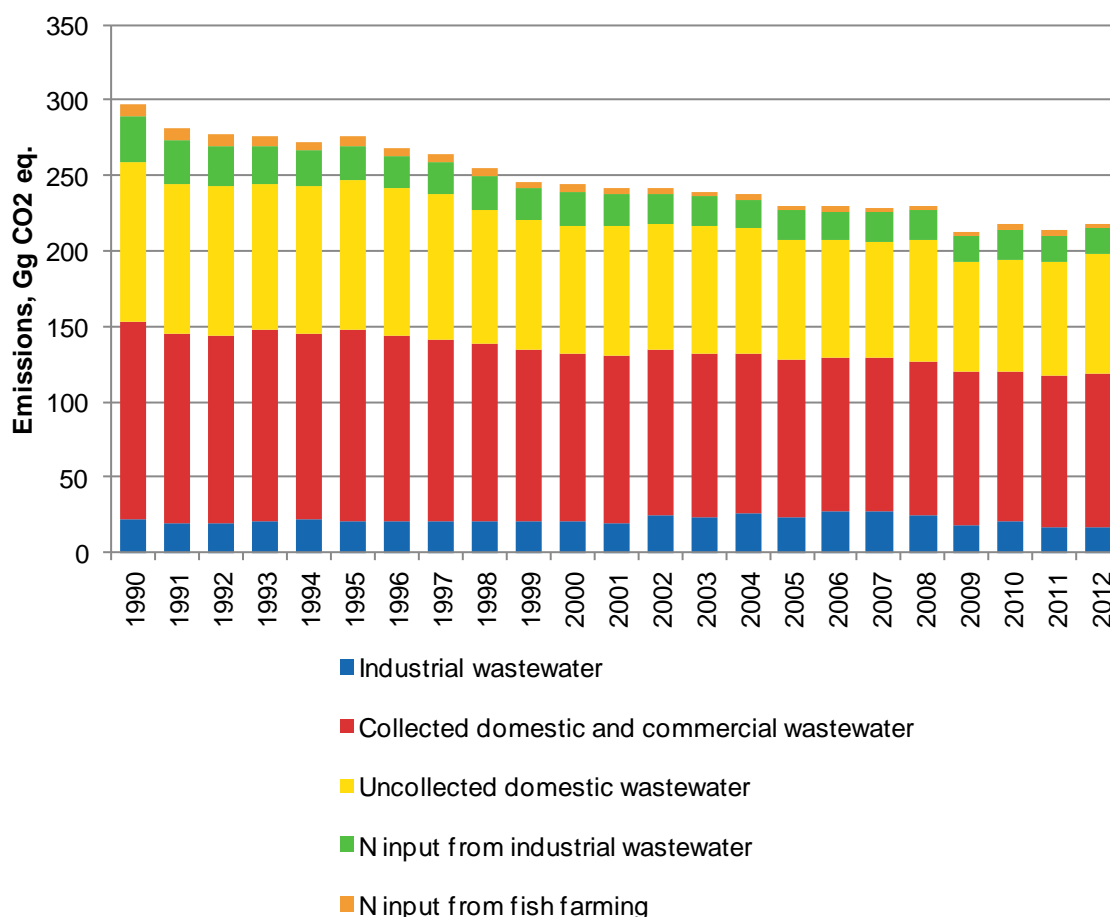
### 8.3.1 Source category description

The emission sources cover municipal (domestic) and industrial wastewater handling plants and uncollected domestic wastewaters for CH<sub>4</sub> emissions. N<sub>2</sub>O emissions are generated from nitrogen input of fish farming as well as from domestic and industrial wastewaters into waterways.

**Table 8.3-1** Reported emissions calculation methods and types of emission factors for the subcategory Wastewater Handling in the Finnish inventory

CRF	Source	Emissions reported	Methods	Emission factors
6.B 1	Industrial Wastewater	CH <sub>4</sub> (N <sub>2</sub> O not estimated)	D	CS
6.B 2	Domestic and Commercial Wastewater	CH <sub>4</sub> , N <sub>2</sub> O	D	CS, D
6.B 3	Other			
	N Input from Industrial Wastewater	N <sub>2</sub> O	CS	D
	N Input from Fish Farming	N <sub>2</sub> O	CS	D

Emissions from wastewater handling have been decreased by 28% since 1990. Emission trends by sources are presented in Figure 8.3-1. The overall trend in domestic wastewaters (the most significant source) is decreasing due to downward trend of population in uncollected wastewaters (methane) and due to nitrogen purification in collected wastewaters.



**Figure 8.3-1** Emissions from wastewater handling by emission source (Gg CO<sub>2</sub> eq.)

Emission trends from wastewater handling by subcategory and gas are presented in Table 8.3-2.

### 8.3.2 Methodological issues

#### Methods

A national methodology that corresponds to the methodology given in the Revised (1996) Guidelines is used in the estimation of the CH<sub>4</sub> emissions. The emissions from municipal wastewater treatment are based on the BOD<sub>7</sub> load (Biochemical Oxygen demand, 7-day test) of the wastewaters. The BOD<sub>7</sub> measurements are converted to the BOD<sub>5</sub> load (5-day test) by dividing them with factor 1.17 (Finnish Water and Waste Water Works Association 1995). The emissions from industrial wastewater treatment are based on the COD load (Chemical Oxygen demand). These DC (Degradable Organic Component) values of wastewaters with shared methane conversion factors have been used for both wastewater and sludge handling. The emissions from sludge disposal on land are, however, estimated and reported in the Solid waste disposal on land (landfills) subsector.

The equations used for calculating CH<sub>4</sub> emissions from domestic (not including uncollected domestic wastewater) and industrial wastewater treatment are described in the Appendix\_8a.

The parameters are based on expert opinions (Jouttijärvi et. al. 1999). The IPCC Guidelines have only two default values for the methane conversion completely aerobic or anaerobic. The DC values of wastewaters with shared methane conversion factors have been used for both wastewater and sludge handling. The estimated methane conversion factors for collected wastewater handling systems (industrial and domestic) are low in Finland because the handling systems included in the inventory are either aerobic or anaerobic with complete methane recovery. In recent years there have been only 2-4 industrial plants using anaerobic wastewater treatment. All the municipal wastewater treatment plants in Finland are aerobic and 14 of them (the most significant) have anaerobic sludge treatment with methane recovery. The emissions factors mainly illustrate exceptional operation conditions (leakages from anaerobic treatment or small anaerobic “corners” in aerobic wastewater treatment plants). For uncollected domestic wastewaters the Check method with the default parameters (GPG 2000) has been used. Septic tanks used in Finland are quite small (about 3 m<sup>3</sup>) having short delay times (Santala 2008), thus the emissions estimated according to IPCC 2006 Guidelines would be on the same level as the estimations according to the Check method. There are no plant-specific measurements for the degradable organic component of sludge in Finland. Especially for domestic wastewater there are good measurement results for DC of wastewaters in Finland.

In Finland, the N input from fish farming and from municipal and industrial wastewaters into the waterways is collected into the VAHTI system. For municipal wastewaters the measured values have been considered more reliable than the N input according to population data. In addition to the IPCC approach, the nitrogen load from industry and fish farming was also taken into account. The assessed N<sub>2</sub>O emissions cover only the emissions caused by the nitrogen load to waterways. These emissions are reported under 6.B.3 Other in the CRF Reporter because they do not describe the N<sub>2</sub>O emissions from wastewater handling plants (for these emissions there is no IPCC method). The emission factor of the reported emissions is the same as in human sewage and as in the Agricultural sector describing the emissions of N load into the waterways.

The Revised (1996) Guidelines present a methodology to calculate the N<sub>2</sub>O emissions from sewage in the Agriculture sector. The IPCC methodology is very rough and the N input into waterways is based on population data. In Finland, the N input from fish farming and from municipal and industrial wastewaters into the waterways is collected into the VAHTI system and these values are based on concentration measurements. For uncollected wastewaters the nitrogen load is based on population data and protein consumption (FAO 2004, Tike 2010 and Tike 2013).

N<sub>2</sub>O emission estimations are consistent with the IPCC method for discharge of sewage nitrogen to waterways:

$$\text{Emissions (Gg N}_2\text{O)} = \text{Nitrogen load into waterways (kg)} * EF_{N_2O \text{ sewage}} * 10^{-6} * 44/28$$

Where

$EF_{N_2O\ sewage}$  = Emission factor (kg N<sub>2</sub>O-N/kg N load), IPCC default = 0.01

### *Emission factors and other parameters*

Emission factors for municipal (domestic) wastewaters are IPCC default factors for the maximum methane producing capacity  $B_o = 0.625$  ( $= 2.5 * 0.25$ ) kg CH<sub>4</sub>/kg BOD and country-specific, based on expert knowledge, for the methane conversion factor  $MCF = 0.01$ .

For the industrial wastewaters the emission factor is the IPCC default for the maximum methane producing capacity  $B_o = 0.25$  kg CH<sub>4</sub>/kg COD and a country-specific emission factor based on expert knowledge for the methane conversion factor  $MCF = 0.005$ .

In the Check method and in the N<sub>2</sub>O calculation the emissions factors are the IPCC default factors.

### *Activity data*

Activity data are based on

- municipal (domestic and commercial) wastewater: Population (Check method); the BOD (BOD<sub>7</sub>) values and N input values of wastewaters from the VAHTI system (1998-2012) and from the Water and Sewage Works Register (1990-1997).
- industrial wastewater: the COD values of wastewaters from the VAHTI system and from the Register for Industrial Water Pollution Control (1990-1995, published in reports by Repo and Hämäläinen (1996) and Repo et al. (1999). Incoming COD loads are calculated from the measured out coming COD values (VAHTI system) using partly estimated efficiencies of wastewater treatment plants and partly the efficiency values from the VAHTI system.

Both built-in queries in the VAHTI operating system and own sampling routines from the VAHTI system have been used for activity data. The results from these queries have been compared with each other and with the results from the above-mentioned Registers.

Nitrogen load from fish farming has been taken from the mimeograph series of the Finnish Environment Institute (Repo & Hämäläinen 1996 and Repo et. al. 1999) and from the summary calculations by M.-L. Hämäläinen from the Finnish Environment Institute (Hämäläinen 2009) and from the information received from Åland (Särs 2013) and from Vahti database (the continent of Finland).

The collected BOD and COD values and Nitrogen input values are presented in Table 8.3-3 and Table 8.3-4, respectively. The population having uncollected domestic wastewater handling system and the protein consumption per person are presented in Table 8.3-5.

**Table 8.3-2** Emissions from wastewater handling by subcategory (Tg CO<sub>2</sub> eq.)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
<b>Methane emissions (Total)</b>	<b>0.154</b>	<b>0.145</b>	<b>0.144</b>	<b>0.147</b>	<b>0.144</b>	<b>0.147</b>	<b>0.143</b>	<b>0.141</b>	<b>0.138</b>	<b>0.134</b>	<b>0.132</b>	<b>0.130</b>	<b>0.134</b>	<b>0.132</b>	<b>0.131</b>	<b>0.128</b>	<b>0.129</b>	<b>0.129</b>	<b>0.127</b>	<b>0.119</b>	<b>0.120</b>	<b>0.117</b>	<b>0.114</b>
Collected dom. & com. wastewater	0.014	0.013	0.012	0.012	0.012	0.013	0.012	0.013	0.013	0.013	0.013	0.013	0.014	0.014	0.014	0.015	0.014	0.015	0.015	0.014	0.014	0.015	0.015
Uncollected domestic wastewater	0.118	0.112	0.113	0.115	0.111	0.113	0.110	0.109	0.105	0.100	0.098	0.097	0.096	0.093	0.092	0.089	0.088	0.087	0.088	0.087	0.085	0.086	0.082
Industrial wastewater	0.022	0.020	0.019	0.020	0.021	0.021	0.021	0.020	0.020	0.020	0.021	0.020	0.024	0.024	0.025	0.024	0.027	0.027	0.024	0.019	0.020	0.016	0.017
<b>Nitrous oxide emissions (Total)</b>	<b>0.144</b>	<b>0.137</b>	<b>0.134</b>	<b>0.128</b>	<b>0.128</b>	<b>0.129</b>	<b>0.125</b>	<b>0.123</b>	<b>0.117</b>	<b>0.112</b>	<b>0.112</b>	<b>0.112</b>	<b>0.107</b>	<b>0.108</b>	<b>0.106</b>	<b>0.102</b>	<b>0.101</b>	<b>0.100</b>	<b>0.103</b>	<b>0.093</b>	<b>0.098</b>	<b>0.096</b>	<b>0.199</b>
Collected dom. & com. wastewater	0.075	0.071	0.070	0.070	0.071	0.071	0.070	0.069	0.062	0.060	0.060	0.061	0.058	0.061	0.059	0.056	0.054	0.053	0.056	0.049	0.051	0.052	0.055
Uncollected domestic wastewater	0.030	0.028	0.029	0.027	0.027	0.028	0.028	0.028	0.028	0.026	0.025	0.026	0.025	0.025	0.025	0.024	0.024	0.024	0.024	0.024	0.024	0.024	0.023
N input from industrial wastewater	0.030	0.029	0.027	0.025	0.024	0.023	0.021	0.021	0.022	0.022	0.022	0.021	0.020	0.019	0.019	0.019	0.020	0.020	0.019	0.017	0.020	0.018	0.018
N input from fish farming	0.008	0.009	0.008	0.007	0.006	0.006	0.006	0.005	0.005	0.005	0.005	0.005	0.004	0.003	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003
<b>Total wastewater</b>	<b>0.297</b>	<b>0.282</b>	<b>0.278</b>	<b>0.276</b>	<b>0.272</b>	<b>0.276</b>	<b>0.268</b>	<b>0.264</b>	<b>0.255</b>	<b>0.246</b>	<b>0.244</b>	<b>0.242</b>	<b>0.241</b>	<b>0.239</b>	<b>0.237</b>	<b>0.230</b>	<b>0.230</b>	<b>0.229</b>	<b>0.230</b>	<b>0.213</b>	<b>0.217</b>	<b>0.213</b>	<b>0.213</b>



**Table 8.3-3** BOD<sub>5</sub> and COD loads (1 000 t)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Collected BOD <sub>7</sub> load (municipal wastewater)	121	118	107	109	110	113	110	112	112	118	118	118	125	127	125	130	123	132	131	125	124	130	131
Collected BOD <sub>5</sub> load (municipal wastewater)	103	101	92	93	94	97	94	96	96	101	101	101	108	109	107	112	106	113	113	107	107	112	112
Uncollected BOD <sub>5</sub> load (domestic wastewater)	23	22	22	23	22	22	22	22	21	20	19	19	19	19	18	18	17	17	18	17	17	17	17
COD load (industrial wastewater)	847	749	736	769	814	810	784	770	778	779	791	755	932	904	962	900	1 025	1 026	915	708	769	608	658

**Table 8.3-4** N input from wastewater (1 000 t)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
N input from collected municipal wastewater	15.4	14.6	14.4	14.3	14.6	14.6	14.4	14.0	12.6	12.3	12.2	12.4	11.9	12.4	12.0	11.4	11.1	10.7	11.4	10.1	10.5	10.6	11.3
N input from uncollected domestic wastewater	6.2	5.8	5.9	5.6	5.5	5.8	5.7	5.8	5.7	5.3	5.2	5.2	5.1	5.1	5.1	4.9	4.9	4.9	5.0	4.9	4.9	5.0	4.8
N input from industrial wastewater	6.2	6.0	5.5	5.0	4.9	4.8	4.3	4.4	4.6	4.4	4.5	4.3	4.1	4.0	3.9	4.0	4.0	4.1	4.0	3.5	4.1	3.6	3.7
N input from fish farming	1.7	1.8	1.6	1.4	1.2	1.2	1.2	1.1	1.0	0.9	1.0	1.0	0.7	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.6	0.6	0.6

**Table 8.3-5** Population (1000 persons) having collected or uncollected wastewater handling system and dry closets and protein consumption (g/persons/a)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Uncollected wastewater	1 067	1 013	1 023	1 041	1 003	1 024	999	983	950	907	884	877	868	847	833	810	796	790	800	786	774	780	744
Collected wastewater	3 813	3 900	3 917	3 921	3 985	3 981	4 026	4 058	4 108	4 168	4 204	4 223	4 246	4 281	4 311	4 355	4 391	4 420	4 433	4 475	4 512	4 530	4 595
Dry closet	107	101	102	104	100	102	100	98	95	91	88	88	87	85	83	81	80	79	80	79	77	78	74
Protein consumption (g/persons/a)	100.3	98.2	98.7	91.7	94.5	97.4	98.4	100.7	102.5	100.9	100.4	102.3	101.0	103.4	105.0	104.4	104.9	106.7	107.2	107.0	107.7	109.2	110.1

### 8.3.3 *Uncertainty and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description uncertainty analysis is provided in Section 1.7.

For the purposes of uncertainty estimation, emissions from wastewater management are divided into the following subgroups: Industrial Wastewater (CH<sub>4</sub> and N<sub>2</sub>O separately), Domestic and Commercial Wastewater from densely populated areas (CH<sub>4</sub> and N<sub>2</sub>O separately), Domestic and Commercial Wastewater from sparsely populated areas (CH<sub>4</sub> and N<sub>2</sub>O separately) and N input from Fish Farming (N<sub>2</sub>O). The uncertainty in wastewater treatment was -60% to +186% in the 2012 inventory (Section 1.7).

Uncertainty in the emission estimates of wastewater handling arises from uncertainties in activity data and emission factors. In methane emissions from industry, activity data (COD) are based on measurements on the input into waters and partly estimated efficiencies of wastewater treatment plants. Due to the measurement data, uncertainty ( $\pm 10\%$ ) is estimated lower than the default uncertainty estimate given by the IPCC.

For the uncertainty estimate, CH<sub>4</sub> emissions from domestic wastewaters are divided into two subcategories, i.e. densely and sparsely populated areas, because these two subcategories are calculated using different methods. For densely populated areas, activity data (BOD) are fairly accurately known ( $\pm 7\%$ ) due to the accurate measurement data of both incoming and outgoing wastewater flows from waste treatment plants. For B<sub>0</sub> the IPCC default uncertainty ( $\pm 30\%$ ) is used and the uncertainty estimate for MCF is based on expert judgement (-60% to +100%).

For sparsely populated areas, the IPCC check method is used in inventory calculations. The uncertainty in the activity data estimate ( $\pm 15\%$ ) is larger than in densely populated areas, because the estimate is based on the population rather than on the measured BOD. The emission factor uncertainty, however, is estimated fairly low in the Check method used for sparsely populated areas (-32% to +20%) and the uncertainty distribution is negatively skewed, because the emission factor of the Check method is likely to overestimate emissions.

Uncertainty in this sector is dominated by the uncertainty in the N<sub>2</sub>O emission factor (-94% to +380%). The methane conversion factor (MCF) is the second most important factor in terms of uncertainty.

Monte Carlo simulation has been used to combine the uncertainties of each calculation parameter in order to get the total uncertainty of the source category. A detailed description of the uncertainty analysis has been presented in Monni & Syri (2003) and Monni (2004).

### 8.3.4 *Source-specific QA/QC and verification*

General descriptions of quality objectives, QA/QC and verification procedures are presented in Section 1.6. The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives. The bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert.

General (Tier 1) Quality Control (QC) procedures applied in category CRF 6.B.

The QA/QC plan for the waste sector includes the QC measures based on the GPG 2000 (Table 8.1) such as:

- Documentation on activity data and emission factors was crosschecked with the corresponding data in the calculation model.
- A sample of input data from each source category was crosschecked for transcription errors.
- Units and conversion factors were checked
- Consistency of EF values of N<sub>2</sub>O and DOC values in different source categories was checked.
- Data aggregation and transcription from lower reporting levels to higher levels were checked.

### 8.3.5 *Source-specific recalculations*

Recalculations have been made for nitrous oxide emissions in uncollected domestic wastewater handling in 2011 for more accurate activity data due to preliminary and corrected information on protein consumption and due to corrected population data. Recalculations have been made for methane emissions in uncollected domestic wastewater handling in 2011 for more accurate activity data due to corrected population data.

### 8.3.6 *Source-specific planned improvements*

The implementation of 2006 IPCC Guidelines may introduce some changes to the methodology and estimates. This will be implemented in the 2015 submission.

## 8.4 Waste Incineration (CRF 6.C)

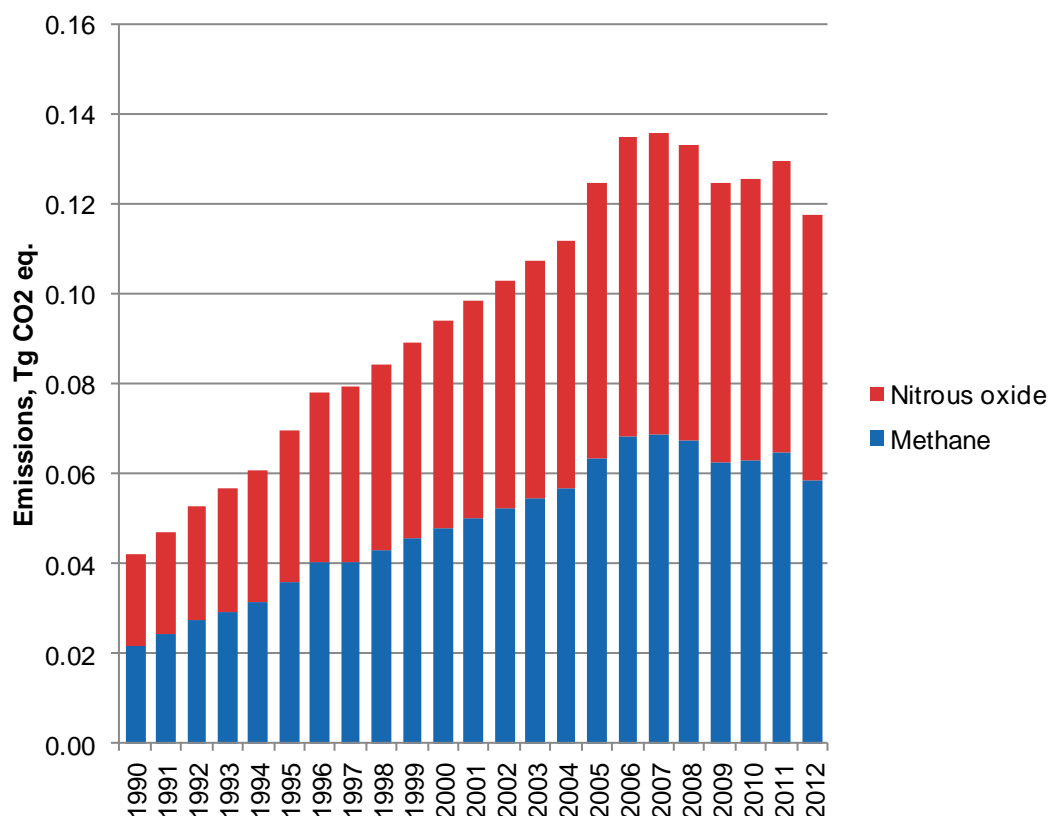
Emissions of greenhouse gases CO<sub>2</sub>, N<sub>2</sub>O and CH<sub>4</sub> from Waste Incineration (CRF 6.C) are reported in the energy sector (CRF 1.A) in the Finnish inventory. There is no waste incineration on landfills in Finland and waste incineration for energy production is included in the energy sector. Waste incineration without energy recovery is nearly zero in combustion plants and it is also included in the energy sector. Waste incineration in households is quite small. In annual reporting of the recycling of wastepaper (according to the decision of the Council of State 883/1998) the incineration of wastepaper is estimated to be only 23,000 tons. The incineration of paper and paperboard in households is estimated to be 31,000 tons together. Hazardous wastes are burned (with energy recovery) mainly in one plant in Finland and the mass of these wastes were approx. 80,000 tons together in 2012.

According to Waste decree if the energy efficiency is over 65 % waste burning is considered as energy use of waste and the treatment code R01 can be used. If the energy efficiency is under 65% code D10 should be used. Waste statistics are done according to these codes and in Finland 0.3% of total municipal solid waste has been incinerated (energy efficiency under 65%) and 33.5% has been burned for energy use (energy efficiency over 65%) in 2012 (Statistics Finland 2014). In addition, almost all of the incineration (D10) concerns poor quality waste components which has been burned at the same with better waste components and the energy efficiency would be over 65% in boiler level.

## 8.5 Composting (CRF 6.D)

### 8.5.1 Source category description

Emissions of greenhouse gases N<sub>2</sub>O and CH<sub>4</sub> from composting are estimated. The emission source includes emissions from composting of biowastes (municipal solid waste, municipal and industrial sludges and industrial solid waste including construction and demolition waste).



**Figure 8.5-1** Greenhouse gas emissions from composting (Gg CO<sub>2</sub> eq.)

**Table 8.5-1** Reported emissions, calculation methods and types of emission factors for the subcategory Composting in the Finnish inventory (OTH = other)

CRF	Source	Emissions reported	Methods	Emission factors
6.D 1	Composting of biowastes			
	Municipal solid waste	CH <sub>4</sub> , N <sub>2</sub> O	OTH	OTH
	Municipal sludge	CH <sub>4</sub> , N <sub>2</sub> O	OTH	OTH
	Industrial sludge	CH <sub>4</sub> , N <sub>2</sub> O	OTH	OTH
	Industrial solid waste, constr. waste	CH <sub>4</sub> , N <sub>2</sub> O	OTH	OTH

Emissions from composting have been increased over doubly since 1990, being 6% of the Waste sector's emissions in 2012. The trend in emissions is presented by subcategory in Table 8.5-3 and in Figure 8.5-1. The waste amounts with degradable auxiliary matter (20%-30%, the information on auxiliary matter from Vahti database has been used when available instead of these default shares) in composting are presented in Table 8.5-4, correspondingly.

## 8.5.2 Methodological issues

### Methods

Emissions from composting have been calculated using the method given in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006).

$$\text{Emissions (Gg CH}_4 \text{ or Gg N}_2\text{O)} = AD * EF / 1000000$$

where

*AD* = Waste amount with auxiliary matter (t)

*EF* = emission factor (g CH<sub>4</sub> or g N<sub>2</sub>O /kg waste treated)

### Emission factors

Emission factors in composting are presented in Table 8.5-2.

**Table 8.5-2** Emission factors in composting (g CH<sub>4</sub>/kg waste treated, g N<sub>2</sub>O/kg waste treated) (IPCC, 2006)

	CH <sub>4</sub> emission factor	N <sub>2</sub> O emission factor
Municipal solid waste, Industrial solid waste	4	0.3
Municipal sludge, Industrial sludge (d.m.)	10	0.6

### Activity data

Activity data are based on the VAHTI system and the Water and Sewage Works Register. The activity data for composted municipal biowaste for the year 1990 are based on the estimates of the Advisory Board for Waste Management (1992) for municipal solid waste generation and treatment in Finland in 1989. Data on 1997, 2004 and 2005 are from the VAHTI system and the intermediate years have been interpolated. In addition, composted solid biowaste in 1991-1996 has been interpolated using auxiliary information from the National Waste Plan until 2005 (Ministry of the Environment 1998). The new composting treatment code and composting plant code in VAHTI system have been used in the calculation of the years 2006-2012. The use of these codes was thoroughly investigated for the last submissions. The classification to the reporting subgroups is based on to the EWC codes of composted wastes (like landfilled wastes with the exception that construction wastes are under industrial solid waste). The amounts of composted sludges have turned down after 2006. In recent years it has been built anaerobic digestion plants in Finland which is probably the main reason for this development.

## 8.5.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.7.

The VAHTI system had no treatment code solely for composting for the years 1997-2005 and the new code for composting was introduced in 2006 and the use of this code might have been slightly unreliable, still. This has meant manual work in estimating the activity data and the uncertainties ( $\pm 40$  in 1990,  $\pm 30\%$  in the early 2000's to the  $\pm 25$  in 2012, Petäjä 2005 and Petäjä 2012) in activity data are higher than in the activity data on landfilled wastes. In addition, several wastewater handling plants do not report separately the incoming wastes to their own composting plants and the sludges are reported only in the outgoing wastes from these handling plants. This means unreliable manual crosschecking because there is the option, also that the sludges are delivered to be composted outside the handling plant to other companies. Also, the yearly data from smaller composting plants which are monitored by municipalities (and not by ELY-centres) is not available in Vahti, anymore. At least part of these waste amounts are worked out by crosschecking the outgoing wastes and by utilising the report from composting plants (Merilehto and Koskinen 2010). Altogether, this means that the uncertainties of the activity data remains on quite high level in future, also.

The uncertainties of the emissions factors are according to the range variations of the IPCC 2006 default emission factors. The total uncertainty in composting was -52% to +61% in the 2012 inventory.

Calculating method for composting is the same through whole time series. Time series for activity data is gathered in a consistent manner (e.g. waste groups) but the origin of the activity data varies (see previous Section).

#### *8.5.4 Source-specific QA/QC and verification*

The QC procedures are performed according to the QA/QC plan in order to attain quality objectives. The bilateral quality meeting, which function as Tier 1 QA review, is held annually between the inventory unit and the sectoral expert.

Composting plants (incoming waste flows) and outgoing waste flows to composting processes from Vahti database were compared to the governmental survey from composting plants and their environmental permits by Finnish Environment Institute and Ministry of the Environment (Merilehto and Koskinen 2010).

General (Tier 1) Quality Control (QC) procedures applied in composting.

The QA/QC plan for the waste sector includes the QC measures based on the GPG 2000 (Table 8.1) such as:

- Documentation on activity data and emission factors was crosschecked with the corresponding data in the calculation model.
- A sample of input data from each source category was crosschecked for transcription errors.
- Units and conversion factors were checked
- Data aggregation and transcription from lower reporting levels to higher levels were checked.

#### *8.5.5 Source-specific recalculations*

No recalculation has been made since the previous submission.

#### *8.5.6 Source-specific planned improvements*

The methodology for estimating emissions from composting is consistent with 2006 IPCC Guidelines, but additional emissions from other biological treatment may be introduced in to the inventory through the implementation of 2006 IPCC Guidelines. This will be evaluated for the 2015 submission.

**Table 8.5-3** Emissions from composting by subcategory (Tg CO<sub>2</sub> eq.)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Methane emissions	0.022	0.024	0.027	0.029	0.031	0.036	0.040	0.040	0.043	0.045	0.048	0.050	0.052	0.054	0.057	0.063	0.068	0.069	0.067	0.063	0.063	0.065	0.058
Municipal solid waste	0.005	0.006	0.006	0.006	0.007	0.009	0.010	0.012	0.013	0.014	0.015	0.016	0.017	0.018	0.018	0.020	0.020	0.024	0.025	0.024	0.026	0.029	0.027
Municipal sludge	0.013	0.015	0.017	0.019	0.020	0.023	0.026	0.025	0.026	0.026	0.027	0.027	0.028	0.029	0.029	0.033	0.033	0.032	0.033	0.025	0.025	0.023	0.021
Industrial sludge	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.002	0.002	0.003	0.003	0.004	0.004	0.005	0.005	0.007	0.010	0.008	0.006	0.007	0.007	0.006	0.004
Industrial solid waste, constr. waste	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.004	0.004	0.005	0.005	0.004	0.007	0.006	0.006	0.006
Nitrous oxide emissions	0.020	0.023	0.026	0.028	0.030	0.034	0.038	0.039	0.041	0.044	0.046	0.048	0.051	0.053	0.055	0.061	0.066	0.067	0.066	0.062	0.063	0.065	0.059
Municipal solid waste	0.006	0.006	0.007	0.007	0.008	0.010	0.011	0.013	0.014	0.016	0.017	0.018	0.019	0.019	0.020	0.022	0.023	0.027	0.027	0.027	0.029	0.032	0.030
Municipal sludge	0.011	0.013	0.015	0.017	0.018	0.020	0.023	0.022	0.023	0.023	0.024	0.024	0.025	0.025	0.026	0.030	0.029	0.029	0.029	0.023	0.022	0.021	0.018
Industrial sludge	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.002	0.002	0.003	0.003	0.004	0.004	0.005	0.006	0.009	0.007	0.006	0.006	0.006	0.005	0.004
Industrial solid waste, constr. waste	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.005	0.004	0.007	0.006	0.007	0.007
<b>Total composting</b>	<b>0.042</b>	<b>0.047</b>	<b>0.053</b>	<b>0.057</b>	<b>0.061</b>	<b>0.070</b>	<b>0.078</b>	<b>0.079</b>	<b>0.084</b>	<b>0.089</b>	<b>0.094</b>	<b>0.099</b>	<b>0.103</b>	<b>0.107</b>	<b>0.112</b>	<b>0.125</b>	<b>0.135</b>	<b>0.136</b>	<b>0.133</b>	<b>0.125</b>	<b>0.125</b>	<b>0.130</b>	<b>0.117</b>

**Table 8.5-4** Composted waste with degradable auxiliary matter by subcategory (1 000 t)

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Municipal solid waste	60	66	72	77	83	102	122	141	154	167	180	190	199	209	218	233	242	287	294	286	310	348	327
Municipal sludge (d.m.)	60	72	83	90	97	110	123	120	123	125	128	131	133	136	138	159	157	154	156	121	120	111	99
Industrial sludge (d.m.)	13	12	12	12	12	12	12	7	10	13	15	18	21	23	26	32	48	37	30	34	31	27	19
Industrial solid waste	12	13	14	16	17	18	19	21	24	28	31	34	38	41	45	45	61	54	43	72	60	75	73



## Appendix\_8a

*The equations used in calculating emissions from the Waste sector (CRF 6)*

### Solid waste disposal on land (CRF 6.A)

The modified Equation 5.1 (IPCC 2000) is as follows:

$$\text{CH}_4 \text{ generated in year } t \text{ (Gg / year)} = \sum_x [A * k * SW(x) * L_0(x) * e^{-k(t-x)}]$$

for  $x$  = initial year to  $t$ ,

where

$t$  = year of inventory

$x$  = years for which input data should be added

$A = (1 - e^{-k}) / k$  ; normalisation factor which corrects the summation

$k$  = Methane generation rate constant (1 / year)

$SW(x)$  = amount of waste disposed at SWDS in year  $x$  (Gg / a)

$L_0(x) = MCF(t) * DOC(x) * DOCF * F * 16 / 12$  (Gg CH<sub>4</sub> / Gg waste)

$L_0(x)$  is methane generation potential

where

$MCF(t)$  = Methane correction factor in year  $t$  (fraction)

$DOC(x)$  = Degradable organic carbon (DOC) in year  $x$  (Gg C / Gg waste)

$DOCF$  = Fraction of DOC dissimilated

$F$  = Fraction by volume of CH<sub>4</sub> in landfill gas

16 / 12 = Conversion from C to CH<sub>4</sub>

Emissions according to Equation 5.2 in GPG 2000 are calculated as follows:

$$\text{CH}_4 \text{ emitted in year } t \text{ (Gg / a)} = [\text{CH}_4 \text{ generated in year } t - R(t)] * (1 - OX)$$

where

$R(t)$  = Recovered CH<sub>4</sub> in inventory year  $t$  (Gg / a)

$OX$  = Oxidation factor (fraction)

### Wastewater handling (CRF 6.B)

Equations used in calculating CH<sub>4</sub> emissions from domestic (not including uncollected domestic wastewater) and industrial wastewater treatment are as follows:

$$\text{Emissions (Gg CH}_4\text{)} = \text{Organic load in wastewaters} * B_0 * MCF / 1000000$$

where

$B_0$  = Maximum methane producing capacity (kg CH<sub>4</sub> / kg BOD or kg COD)

$MCF$  = Methane conversion factor (fraction)

CH<sub>4</sub> emissions from uncollected domestic wastewater are estimated according to the Check method:

$$\text{Emissions (Gg CH}_4\text{)} = P * D * SBF * EF * FTA * 365 / 1000000$$

where

$P$  = Population with uncollected wastewaters (septic tanks)

$D$  = Organic load kg BOD /person /day, default = 0.06 kg BOD /person /day

$SBF$  = Fraction of BOD that readily settles, default = 0.5

$EF$  = Emission factor (kg CH<sub>4</sub> / kg BOD), default = 0.6

$FTA$  = Fraction of BOD in sludge that degrades anaerobically, default = 0.8

## Appendix\_8b

### *List of landfill gas recovery plants and volume of collected gas in 2012 (Huttunen and Kuittinen 2013)*

Name of a plant	Volume of collected gas, 1 000 m <sup>3</sup>
Vuosaari, Helsinki	890
Seutula, Vantaa	1 030
Kiertokapula, Hyvinkää	2 000
Kiertokapula, Hämeenlinna	1 800
Porvoo	790
Ämmässuo, Espoo	51 722
Mankkaa, Espoo	3 300
Tampere	2 400
Oulu	5 267
Kerava	0
Lappeenranta	247
Lohja	497
Joensuu	1 500
Pori	1 288
Simpele	277
Lahti	2 640
Jyväskylä	3 400
Nokia	1 900
Sammalsuo, Kouvola	800
Iisalmi	430
Järvenpää	100
Mikkeli	270
Raisio	100
Rovaniemi	1 400
Turku	1 100
Uusikaupunki	200
Kajaani	984
Myllykoski Paper, Anjalankoski	400
Silmäsuo, Kuopio	400
Heinälamminrinne, Kuopio	1 820
Keltakangas, Anjalankoski	500
Keltakangas2, Kouvola	550
Vaasa	600
Imatra	580
Savonlinna	800
Salo	300
Stormossen, Mustasaari	161
Heinsuo, Kotka	568
UPM, Kajaani	200
Hevossuo, Rauma	1 300

Methane content of the landfill gas is estimated to be 50% and the density of methane is estimated to be 0.718 kg/m<sup>3</sup>. Kerava plant was not in use in 2012 because of reparation of landfill structures.

## Appendix\_8c

### Industrial solid waste composition

Industrial solid waste without inert wastes																							
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
DOC (-)	0.188	0.187	0.185	0.177	0.166	0.154	0.138	0.116	0.104	0.089	0.103	0.090	0.082	0.070	0.073	0.071	0.069	0.065	0.060	0.068	0.064	0.073	0.068
Landfilled wastegroups, wet																							
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Inert (1 000 t)																							
Plastics	23.5	23.5	23.5	19.1	14.7	10.3	5.9	1.5	7.7	4.4	12.8	2.9	2.3	0.3	0.4	0.3	0.2	0.6	0.8	0.4	0.3	0.3	1.9
Other comb.	4.0	4.0	4.0	4.5	5.0	5.5	6.0	6.5	2.9	4.2	9.6	9.3	14.9	15.5	11.1	26.9	11.1	10.8	10.3	23.9	17.4	0.3	0.4
Other incomb.	226	227	228	203	178	153	128	103	123	376	686	597	534	525	2 025	2 104	2 293	348	1 524	1 432	1 132	1 517	1 645
Ash	714	718	722	709	697	684	671	659	575	1 114	954	1 375	1 461	1 946	1 629	1 445	1 744	1 451	723	1 007	1 113	712	812
Sludges	521	521	521	426	331	237	142	47	297	516	465	402	320	303	826	834	799	887	864	813	125	223	606
Default (1 000 t)																							
Garden	6.5	6.5	6.5	6.0	5.6	5.1	4.6	4.1	1.9	0.8	3.8	0.7	0.4	0.2	0.4	0.5	0.5	0.2	0.9	0.03	0.1	0.1	0.1
Other comb.	15.0	15.0	15.0	13.7	12.3	11.0	9.7	8.3	9.5	7.5	4.8	6.1	19.7	21.4	38.4	28.5	29.6	53.5	59.5	91.1	4.5	9.3	7.7
Oil	2.0	2.0	2.0	1.6	1.3	0.9	0.6	0.2	2.2	2.3	4.7	4.4	3.6	3.4	3.3	2.8	3.5	3.9	2.2	1.7	1.3	3.0	2.0

## Landfilled wastegroups, wet

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Fast (1 000 t)																							
Food	59.0	59.0	59.0	52.0	44.9	37.9	30.8	23.8	11.5	16.0	17.8	23.5	23.8	22.5	31.9	33.3	25.4	15.6	12.5	10.8	9.4	9.3	8.5
Slow (1 000 t)																							
Textiles	5.5	5.5	5.5	4.5	3.4	2.4	1.3	0.3	1.4	1.6	0.6	0.2	0.2	0.1	0.1	0.3	0.8	0.7	0.3	0.7	0.6	0.7	0.6
Paper	74	69	64	53	41	30	19	7.6	8.7	4.7	3.4	3.9	0.7	1.9	2.2	1.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0
De-inking	20	20	20	23	25	28	30	33	45	29	27	22	12.5	12.3	12.8	10.0	11.2	8.3	6.0	4.5	13.3	2.7	2.6
Other comb.	55	55	55	54	53	53	52	51	60	52	39	45	37	65	63	60	67	68	66	63	126	159	131
Very slow (1 000 t)																							
Wood	189	177	164	148	131	115	99	83	69	58	50	43	34	15	18	16	20	15	12	8.6	6.6	4.8	1.2
Green l. sl.	220	205	190	176	161	147	132	118	130	129	112	124	98	110	120	119	136	133	154	113	111	101	93

## Landfilled wastegroups, in default moisture

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Inert (1 000 t)																							
Plastics	23.5	23.5	23.5	19.1	14.7	10.3	5.9	1.5	7.7	4.4	12.8	2.9	2.3	0.3	0.4	0.3	0.2	0.6	0.8	0.4	0.3	0.3	1.9
Other comb.	4.0	4.0	4.0	4.5	5.0	5.5	6.0	6.5	2.9	4.2	9.6	9.3	14.9	15.5	11.1	26.9	11.1	10.8	10.3	23.9	17.4	0.3	0.4
Other incomb.	226	227	228	203	178	153	128	103	123	376	686	597	534	525	2 025	2 104	2 293	348	1 524	1 432	1 132	1 517	1 645

## Landfilled wastegroups, in default moisture

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Ash	714	718	722	709	697	684	671	659	575	1 114	954	1 375	1 461	1 946	1 629	1 445	1 744	1 451	722	1 005	1 113	712	812
Sludges	521	521	521	421	321	221	121	21	62	144	142	130	95	152	363	383	371	419	420	374	84	145	345
Default (1 000 t)																							
Garden	6.5	6.5	6.5	6.0	5.6	5.1	4.6	4.1	1.9	0.8	3.8	0.6	0.4	0.2	0.4	0.5	0.5	0.2	0.9	0.0	0.1	0.1	0.1
Other comb.	15.0	15.0	15.0	13.7	12.3	11.0	9.7	8.3	9.5	7.5	4.8	6.1	19.7	21.4	38.4	28.5	29.6	53.5	59.5	91.1	4.5	9.3	7.7
Oil	2.0	2.0	2.0	1.6	1.3	0.9	0.6	0.2	2.2	2.2	4.5	4.1	3.3	3.1	3.1	2.6	3.3	3.8	1.4	1.1	1.0	2.8	2.0
Fast (1 000 t)																							
Food	59	59	59	52	45	38	31	24	11	16	18	24	24	23	32	33	25	16	13	11	9.4	9.3	8.5
Slow (1 000 t)																							
Textiles	5.5	5.5	5.5	4.5	3.4	2.4	1.3	0.3	1.4	1.6	0.6	0.2	0.2	0.1	0.1	0.3	0.8	0.7	0.3	0.7	0.6	0.7	0.6
Paper	74	69	64	53	41	30	19	7.6	8.7	4.6	3.4	3.9	0.7	1.9	2.2	1.2	0.1	0.1	0.0	0.0	0.0	0.0	0.0
De-inking	6.0	6.0	6.0	7.1	8.2	9.3	10.4	11.6	12.7	9.0	12.8	11.6	4.2	4.1	4.3	3.4	4.0	3.0	2.2	1.8	5.9	1.1	1.0
Other comb.	55	55	55	54	53	53	52	51	60	52	39	45	37	65	63	60	67	68	66	63	126	159	131
Very slow (1 000 t)																							
Wood	164	153	142	124	106	88	70	53	46	32	35	27	18	7.3	8.0	7.5	10.9	6.3	5.1	3.3	2.7	3.1	0.6
Green l. sl.	110	102	95	87	79	71	63	55	60	60	56	60	45	52	55	54	62	62	75	54	52	48	44

## 9 *OTHER (CRF 7)*

Finland does not report any emissions under the Other sector.

## 10 RECALCULATIONS AND IMPROVEMENTS

### *10.1 Explanations and justification for recalculations, implications on emission levels and trends including time series' consistency*

The main driving forces in applying recalculations to Finland's greenhouse gas inventory are the implementation of the guidance given in the GPG 2000 and GPG LULUCF 2003 and the recommendations from the UNFCCC inventory reviews taking into account the significance of the sources based on the results of the key category and uncertainty analyses. The recalculations made since the previous inventory submission are described in detail in the sector Chapters 3-9. The reasoning and impact of the recalculations for the years 1990-2011 can also be found in CRF tables 8(a)s1-8(a)s2 and 8(b) of the relevant years.

Some recalculations were made to correct errors in the plant level data in **the Energy sector (1.A)**. As in the previous submissions, there were some minor corrections in the plant level data; for example some fuel codes and erroneous or missing fuel data were corrected. Some erroneous formulas were also corrected, as well as some preliminary data.

It was discovered, that there was error in total gasoline consumption in the Energy statistics; this also affected to bioshare of gasoline. This correction was reflected in transport subsectors. There were also minor updates in total consumption of woodfuels, peat and gasoil; these affected mainly in sectors 1.A.1., 1.A.2 and 1.A.5.

Activity data of 2011 in subcategory 'Non-specified emissions of Fuels from non-energy use' of 1.A.5a was corrected.

New estimates were made for civil aviation (CRF 1.A.3a) for years 2005-2010. This correction is based on the data received from Eurocontrol and EU ETS, although the final estimates required a compromise between contradictory data sets.

There was also recalculation in MSW/REF combustion in sectors 1.A.1 and 1.A.2. Plant specific CO<sub>2</sub> emission factors were taken from the ETS data for those plants (around 5-10), which are obliged to measured EFs instead of default values (from 2008 on).

In the **Fugitive emissions from fuels (CRF 1.B)** roundings of emission data in CRF reporter was removed and therefore emissions changed for the whole time-series (except 1990).

Under **Industrial Processes (CRF 2)** emission data of one limestone using plant was included and emission data in iron and steel industry was corrected the inventory for the whole time series. Also activity data of one hydrogen plant were corrected for years 2010-2012.

In the **Solvent and Other Product Use (CRF 3)** as a result of 2011 inventory review indirect CO<sub>2</sub> from NMVOC emissions of fat and edible oil extraction were removed from whole time-series due to being of biological origin.

In the **F-gases category** HFC emissions from CRF 2.F 2 Foam blowing were recalculated for 2010 and 2011 due to inclusion of HFC-152a emissions from the manufacturing of extruded polystyrene. A new XPS plant using HFC-152a as a blowing agent started operation in Finland in 2010 and the plant was discovered in the inventory in 2013. Therefore the emissions were included in the inventory. As a result of the recalculation the total 2010 and 2011 HFC actual emissions from foam blowing increased 67% and 65%, respectively.

In the **Agriculture sector (CRF 4)**, the number of fur animals was updated for the year 2011. The daily weight gain of cattle was updated and the values are calculated separately for each year based on functions of mature weight and age. The mature weight of heifers and calves was updated so that the simple averages were replaced with weighed averages. New EFs for different swine classes were taken to use. Number of fur



animals for 2011 was updated. Nitrogen excretion for the whole time series of sows was updated and the VS of poultry was corrected for the whole time series. The fraction of total residue burned changed a little due to the addition of mixed grain with pulses to the amount of total residue.

In the **LULUCF sector** (CRF 5), the areas of land-use categories and sub-categories (converted/remaining, mineral/organic soil, drained/undrained peatlands) were recalculated. Reasons for area recalculation were i) to implement the data which were prepared using different information sources to increase the reliability of areas of land-use changes, and ii) to employ the latest NFI data measured in 2012. Due to the area recalculation, almost all the emissions by sources and removals by sinks by land-use categories were recalculated. In addition to the above-mentioned reasons, the employment of the NFI data of 2012 induced recalculation of gains in living biomass, recalculation of biomass conversion factors used to convert growing stock volume, increment of growing stock and drain of growing stock to biomass.

In **KP-LULUCF-reporting** the same kind of recalculations were done as for LULUCF sector. The areas of Article 3.3 activities (ARD) and Article 3.4 activity Forest Management were recalculated. The aim of the employment of the newer data was to increase accuracy of the ARD areas, and other area-depended estimates.

In the **Waste sector** (CRF 6) recalculations have been made for nitrous oxide emissions in uncollected domestic wastewater (CRF 6.B 2) for the year 2011 to improve the accuracy of the activity data by correcting the preliminary information on protein consumption. Also, recalculations have been made for nitrous oxide and for methane emissions in uncollected domestic wastewater (CRF 6.B 2) for the year 2011 for more accurate activity data due to corrected population data.

**Table 10.1-1** Recalculations made for the 2014 inventory submission by CRF category and their implications to the emission level in 1990 and 2011

CRF Category	Recalculation	Reason for the recalculation	Implication to the CRF category level (Gg CO <sub>2</sub> eq.)		Implication to the Total emission level without LULUCF (%)	
			in 1990	in 2011	in 1990	in 2011
<b>1. Energy</b>			<b>0.12</b>	<b>-78.30</b>	<b>-0.00</b>	<b>-0.12</b>
1.A. Fuel combustion			-0.12	-78.58	-0.00	-0.12
1. Energy Industries	Corrections in activity data, plant specific emission factors for MSW/REF	Preliminary or erroneous activity data, more accurate EF	-6.39	119.71	-0.01	0.18
2. Manufacturing industries and construction	Corrections in activity data, plant specific emission factors for MSW/REF	Erroneous fuel codes and activity data, more accurate EF	11.06	-38.19	0.02	-0.06
3. Transport	Corrections in activity data and erroneous formula	Updated total sales of gasoline and bioshare of gasoline; updated estimates for domestic aviation	0	0.37	0	0.00
4. Other sectors	Corrections in activity data	Updates in space heating model and fuel consumption data in agriculture	-0.01	-56.37	0	-0.08
5. Other	Corrections in activity data	Updates in other categories are reflected here. 2011: statistical correction in total consumption of gasoil	-4.55	-104.11	-0.01	-0.16
1.B. Energy - Fugitive emissions	Removing of roundings	Removing of roundings	0	0.28	0	0.00
Bunkers	Corrections in emission factors	Emission factors follow changes in domestic aviation	0	4.04		
<b>2. Industrial Processes</b>			<b>1.66</b>	<b>-8.86</b>	<b>0.00</b>	<b>-0.01</b>
A. Mineral Products	Correction in activity data	Emissions of new plant was included.	1.66	6.82	0.00	0.01
B. Chemical Industry	Correction in activity data	Emissions of one hydrogen plant was corrected	0	-6.31	0	-0.01
C. Metal Production	Correction of erroneous data	Emission data were corrected	0	-15.24	0	-0.02
F. Consumption of Halocarbons and SF <sub>6</sub>	HFC emissions from CRF 2.F2 Foam blowing for 2010 and 2011	Inclusion of HFC-152a emissions from one new XPS plant discovered in the inventory in 2013	0	5.87	0	0.01
<b>3. Solvent and other product use</b>			<b>-0.44</b>	<b>-0.26</b>	<b>-0.00</b>	<b>-0.00</b>
A. Paint application			0	0	0	0
C. Chemical Products,			0	0	0	0

CRF Category	Recalculation	Reason for the recalculation	Implication to the CRF category level (Gg CO <sub>2</sub> eq.)		Implication to the Total emission level without LULUCF (%)	
			in 1990	in 2011	in 1990	in 2011
Manufacture and Processing						
D. Other	CO <sub>2</sub> emissions from NMVOC emissions of fat and edible oil extraction were removed	Emissions are biological origin	-0.44	-0.26	-0.00	-0.00
<b>4. Agriculture</b>			<b>-124.55</b>	<b>-84.64</b>	<b>-0.18</b>	<b>-0.13</b>
A. Enteric Fermentation	Cattle weight gain and mature weight of heifers and calves updated, new EFs for swine.	Better data became available	-114.94	-48.99	-0.16	-0.07
B. Manure Management	Cattle weights updated and poultry VS corrected N excretion of sows updated	Better data became available	-46.12	-54.90	-0.07	-0.08
D. Agricultural Soils	Crop residues of mixed cereals+pulses were added	New statistics available	36.51	19.24	0.05	0.03
F. Field Burning of Agricultural Residues			0	0	0	0
<b>5. Land use, Land Use Change and Forestry</b>			<b>1 486.96</b>	<b>463.37</b>		
A. Forest land	Carbon stock changes in living biomass, litter, dead wood and soil organic carbon. N <sub>2</sub> O emissions from drained forest lands.	Activity data recalculated (area estimates). The latest NFI data were applied to estimate biomass increments, -stocks and litter production for soil model. Weather data from 2012 were added to climate average calculation, producing also new steady state estimation for soil carbon. The N <sub>2</sub> O emissions from drained organic forest lands were estimated and reported in CRF tables.	1 112.18	909.46		
B. Cropland	Areas updated	Improved data source + error corrected	304.45	51.10		
C. Grassland	Areas updated	Improved data source	-2.59	104.10		
D. Wetlands	Carbon stock change in living biomass, SOM, DOM, CH <sub>4</sub> .	Activity data recalculated (area estimates).	73.03	-174.12		
E Settlements			-0.12	-453.59		
G. Harvested Wood Products	CO <sub>2</sub> .	Time series was recalculated due to corrections/updates in FAOSTAT timber	0	26.42		

CRF Category	Recalculation	Reason for the recalculation	Implication to the CRF category level (Gg CO <sub>2</sub> eq.)		Implication to the Total emission level without LULUCF (%)	
			in 1990	in 2011	in 1990	in 2011
		statistics.				
<b>6. Waste</b>			<b>0</b>	<b>-0.26</b>	<b>0</b>	<b>-0.00</b>
A. Solid Waste Disposal on Land			0	0	0	0
B. Wastewater Handling	Protein consumption data (per person in population) for 2011 and population under uncollected wastewater handling	Corrected preliminary data and corrected population data.	0	-0.26	0	-0.00
D. Composting			0	0	0	0
<b>KP-LULUCF</b>						
KP A. Article 3.3	Carbon stock change in living biomass, SOM, DOM, N <sub>2</sub> O.	The areas of ARD activities were recalculated due to the changes in the area estimation and due to updated NFI data. Weather data from 2012 were added to climate average calculation, producing also new steady state estimation for soil carbon. The N <sub>2</sub> O emissions from drained organic AR and D lands were estimated and reported under biomass burning in CRF tables.	-	-844.4		
KP B. Article 3.4	Carbon stock change in living biomass, SOM, DOM, N <sub>2</sub> O.	The areas of FM activities were recalculated due to the changes in the area estimation. New NFI data were used for litter input estimates. The N <sub>2</sub> O emissions from drained organic FM lands were estimated and reported in CRF tables.	-	-1 216.0		

## *10.2 Implications for emission levels*

See Section 10.1.

## *10.3 Implications for emission trends, including time series' consistency*

See Section 10.1.

## 10.4 Recalculations, including in response to the review process, and planned improvements to the inventory

Statistics Finland co-ordinates the development of the inventory's different sectors. Each organisation participating in the inventory preparation bears the primary responsibility for the development of its own sector. The advisory board of the inventory handles horizontal development projects and the resources needed for development.

The development of the greenhouse gas inventory aims to improve the calculation and reporting of the inventory so that the inventory fulfils the quality objectives set for it and produces accurate estimates for the total emissions of greenhouse gases in different emission categories.

Statistics Finland collects the different horizontal development needs and those detected in different calculation sectors and the planned or proposed improvement measures, to compile a yearly inventory improvement plan. The inventory improvement plan is discussed in the advisory board set up by Statistics Finland before starting the next calculation round.

Table 10.4-1 summarises planned sectoral improvements for the forthcoming inventories identified by the Finnish experts responsible for the calculations and/or brought out in the review processes. The table includes also a tentative timeline for the implementation the improvement in future submissions. More detailed information about planned improvements can be found under the sectoral chapters.

**Table 10.4-1** Sector-specific improvement needs of Finland's national greenhouse gas inventory)

CRF category	Planned improvement	Tentative submission
All sectors	Implementation of the new UNFCCC reporting GLs including 2006 IPCC Guidelines	2015
CRF 1	Plan for systematic review and update of EFs in the energy sector	2013 plan, thereafter continuous
CRF 1.A 3	Increased use of emission data for aviation from Eurocontrol's (also alternative sources will be explored)	2014/2015 (depends on data availability)
CRF 1.A 3	The transport emission calculation system LIPASTO at VTT will be renewed. The renewal concerns road (LIISA), railway (RAIL), domestic navigation (MEERI) and other transportation (TYKO) models. This renewal is expected to resolve also the inconsistencies in kilometrage and fuel combustion data for road transportation.	2015
CRF 2 and 3	Review of air emission time series (may result in changes in NMVOC and indirect CO <sub>2</sub> emission data)	2015
CRF 1 and 2	Review of use of EU ETS data in the inventory. The ETS data will be included in the ILMARI calculation system to enhance the comparison with ETS and other AD sources used in the inventory, and also to improve the automatic imputation of data .	Continuous
CRF 4	Possibility of updating the AWMS will be explored as a new dataset becomes available	2015
CRF 5 and KP art. 3.3 and 3.4	Improvement of tree biomass removal estimates. Investigation on the possibility to use NFI sample plot data with forests statistics to quantify annual drain more accurately by land-use category and soil type.	2016-2017
CRF 5 and KP art. 3.3 and 3.4	Improvement of estimation of GHG emissions/removals from DOM and SOM in mineral soils (including the implementation of results of the AgriYasso project) and continued verification of the estimates	2014-2016

Table 10.4-2 summarises Finland's responses to the review of the 2013 inventory submission. Only issues, which were not resolved during the review, are addressed in the table.

**Table 10.4-2** Response to the review of the 2013 inventory submission

CRF	Comment	Finland's response	Where in NIR
QA/QC	15. Statistics Finland has overall responsibility for the inventory quality assurance/quality control (QA/QC) procedures. The NIR presents an extensive description of Finland's quality objectives and QA/QC plan; category-specific QA/QC and verification activities are also included in the relevant chapters in response to an encouragement made in the previous review report. However, some inconsistencies are still observed regarding the conformity of information reported in the NIR and that reported in the relevant CRF tables (e.g. CRF table NIR-3 in regards to information on key categories; reporting of the emission factor (EF) for liquid fuels in road transportation (see para. 45 below); area of wetlands remaining wetlands (see para. 71 below); CO <sub>2</sub> emissions from agricultural lime application (see para. 72 below); data on liming (see para. 82 below)). The ERT recommends that Finland check the description in the NIR against the information and figures reported in the CRF tables in its annual submission.	NIR tables and figures are produced based on CRF data to ensure consistency between CRF Tables and NIR. This is continuously improved in order to avoid any discrepancies.	Section 1.6.3
1A	26. In the previous review report, the ERT noted that the AD in the energy sector presented in the NIR were aggregated in terms of both categories and fuels, making it difficult to interpret the fluctuations in the time series of implied emission factors (IEFs) and consequently causing the same questions to arise regularly during reviews. In the follow-up to recommendations made in the previous review report, Finland provided qualitative information regarding the most important fuels included in the other fuels categories; however, disaggregated data were not provided. In response to a question raised by the ERT during the review, Finland stated that further disaggregation would require changes to the entire time series and inventory system, which would not be resource efficient to implement for one year. Therefore, this will only be considered for the 2015 annual submission. The ERT accepts that these changes may be resource-heavy and therefore recommends that efforts be made to provide disaggregated data in the 2015 annual submission.	The qualitative information on the most important fuels included in the other fuels categories is presented in Tables 3.2-7 and 3.2-8. Possibility to provide disaggregated data will be considered for the 2015 annual submission.	Section 3.2.2.3 and 3.2.6
1	33. Finland has reported information on the non-energy use of fuels in the subcategory feedstocks and non-energy use of fuels (CRF table 1.A(d)). The ERT noted that in the case of lubricants, the additional information part of the CRF table is not complete. In response to a question raised by the ERT during the review, Finland stated that it is awaiting clarification of the assumptions and allocation of emissions related to the use of lubricants (postponed until the 2014 annual submission). The ERT recommends that Finland complete the additional information part of CRF table 1.A(d) for lubricants.	Missing additional information part has been added to the CRF Table 1A(d).	Section 3.4.2.1
1	34. In the previous review report, the ERT noted that for lubricants and coke the fraction of carbon stored was reported as 0.33 and 0.46, respectively, in CRF table 1.A(d) with the indication that the remaining carbon has been included in the reporting on fuel combustion. However, it was not completely clear from the CRF tables and the NIR how the emissions were allocated. In response to a question raised by the ERT during the review, Finland provided detailed information on the assumptions and allocation of emissions related to the use of lubricants. The ERT reiterates the recommendation made in the previous review report that Finland include this information in its annual submission.	The NIR descriptions have been improved. An additional table has been included.	Section 3.4.2.1, Table 3.4-1
1	35. A discrepancy exists between the liquid fuels data given in CRF tables 1.A(c) and 1.A(d) for the years 2002 and 2011 (–0.04 PJ and 1.2 PJ, respectively). In response to a question raised by the ERT during the review, Finland stated that these were due to errors in the tables (table 1.A(c)). The ERT recommends that Finland correct these in its annual submission.	This discrepancy has been corrected.	Section 3.4.2.1
1	40. Beginning with its 2012 annual submission, Finland has started to use plant-specific data (e.g. on carbon contents and calorific values) as a basis for the estimation of the CO <sub>2</sub> EF for coal used in public electricity and heat production. These EFs are somewhat lower than the country-specific EF used for the period 1990–2007. Given the detailed data provided by the plants in accordance with the monitoring guidelines under the EU ETS, the previous review report considered these plant-specific CO <sub>2</sub> EFs to be accurate and to have been prepared in accordance with the IPCC good practice guidance. The ERT noted that, in annex 3 to the NIR, Finland has described a study that examined the applicability of the default EF to Finnish conditions and that the study concluded that the default EF was suitable. However, the ERT also noted that the rapid decrease in the CO <sub>2</sub> EF between 2007 and 2008 could indicate that the emissions for the preceding years have been overestimated. The ERT agrees with the finding of the previous review report and recommends that Finland investigate the time-series consistency of the CO <sub>2</sub> EF; for example, Finland could explore whether there have been changes in the country of origin of the coal or whether changes in the net calorific value of coal could explain the decrease in the CO <sub>2</sub> EF and report thereon in its NIR. In response to the draft review report Finland informed the ERT that the applicability of the default EF in Finland for the years 2004–2007 could be further investigated, but that Finland will not prioritize this matter over more urgent development needs. The ERT agrees that this is not a matter of urgency and that other improvements should be given higher priority.	The applicability of the CO <sub>2</sub> emission factor for coal to the Finnish conditions has been described in the NIR.	Section 3.2.3 and Annex 3

CRF	Comment	Finland's response	Where in NIR
1	42. The previous review report identified that the CO <sub>2</sub> IEF value for liquid fuels used in petroleum refining decreased significantly between 2004 and 2005 (by 6.6 per cent). This was because plant-specific data were used to calculate the CO <sub>2</sub> EF from 2005 onwards, while information received from the plants in the late 1990s was used to calculate a CO <sub>2</sub> EF that was kept constant between 1990 and 2004. While the ERT considered the plant-specific data to be accurate and to have been prepared in accordance with the IPCC good practice guidance, it noted that the large drop in the CO <sub>2</sub> IEF from 2004 to 2005 was not realistic and could infer an overestimation of emissions for the earlier part of the time series, including for 1990. The ERT recommends that Finland include the improvement or revision of the time-series consistency of the CO <sub>2</sub> EF for liquid fuels used in petroleum refining in the inventory improvement plan and report thereon in its annual submission. In response to the draft review report Finland informed the ERT that work on finding the reason for the decrease in the IEF has been initiated, but currently there is no clear explanation available and therefore it would not be possible to clarify the issue in the 2014 annual submission.	This matter has been addressed in the NIR.	Section 3.2.3 and 3.2.6
1	45. The ERT noted that the CO <sub>2</sub> IEF for biomass in road transportation increased from 65.47 t/TJ in 2010 to 71.26 t/TJ in 2011. This did not seem correct, as the AD suggest that a large share of biomass consumption in road transportation was composed of the biogenic part of motor gasoline which, according to table 3.2-3 of the NIR, had an EF of 59 t/TJ. In response to a question raised by the ERT during the review, Finland explained that the EF and net calorific value of the biogenic part of motor gasoline varies depending on its composition, and that the values given in table 3.2-3 were not representative of the actual situation. The ERT recommends that Finland include the correct range of values in its annual submission.	Correct range of values has been added to the NIR.	Table 3.2.3
2	48. The ERT noted that notation keys in some specific categories (e.g. SF <sub>6</sub> used in aluminium and magnesium foundries, and other (chemical industry – ethylene)) are not used in line with the requirements of the “Guidelines for the preparation of national communications by Parties included in Annex I to the Convention, Part I: UNFCCC reporting guidelines on annual inventories” (hereinafter referred to as the UNFCCC reporting guidelines). In both cases notation key “NO” (not occurring) is used instead of “NA” (not applicable) in CRF tables 2(II).C and 2(I).A-Gs1. The ERT recommends that Finland correct the use of notation keys in the above-mentioned categories in its annual submission.	The notation key of ethylene production was changed to NA for the 2012 inventory. The notation key of SF <sub>6</sub> used in magnesium foundries was changed to NA for the 2012 inventory.	Table 10.4-2 and in CRF reporter.
3	50. Non-methane volatile organic compound (NMVOC) emissions from other (fat, edible and non-edible oil extraction) are used to estimate indirect CO <sub>2</sub> emissions. The ERT noted that the NIR includes a detailed methodology description, including that NMVOC/CO <sub>2</sub> emissions from this category arise from biomass. The CRF tables do not facilitate distinguishing between CO <sub>2</sub> emissions from biomass and fossil components under the category total solvent and other product use. This approach slightly overestimates national total CO <sub>2</sub> emissions, as CO <sub>2</sub> emissions from biomass are accounted for under fossil CO <sub>2</sub> emissions. The ERT recommends that Finland develop a way of reporting indirect CO <sub>2</sub> emissions which will allow CO <sub>2</sub> emissions from biomass to be distinguished from those from the fossil component and use this in the CRF tables of its annual submission, and provide an appropriate methodology and process description in its NIR.	It is not possible to develop on a system which would identify CO <sub>2</sub> emissions between fossil and biological. These separations must be done case by case.	Section 5.3.3.2.
4	52. Based on the recommendations made in the previous review report, Finland has improved the presentation of uncertainties in annex 6 to the NIR, reviewed and carried out QC of its N balance model, modified its pasture, range and paddock N <sub>2</sub> O model such that ammonia (NH <sub>3</sub> ) is not subtracted before calculating N <sub>2</sub> O and improved the transparency around the description of the procedure for estimating emissions from organic soils. The ERT commends the Party for rapidly integrating these improvements into its reporting system. The ERT recommends that the Party ensure that it integrates all documentation and explanations associated with these improvements into the NIR in a clear and transparent manner and review the previous review report to ensure that the recommendations and encouragements to improve the transparency of text that were outlined in that report are integrated into the NIR text; in particular, an improved explanation of the placement of fertilizers and an improvement to the transparency of the description of category-specific QA/QC procedures.	The descriptions have been improved.	Sections 6.4.2.2 and 6.2.4, 6.3.4, 6.4.4
4	54. The ERT noted that in the category-specific QA/QC and verification sections of the NIR that the Party often refers to “comparing emission factors with national data”, (e.g. in the tier 2 QC for the EFs section of the enteric fermentation category, page 230). During the review, the Party was asked how comparisons are done, how tier 2 quality verifications are documented and if it could provide examples of recent comparisons between EFs and national (experimental) data for the emission categories for which comparisons are stated to have been carried out, such as enteric fermentation. Finland responded that national measurements on emissions from enteric fermentation have begun recently but no data are published yet. The Party provided the example of the measurement of emissions from slurry storage (unpublished data) in which it was observed that EFs for cattle slurry and dung were fully in accordance with the measurements but those for pig slurry deviated more from the measurements. Since the data were unpublished, the comparison was not included in the NIR. The ERT holds that discussions of verification entail the comparison of model estimates with experimental data. When discussing these verifications in the NIR, there should be	The references to the comparisons that were planned but not done yet were removed.	Sections 6.2.4, 6.3.4 and 6.4.4



CRF	Comment	Finland's response	Where in NIR
	a logical presentation of the process: a specific aspect of the emissions model that was compared with specific research results and a presentation of the verification results that were either the same or different. The ERT recommends that Finland improve the transparency of text referring to the verification of the emissions model estimates by including the results of comparisons or removing this text in the "source-specific QA/QC and verification" section of the NIR.		
4	57. Finland reported that a weight gain of zero was used in calculations of enteric fermentation for dairy cows and suckler cows, on page 227 of its NIR; however, in table 6.2-5 in the NIR, live weights are reported that are less than mature weights for the individual cattle categories. This difference would suggest that on average cattle herds are in fact still growing. The choice of zero for this parameter will have an impact on the net energy of growth and probably on N excretion rates in the national N budget model. In response to a question raised by the ERT during the review on the basis for the choice of this growth rate, the Party replied that weight gain figures are based on rather old expert judgements but acknowledged that new values were available that had been integrated into the N excretion model but had not been integrated into the CH <sub>4</sub> model. The ERT noted that this was not in accordance with a single livestock classification outlined in section 4.1 of the IPCC good practice guidance and recognized this issue as an underestimation of enteric fermentation emissions. Finland agreed with this recommendation and submitted revised CRF tables during the review week with growth rates for mature cattle consistent with the N excretion model. The recalculations increased agricultural emissions of CH <sub>4</sub> for all years by less than 1% (14.6 Gg CO <sub>2</sub> eq in 2011) associated with a small increase in gross energy intake for these cattle categories. The ERT recommends that Finland review all aspects of its livestock characterization data, ensure consistency between its N excretion model and its enteric fermentation model in its annual submission and clearly document that a consistent livestock characterization is used in the two models.	The data used for calculation of enteric fermentation and N excretion are now uniform.	Section 6.2.5
4	59. In the 2011 review report, Finland was encouraged to provide information in the NIR related to the development of a country-specific EF for manure management systems that separates the solid and urine portions of manure. This information is now provided on page 245 of the NIR. In the explanation, no information was given about the proportional division of N between the urine and dung used in the weighting of the EF. This parameter is not universally known and will vary among animals and among animal feeding systems. The ERT contends that, for transparency, the Party must provide this factor and provide the source and assumptions behind the use of that ratio in its methodological description. During the review, Finland supplied an example of the calculation that is carried out to produce this EF, with the rationale included. The ERT recommends that the Party report in the NIR the ratio that is used to divide N between urine and dung, and provide a reference to the source of that information, in its annual submission.	The description will be further improved for the next submission. The reference is still missing but the N allocation is based on analysis of N content in slurries, dung and urine.	Section 6.3.2.1
4	60. On page 237 of the NIR, Finland stated that N utilization for animals had improved but did not supply information about how this had been achieved. The N excretion model is described in the report on the N balance model (Grönroos et al., 2009), not in the NIR, and the ERT observed that detail was missing in the document about N excretion. It was not clear what parameters had changed in Finland that resulted in an improved N balance. During the review, a question was posed to the Party about the text in section 6.3.2.2 of the NIR and the external report linked to the NIR (Grönroos et al., 2009) regarding how the calculation of N excretion is carried out. Supplementary information was provided to the ERT on the details on animal feed that are fed into the model. The ERT takes the position that when statements about trends in emissions are made, for transparency, the Party should clearly indicate what has changed and how that change has been integrated into calculations of emissions by making reference to the type of data and the data source. The ERT recommends that the Party integrate into the NIR a more detailed explanation of the N excretion methodology related to feed input trends, as well as productivity data trends, including references for the sources of those data, in its annual submission.	A new appendix has been added.	Appendix 6b
4	62. In table 6.4-5 in the NIR, Finland reported crop yields, referring to the total national crop production (Gg/annum). In evaluating emission trends and AD the ERT noted that the total of all the crops listed for 1990 (adding all crops together) was 20.0 per cent greater than the average for the rest of the reporting period, between 1991 and 2011. In response to a question raised by the ERT during the review the Party responded that agricultural production changed considerably in the beginning of the 1990s due to Finland's decision to join the EU. Many farms were given up and the area of fallow more than doubled in 1990–1991 and remained at that level in 1991–1995. The total area (including fallow) diminished by 7.0 per cent in 1995–1996 after Finland joined the EU in 1995. Thus, first the production of grain was diminished and the respective area of fallow land increased and later the area was transferred to other land uses. The ERT accepts this explanation, but recommends that Finland include this information in its discussion of trends in agricultural emissions, as the reduction in emissions from agricultural soils appears to be the most predominant trend in the time series, in its annual submission.	More text on the trend variations was added.	Section 6.1.1

CRF	Comment	Finland's response	Where in NIR
4	63. In CRF table 4.D, Finland has reported the value for FracNCRBF as "NA", whereas it has been reported as a value in previous submissions. The Party noted that in the past, the reported value has been a simple average of the N fraction in N-fixing plants and it has not taken crop yields and dry matter contents into account. In the actual calculation each plant is calculated separately and then N amounts summed up. Total FracNCRBF has only been used for reporting. The ERT recommends that the Party add the FracNCRBF value to the CRF tables in the form of a weighted average in its annual submission.	Weighted averages were now reported.	Table 6.5-2
4	65. The ERT noted that Finland uses a low fraction of synthetic fertilizer N applied to soils that volatilises as NH <sub>3</sub> and nitrogen oxides (NO <sub>x</sub> ) (FracGASF) (0.0146), which is lower than the IPCC default value of 0.1 from table 4-19 in the Revised 1996 IPCC Guidelines and among the lowest of all reporting Parties (0.0075–0.25). The use of this low factor appears to be due to both the fertilizer application methods and the types of fertilizers that are sold in Finland; for example, according to table 12 in the document by Grönroos et al. (2009), 80.2 per cent of applied fertilizers are "other NK and NPK", and there is no urea applied in Finland. The Party was asked to supply some supplemental information as to what the "other NK and NPK" fertilizers are, and explain why urea, an abundant and low-cost fertilizer, is not used in Finland. As a follow-up, and based on data from FAOSTAT, the database of the Food and Agriculture Organization of the United Nations (FAO), the Party noted that urea does appear in an irregular manner in Finland. A second inquiry was sent about observations of urea imports contained in FAOSTAT. The Party responded that "other NK and NPK" fertilizers consist of tens of different fertilizers which have an N content ranging from 3.0 to 27.0 per cent (as ammonium (NH <sub>4</sub> -N) and nitrate nitrogen (NO <sub>3</sub> -N)) and that urea is only rarely used in Finnish agriculture and the main use of the urea that is sold is in forestry. The FAO data were noted to be inconsistent, and the Party stated that inconsistencies demonstrating greater urea use in 2009–2010 are probably errors in the FAO data. Inquiries to TIKE (Information Centre of the Ministry of Agriculture and Forestry) showed that no surveys have been done on the use of urea in agriculture. Finland acknowledged that it has not identified a suitable method for estimating the consumption of urea but all available expert judgements estimate that the use is of minor importance and that urea is not really suitable for use in a country with a short growing season and acid soils. The ERT accepts this explanation but recommends that Finland review national data on fertilizer use and provide in the NIR a description of the distribution of fertilizer types used in Finland and document the source of that information in its annual submission.	A table on fertilizers was added.	Table 6.4-8
4	66. In section 6.3.2.3 of the NIR, Finland explains why the methane conversion factor (MCF) of 10.0 per cent is chosen for liquid manure CH <sub>4</sub> emissions, stating that a Swedish review supported the use of this value, as well as the 2006 IPCC Guidelines (10.0 per cent referring to storage with natural crust cover). The Party was asked to supply supplemental information with respect to the particular characteristics of the liquid storage systems in Finland which, in its opinion, support the use of a value that is lower than the lowest default value for liquid manure management systems in the IPCC good practice guidance (39 per cent in table 4.10). According to the Party, a paper by Sommer and Husted (1995) <sup>4</sup> represents one of the few studies that could be found which includes measurements over a full seasonal cycle in a cold climate and is one of the few studies found in which there is sufficient information reported to allow MCF values to be calculated without making vast assumptions regarding manure volumes and characteristics. The ERT agrees that the Party has based its MCF on studies and practices in countries with similar climates and similar agricultural practices. The MCF is a parameter that has a great deal of uncertainty. Finland has been consistent throughout its inventories in its use of this MCF but has not provided country-specific data that specifically support this choice. The ERT recommends that Finland produce and report in its NIR country-specific information or data that justify its choice of an EF that is lower than the default EF.	Conditions in Finland and Sweden are similar and thus we believe that the reference to Swedish studies show that the selected MCF is suitable for Finland.	Section 6.3.2.3
5	68. The ERT identified that Finland has reported cropland conversion to forest land, but the Party continues to report other conversions to forest land as "IE" in CRF table 5.A. In response to a question raised by the ERT during the review, Finland explained the reason for this reporting is that the losses in carbon stocks in the living biomass of trees were not estimated separately because the method used gives an estimate of the average net growth of the growing stock. The ERT reiterates the recommendation made in the previous review report on this matter that Finland include in its annual submission an enhanced description of the method used for estimating and reporting losses in carbon stocks in living biomass for all types of land converted to forest land.	The reason why the conversion from cropland to forest land is reported in a different way than other land use changes to forest land is, because the losses in carbon stock in conversion from cropland to forest land is from the crop biomass in the year of conversion. Such biomass is not on other types of lands. The gains and losses in living tree biomass is	Described and justified in the Section 7.2.3.2

CRF	Comment	Finland's response	Where in NIR
5	69. Finland has reported carbon stock changes in living biomass as "NE" in CRF table 5.C. The ERT considers that this reporting is not in line with the IPCC Good Practice Guidance for Land Use, Land-Use Change and Forestry (hereinafter referred to as the IPCC good practice guidance for LULUCF). The ERT reiterates the recommendation made in the previous review report that Finland report carbon stock changes associated with the living biomass pool in its annual submission.	estimated and reported in a same way for all LUC types; an aggregate estimate for gains and losses. We agree that there may be some woody biomass on abandoned fields that are included in GL. Since cutting of biomass does not occur on these areas they are a missing sink, not a source. New data on the woody biomass will be available during the coming years and an estimate of the biomass C changes will be reported as soon as possible.	7.4.6
5	70. Finland has reported a total uncertainty in grassland remaining grassland in the range of -256 to +328 per cent, and a corresponding range for land converted to grassland of -412 to +455 per cent (see NIR, page 310). The ERT considers this to be high because the overall emission uncertainty is ranged only -25 per cent to +34 per cent (see NIR, page 506). In response to a recommendation of the previous review report, Finland indicated that it plans to improve its methods for estimating uncertainties for all land-use categories. The ERT recommends that Finland report on its progress to improve the uncertainties in the LULUCF sector in its annual submission.	The method of estimating the uncertainties has been improved but the values remain high as long as the biological diversity of fields is high and the GL areas and especially the converted areas are a small percentage of the total area.	7.4.3 and Section 1.7
5	71. Finland reported in CRF table 5.D for 2011 an area of 2,867.52 kha as wetlands remaining wetlands that excludes inland waters. In table 7.1-4 of the NIR, the area of wetlands remaining wetlands is 2,957 kha. The ERT recommends that Finland correct this inconsistency in the annual submission.	There was an error in the footnote text in Table 7.1-4. Table note corrected and text added.	Table 7.1-4
5	72. Finland reported different CO <sub>2</sub> emissions from agricultural lime application between NIR table 7.1-2 and CRF table 5(IV). During the review, Finland informed the ERT that there are erroneous figures in table 7.1-2 in the row "Liming". Only liming of cropland is included in these figures and the liming of grassland is missing. The ERT recommends that Finland accurately report these figures in its annual submission.	The figures are now corrected.	Table 7.1-2
6	74. The ERT found that the transparency of the waste incineration category could be improved with information on waste types, incineration technology and energy recovery. In response to a question raised by the ERT during the review, Finland provided such information about hazardous, clinical waste, papers and paperboards incineration practices and the energy recovery practice from incineration The ERT recommends that Finland include this information in its annual submission.	Emissions on waste incineration are reported under energy sector and the description of waste incineration practices is added in energy sector in the NIR. In addition, a shorter description about waste incineration and energy recovery is added under waste sector.	Section 3.2.2.3 and 8.4.
6	77. The composition of MSW that is deposited on landfills is derived from the estimated composition of generated MSW and waste fraction data. Data for landfill gas recovery were taken from the Finnish Biogas Plant Register. The ERT noted that there is an observed significant increase in the gas recovery from 2000 that corresponds with the implementation of the regulations of landfill gas recovery (Council of State Decree 861/1997 on Landfills). In response to a question raised by the ERT during the review in relation to the reported zero recovery figures for several plants presented in the list of the landfill gas recovery plants (see Appendix 8(b) in the NIR), Finland explained that this is due to the temporary inoperativeness of the plants. The ERT recommends that the Party include this clarification in its annual submission.	Clarification is added.	Appendix 8(b)
6	78. Emissions from composting have steadily increased. The ERT reiterates a recommendation made in the previous review report that the Party improve the transparency of the composting category in relation to enhanced descriptions in the NIR on AD for composted waste and the destination of industrial waste and sludge from wastewater handling plants in its annual submission.	Transparency is improved.	Section 8.5.2 and 8.5.3
6	79. The ERT noted that N <sub>2</sub> O emissions from industrial wastewater are reported as "NE" in CRF table 6.B. However, Finland reports on N input-	Clarification is added. Already, there	Section 8.3.2

CRF	Comment	Finland's response	Where in NIR
	related N <sub>2</sub> O emissions from industrial wastewater and fish farming in the category other (wastewater handling) in CRF table 6.B. The ERT commends the Party for including these emissions, and encourages Finland to provide an enhanced explanation in its next annual submission on why these emissions are not presented under industrial wastewater.	have been several sentences on this subjects and more is added now in the NIR.	
KP	81. Finland is planning to further develop the methods for area estimation as well the methods for estimating the emissions and removals of GHGs for each Article 3, paragraph 3, activity. The ERT noted from the 2013 NIR (section 11.3.1.5) that Finland intends by the 2014 annual submission to have enhanced the estimation of afforestation and reforestation areas, and to use the NFI data for 2009–2012 to improve the increment estimates for the growing stock on afforestation and reforestation areas. The ERT commends Finland on its efforts to significantly enhance its KP-LULUCF inventory and recommends that the Party report thereon in its annual submission.	Descriptions of enhancement of estimation methods are given in the NIR in proper sections.	Section 11.3.1.3 Changes in data and methods since the previous submission and Sections 7.1.2, 7.1.3 and 7.2.3.2.
KP	82. The emissions from liming, including limestone, dolomite and briquette lime, have been reported under deforestation. The method and EFs used are in line with the IPCC good practice guidance for LULUCF. However, the ERT could not reconcile easily why AD are not obtained/derived from the same sources. The description provided in the NIR (section 7.3.2.3) differs from the corresponding description provided in CRF table 5(KP-II)4, which indicates that the data are based on using an average amount of 19 t/ha of lime. The ERT recommends that Finland in its annual submission clearly explain the source of liming data and/or how they are derived and any differences in its treatment in reporting deforestation under the Convention and under the Kyoto Protocol.	In section 7.3.2.3 the data source is sales statistics and thus the amount of lime applied on CL and GL is based on the total amount of lime products sold. In KP we report the liming of new fields. The amount of lime applied on recently cleared fields is higher than the annual lime application in the later years of cultivation. The amount 19 tonnes per ha is based on an expert judgement on the amount of liming needed in the first year after the clearance of a new field	11.3.1
Registry	90. The ERT concluded that, taking into account the confirmed changes in the national registry, including additional information provided to the ERT during the review, Finland's national registry continues to perform the functions set out in the annex to decision 13/CMP.1 and the annex to decision 5/CMP.1 and continues to adhere to the technical standards for data exchange between registry systems in accordance with relevant decisions of the Conference of the Parties serving as the meeting of the Parties to the Kyoto Protocol (CMP). With respect to the provision of information related to database structure specifically, the ERT encourages the Party to provide additional information in the NIR. The ERT recommends that Finland include all other additional information in response to the SIAR findings in its NIR in accordance with decision 15/CMP.1, annex, chapter I.G.	The relevant additional information of the database structure and other information on changes that have occurred in the national registry, compared with information reported in the last submission (2013) are included in the Chapter 14 of the NIR 2014 submission.	Chapter 14

# 11 KP-LULUCF

## 11.1 General information

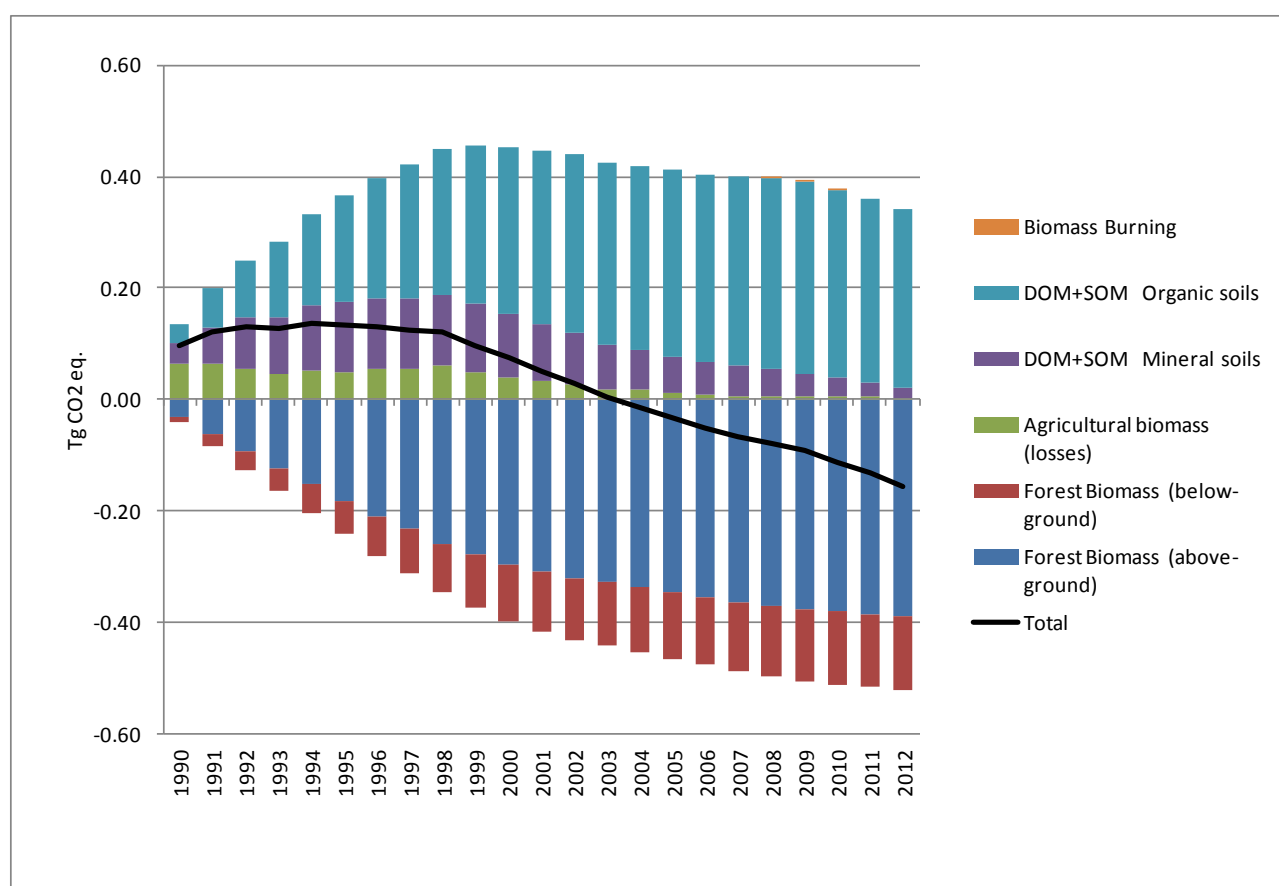
Under Article 3, paragraph 3 of the Kyoto Protocol (KP), Finland reports emissions and removals from activities Afforestation (A), Reforestation (R) and Deforestation (D), and under Article 3, paragraph 4 emissions and removals from Forest Management (FM). The estimates for emissions and removals under Articles 3.3 and 3.4 are prepared and reported consistent with the IPCC Good Practice Guidance for Land Use, Land Use Change and Forestry 2003 (IPCC 2003) and Decisions 15/CMP.1 and 16/CMP.1 of the KP.

There are no emissions reported under Articles 3.3 and 3.4 that would overlap with those reported under KP Annex A. Agricultural non-CO<sub>2</sub> emissions are reported under the agriculture sector, with the exception of N<sub>2</sub>O emissions from disturbances associated with land conversions from forest to cropland, which are reported under D.

Forest Management is a voluntary activity which Finland elected to report in the first KP commitment period. ARD activities are considered as a land-use change between forest and other land use. The emissions and removals are estimated separately for AR, D and FM activities based on the area of each activity. Total land area is allocated to AR, D and FM activities, and to lands not covered by any mandatory or elected KP activity. This method assures that also emissions and removals from FM are not included in the emissions and removals from ARD activities.

All N<sub>2</sub>O emissions from the N fertilisation of forest soils are reported under FM. Reasoning to this course of action is, that it is not a common practice in Finland to apply N fertilizers to young AR forests.

Net emissions from Article 3.3 activities were 2,351Gg CO<sub>2</sub> eq. in 2012 (Table 11.1-1). Afforestation and reforestation were a net sink of 135Gg CO<sub>2</sub> eq. (Figure 11.1-1) while deforestation resulted in a net emission of 2,486 Gg CO<sub>2</sub> eq. (Figure 11.1-2). The area subject to AR was 167,284 ha at the end of the first commitment period (Table 11.4-1). During 1990-2012 AR areas have steadily declined from an average of 12,000 ha observed in the 1990s to an average of 3,600 ha observed in the 2000s (Table 11.4-1). Yearly deforestation areas increased from 6,800 ha in 1990 until 2004, when deforestation reached its maximum, 22,500 ha per year (Table 11.4-1). Since then, yearly D areas have been in steady decline. D area in 2012 was approximately 7,700 ha. At the end of 2012, the total area deforested since 1 January 1990 was 324,378 ha (Table 11.4-1). The transition from forest to built-up land and infrastructure, that is, the land-use changes from forest land to settlements, has been the most important activity under deforestation. Net removals from FM under Article 3.4 were 35,596 CO<sub>2</sub> eq. in 2012 (Figure 11.1-3).



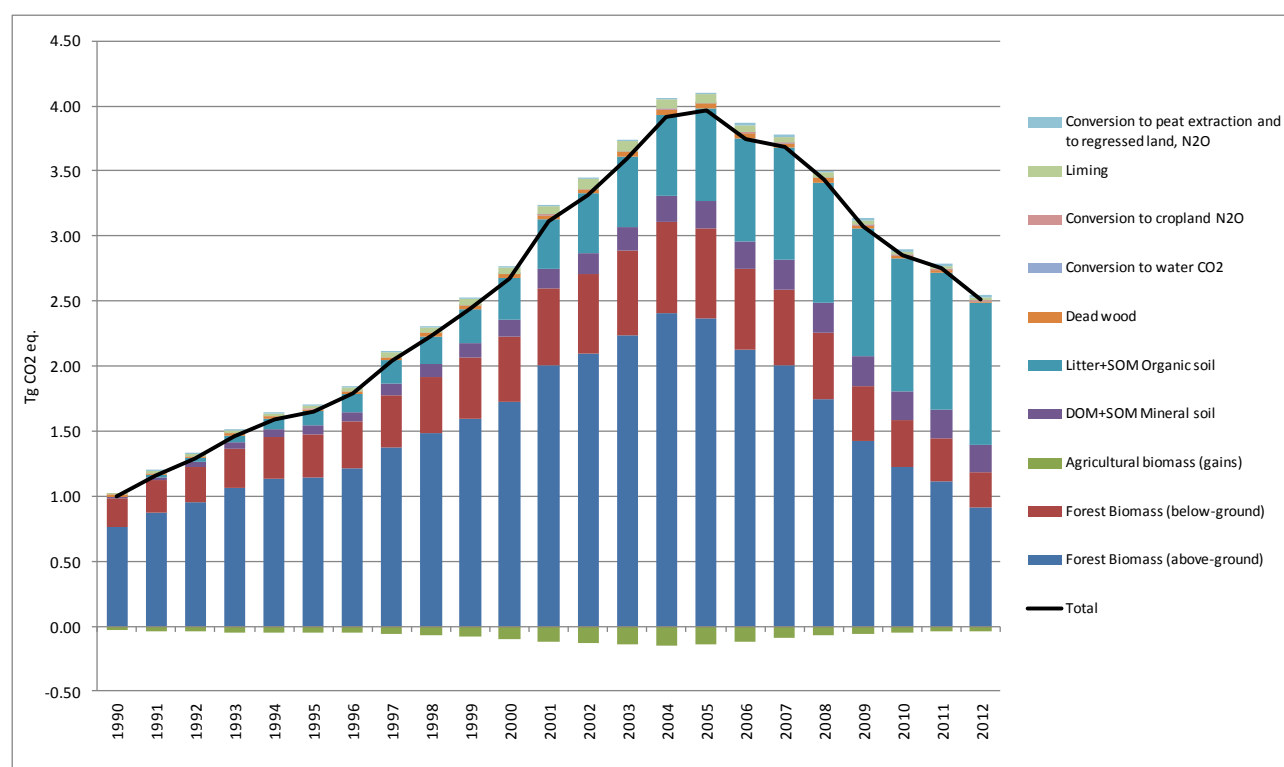
**Figure 11.1-1** Net emissions and removals from the AR activities under Article 3.3, Tg CO<sub>2</sub> eq.

The emissions and removals from ARD lands vary substantially between the years. This variation is because the timing and quantity of land-use changes vary depending on the economy and incentives.

The inter-annual variation in CO<sub>2</sub> removals on lands under forest management is mainly due to variation in the amount of logging, which has a direct impact on the biomass sink. Also, the changes in soil carbon vary according to the variation in the vegetation, but the changes occur at a slower rate than they do for biomass.

**Table 11.1-1** Net emissions and removals under Articles 3.3, Gg CO<sub>2</sub> eq. in 2012

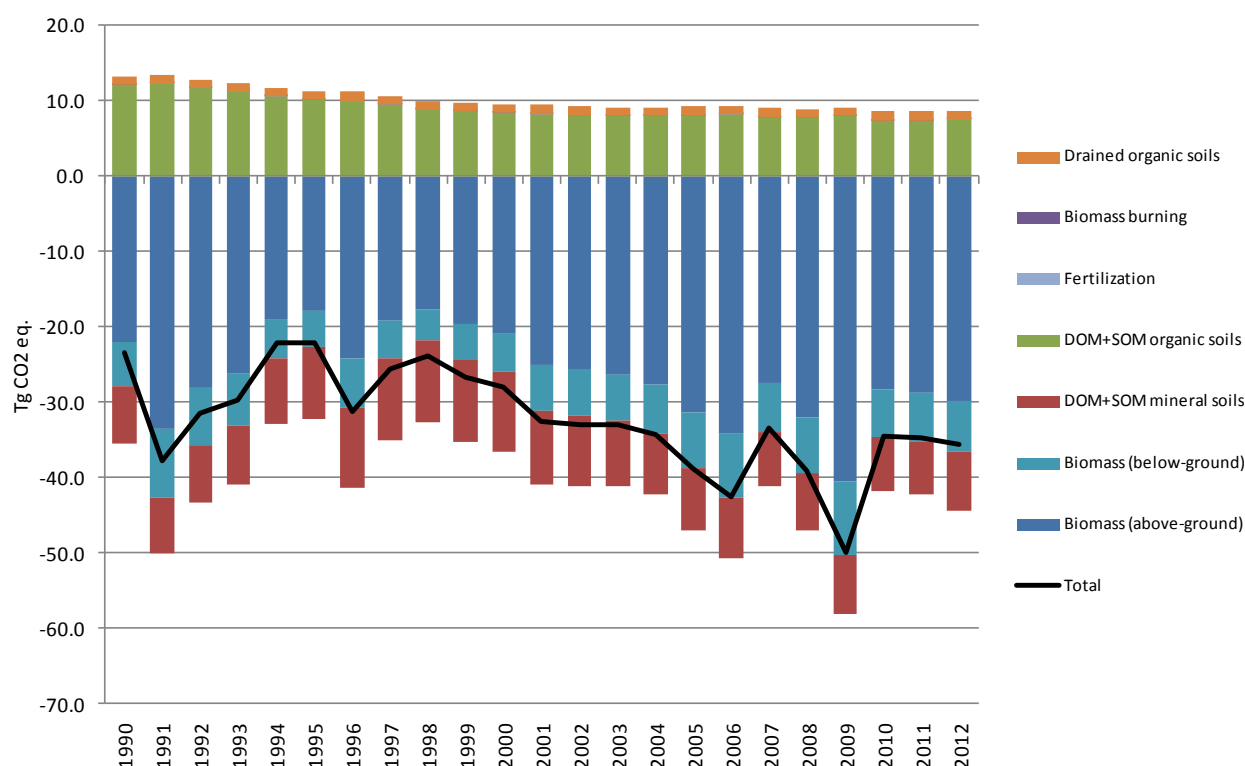
		Carbon pools	Liming	N <sub>2</sub> O emissions from disturbance	Biomass burning			N <sub>2</sub> O emission from drainage
					CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	N <sub>2</sub> O
Afforestation/Reforestation	Region 1	-144			NO	NO	NO	14.0
	Region 2	-37						9.9
	Total	-181			NO	NO	NO	23.9
Deforestation	Region 1	1 828	12	4.9				18.4
	Region 2	633	8	0.0				8.8
	Total	2 462	20	4.9				27.2
Total		2 281	20	4.9	NO	NO	NO	51.1



**Figure 11.1-2** Net emissions and removals from the D activities under Article 3.3, Tg CO<sub>2</sub> eq.

**Table 11.1-2** Net removals and emissions under forest management in 2008 - 2012 (Gg CO<sub>2</sub> eq.)

		2008	2009	2010	2011	2012
Region 1	CO <sub>2</sub>	-22 926	-29 286	-16 971	-17 837	-19 123
	CH <sub>4</sub>	1.1	0.6	0.6	0.6	0.3
	N <sub>2</sub> O	649	639	636	631	627
	Total	-22 277	-28 646	-16 335	-17 205	-18 496
Region 2	CO <sub>2</sub>	-16 234	-20 793	-17 458	-16 936	-17 667
	CH <sub>4</sub>	0.1	0.5	0.1	0.4	0.2
	N <sub>2</sub> O	553	555	558	564	564
	Total	-15 681	-20 237	-16 900	-16 372	-17 103
Total		-37 958	-48 884	-33 235	-33 577	-35 598



**Figure 11.1-3** Net emissions and removals from the FM activities under Article 3.4 in 1990-2012, Tg CO<sub>2</sub> eq.

The emissions by sources and removals by sinks and non-CO<sub>2</sub> emissions for ARD and FM were estimated with the same principals and methods as for the Convention reporting. Also the same QA/QC-procedures were done.

For the 2015 submission, the IPCC 2006 Guidelines and the KP Supplement will be implemented and the reporting also otherwise will be developed to fulfil the requirements of the KP reporting in the second commitment period.

### 11.1.1 Definition of forest and any other criteria

Under the KP, Finland has defined forest as land with a tree crown cover of more than 10% and a minimum area of 0.5 ha. The trees should be able to reach a minimum height of 5 m at maturity in situ. Young natural stands and all plantations established for forestry purposes that have yet to reach a crown density of 10% or a tree height of 5 m are included under forest, as are areas normally forming a part of the forest area that are temporarily unstocked as a result of human intervention or natural causes, but that are expected to revert to forest. Forest roads, cleared tracts, firebreaks and other open areas within the forest, as well as protected forest areas, are included under forest.

**Table 11.1-3** Elected values for forest parameters

Parameter	Selected value
Minimum area	0.5 ha
Minimum width	20 m
Minimum tree crown cover	10%
Minimum tree height	5 m

The elected forest parameters were reported in Finland's initial report under the Kyoto Protocol (Table 11.1-3). The UNFCCC and the Kyoto Protocol reporting are not fully comparable. The difference between the UNFCCC reporting and the Kyoto Protocol reporting is that in the Convention reporting Finland uses a minimum area of 0.25 ha to cover all forest land for South Finland (see Section 7.1.2 and Section 7.2.1).



Forests with an area of less than 0.5 ha are excluded from the Kyoto Protocol reporting to fulfil the definition in the initial report. The area of forest land has been estimated using the NFI data, where the minimum width has been set at 20 m.

*Exclusion of small forests (area less than 0.5 ha)*

The NFI sample plots that were located in these small forests have been identified using GIS analysis. The digital vector map data from the National Land Survey were rasterised to a 20 m pixel size covering the whole country. The rasterisation was carried out earlier by Metla for multi-source forest inventory purposes. That particular raster map includes information on land use and the size of the forest area, i.e. whether it is under or over 0.5 ha. The raster map values were extracted for the NFI sample plots. The NFI sample plots located in forests of less than 0.5 ha on the map were also double-checked visually. Otherwise, the classification relied on field assessments for the land use. A general comparison between the field plot data and raster map data was done. The proportion of sample plots under 0.5 ha forests was 0.1%.

The forest area reported under the Kyoto Protocol for the years 1990, 2005 and 2010 has been compared with the forest land area in the UNFCCC reporting, with the forest area provided to the FAO for the Global Forest Resource Assessment 2010 (FRA 2010) and with the combined national forest land and poorly productive forest land area reported using the NFI field data. The KP forest area is smaller than the UNFCCC forest land area, as it should be when taking the differences in the definitions into account. The UNFCCC and the FRA forest definitions are based on the canopy cover, whereas the national definitions are based on the annual increment of stem wood (see Appendix\_7a, figure 1\_App\_7a). The minimum area for forest land and poorly productive forest land is not exact, but, rather, a guide of 0.25 ha for South Finland and 0.5 ha for North Finland is given. The diverse total land areas are presented in Table 11.1-4. Due to the improved geodetical methods, Finland's official land area has changed from year to year. Despite that, in general the forest resource results have not been recalculated by employing the corrected land area, unlike for the UNFCCC and KP reportings.

**Table 11.1-4** Comparison of the KP forest area with areas reported to the UNFCCC and to the FAO FRA2010 assessment, and with the aggregate national forest land and poorly productive forest land area

Reporting	Forest area			Total land area		
	1990	2005	2010	1990	2005	2010
KP (FM+AR)	22 158	22 072	22 008	30 392	30 390	30 389
UNFCCC (Forest land)	22 187	22 104	22 038	30 392	30 390	30 389
FRA2010 (Forest)	21 889	22 157	22 157	30 409	30 409	30 409
National forest land + poorly productive forest land	23 057 <sup>1</sup>	22 820 <sup>2</sup>	25 977 <sup>3</sup>	30 459 <sup>1</sup>	30 415 <sup>2</sup>	30 389 <sup>3</sup>

<sup>1</sup> NFI8, measured in 1986-1994 (Tomppo et al. 2001).

<sup>2</sup> NFI10, measured 2004-2008 (Source: Finnish Statistical Yearbook of Forestry 2009).

<sup>3</sup> NFI11, measurement years 2009-2012 (Source: Finnish Statistical Yearbook of Forestry 2013).

fra2010=[www.fao.org/docrep/013/al505E/al505E.pdf](http://www.fao.org/docrep/013/al505E/al505E.pdf)

### 11.1.2 Elected activities under Article 3, paragraph 4 of the Kyoto Protocol

Finland has elected to account for emissions and removals from forest management (FM) under Article 3, paragraph 4 of the Kyoto Protocol. The definition of forest management is interpreted using the broader approach described in the GPG LULUCF 2003. All forests fulfilling the definition of forest, as given above, are considered managed and are under forest management. Forest management activities are not identified at either a stand-level or a landscape-level; rather, they are identified for two larger land areas subject to forest management and for which geographical boundaries are defined and reported (Table 11.2-1).

### *11.1.3 Description on 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*

Afforestation/reforestation and deforestation (ARD) areas have been estimated from a database based on the 10<sup>th</sup> and 11<sup>th</sup> forest inventories (NFI10 and NFI11). The database contains sample plot data, stand-level data and tree data. The land use at the end of 1989 for each sample plot has been derived from the information on land use and land-use changes assessed in the field and with aerial photos, satellite images and digital map data. The time series for ARD activities were established from data using the same principles and definitions for forest and ARD activities. The NFI will continue to monitor forest and other land uses also during the subsequent commitment periods. The forests, other land uses and land-use changes will be monitored every year throughout the whole country, excluding the most northern part of Lapland and the Åland Islands, which are monitored once every five years.

The time series for the FM area have been estimated using the same database as for the ARD areas. The forest area estimation was computed in the same way as in the Convention reporting (Section 7.1.2 and Appendix\_11a). The FM area in each year is derived from the total forest land area and from the annual AR and D areas (see Section 7.1.2). The total forest land area under KP is FM+AR. The FM area at the end of 1989 was the same as the forest area. A detailed description of area calculations is given in Appendix\_7b.

The procedure for identifying ARD and FM activities using NFI data is described in Appendix\_11a.

### *11.1.4 Description of precedence conditions and/or hierarchy among Article 3.4 activities, and how they have been consistently applied in determining how land was classified*

Finland has elected to report forest management under Article 3.4 activities. Therefore, there has not been a need to establish a hierarchy between forest management and other Article 3.4 activities. To ensure that the reported forest management activities have occurred on forest land, the total land area was classified into six land-use categories as for the UNFCCC reporting, and each land area was classified only under one land-use category (Section 7.1.2). Land-use areas were calculated using the NFI10 and NFI11 data and every sample plot, or, to be precise, the mid-points of the sample plots, were classified under one IPCC land-use category.

## 11.2 Land related information

Finland implements Reporting Method 1 for lands subject to Article 3.3 and Article 3.4 activities. The area of Finland is divided into two regions: Region 1 covers South Finland and Region 2 the North Finland (Figure 11.2-1). Ecological considerations and the NFI sampling design argue for the boundary between Regions 1 and 2. The dividing line follows the boundary between two NFI sampling density regions (see Appendix\_7a Figure 1\_App\_7a). These areas include multiple units of land subject to afforestation/reforestation and deforestation and land areas subject to forest management. In the reporting, the same geographical boundaries were used for Article 3.3 and Article 3.4 activities. Approach 3 is used for representing the land areas.

Data for land use and land-use changes were obtained from the National Forest Inventory (NFI). The NFI is a sampling based inventory system that covers all land-use categories. The sampling unit for area estimation is a point. In a sample plot, the point is the midpoint of the plot. The midpoint determines the land-use category, land-use change type or activity of the area.

### 11.2.1 Spatial assessment unit used for determining the area of the units of land under Article 3.3

The spatial assessment unit for determining the area of units of land under Article 3.3 is 0.5 ha, which is the same as the minimum area of forest.

### 11.2.2 Methodology used to develop the land-use transition matrix

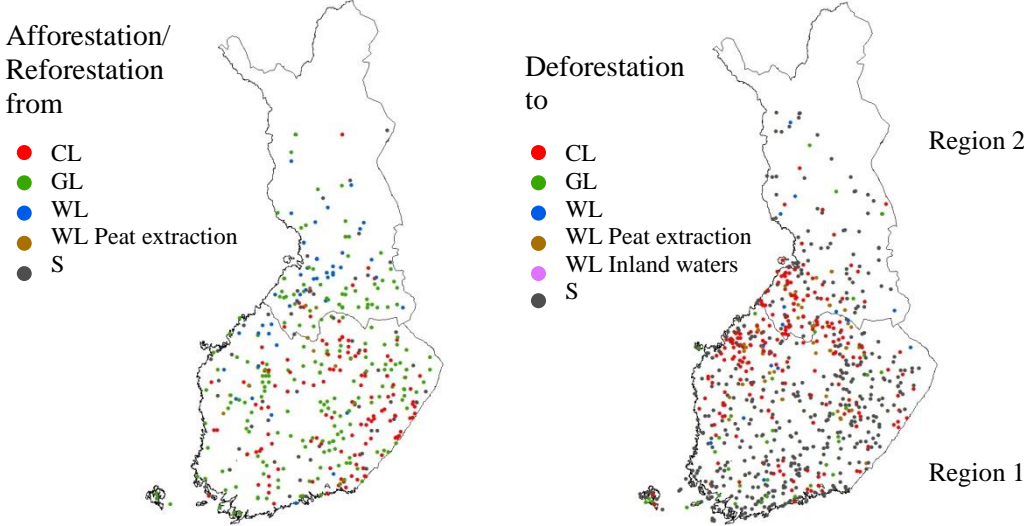
The forest inventory database contains information on the IPCC land use and the land-use change category for each sample plot. The data in the database were measured in 2005-2012. The annual land-use change areas were calculated for the years 1990-2012. The method is described in Section 7.1.2. The matrix was developed by adding and subtracting the conversion areas to and from the land-use category areas. The matrix was first developed for the period from 1 January 1990 to 31 December 2011 and then for the year 2012 (Table 11.2-1).

**Table 11.2-1** Land-use transition matrix for 2012 (1 000 ha)

2012		Article 3.3 activities		Article 3.4 activities		Other		Total
		A/R	D	FM	CM	GM	RV	
Article 3.3 activities	A/R	166	0					166
	D		317					317
	FM		8	21 827				21 834
Article 3.4 activities	CM	NA	NA		NA	NA	NA	NA
	GM	NA	NA		NA	NA	NA	NA
	RV	NA			NA	NA	NA	NA
Other		1	NO	NO	NA	NA	NA	11 524
Total		167	324	21 827	NA	NA	NA	33 842

### 11.2.3 Maps and database to identify the geographical locations, and the system of identification codes for the geographical locations

The emissions and removals from ARD and FM activities are reported for two regions, which are geographically bounded. The ID-codes are *Region1* and *Region2* (Figure 11.2-1). The ARD and FM activities were identified for the NFI sample plots. In the field, the sample plots have been located by GPS whereupon it was possible to place them in the appropriate regions.



**Figure 11.2-1** Geographical locations of the two reporting regions and their identification codes. The sample plots under ARD activities for the years 1990-2012 are plotted on the map. Different land use conversions from or to forest are presented in different colours

## 11.3 Activity-specific information

### 11.3.1 Methods for carbon stock change and GHG emission and removal estimates

#### *Description of the methodologies and the underlying assumptions used*

##### *Carbon stock changes in living biomass*

The total biomass increment of trees in all forests was obtained by assuming that the mean increment per area unit is the same as in the forest land under the UNFCCC reporting. This mean increment was multiplied by the area estimate for all forests included in the Kyoto Protocol reporting (excluding small forests with areas less than 0.5 ha) to obtain the total increment of growing stock of Kyoto forests (See Section 7.2.3.1).

Afforestation/reforestation sites were classified according to the identified land-use change, and the mean increment was estimated for each type of AR in the same way as that of the sites converted to forest land in the UNFCCC reporting based on the afforested/reforested NFI plots (since 1990; for details, see Section 7.2.3.2). Again, these mean increments were multiplied by the appropriate area estimates, and the results were totalled to obtain the total increment in afforestation sites.

The increment for sites under forest management was then obtained as the difference between the increment in all forests and the increment in afforestation sites.

A similar approach was applied for the drain. The tree biomass loss due to deforestation was estimated in classes formed according to the new land use by multiplying the respective area estimate by the mean tree biomass stock in forests where the given type of deforestation is likely to occur. For details, see Sections 7.3.2.2, 7.4.2.2, 7.5.2.2 and 7.6.2.2.

The drain for sites under forest management was obtained as the difference between the total drain and the drain estimated to be due to deforestation.

The loss in carbon stock due to the removal of annual non-woody crops from conversion of cropland to forest land in a given year was 4 t C/ha, which is a national value of mean crop biomasses based on yields. Similar subtractions were not done for the other conversion types, because it was assumed the initial vegetation will not be removed during the conversion.

##### *Carbon stock changes in dead wood, litter and soil organic matter*

For carbon stock change estimations for soil, litter and dead wood, the same methodology was used as in the reporting under the UNFCCC, where an aggregated estimate was provided for these pools.

The Yasso07 soil carbon model (Appendix\_7f) was applied for mineral soils under forest management activity and for mineral soil areas under land-use change.

For organic soils national emission factors were applied. The main principle was to deduct the below-ground litter input from the emissions of peat decomposition. This approach was also used for afforestation, reforestation and deforestation sites. For afforestation/reforestation sites over 20 years old the emission factors of forest management are applied to remain consistency with the UNFCCC reporting.

For details about the methods, see the discussion of UNFCCC reporting methods on Forest land remaining Forest land in Section 7.2.3.1 and for lands converted to Forest land in Section 7.2.3.2. For more on deforestation as a result of forest lands being converted to other land uses, see Sections 7.3.2.2, 7.4.2.2, 7.5.2.2 and 7.6.2.2 for details.

For afforestation and reforestation sites, the accumulation of dead wood was assumed marginal during the years first 20 years after afforestation or reforestation. The accumulation of dead wood starts after natural

mortality or thinnings occur and when the trees reach the dimensions set to dead wood (diameter 10 cm), which on average is at the stand age of over 20 years (Tomppo et al. 2011). For this reason the carbon stock change in the deadwood pool is considered for afforestation/reforestation sites older than 20 years only.

Emissions due to the removal of the dead wood pool during the deforestation as a result of converting organic forest lands to agriculture and forest lands to settlements were estimated based on the dead wood measurements for the NFI10 inventory. The methodology for estimating the carbon stock of the lost dead wood pool is similar to that used in the UNFCCC reporting concerning the dead-wood carbon pool change on organic forest land (see Section 7.2.3.1). For forests deforested for settlements IPCC (2006) default methods were applied when emissions due to carbon stock changes in litter and soil organic matter were estimated. For further details, see section “Land converted to Settlements” under UNFCCC reporting.

#### *Other GHG emissions*

##### *N<sub>2</sub>O emissions from N fertilisation*

The total amount of nitrogen for forest fertilisation is based on the annual sales statistics for forest fertilisers. The direct N<sub>2</sub>O emissions from N fertilisation under FM were estimated by applying the same method as under CRF 5(I) Category (Section 7.8.3). The sales statistics do not allocate the sales between South and North Finland (Region 1 & 2). In order to allocate the total amount, statistics on forest fertilisation areas were used to obtain a ratio for South and North Finland for each year of the time series. It was assumed that the same amount of fertiliser is applied per hectare in both South and North Finland.

In the years 1990-1999 the Finnish Statistical Yearbook of Forestry divided forest fertilisation areas into mineral soils and peatland forests. In these years, areas of mineral soils have been considered in the calculations. In the years 2000-2012 the Finnish Statistical Yearbook of Forestry (2013) divided forest fertilisation areas into remedial fertilisation and fertilisation for growth areas. In these years, areas of fertilisation for growth have been considered in the calculations.

The calculations are based on the fact that nitrogen fertilisers are not applied to organic soils as there is no need for nitrogen in peatlands. Because remedial fertilisations are applied only on organic soils, it can be deducted that remedial fertilisations are nitrogen-free.

After the 2010 submission, an enquiry on the use of N fertilisers on afforested and reforested areas was carried out. According to the results, N fertilisers were not applied to the AR areas. In the case of afforested/reforested arable land, the soil does not need additional N fertilisation. Remedial fertilisations are possible on drained peatland or former peat extraction areas, and in these cases, potassium and phosphorus are applied, but not nitrogen.

##### *N<sub>2</sub>O emissions from drainage*

N<sub>2</sub>O emissions from drained forest lands, including those under forest management, afforestation and reforestation and deforestation activities were estimated using the same method as described in Section 7.8.2. N<sub>2</sub>O emissions for FM lands were reported under Table 5(KP-II)2, while N<sub>2</sub>O emissions from ARD activities for South and North Finland were reported as an aggregated value under Table 5(KP-II)5 GHG emissions from biomass burning. This table was used for reporting due to fact that in the CRF tables there are no appropriate table for N<sub>2</sub>O emissions estimations from drained organic forest lands with AR and D activities.

##### *N<sub>2</sub>O emissions from disturbances*

N<sub>2</sub>O emissions from disturbances associated with land-use conversion to cropland were estimated using the same method as described in Section 7.8.3.

### *Biomass burning*

GHG emissions from biomass burning in FM areas were estimated using the same method as described in Section 7.7.4. For this submission, CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions were allocated to Region 1 and Region 2.

It is not possible to directly provide data separately for wildfires on FM and AR areas based on the statistics. NFI10 data gave evidence that forest fires had occurred during the years 2008-2010, but not during 2011-2012 on AR areas. However, the NFI data were not suitable for estimating areas for that purpose. Therefore, the emissions from wildfires on AR areas were estimated as follows.

The area of wildfires on AR lands was calculated by using the share of AR land area to total forest area and allocating the total wildfire areas accordingly. Burning biomass on AR lands was calculated as the mean biomass weighted with the area of each AR category for the growing stock on converted land areas in the NFI10 inventory (see Section 11.4 for AR categories). Separate combustion efficiencies for AR areas were not available, and so the combustion efficiencies of forest land were used (see Section 7.7.4).

Biomass burning on D areas is not reported since residue burning is not a common practice when clearing new fields or grasslands.

### *Liming*

CO<sub>2</sub> emissions from liming were estimated for the area of deforestation. It was supposed that an average amount of 19 t/ha of lime (Saarela, 2010) was applied on both forest land converted to cropland and on forest land converted to grassland. The amount per hectare is higher than in the LULUCF reporting on average since the amount of lime used on recently cleared fields is higher than that applied on older fields. The method of calculation is described in Section 7.3.2.3. Liming under the other LULUCF activities (AR and FM) does not take place in Finland.

#### *11.3.1.1 Justification when omitting any carbon pool or GHG emissions/removals from activities under Article 3.3 and elected activities under Article 3.4*

For deforestation sites where the new land use is peat extraction, carbon stock changes are reported in CRF Table 5(KP-I)A.2. For UNFCCC reporting, the CH<sub>4</sub> emissions are also reported in the CRF tables, whereas there is no place for them in the reporting tables under the Kyoto Protocol. The estimates for the CH<sub>4</sub> emissions from deforested peat extraction sites have therefore only been provided as additional information in the NIR (see Section 11.4.4).

#### *11.3.1.2 Information on whether or not indirect and natural GHG emissions and removals have been factored out*

Finland has not factored out removals from elevated carbon dioxide concentrations, indirect nitrogen deposition or the dynamic effects of the age structure resulting from activities prior to 1 January 1990. The IPCC does not give methods for factoring them out. For the first commitment period, the effect of indirect and natural removals will be considered via the cap under Article 3.4 on credits from FM. For Finland, the cap is 0.16 Mg C yr<sup>-1</sup>.

#### *11.3.1.3 Changes in data and methods since the previous submission (recalculations)*

The areas of Article 3.3 activities and Forest Management were recalculated. ARD activities are defined as land-use changes between forest and other land uses. The estimation method for land-use changes was improved, data for transitions were implemented and the latest NFI11 data measured in 2012 were employed thus the areas were recalculated since the previous submission. The land-use information of the NFI data was also updated to the end of 2012 by means of spatial data. Methodology for updating was developed under a separate research project at METLA during 2012-2013 (Metla Project 7501, 2014). Also found errors in data and calculations were also corrected.

New data from the NFI11 inventory measured in 2012 became available for biomass estimation for AR and FM activities. This implied changes in the interpolated values for all years after the mean measurement date for the NFI10 inventory (which is 2006) for the biomass stock and after the mean date for the five-year increment measurement period (approx. at the beginning of 2004) for the biomass increment.

Also, weather data were updated to include the data for the latest inventory year. The soil carbon change estimation was also updated due to the changed biomass estimation, which has a direct impact on the litter input.

For drained organic soils, the estimation method was similar to that in the previous submission, but, due to improvements in the biomass estimation, these values have changed also.

The activity data for biomass burning changed due to updates in the FM and AR areas. This resulted in minor recalculations for the emissions in the years 2008-2010.

The whole time series was recalculated as the result of updated time series for the area data. An error was corrected in the calculation of N<sub>2</sub>O emissions from disturbance. It was earlier calculated only for the first year of clearance but now it was extended to the period of 20 years.

#### 11.3.1.4 Uncertainty estimates

It was assumed that uncertainty estimates developed for forest land apply also for lands under FM (see Section 7.2.4.4 for carbon stock changes, Section 7.8.1.3 for N fertilisation, Section 7.8.5.3 for biomass burning). For the uncertainty in tree biomass carbon stock changes, the sampling uncertainty in volume increment of NFI, 5% uncertainty in commercial timber removals, NFI sampling uncertainty in all BCEF (biomass conversion and expansion factor) estimates was combined with the biomass model parameter uncertainty in the net change. The uncertainty for carbon stock changes in dead wood, litter and soil organic matter was estimated separately for mineral- and for drained peatland soils. The uncertainty was estimated by combining uncertainties of biomass, litter turnover rates and that of Yasso07 model for mineral soils (see Appendix\_7f and Appendix\_7i). For drained peatlands the uncertainty of applied peat decomposition emission factors and those for activity data were combined.

The estimated change of carbon stock on afforestation sites is practically the same as that on lands converted to forest land. Hence the uncertainty assessment in Section 7.2.4.4 applies also here. The uncertainty carbon stock change of ARD lands is substantially larger due to small land areas and therefore higher sampling error for activity data.

For the annual deforestation areas, the uncertainty due to NFI sampling is approximately 30%. Applicable data is currently not available for assessing the uncertainty in the average loss of tree biomass per area unit. For emissions from soils resulted from activities Forest land converted to Cropland and Grassland the preliminary estimates of the uncertainty of emission factors range from 60 to 150%.

The relative uncertainties used in tier 2 uncertainty analysis for KP reporting were same as those for UNFCCC reporting, but the aggregation of uncertainties of the subcategories between these reportings differs. Uncertainty estimation for ARD and FM activities are under development.

**Table 11.3-1** Relative uncertainties estimated using tier 2 methods for Kyoto Protocol activities 3.3 and 3.4

	Emission 2012	Emission uncertainty
Total KP-LULUCF	-33 237	±36 %
KP 3.3.a AR	-35 596	±249 %
KP 3.3.b. D	-127	±64 %
KP 3.4. FM	2 486	±33 %



*Comparison of ARD area estimates with statistics*

A comparison between estimated ARD areas and areas from other data sources was done to have a qualitative estimate of the reliability of the employed activity data.

The afforested and reforested areas given in Table 11.4-1 have been compared with the statistics on the afforestation of arable land (Finnish Statistical Yearbook of Forestry 2012). The reported AR areas and the statistics for the afforested areas are presented below in Table 11.3-2. The reported conversion area from cropland and grassland to forest is less than in the statistics. The first reason for this difference is that the minimum area reported in the statistics is unknown; it can be assumed that it is smaller than 0.5 ha. In addition, the areas that have been converted to other land use after afforestation or reforestation are missing from the reported AR areas.

The deforested areas were compared to the forest statistics for other cuttings, which include, e.g., fellings done along ditch and road-construction lines and fellings when clearing land for agricultural purposes (Finnish Statistical Yearbook of Forestry 2012). The deforested areas of the report and the statistics resemble each other in magnitude despite the difficulties in comparing them (Table 11.3-3). It is not evident whether all the areas converted to settlements are included in the statistics. At least the conversions from forest to wetlands (drained peatlands) are not included. Storm damages were substantially larger in forests in 2010 than in previous years, which may explain the increase of the area in the statistics. Fellings in forests damaged by storms are reported under other fellings in the statistics and the statistical deforestation area is derived from them (Finnish Statistical Yearbook of Forestry 2012).

**Table 11.3-2** Comparison of reported afforestation and reforestation areas with the statistics (areas in 1 000 ha)

Year	AR of cropland and grassland	AR total	Afforestation of arable land in Metla's statistics
1990	10.5	13.5	8.5
1991	11.1	14	10.5
1992	10.6	13.8	17.1
1993	9.2	12.3	17.7
1994	9.5	12.8	8.8
1995	8.7	12.1	4.1
1996	8.1	11.8	9
1997	7.4	10.4	9.3
1998	7.5	10.6	7.1
1999	6.1	8.8	6.2
2000	4.9	6.9	5.8
2001	4.1	5.5	6
2002	3.4	4.7	2.7
2003	2.5	3.5	2
2004	3	4.1	2.4
2005	3	3.9	2.3
2006	2.7	3.7	2.3
2007	2.8	3.8	3.1
2008	2.6	3.3	3.5
2009	2	2.3	3.6
2010	1.9	2.2	2.9
2011	1.6	1.8	2.2
2012	1.3	1.4	1.7
<b>All</b>	<b>124.4</b>	<b>167.3</b>	<b>138.7</b>

**Table 11.3-3** Comparison of reported deforestation areas with the statistics (areas in 1 000 ha)

Year	Deforestation	Deforestation in Metla statistics	Difference
1990	6.8	4.1	2.7
1991	7.9	3.7	4.2
1992	8.7	4.6	4.1
1993	9.8	8	1.8
1994	10.5	13.7	-3.2
1995	11	5.7	5.3
1996	11.6	5.1	6.5
1997	13.2	5	8.2
1998	13.8	6.1	7.7
1999	14.9	4.8	10.1
2000	16.1	8.3	7.8
2001	18.4	11.2	7.2
2002	19.3	11.6	7.7
2003	20.6	11.1	9.5
2004	22.5	14.7	7.8
2005	22.2	8.8	13.4
2006	20.3	9.6	10.7
2007	18.8	9.7	9.1
2008	16.7	10.7	6
2009	13.1	12.8	0.3
2010	10.8	27.3	-16.5
2011	9.6	15.2	-5.6
2012	7.7	17.47	-9.77
<b>All</b>	<b>324.3</b>	<b>229.27</b>	<b>95.03</b>

#### 11.3.1.5 Information on other methodological issues

Finland has decided to account for the emissions and removals under Article 3, paragraphs 3 and 4 at the end of the commitment period. Finland has developed the methods for area estimation as well the methods for estimating the emissions and removals of greenhouse gases and their uncertainties during the first commitment period. For that reason, the estimates presented in this submission for the years 2008-2011 have changed since the previous submission .

#### 11.3.1.6 The year of the onset of an activity, if after 2008

Not relevant for the Finnish inventory (no such activities).

## 11.4 Article 3.3

Finland reports all emissions by sources and removals by sinks from AR activities under Category A.1.1 Afforestation/Reforestation: units of land not harvested. Finland interprets harvesting as the clear cutting done in short rotation forests; thinnings are not included (GPG LULUCF 2003, p. 4.55). Forests afforested or reforested since 1990 have not reached their regeneration age by the first commitment period. According to guidance for good silviculture, the rotation time varies from 50 to 160 years depending on the tree species, the site fertility and the geographical location of a forest.

### *Subcategories of ARD-lands*

Finland has subdivided the ARD areas according to the land-use change and soil types. Emissions and removals are reported for seven AR types and eight D types. The subdivision name refers to the initial (AR) or current (D) land-use category. The AR types and their codes in the CRF tables are as follows:

- Cropland, mineral soils (CLmin)
- Cropland, organic soils (CLorg)
- Grassland, mineral soils (GLmin)
- Grassland, organic soils (GLorg)
- Wetlands, peat soil (WLorg)
- Wetlands, peat extraction (WLpeat)
- Settlement (SL).

The D types are as follows:

- Cropland, mineral soils (CLmin)
- Cropland, organic soils (CLorg)
- Grassland, mineral soils (GLmin)
- Grassland, organic soils (GLorg)
- Wetlands, peat soil (WLorg)
- Wetlands, peat extraction (WLpeat)
- Wetlands, inland waters (WLwaters)
- Settlement (SL).

The areas of Article 3.3 activities are estimated in the manner described in Section 11.2.2. The cumulative sum of areas afforested/reforested and deforested since 1990 is provided in Table 11.4-1 and shown also in Figure 11.4-1.

**Table 11.4-1** Cumulative sums of areas under Article 3.3 activities for Afforestation/Reforestation and Deforestation (ha).

	Afforestation/Reforestation			Deforestation		
	Region_1	Region_2	Total	Region_1	Region_2	Total
1990	10 184	3 334	13 518	5 580	1 174	6 754
1991	20 740	6 741	27 481	11 944	2 714	14 658
1992	30 534	10 728	41 262	19 036	4 326	23 362
1993	38 728	14 801	53 529	26 863	6 347	33 210
1994	47 377	18 919	66 296	35 167	8 568	43 735
1995	55 485	22 941	78 426	43 440	11 279	54 719
1996	63 385	26 860	90 245	52 166	14 196	66 362
1997	70 591	30 030	100 621	61 600	17 973	79 573
1998	77 874	33 349	111 223	71 883	21 499	93 382
1999	83 794	36 232	120 026	82 886	25 417	108 303
2000	88 516	38 458	126 974	94 565	29 805	124 370
2001	92 178	40 319	132 497	108 024	34 724	142 748
2002	95 339	41 816	137 155	121 675	40 413	162 088
2003	97 976	42 692	140 668	136 246	46 421	182 667
2004	101 120	43 668	144 788	151 454	53 663	205 117
2005	104 237	44 499	148 736	166 247	61 110	227 357
2006	107 319	45 121	152 440	179 279	68 378	247 657
2007	110 294	45 984	156 278	192 106	74 390	266 496
2008	112 912	46 697	159 609	202 970	80 211	283 181
2009	114 800	47 098	161 898	212 163	84 156	296 319
2010	116 489	47 580	164 069	220 197	86 892	307 089
2011	117 911	47 982	165 893	227 645	89 061	316 706
2012	119 061	48 223	167 284	233 710	90 668	324 378

#### *11.4.1 Information that demonstrates that the activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2012 and are directly human-induced*

Changes in the forest area are detected based on NFI sample plot data. The land-use category at the end of 1989 was assessed either during the field measurements or by interpretation based on aerial photos and satellite images. Since the land-use category just before 1 January 1990 was known, the reported land-use changes have occurred since then. Each type of land-use change since 1990 is known and the changes that were not directly human-induced have been excluded from the reporting. Changes that are not directly human-induced occur when due to the land lift seawater turns to land and, thereafter, gradually into forest. In addition, the conversion from other land to forest land was excluded since that transition type is not human-induced; rather, it is a natural occurrence.

The reported AR activities are directly human-induced because those activities are based on decisions not to continue with the previous activities and to use the forest management activities instead. This means that the area is changed into forest land and that the Forest Act is then applied to the area (Forest Act 1093/1996). Usually, the area is planted or seeded. In some cases, the area can be left to naturally revert to forest land, such as when the area is surrounded by one owner's forest and the edge forest is not too far away. This method is carried out on arable lands where natural seedlings grow instantly once the land is no longer being farmed. Another case is a wetland on which a sparse tree cover has existed before drainage. The drainage changes the site's water conditions and enhances tree growth and vitality. The change to forest does not happen as quickly as on arable lands and the drainage and other silvicultural activities require maintenance. The unit of land is not accounted for as AR area until it is evident that the seedlings (planted, seeded or

natural origin) are expected to reach the parameter thresholds of the forest at maturity. The situation is assessed in the NFI sample plot that is filed.

The reported D activities are directly human-induced. Either a plan approved by the authorities or a permit is needed to change the land use from forest to other use (Land Use and Building Act 132/1999, Forest Act 1093/1996). Forest owners have to make an announcement to the forestry authority and have the appropriate permits when a forest area is felled and the land used for a different purpose. Depending on the conversion type, the permits may be obtained from agricultural, environmental or local administrations. Permission is needed for all reported D-type activities except for the conversion of land from forest to wetlands (WLorg). That type of conversion is in contrast to land being converted from wetlands to forest (WLorg). While the area satisfies the definition of a forest after the drainage, it is, according to current forest management guidelines, considered unprofitable and FM practices are no longer applied. Because the drainage is not maintained, the ditches will be blocked or filled in by vegetation and the growth of trees will regress.

#### *11.4.2 Information on how harvesting or forest disturbance that is followed by the re-establishment of forest is distinguished from deforestation*

Extensive forest disturbances have been rare in Finland. If a large forest area is totally damaged, the legislation on the prevention of insect and fungus disturbances in forests requires that the owner remove the rest of the damaged trees. After that, the re-establishment work should be started immediately, if possible.

Finnish forest area is treated with clear cuttings of 90,000 to 170,000 ha annually (Finnish Statistical Yearbook of Forestry 2012). When a clear-cut area is located in an NFI sample plot, the surveyor assesses whether the cutting has been done for regeneration purpose or for land-use change. The distinction between these two cases can generally be made on a reliable basis. Clear signs of a land-use change can be seen in the surrounding and location of the area: construction projects, stacked cutting residuals or if the area is under a regional or town plan. The re-establishment of a forest usually starts within two years after the harvesting. The Forest Act lays down provisions that a new forest must be established within three years after the regeneration cutting.

#### *11.4.3 Information on the size and geographical location of forest areas that have lost forest cover but which are not yet classified as deforestation*

Clear-cut forest areas that have not been classified as deforestation lands were classified as temporarily unstocked forests. Cutting areas in the years 2008-2012 were as follows (Finnish Statistical Yearbook of Forestry 2013):

**Table 11.4-2** Clear-cut forest areas (1 000 ha)

	2008	2009	2010	2011	2012
Region 1	90.6	63.6	101.4	73.4	84.7
Region 2	17.5	28.9	43.4	35.7	37.5
Total	108.1	92.5	144.8	109.1	122.2

#### *11.4.4 Emissions and removals under Article 3.3*

The AR activities were a net sink of 135 Gg CO<sub>2</sub> eq. in 2012 and the D activities were a net source of 2,486 Gg CO<sub>2</sub> eq. (Table 11.4-3).

**Table 11.4-3** Net emissions and removals from the activities under Articles 3.3, Gg CO<sub>2</sub> eq.

	Afforestation (A) / Reforestation ( R )							Deforestation (D)										Items not in CRF	
	Forest Biomass (gains)	Agricultural biomass (losses)	DOM+SOM Mineral soils	DOM+SOM Organic soils	Biomass Burning	Drained organic soils, N2O	Total	Forest Biomass (losses)	Agricultural biomass (gains)	DOM+SOM Mineral soil	Litter+SOM Organic soil	Dead wood	Conversion to water CO2	Conversion to cropland N2O	Liming	Conversion to peat extraction and to regressed land, N2O	Total	Conversion to peat extraction, CH4	Conversion to water, CH4
	Gg CO2eq							Gg CO2eq										Gg CO2eq	
1990	-41	63	38	34	NO	2.2	96	983	-28	10	5	13	NO	0.1	12	0.0	995	0	NO
1991	-84	63	68	69	NO	4.5	120	1 125	-36	21	15	14	NO	0.2	16	0.4	1 155	0	NO
1992	-126	56	91	103	NO	6.7	130	1 228	-40	32	31	15	NO	0.3	18	1.0	1 284	1	NO
1993	-165	44	104	134	NO	8.6	126	1 368	-44	43	54	17	NO	0.4	21	2.0	1 461	1	NO
1994	-205	51	117	164	NO	10.5	138	1 459	-45	54	80	18	NO	0.6	22	3.1	1 591	2	NO
1995	-243	49	125	190	NO	12.2	134	1 478	-47	63	110	19	NO	0.7	23	4.2	1 651	2	NO
1996	-280	53	127	217	NO	13.9	131	1 573	-48	73	141	21	NO	0.9	25	5.2	1 791	3	NO
1997	-313	55	126	240	NO	15.3	123	1 779	-64	85	179	25	NO	1.1	33	5.8	2 044	3	NO
1998	-347	59	128	264	NO	16.6	120	1 918	-73	97	217	25	NO	1.3	38	6.2	2 229	3	NO
1999	-375	48	123	283	NO	17.8	97	2 068	-84	111	263	26	0.16	1.6	45	6.8	2 438	3	0.02
2000	-398	39	114	299	NO	18.8	73	2 229	-98	126	321	28	0.31	1.9	53	7.4	2 669	4	0.05
2001	-416	32	103	312	NO	19.7	51	2 601	-118	144	386	31	0.47	2.2	64	8.0	3 118	4	0.07
2002	-431	26	92	322	NO	20.4	30	2 706	-132	162	461	32	0.63	2.7	72	8.5	3 313	4	0.10
2003	-442	18	80	327	NO	20.9	3	2 887	-143	181	544	34	0.79	3.1	77	9.3	3 593	5	0.12
2004	-455	17	71	332	NO	21.5	-13	3 108	-148	197	628	40	0.79	3.5	76	10.2	3 915	5	0.12
2005	-466	13	63	336	NO	22.0	-32	3 057	-141	210	710	41	0.79	3.9	69	11.4	3 962	6	0.12
2006	-477	9	58	338	NO	22.3	-50	2 743	-122	218	790	40	0.79	4.1	59	12.8	3 745	6	0.12
2007	-489	7	53	340	NO	22.7	-66	2 590	-93	224	861	37	0.79	4.3	44	14.8	3 683	7	0.12
2008	-499	7	46	344	0.022	23.1	-79	2 260	-74	228	924	34	0.79	4.4	35	16.8	3 430	8	0.12
2009	-505	5	40	345	0.013	23.3	-92	1 847	-58	231	978	26	0.63	4.6	29	18.5	3 076	9	0.12
2010	-512	4	34	337	0.013	23.6	-114	1 582	-47	227	1020	20	0.47	4.7	25	19.8	2 852	10	0.12
2011	-517	5	26	329	NO	23.8	-133	1 442	-40	222	1058	17	0.31	4.8	22	21.1	2 748	11	0.12
2012	-521	2	19	320	NO	23.9	-157	1 183	-37	215	1087	13	0.16	4.9	20	21.9	2 508	11	0.12

The common reporting format does not allow reporting of CH<sub>4</sub> and N<sub>2</sub>O emissions from lands deforested for peat extraction and CH<sub>4</sub> emissions from lands deforested for inland waters. The net emissions for these lands have been given in Table 11.4-4.

**Table 11.4-4** Net emissions of CH<sub>4</sub> and N<sub>2</sub>O from lands deforested to peat extraction and inland waters since 1990, Gg CO<sub>2</sub> eq. in 2008-2012

		2008	2009	2010	2011	2012
Peat extraction						
Region 1	CH <sub>4</sub>	6.05	6.74	7.28	7.91	8.31
	N <sub>2</sub> O	11.56	12.89	13.92	15.12	15.89
	Total	17.61	19.63	21.20	23.02	24.20
Region 2	CH <sub>4</sub>	2.43	2.66	2.77	2.85	2.85
	N <sub>2</sub> O	4.65	5.08	5.30	5.44	5.44
	Total	7.09	7.74	8.07	8.29	8.29
Total		24.69	27.38	29.27	31.31	32.49
Inland waters						
Region 1	CH <sub>4</sub>	0.120	0.120	0.120	0.120	0.120
Region 2	CH <sub>4</sub>	NO	NO	NO	NO	NO
Total		0.120	0.120	0.120	0.120	0.120

## 11.5 Article 3.4

### 11.5.1 Information that demonstrates that the activities under Article 3.4 have occurred since 1 January 1990 and are human-induced

Forest area, AR and D area were calculated for the years 1990-2012 using the national forest inventory data (see Sections 11.2.2 and 11.4.1). Lands that were forests on 1 January 1990 were included under FM because Finland considers all forests to be managed. It is not possible to leave out any forest areas from FM activities except for those categorized as AR lands, and therefore all FM activities have occurred in or after 1990 and have been human-induced.

### 11.5.2 Information relating to Forest Management

Finland interprets the definition for forest management using a broad approach. FM is a system of forest management practices that occur within two identified areas: Region 1 and Region 2 (Figure 11.2-1). In commercially managed forests, fellings for natural and artificial regeneration, site preparation, drainage, planting, seeding, thinnings, pruning, fertilisation, the harvesting of cutting residues and the conservation of important habitats are all practices that occur at stand-level. In practice, these activities are directed by the Forest Act, the Forest Decree and forest management guidance procedures. The National Forest Programme, Regional Forestry Programmes and the management plan for state-owned forests define the rules for sustainable forest management in Finland. Protected forest areas are also covered by the management plans, which are prepared for the national and regional level, for the landscape level and for individual conservation areas. All forests, both those that are commercially managed and the protected areas, are under fire prevention watch. To some extent, fires inside protected areas are allowed, but generally all fires are put out as soon as possible due to the fire follow-up system.

The area under forest management for the years 1989-2012 is provided in Table 11.5-1.

**Table 11.5-1** Area of forest management since 31 December 1989 (1 000 ha)

	Region_1	Region_2	Total
1989	11 578	10 573	22 151
1990	11 572	10 572	22 144
1991	11 566	10 570	22 136
1992	11 559	10 569	22 128
1993	11 551	10 567	22 118
1994	11 543	10 564	22 107
1995	11 535	10 562	22 096
1996	11 526	10 559	22 085
1997	11 516	10 555	22 071
1998	11 506	10 551	22 058
1999	11 495	10 548	22 043
2000	11 483	10 543	22 027
2001	11 470	10 538	22 008
2002	11 456	10 533	21 989
2003	11 442	10 527	21 968
2004	11 427	10 519	21 946
2005	11 412	10 512	21 924
2006	11 399	10 505	21 903
2007	11 386	10 499	21 884
2008	11 375	10 493	21 868
2009	11 366	10 489	21 855
2010	11 358	10 486	21 844
2011	11 350	10 484	21 834
2012	11 344	10 482	21 827



### *11.5.2.1 Information that FM conforms with the forest definition*

Forest management activity is practised in forest areas as defined above. At the end of 1989, the area of forests and the area under FM were equal. The area under FM was calculated using the same forest inventory database as the forest area.

### *11.5.2.2 Forest management is a system of practices for stewardship and use of forest land aimed at fulfilling the relevant ecological (including biological diversity), economic and social functions of the forest in a sustainable manner (paragraph 1(f) of the annex to Decision 16/CMP.1 on land use, land-use change and forestry)*

Private forest owners manage 65% of Finland's forests and the state and forest companies own the rest. In general, private forest owners and forest companies manage their forest for wood production. Wood production is an important area of operation in state-owned forests too, but the ecological and social functions are also a priority. Biological diversity also plays a significant role in private forests and those owned by companies. The Forest Act and Forest Decree regulate all forests.

The Forest Act lays down provisions on the management and utilisation of forests. The purpose of the Forest Act is to ensure that forests are managed and utilised in an economically, ecologically and socially sustainable manner and that forests provide a sustainable satisfactory yield while at the same time maintaining biological diversity (Forest Act 1093/1996). The Forest Act is not applied to all forests; some forests are under the Nature Conservation Act (protected areas), the Land Use and Building Act (protection areas) and the Act on Wilderness Reserves.

The Forest Act applies to forests in areas that are classified as forestry land. The Forest Act lays down provisions on changing the form of land use, the regional target programme for forestry, fellings and the regeneration of forest, safeguarding the diversity of forests' habitats, timberline forests and protection zones and legal instructions and consequences.

The regional forestry administration, that is, the thirteen regional units of the Finnish Forestry Centres, draw up a target programme for forestry with general objectives to promote sustainable management and the use of forests. The Finnish Forestry Centres monitor the implementation of the forestry programme. The Ministry of Agriculture and Forestry prepares the National Forest Programme, which the Finnish Government approves. The present programme extends through the year 2015.

Among other things, the Finnish Forestry Centres give guidance to private forest owners on forest management and on conserving forest nature and they supervise the Forest Act within their own regions. Metsähallitus is responsible for the state-owned forests. In both privately owned forests and state-owned forests, silvicultural measures are implemented according to the silvicultural guidelines, which are based on long-term practical experience and research results.

## *11.5.3 Emissions and removals from Forest Management*

Forest management was a net sink of -35,596 Gg CO<sub>2</sub> eq. in 2012. The net removals from carbon stock changes were -36,791 Gg CO<sub>2</sub> and the emissions from drainage of organic soils, biomass burning and N fertilisation were 1,194 Gg CO<sub>2</sub> eq. (Table 11.5-2).

**Table 11.5-2** Net emissions and removals from the activities under Article 3.4 (Gg CO<sub>2</sub> eq.).

	Biomass	DOM+SOM <i>mineral soils</i>	DOM+SOM <i>organic soils</i>	Forest Management					Total
				Biomass burning			Fertilization	Drained organic soils	
				CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	N <sub>2</sub> O	N <sub>2</sub> O	
				Gg CO <sub>2</sub> eq.					
1990	-27 821	-7 730	12 175	3	4	0	27	1 128	-22 213
1991	-42 735	-7 347	12 325	2	2	0	20	1 131	-36 602
1992	-35 755	-7 464	11 711	9	3	0	9	1 134	-30 354
1993	-33 151	-7 837	11 253	0	1	0	3	1 137	-28 593
1994	-24 082	-8 736	10 619	7	2	0	12	1 139	-21 038
1995	-22 570	-9 652	10 177	4	2	0	6	1 142	-20 890
1996	-30 651	-10 668	10 069	4	1	0	8	1 145	-30 092
1997	-24 182	-10 828	9 443	10	2	0	13	1 147	-24 395
1998	-21 871	-10 810	8 865	1	1	0	13	1 150	-22 651
1999	-24 321	-11 009	8 618	5	2	0	10	1 150	-25 544
2000	-25 925	-10 594	8 431	3	1	0	10	1 152	-26 922
2001	-31 066	-9 870	8 317	2	3	0	11	1 152	-31 452
2002	-31 865	-9 320	8 081	5	3	0	12	1 154	-31 929
2003	-32 445	-8 603	7 991	6	2	0	11	1 156	-31 881
2004	-34 203	-8 008	7 979	3	1	0	12	1 158	-33 058
2005	-38 758	-8 208	8 047	4	1	0	11	1 160	-37 742
2006	-42 564	-8 075	8 137	13	2	0	18	1 163	-41 305
2007	-34 058	-7 118	7 830	5	1	0	17	1 164	-32 159
2008	-39 447	-7 474	7 752	8	1	0	35	1 167	-37 958
2009	-50 180	-7 893	7 990	5	1	0	25	1 169	-48 884
2010	-34 658	-7 193	7 417	5	1	0	23	1 171	-33 235
2011	-35 206	-6 935	7 363	5	1	0	21	1 173	-33 577
2012	-36 519	-7 850	7 579	1	0	0	15	1 176	-35 598

## *11.6 Other information*

### *11.6.1 Key category analysis for Article 3.3 activities and elected activities under Article 3.4*

Key category analysis for KP-LULUCF was performed according to Section 5.4 of the GPG LULUCF 2003. The key categories, which are also reported in CRF Table NIR.3, are CO<sub>2</sub> removals due to afforestation/reforestation and CO<sub>2</sub> emissions from deforestation. CO<sub>2</sub> removals due to forest management are also a key category.

## *11.7 Information relating Article 6*

No projects under Article 6 are implemented in Finland.

## Appendix\_11a

### *Identification of ARD Activities*

The areas of ARD activities were calculated using National Forest Inventory data (NFI). The data included field records from the 10<sup>th</sup> and 11<sup>th</sup> NFI database measured in 2005-2008 (NFI10) and 2009-2012 (NFI11). The field measurements are carried out in five-year cycles for NFI plots and combined NFI10 and NFI11 data from 5 measurement years were utilised for area estimations. To avoid recalculating the time series, the measurement years 2005-2009 were used when possible, i.e. for the years 1990-2004. Land-use changes may have occurred in the latter part of the measurement year after the field data collection; therefore, the data were only applied for the years preceding the measurements. To provide a full dataset also for the latest years, land-use information of the NFI data was updated by means of aerial photo interpretation to the end of 2012. Interpretation used newest possible aerial photos made freely available by Land Survey of Finland (Land Survey of Finland 2013). There were also other data sources for the updating, i.e., Landsat images and land parcel register for croplands. Land-use changes were estimated as five-year moving averages in order to decrease the sampling error caused by a small number of sample plots, where land-use change has occurred in one specific year.

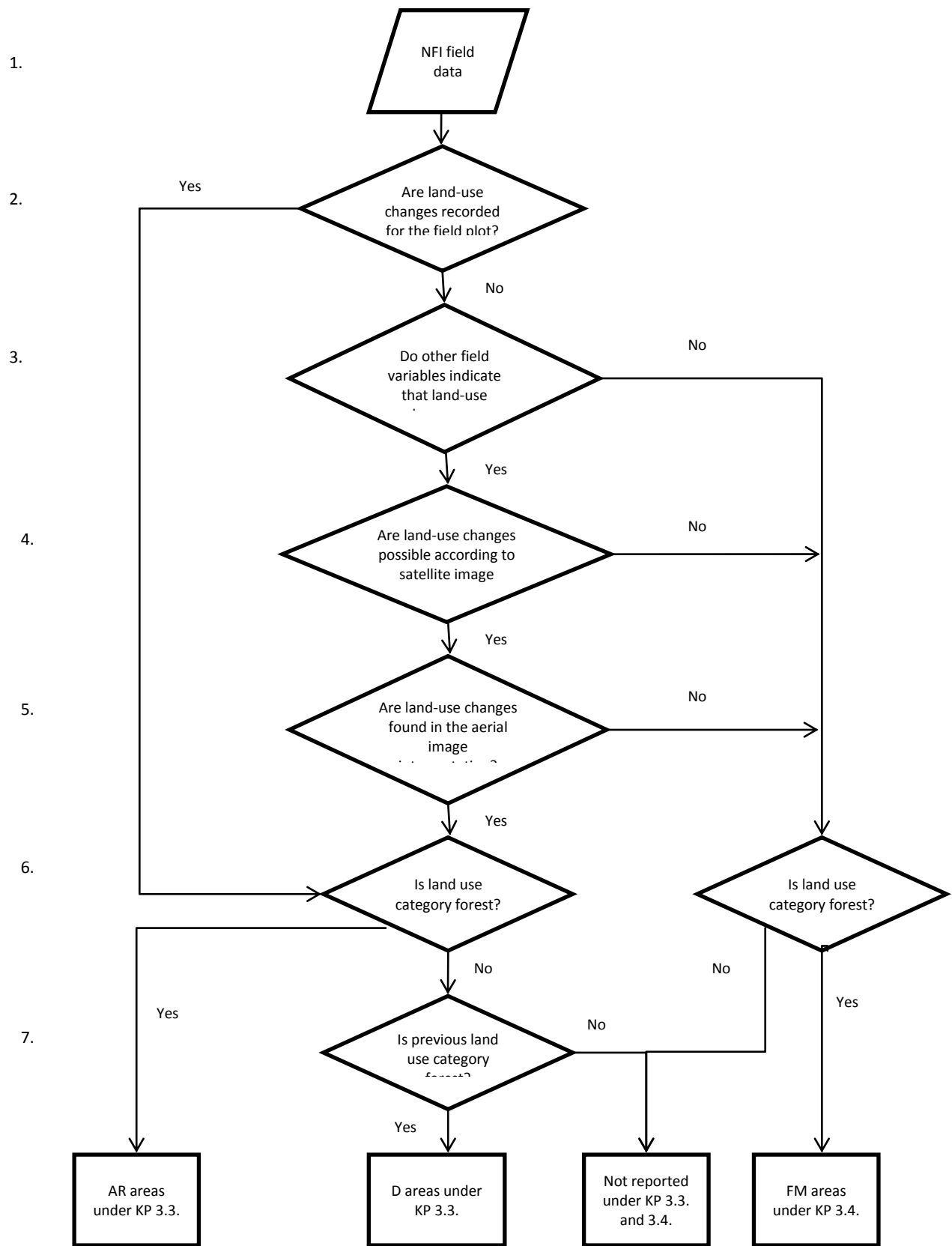
Land-use changes are recorded in NFI for past 20 years or since 1990. In addition, plots with no recorded land use change were checked by means of other field parameters, remote sensing data and when found possible changes, then interpreted from aerial images. The NFI data were complemented by the findings of image interpretation. The image interpretation is also described in the flow chart (Fig. 2\_App\_11a):

1. Updated NFI data were used for calculating FM, AR and D areas.
2. Plots where AR and D activities were recorded were utilised in the area calculations.
3. In addition, in the plots where land-use changes were not observed in the field, the possibility of land-use changes was double-checked by means of other field variables, for example the stand age of the forest was utilised.
4. If land-use changes were considered possible according to field variables, a satellite image interpretation was carried out. Old numerical maps and thematic maps were also utilised both with 25 m resolution. The satellite images were Landsat TM images from the years 1987-1994.
5. At the final stage, an aerial image interpretation was carried out to detect land-use changes. The aerial images had a 0.5 meter resolution and they were from around the year 1990.

The number of plots and plots with land use changes is given in Section 7.1.3. Plots were plotted on the images for interpretation (Fig. 1\_App\_11a).



**Figure 1\_App\_11a** Land use in NFI plots with no land use changes detected in the field were checked from old map data, satellite images and thematic maps to find possible missed land-use changes. In the example above land use has been converted from forest land to cropland (images from 1990 and 2009). Aerial photo 1990 ©Topografikunta and aerial photo 2009 © Land Survey of Finland 53/MML/11



**Figure 2\_App\_11a** A flow chart of the calculation procedure for forest management, afforestation, reforestation and deforestation areas

# 12 INFORMATION ON ACCOUNTING OF KYOTO UNITS

## 12.1 Background information

The standard electronic format tables are included in the submission (see SEF\_FI\_2014-1\_10-30-11 10-1-2014.xls). The SEF tables include information on the AAU, ERU, CER, t-CER, l-CER and RMU in the Finnish registry 31.12.2013 as well as information on transfers of the units in 2013, to and from other Parties of the Kyoto Protocol.

## 12.2 Summary of information reported in the SEF tables

The total number of AAU units in the registry at the end of the year 2013 corresponded to 326,415,793 tonnes CO<sub>2</sub> eq.

The number of units of ERU in registry corresponded to 6,394,971 tonnes CO<sub>2</sub> eq.

The units of CERs in the registry corresponded to 15,802,968 tonnes CO<sub>2</sub> eq.

The registry did not contain any RMUs, t-CERs or l-CERs. And no units were in the Article 3.3/3.4 net source cancellation accounts and the t-CER and l-CER replacement accounts.

The total amount of the units in the registry corresponded to 348,613,732 tonnes CO<sub>2</sub> eq. Finland's assigned amount is 355,017,545 tonnes CO<sub>2</sub> eq.

## 12.3 Discrepancies and notifications

No discrepancies and notifications occurred in 2013.

## 12.4 Publicly accessible information

Part of publicly accessible information is on the webpages of the Energy Authority (<http://www.energiavirasto.fi/en/web/energy-authority/public-reports>), who is the national administrator of the Finnish part of the Union registry and part of the information is on the [European Union Transaction Log](#) webpages:

### **Public information required by Decision 13/CMP.1:**

Account information

JI projects in Finland

Holding and transaction information of units

Account holders authorised to hold Kyoto units in their account

### **Public information in accordance with the Act on the use of Kyoto mechanisms (109/2007):**

Approvals and authorisations concerning JI projects given by the Ministry of the Environment

Approvals and authorisations concerning CDM projects given by the Ministry for Foreign Affairs of Finland

### **Public information in accordance with the Commission regulation (EU) N:o 389/2013:**

On the webpage of the European Union Transaction Log (EUTL)

### **Other public information:**

National allocation plan for Finland (NAP), original allocation decision

Maximum amounts of project units (CER, ERU) that installations can use for surrendering, original allocation decision

National allocation plan for Finland (NAP) and maximum amounts of projects units (CER, ERU) that installations can use for surrendering, current situation in the registry

Allocated allowances vs. verified emissions (in Finnish only)

## 12.5 Calculation of the commitment period reserve (CPR)

Finland's assigned amount is 355,017,545 tonnes of CO<sub>2</sub> eq. and the commitment period reserve, calculated as 90% of the assigned amount amounts to 319,515,790 tonnes of CO<sub>2</sub> eq.

The commitment period reserve has not changed since the previous submission, as 100 per cent times the most recent inventory would amount to a higher value (2012 inventory: 60,965,731 tonnes of CO<sub>2</sub> eq. times five equals 304,828,656 tonnes of CO<sub>2</sub> eq.).

## 12.6 KP-LULUCF accounting

Finland has elected accounting of all KP-LULUCF activities at the end of the commitment period. No information on the accounting of the KP-LULUCF is therefore included in the SEF tables.

In Table 12.6-1 data on accounting for the KP-LULUCF activities based on the reporting for the year 2012 are given. According to this information, Finland would at the end of the commitment period be able to issue RMUs corresponding to the amount of 2.9 Tg CO<sub>2</sub> eq., which is Finland's cap value for forest management for the whole commitment period

**Table 12.6-1** Information table on accounting for activities under Articles 3.3 and 3.4 of the Kyoto Protocol

GREENHOUSE GAS SOURCE AND SINK ACTIVITIES	Emissions / removals in the base year	Net emissions/removals						Accounting parameters	Accounting quantity	
	2008	2009	2010	2011	2012	Total				
	(Gg CO <sub>2</sub> equivalent)									
A. Article 3.3 activities										
A.1. Afforestation and Reforestation										- 476
A.1.1. Units of land not harvested since the beginning of the commitment period		- 62	- 74	- 94	- 112	- 135	- 476			- 476
A.1.2. Units of land harvested since the beginning of the commitment period		NA	NA	NA	NA	NA	NA			NA
Region 2		NA	NA	NA	NA	NA	NA			NA
Region 1		NA	NA	NA	NA	NA	NA			NA
A.2. Deforestation		3 413	3 057	2 832	2 727	2 486	14 516			14 516
B. Article 3.4 activities										
B.1. Forest Management (if elected)		-37 958	-48 884	-33 235	-33 577	-35 596	-189 250			-16 973
3.3 offset								14 040		-14 040
FM cap								2 933		-2 933
B.2. Cropland Management (if elected)	0	NA	NA	NA	NA	NA	NA	0		0
B.3. Grazing Land Management (if elected)	0	NA	NA	NA	NA	NA	NA	0		0
B.4. Revegetation (if elected)	0	NA	NA	NA	NA	NA	NA	0		0



## *13 INFORMATION ON CHANGES IN NATIONAL SYSTEM*

No changes were implemented in Finland's national system during 2012.

# 14 INFORMATION ON CHANGES IN NATIONAL REGISTRY

The following changes to the national registry of Finland have therefore occurred in 2013.

**Table 14.1-1** Changes to the national registry of Finland

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(a) Change of name or contact	No change in the name or address information of the registry administrator occurred during the reported period. However, at the beginning of 2014 the name of the Energy Market Authority was changed to Energy Authority. The address and phone number of the Authority will remain unchanged and they are available on the homepage: <a href="http://www.energiavirasto.fi/en/web/energy-authority/home">http://www.energiavirasto.fi/en/web/energy-authority/home</a>
15/CMP.1 annex II.E paragraph 32.(b) Change regarding cooperation arrangement	No change of cooperation arrangement occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(c) Change to database structure or the capacity of national registry	An updated diagram of the database structure is attached as Annex A. Iteration 5 of the national registry released in January 2013 and Iteration 6 of the national registry released in June 2013 introduces changes in the structure of the database. Changes introduced in release 5 and 6 of the national registry were limited and only affected EU ETS functionality. No change was required to the database and application backup plan or to the disaster recovery plan. No change to the capacity of the national registry occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(d) Change regarding conformance to technical standards	Changes introduced in release 5 and 6 of the national registry were limited and only affected EU ETS functionality. However, each release of the registry is subject to both regression testing and tests related to new functionality. These tests also include thorough testing against the DES and were successfully carried out prior to the relevant major release of the version to Production (see Annex B). Annex H testing was carried out in February 2014 and the successful test report has been attached. No other change in the registry's conformance to the technical standards occurred for the reported period.
15/CMP.1 annex II.E paragraph 32.(e) Change to discrepancies procedures	No change of discrepancies procedures occurred during the reported period.
15/CMP.1 annex II.E paragraph 32.(f) Change regarding security	No change of security measures occurred during the reporting period
15/CMP.1 annex II.E paragraph 32.(g) Change to list of publicly available information	Finland has added the relevant links, according to the assessor recommendations, on the website of the national registry so that the public information (containing the account information and the information of legal entities) is now controlled by the Party. The information is updated on a monthly basis. Public reports are available on the Energy Authority's website: <a href="https://www.beta.ev.soft.ware.fi/en/web/energy-authority/public-reports">https://www.beta.ev.soft.ware.fi/en/web/energy-authority/public-reports</a>
15/CMP.1 annex II.E paragraph 32.(h) Change of Internet address	No change of the registry internet address occurred during the reporting period.

Reporting Item	Description
15/CMP.1 annex II.E paragraph 32.(i) Change regarding data integrity measures	No change of data integrity measures occurred during the reporting period.
15/CMP.1 annex II.E paragraph 32.(j) Change regarding test results	Changes introduced in release 5 and 6 of the national registry were limited and only affected EU ETS functionality. Both regression testing and tests on the new functionality were successfully carried out prior to release of the version to Production. The site acceptance test was carried out by quality assurance consultants on behalf of and assisted by the European Commission; the report is attached as Annex B. Annex H testing was carried out in February 2014 and the successful test report has been attached.

The Decision 280/2004/EC of the European Parliament and of the Council requires EU member states to provide information on the legal entities authorised to participate in the mechanism under Articles 6, 12 and 17 of the Kyoto Protocol in the National Inventory report. This information is provided in the Annex 7.

## 15 INFORMATION ON MINIMISATION OF ADVERSE IMPACTS IN ACCORDANCE WITH ARTICLE 3, PARAGRAPH 14

Finland has provided information on minimization of adverse impacts in accordance with Article 3, paragraph 14 in previous national inventory reports and national communications in accordance with the guidelines for the preparation of the information required under Article 7 of the Kyoto Protocol (Decision 15/CMP.1, Section I. H. and in paragraph 36 in Section II. G.). The information was updated in Finland's 6th National Communication and the corresponding changes have been incorporated into this inventory report. The main principles of minimising adverse impacts have not changed since the previous inventory submission. However, in the reporting has been updated and complemented. More emphasis has been put to describe how Finland strives to minimise adverse impact in other countries and the areas prioritized in this context.

Finland strives to implement its commitments under the Kyoto Protocol in such a way that social, environmental and economic impacts on other countries, and on developing countries in particular, are minimised. Applicable notification requirements under international trade conventions are also followed. Finland takes into account knowledge on and understanding of the possible adverse impacts of its measures based on available information received from other Parties.

All major policies and activities undergo environmental impact assessment, including impacts in other countries. Environmental impact assessments have been performed on Finland's national energy and climate strategies. The assessments have identified on a qualitative level the kind of impacts that the measures may have. A lifecycle analysis of fuel import takes into account impacts arising beyond the Finnish borders. Finland has also participated in the work on developing sustainability criteria for biofuels through scientific studies. In line with the most recent energy and climate strategy, the identified potential adverse environmental impacts due to the increased use of bioenergy are addressed as early as possible.

Finland strives to minimise the adverse effects of climate change on developing countries by including in its development policy both climate change mitigation and adaptation in developing countries (see Chapter 7 of Finland's 6<sup>th</sup> National Communication for more details). Finland promotes low carbon development and the capacity of its partner countries to adapt to climate change, and it furthers the integration of these goals into partner countries' own development planning. Particular attention is paid to the roles of women, children and indigenous peoples in adapting to and combating climate change. Finland has adopted a climate sustainability tool for assessing the climate change impacts of its development policy and preventing the adverse impacts of climate change, including disaster risk reduction. Thus, climate change has been mainstreamed in Finland's development programming. Finland aims to support programmes and projects that focus on saving energy, increasing energy efficiency and promoting renewable energy production, focusing on poor countries and regions in particular. According to its development policy, Finland supports access to sustainable renewable energy and also promotes energy and overall resource efficiency and research on those issues. In its own development cooperation, Finland aims to achieve carbon neutrality as soon as possible.

Finland's Development Policy Programme has the eradication of extreme poverty as an overarching goal. Regarding the minimisation of adverse social impacts, the Ministry for Foreign Affairs commissioned a study on integrating poverty reduction and climate change response measures in Finland's development cooperation and CDM activities. The results showed that the level of coherence between climate funding and development co-operation objectives has progressed, although there is still room for learning how to focus in particular on CDM activities in such a way that they also contribute to poverty reduction.

Finland supports developing countries by helping them to build their capacities and develop their economic infrastructure, thus helping them diversify their economies and improve energy production. Economic diversification and private sector development are particularly important targets in various Finnish bilateral programmes and Finnish-supported multilateral programmes in Zambia, southern Africa and the Mekong region. Regional programmes that promote the role of the private sector in providing energy services are

being promoted in Latin America, Sub-Saharan Africa and parts of Asia (see Chapter 7 of Finland's 6<sup>th</sup> National Communication for more details).

Among the actions listed in the Annex to Decision 15/CMP.1, Part I.H, 'Minimization of adverse impacts in accordance with Article 3, paragraph 14', Finland gives particular priority to the following actions:

- Action (a): Finland has addressed the progressive reduction or phasing out of market imperfections, fiscal incentives, tax and duty exemptions and subsidies in all greenhouse-gas-emitting sectors
  - domestically, with a major revision in energy taxation (2011), according to which all fuels are taxed based on their energy and fossil carbon content,
  - in its development policy by including in the support provided to developing countries through multinational development banks criteria that are targeted at removing subsidies for fossil fuels and phasing out support for investments based on fossil fuels by the year 2050.
- Action (d): Finland has cooperated in the development, diffusion, transfer and wider use of less-greenhouse-gas-emitting, advanced fossil-fuel technologies and technologies that capture and store greenhouse gases from fossil fuel use by supporting, at a policy level, methane capture for electricity generation instead of gas flaring, clean coal technologies and carbon capture and storage.
- Action (f): Finland has assisted developing country Parties that are highly dependent on the export and consumption of fossil fuels in diversifying their economies in several projects:
  - In Lao PDR, Finland has implemented a policy level programme that aims to diversify the economy and energy mix towards renewable sources that will provide local employment and increase energy and income security.
  - Through the Energy and Environment Partnership Programme (EEP), Finland supports the participating developing countries in developing, adopting and scaling-up appropriate and affordable renewable energy and energy efficiency technologies for improved energy access and local employment. Finnish-supported EEP programmes are executed in Central America, the Mekong Region, southern and eastern Africa, the Andean Region and Indonesia.

More details on the actions being taken by Finland to minimise the adverse impact of response measures in developing countries is provided in Table 15.1-1 below.

Finland is committed to policy coherence for development and promotes its implementation at the national level and in relation to its own partner countries and other donors. Finland also promotes policy coherence actively in the EU. Regarding policy coherence for development, Finland implements the recommendations of the OECD. The OECD's tool for policy coherence will be piloted on the themes of food security and the right to food. Policy coherence on other themes, such as trade and development, tax and development, migration and development, and security and development, will be strengthened both nationally and internationally. The Government will submit a communication to the Parliament on aid effectiveness and policy coherence for development in the first half of 2014.

**Table 15.1-1** Summary of specific actions to minimise the adverse impact of response measures in developing countries

Action	Implementation in Finnish policy
(a) The progressive reduction or phasing out of market imperfections, fiscal incentives, tax and duty exemptions and subsidies in all greenhouse-gas-emitting sectors, taking into account the need for energy price reforms to reflect market prices and externalities.	<p>These factors are taken into account for all greenhouse gas emitting sectors, together with consideration of national preferences and circumstances and the need for economic efficiency and feasibility. Various methodologies, including economic modelling, are used in the planning of economic instruments.</p> <p>Starting in January 2011 Finland made a major revision in energy taxation according to which all fuels are taxed based on their energy and fossil carbon content.</p> <p>Finland is supporting the Government of Cambodia to achieve its climate policy goals through developing Cambodian capacity for producing energy statistics and conducting energy planning, taking into account economic, social and environmental sustainability.</p> <p>Finnish development policy guidelines for support to developing countries through multinational development banks include criteria that are targeted at removing subsidies to fossil fuels and phasing out the support to fossil-fuel-fired investments by year 2050.</p>
(b) Removing subsidies associated with the use of environmentally unsound and unsafe technologies.	Finland does not have any support activities in this field.
(c) Cooperating in the technological development of non-energy uses of fossil fuels and supporting developing country Parties to this end.	Finland does not have any support activities in this field.
(d) Cooperating in the development, diffusion, and transfer of less-greenhouse-gas-emitting advanced fossil-fuel technologies, and/or technologies, relating to fossil fuels, that capture and store greenhouse gases, and encouraging their wider use; and facilitating the participation of the least developed countries and other non-Annex I Parties in this effort.	<p>Several actions have been undertaken in the area of promoting technologies that emit less greenhouse gases both at policy and programme/project level, with main focus on increased energy efficiency and promotion of renewable energy, instead of fossil-fuels. At fossil fuel sector, Finland supports methane capture for electricity generation instead of gas-flaring, clean coal technologies and carbon capture and storage at policy level. At programme level, support is given to improving the efficiency in energy distribution, for example, in Tanzania through automated network control systems and in Mozambique, through piloting a rural energy smart grid (back-up powered by diesel generators). Several projects for capturing landfill methane for biogas and electricity generation are also supported both in Nepal, in Southern and Eastern Africa as well as in Mekong Region.</p>
(e) Strengthening the capacity of developing country Parties identified in Article 4, paragraphs 8 and 9, of the Convention for improving efficiency in upstream and downstream activities relating to fossil fuels, taking into consideration the need to improve the environmental efficiency of these activities.	Finnish development policy supports low carbon development paths in developing countries. Finland has started to prepare guidelines for this purpose. Finland is also supporting Cambodia and Namibia to develop comprehensive energy strategies, data and planning capacity, taking into account sustainability as well as efficiency issues.
(f) Assisting developing country Parties that are highly dependent on the export and consumption of fossil fuels in diversifying their economies.	Action has been undertaken both through support by international organisations such as UNCTAD (United Nations Conference on Trade and Development) and through bilateral partnerships.
	Examples on bilateral partnerships include capacity-building

Action	Implementation in Finnish policy
	<p>support to Southern African Development Community (SADC) secretariat to develop regional renewable energy strategy and action plan as well as support to the Lao PDR in development and implementation of renewable energy strategy. These policy level programmes aim at diversifying the economies and energy mix of partner countries towards renewable sources that provide local employment and increase energy and income security.</p> <p>Finland is also supporting the Energy and Environment Partnership Programme with Central America (EEP), launched during the United Nations World Summit on Sustainable Development in 2002, implemented by 8 Central American partner countries. Austria and EU has joined as donors. In 2009/2010 Finland has replicated the EEP model in 4 other regions: the Mekong Region covering Lao PDR, Cambodia, Vietnam and Thailand; Southern and Eastern Africa covering 13 countries: Botswana, Burundi, Kenya, Lesotho, Mozambique, Namibia, Rwanda, Seychelles, South Africa, Swaziland, Tanzania, Uganda, Zambia; Andean Region covering Bolivia, Colombia, Peru and Ecuador; and Indonesia covering initially 2 provinces.</p> <p>The EEP programmes focus on supporting the participating countries in developing, adopting and scaling-up appropriate and affordable renewable energy and energy efficiency technologies for improved energy access and local employment. The programmes support thematic policy studies, feasibility studies and pilot and demonstration projects as well as some R&amp;D&amp;I projects. The projects are developed and implemented by partnerships of public, private and civil society actors. The regional approach supports South-South co-operation, regional integration and knowledge sharing.</p>

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# ANNEXES TO THE NATIONAL INVENTORY REPORT

## *ANNEX 1. Key categories*

This annex describes the methodology used to identify key categories and provides information on the level of disaggregation. Key categories are also in CRF table 7. Analysis tables with numerical results are here below Table A1-1, detailed supplementary information can be found in UA-KCA\_FIN-2014-2012-v1.5.xlsx, and UA-KCA\_KP-FIN-2014-2012-v1.5.xlsx for this data.

We have coded the methods of IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories 2000 and IPCC Good Practice Guidance for Land Use, Land Use Change and Forestry 2003 into a SAS program. This program reads the Excel tables produced by the CRF Reporter and outputs uncertainty and key category tables to result Excel file. The process is fast and all errors can be traced back into either the data or the program, because manual operations (such as copy-paste) do not take place. Uncertainties used in key category analysis are from tier 2 method, and key categories reported are from tier 2 analysis. Analyses were made first without LULUCF, and then with LULUCF. Summary of the results is in Section 1.5.

The level of disaggregation is based on the recommendation in GPG 2000 and GPG LULUCF 2003.

The uncertainty and key category analysis, and especially the aggregation of categories, have been revised in 2013. The emissions are aggregated in uncertainty analysis mainly to the 3rd category level, and in energy sector also divided by CRF fuel types.



**Table 1.** Key category analysis, base year level assessment (Tier 2) excluding LULUCF sector

Category	(crf fuel)	Gas	Emissions base year (Gg CO <sub>2</sub> eq.)	Level assessment	Contribution to level	Cumulative sum of contribution	Key in level analysis
4.D.1. Direct Soil Emissions		N <sub>2</sub> O	3 068.9	0.052	0.234	0.234	yes
4.D.3. Indirect Emissions		N <sub>2</sub> O	766.8	0.033	0.148	0.382	yes
2.B.2. Nitric Acid Production		N <sub>2</sub> O	1 655.7	0.024	0.107	0.488	yes
6.A. Solid Waste Disposal on Land		CH <sub>4</sub>	3 635.3	0.012	0.054	0.542	yes
1.A.4. Other Sectors	1 Liquid	CO <sub>2</sub>	6 634.6	0.010	0.044	0.586	yes
2.C.1. Iron and Steel Production		CO <sub>2</sub>	1 935.2	0.008	0.036	0.622	yes
4.A. Enteric Fermentation		CH <sub>4</sub>	1 831.9	0.007	0.030	0.652	yes
1.A.1. Energy Industries	2 Solid	CO <sub>2</sub>	9 640.1	0.006	0.027	0.679	yes
6.B.2. Domestic and Commercial Wastewater		N <sub>2</sub> O	105.3	0.006	0.025	0.704	yes
4.D.2. Pasture, Range and Paddock Manure		N <sub>2</sub> O	190.5	0.005	0.024	0.728	yes
4.B. Manure Management		N <sub>2</sub> O	486.7	0.005	0.021	0.749	yes
1.A.5.a.3. Other non-specified	1 Liquid	CO <sub>2</sub>	985.7	0.004	0.020	0.769	yes
1.A.1. Energy Industries	5 Other	CO <sub>2</sub>	3 950.0	0.004	0.018	0.787	yes
1.A.5.a.1. Indirect N <sub>2</sub> O emissions from NO <sub>x</sub>		N <sub>2</sub> O	439.4	0.004	0.018	0.805	yes
1.A.2 Manufacturing Industries and Construction	1 Liquid	CO <sub>2</sub>	4 552.0	0.004	0.017	0.822	yes
1.A.4. Other Sectors	4 Biomass	CH <sub>4</sub>	161.3	0.003	0.014	0.836	yes
1.A.2 Manufacturing Industries and Construction	2 Solid	CO <sub>2</sub>	4 842.8	0.003	0.012	0.848	yes
1.A.3.b. Road Transportation	1 Liquid - gasoline	CO <sub>2</sub>	5 882.5	0.002	0.010	0.858	yes
1.A.3.e. Other Transportation	1 Liquid	CO <sub>2</sub>	659.9	0.002	0.010	0.868	yes
1.A.1. Energy Industries	1 Liquid	CO <sub>2</sub>	2 838.0	0.002	0.009	0.877	yes
1.A.3.b. Road Transportation	1 Liquid - gasoline	N <sub>2</sub> O	91.8	0.002	0.009	0.886	yes
1.A.2 Manufacturing Industries and Construction	5 Other	CO <sub>2</sub>	1 597.7	0.002	0.008	0.894	yes
6.B.3.b. Other (N input from industrial wastewater)		N <sub>2</sub> O	30.2	0.002	0.007	0.901	yes

**Table 2.** Key category analysis, base year level assessment (Tier 2) including LULUCF sector

Category	(crf fuel)	Gas	Emissions/ removals base year (Gg CO <sub>2</sub> eq.)	Level assessment	Contribution to level	Cumulative sum of contribution	Key in level analysis
5.A.1. Forest Land remaining Forest Land		CO <sub>2</sub>	-23 111.0	0.125	0.358	0.358	yes
5.B.1. Cropland remaining Cropland		CO <sub>2</sub>	4 716.1	0.040	0.113	0.472	yes
4.D.1. Direct Soil Emissions		N <sub>2</sub> O	3 068.9	0.035	0.099	0.570	yes
4.D.3. Indirect Emissions		N <sub>2</sub> O	766.8	0.022	0.063	0.633	yes
2.B.2. Nitric Acid Production		N <sub>2</sub> O	1 655.7	0.016	0.045	0.678	yes
5.C.1. Grassland remaining Grassland		CO <sub>2</sub>	868.5	0.008	0.023	0.701	yes
6.A. Solid Waste Disposal on Land		CH <sub>4</sub>	3 635.3	0.008	0.023	0.724	yes
1.A.4. Other Sectors	1 Liquid	CO <sub>2</sub>	6 634.6	0.007	0.019	0.742	yes
5.E.2. Land converted to Settlements		CO <sub>2</sub>	929.4	0.005	0.016	0.758	yes
2.C.1. Iron and Steel Production		CO <sub>2</sub>	1 935.2	0.005	0.015	0.773	yes
5.B.2. Land converted to Cropland		CO <sub>2</sub>	627.5	0.005	0.013	0.786	yes
4.A. Enteric Fermentation		CH <sub>4</sub>	1 831.9	0.004	0.012	0.799	yes
5.A.2. Land converted to Forest Land		CO <sub>2</sub>	130.7	0.004	0.012	0.810	yes
1.A.1. Energy Industries	2 Solid	CO <sub>2</sub>	9 640.1	0.004	0.011	0.822	yes
5.D.2. Land converted to Wetlands		CO <sub>2</sub>	1 310.8	0.004	0.011	0.833	yes
6.B.2. Domestic and Commercial Wastewater		N <sub>2</sub> O	105.3	0.004	0.011	0.843	yes
5.C.2. Land converted to Grassland		CO <sub>2</sub>	- 117.6	0.004	0.010	0.853	yes
4.D.2. Pasture, Range and Paddock Manure		N <sub>2</sub> O	190.5	0.004	0.010	0.864	yes
5.II Non-CO <sub>2</sub> emissions from drainage of soils and wetlands		N <sub>2</sub> O	1 215.2	0.003	0.010	0.874	yes
4.B. Manure Management		N <sub>2</sub> O	486.7	0.003	0.009	0.882	yes
1.A.5.a.3. Other non-specified	1 Liquid	CO <sub>2</sub>	985.7	0.003	0.008	0.891	yes
1.A.1. Energy Industries	5 Other	CO <sub>2</sub>	3 950.0	0.003	0.008	0.899	yes
1.A.5.a.1. Indirect N <sub>2</sub> O emissions from NO <sub>x</sub>		N <sub>2</sub> O	439.4	0.003	0.007	0.906	yes

**Table 3.** Key category analysis, year 2012 level assessment (Tier 2) excluding LULUCF sector

Category	(crf fuel)	Gas	Emissions 2012 (Gg CO2 eq.)	Level assessment	Contribution to level	Cumulative sum of contribution	Key in level analysis
4.D.1. Direct Soil Emissions		N2O	2 727.8	0.052	0.310	0.310	yes
4.D.3. Indirect Emissions		N2O	583.5	0.029	0.171	0.480	yes
6.A. Solid Waste Disposal on Land		CH4	1 737.1	0.009	0.051	0.531	yes
4.A. Enteric Fermentation		CH4	1 544.1	0.006	0.037	0.568	yes
4.D.2. Pasture, Range and Paddock Manure		N2O	185.7	0.006	0.036	0.604	yes
1.A.4. Other Sectors	4 Biomass	CH4	243.9	0.005	0.032	0.636	yes
6.B.2. Domestic and Commercial Wastewater		N2O	78.3	0.005	0.028	0.664	yes
4.B. Manure Management		N2O	415.6	0.005	0.027	0.691	yes
1.A.4. Other Sectors	1 Liquid	CO2	3 523.6	0.004	0.024	0.714	yes
1.A.5.a.3. Other non-specified	1 Liquid	CO2	894.6	0.003	0.017	0.732	yes
1.A.3.b. Road Transportation	1 Liquid - diesel oil	N2O	110.1	0.003	0.016	0.748	yes
1.A.1. Energy Industries	5 Other	CO2	5 796.3	0.003	0.016	0.764	yes
1.A.2 Manufacturing Industries and Construction	1 Liquid	CO2	3 023.0	0.003	0.015	0.779	yes
2.C.1. Iron and Steel Production		CO2	2 277.8	0.002	0.014	0.793	yes
1.A.5.a.1. Indirect N2O emissions from NOx		N2O	218.4	0.002	0.013	0.806	yes
1.A.3.b. Road Transportation	1 Liquid - diesel oil	CO2	6 913.0	0.002	0.012	0.818	yes
2.F.1. Refrigeration and Air Conditioning Equipment		HFC	861.0	0.002	0.012	0.830	yes
1.A.3.b. Road Transportation	1 Liquid - gasoline	CO2	4 129.8	0.002	0.010	0.840	yes
1.A.1. Energy Industries	2 Solid	CO2	7 709.3	0.002	0.010	0.851	yes
1.A.3.e. Other Transportation	1 Liquid	CO2	633.3	0.002	0.009	0.860	yes
1.A.2 Manufacturing Industries and Construction	2 Solid	CO2	2 237.9	0.001	0.009	0.868	yes
1.A.5.a.3. Other non-specified	3 Gaseous	CO2	203.0	0.001	0.007	0.876	yes
1.A.1. Energy Industries	4 Biomass	N2O	118.1	0.001	0.007	0.883	yes
6.B.3.b. Other (N input from industrial wastewater)		N2O	17.8	0.001	0.006	0.889	yes
1.A.1. Energy Industries	1 Liquid	CO2	2 431.6	0.001	0.006	0.895	yes
1.A.3.b. Road Transportation	1 Liquid - gasoline	N2O	40.5	0.001	0.005	0.900	yes

**Table 4.** Key category analysis, year 2012 level assessment (Tier 2) including LULUCF sector

Category	(crf fuel)	Gas	Emissions/ removals 2012 (Gg CO2 eq.)	Level assessment	Contribution to level	Cumulative sum of contribution	Key in level analysis
5.A.1. Forest Land remaining Forest Land		CO2	-38 321.4	0.087	0.342	0.342	yes
5.B.1. Cropland remaining Cropland		CO2	5 448.1	0.039	0.152	0.495	yes
4.D.1. Direct Soil Emissions		N2O	2 727.8	0.029	0.112	0.607	yes
4.D.3. Indirect Emissions		N2O	583.5	0.016	0.062	0.669	yes
5.B.2. Land converted to Cropland		CO2	1 295.9	0.008	0.033	0.702	yes
5.C.1. Grassland remaining Grassland		CO2	326.8	0.006	0.023	0.726	yes
5.E.2. Land converted to Settlements		CO2	906.4	0.005	0.020	0.745	yes
6.A. Solid Waste Disposal on Land		CH4	1 737.1	0.005	0.018	0.763	yes
5.D.2. Land converted to Wetlands		CO2	1 753.1	0.004	0.017	0.781	yes
5.II Non-CO2 emissions from drainage of soils and wetlands		N2O	1 297.7	0.004	0.014	0.795	yes
4.A. Enteric Fermentation		CH4	1 544.1	0.003	0.014	0.808	yes
4.D.2. Pasture, Range and Paddock Manure		N2O	185.7	0.003	0.013	0.821	yes
5.C.2. Land converted to Grassland		CO2	- 9.8	0.003	0.012	0.833	yes
1.A.4. Other Sectors	4 Biomass	CH4	243.9	0.003	0.011	0.845	yes
5.G. Other (Harvested Wood Products)		CO2	1 287.5	0.003	0.011	0.856	yes
6.B.2. Domestic and Commercial Wastewater		N2O	78.3	0.003	0.010	0.866	yes
4.B. Manure Management		N2O	415.6	0.002	0.010	0.876	yes
5.A.2. Land converted to Forest Land		CO2	- 116.1	0.002	0.009	0.885	yes
1.A.4. Other Sectors	1 Liquid	CO2	3 523.6	0.002	0.009	0.893	yes
1.A.5.a.3. Other non-specified	1 Liquid	CO2	894.6	0.002	0.006	0.900	yes
1.A.3.b. Road Transportation	1 Liquid - diesel oil	N2O	110.1	0.001	0.006	0.906	yes

**Table 5.** Key category analysis, trend assessment (Tier 2) excluding LULUCF sector

Category	(crf fuel)	Gas	Trend assessment	Contribution to trend	Cumulative sum of contribution	Key in trend analysis
6.A. Solid Waste Disposal on Land		CH4	0.008	0.149	0.149	yes
4.D.3. Indirect Emissions		N2O	0.005	0.086	0.235	yes
2.B.2. Nitric Acid Production		N2O	0.004	0.068	0.304	yes
1.A.4. Other Sectors	1 Liquid	CO2	0.003	0.055	0.358	yes
1.A.4. Other Sectors	4 Biomass	CH4	0.003	0.049	0.407	yes
2.F.1. Refrigeration and Air Conditioning Equipment		HFC	0.002	0.042	0.450	yes
1.A.5.a.1. Indirect N2O emissions from NOx		N2O	0.002	0.036	0.485	yes
4.D.1. Direct Soil Emissions		N2O	0.001	0.028	0.513	yes
1.A.2 Manufacturing Industries and Construction	2 Solid	CO2	0.001	0.027	0.540	yes
1.A.3.b. Road Transportation	1 Liquid - diesel oil	N2O	0.001	0.027	0.568	yes
1.A.1. Energy Industries	4 Biomass	N2O	0.001	0.024	0.592	yes
1.A.1. Energy Industries	5 Other	CO2	0.001	0.023	0.615	yes
1.A.5.a.3. Other non-specified	3 Gaseous	CO2	0.001	0.021	0.636	yes
1.B.2.d. Other (CO2 from NMVOC)		CO2	0.001	0.019	0.655	yes
1.A.3.b. Road Transportation	1 Liquid - gasoline	N2O	0.001	0.018	0.673	yes
6.B.2. Domestic and Commercial Wastewater		N2O	0.001	0.017	0.690	yes
1.A.2 Manufacturing Industries and Construction	1 Liquid	CO2	0.001	0.017	0.707	yes
1.A.3.b. Road Transportation	1 Liquid - diesel oil	CO2	0.001	0.017	0.724	yes
2.F.8. Electrical Equipment		SF6	0.001	0.016	0.740	yes
4.D.2. Pasture, Range and Paddock Manure		N2O	0.001	0.014	0.754	yes
2.C.1. Iron and Steel Production		CO2	0.001	0.014	0.768	yes
3. Solvent and Other Product Use		CO2	0.001	0.013	0.781	yes
2.B.5.g. Hydrogen		CO2	0.001	0.013	0.794	yes
6.D. Other (compost production)		N2O	0.001	0.013	0.807	yes
1.A.5.b. Mobile	1 Liquid	CO2	0.001	0.012	0.818	yes
6.B.3.b. Other (N input from industrial wastewater)		N2O	0.001	0.011	0.829	yes
6.D. Other (compost production)		CH4	0.001	0.010	0.840	yes
1.A.1. Energy Industries	5 Other	N2O	0.001	0.010	0.850	yes
1.A.3.a. Civil Aviation	1 Liquid	CO2	0.000	0.009	0.859	yes
1.A.3.b. Road Transportation	1 Liquid - gasoline	CO2	0.000	0.009	0.868	yes
1.A.5.a.2. Non-specified emissions of Fuels from	1 Liquid	CO2	0.000	0.009	0.876	yes
1.A.4. Other Sectors	4 Biomass	N2O	0.000	0.007	0.884	yes
1.A.1. Energy Industries	3 Gaseous	CO2	0.000	0.007	0.891	yes
1.A.3.b. Road Transportation	1 Liquid - gasoline	CH4	0.000	0.006	0.897	yes
6.B.3.a. Other (N input from fish farming)		N2O	0.000	0.005	0.903	yes

**Table 6.** Key category analysis, trend assessment (Tier 2) including LULUCF sector

Category	(crf fuel)	Gas	Trend assessment	Contribution to trend	Cumulative sum of contribution	Key in trend analysis
5.C.2. Land converted to Grassland		CO2	0.035	0.204	0.204	yes
5.B.1. Cropland remaining Cropland		CO2	0.029	0.170	0.373	yes
5.A.1. Forest Land remaining Forest Land		CO2	0.019	0.110	0.483	yes
4.D.1. Direct Soil Emissions		N2O	0.014	0.082	0.565	yes
5.B.2. Land converted to Cropland		CO2	0.010	0.056	0.621	yes
5.G. Other (Harvested Wood Products)		CO2	0.007	0.039	0.660	yes
5.C.1. Grassland remaining Grassland		CO2	0.006	0.036	0.697	yes
4.D.3. Indirect Emissions		N2O	0.005	0.028	0.724	yes
5.D.2. Land converted to Wetlands		CO2	0.004	0.022	0.747	yes
5.A.2. Land converted to Forest Land		CO2	0.003	0.020	0.767	yes
5.E.2. Land converted to Settlements		CO2	0.003	0.017	0.784	yes
1.A.4. Other Sectors	4 Biomass	CH4	0.003	0.016	0.800	yes
5.II Non-CO2 emissions from drainage of soils and wetlands		N2O	0.002	0.014	0.814	yes
6.A. Solid Waste Disposal on Land		CH4	0.002	0.013	0.827	yes
4.D.2. Pasture, Range and Paddock Manure		N2O	0.002	0.011	0.839	yes
2.B.2. Nitric Acid Production		N2O	0.002	0.011	0.850	yes
2.F.1. Refrigeration and Air Conditioning Equipment		HFC	0.002	0.010	0.860	yes
1.A.3.b. Road Transportation	1 Liquid - diesel oil	N2O	0.001	0.009	0.869	yes
4.A. Enteric Fermentation		CH4	0.001	0.009	0.877	yes
1.A.1. Energy Industries	5 Other	CO2	0.001	0.008	0.885	yes
4.B. Manure Management		N2O	0.001	0.006	0.892	yes
1.A.3.b. Road Transportation	1 Liquid - diesel oil	CO2	0.001	0.006	0.898	yes
2.C.1. Iron and Steel Production		CO2	0.001	0.006	0.903	yes

## ANNEX 2. Description of the Compliance Monitoring Data System VAHTI

The VAHTI compliance data system functions as a tool for the 13 Centres for Economic Development, Transport and the Environment in their work on processing and monitoring environmental permits. The data system contains information on the environmental permits of clients and on their wastes generated, discharges into water and emissions to air. This baseline data are used by the Centres for Economic Development, Transport and the Environment and by other interested parties. Additionally, case management has been incorporated into the system.

VAHTI contains information on how installations comply with environmental regulations. At the beginning of 2005, a new application was added which contains data on how the Centres for Economic Development, Transport and the Environment carry out their compliance monitoring.

Currently, there are 200 active users of the system and it has a sound reputation as an effective tool in the everyday work of the environmental administration. Moreover, the data system already provides substantial reports for the diverse needs of the administration and for other interested parties needing information.

The user interface makes it possible to add new customers, change or add customers' data, retrieve reports from the database and write inspection reports. Additionally, the system has other helpful functions, such as mapping functions and a calendar to remind an inspector of time limits.

VAHTI is a customer information system (operators must have an environmental permit from the authorities) containing, for example, the following information (Figure 1):

- identification details
- contact persons
- respective authorities
- licence conditions
- environment insurance
- loading points (stacks and sewers)
- emissions control equipment
- treatment plans
- boilers and fuels used
- landfills
- emissions to air, discharges to water and wastes
- energy and other production
- raw materials and water consumption
- production
- water consumption
- fish farming
- peat production area
- animal shelters
- analyses



**Figure 1.** Structure of the VAHTI Data System

The table below shows the number of installations that reported environmental loading of waste or into water or air.

**Table 1.** Facilities reporting information to the VAHTI Data System in 2009

Activity	Water	Air	Waste	Total
Energy production and industrial installations	1 018	699	809	2 526
Municipalities	497	5	297	799
Fish farms	218	-	22	240
Others	103	371	1 087	1 561
Total	1 836	1 075	2 215	5 126

### Emission data reported by the facilities

The permit or the plant specific emission monitoring and reporting programme annexed to the permit includes orders on what the operator (i.e. the person or legal person in charge of a facility) must report to the authorities. The annual reporting obligation of an installation concerns emissions for which the installation has an emission limit value (ELV) in the environmental permit. The monitoring system for these substances is stipulated together with the ELV for these compounds. Of those emissions reported to the UNFCCC, ELVs are usually given for emissions of sulphur (as SO<sub>2</sub>) and nitrogen oxides (as NO<sub>2</sub>), but not for carbon dioxide, methane or nitrous oxide. However, the operators may also report these compounds based on the reporting obligations to the integrated emission registers such as the European Pollutant Release and Transfer Register (E-PRTR)<sup>13</sup> and previously European Polluting Emissions Register (EPER). The PRTR and EPER reporting substance lists also include carbon dioxide, nitrous oxide and F-gases. However, the data to the integrated emission registers are reported as total emissions for the industrial site and cannot be split between the CRF reporting categories.

In addition to emission data the operators also report on the types, characteristics and consumption of fuels, though these data may not be as complete as emission data. In addition, waste amounts (with classification data) to solid waste disposal sites and wastewater handling data are reported to the VAHTI Data System.

### Quality checking carried out by the supervising authority

When receiving the emission report from the operator the supervising authority checks whether the data are produced according to the methods agreed in the permit or in a separate monitoring programme for the plant. The methods usually include use of international standards or approved in-house methods. The principles of the EU IPPC Reference Document on Monitoring of Emissions (Monitoring BREF) are also followed.

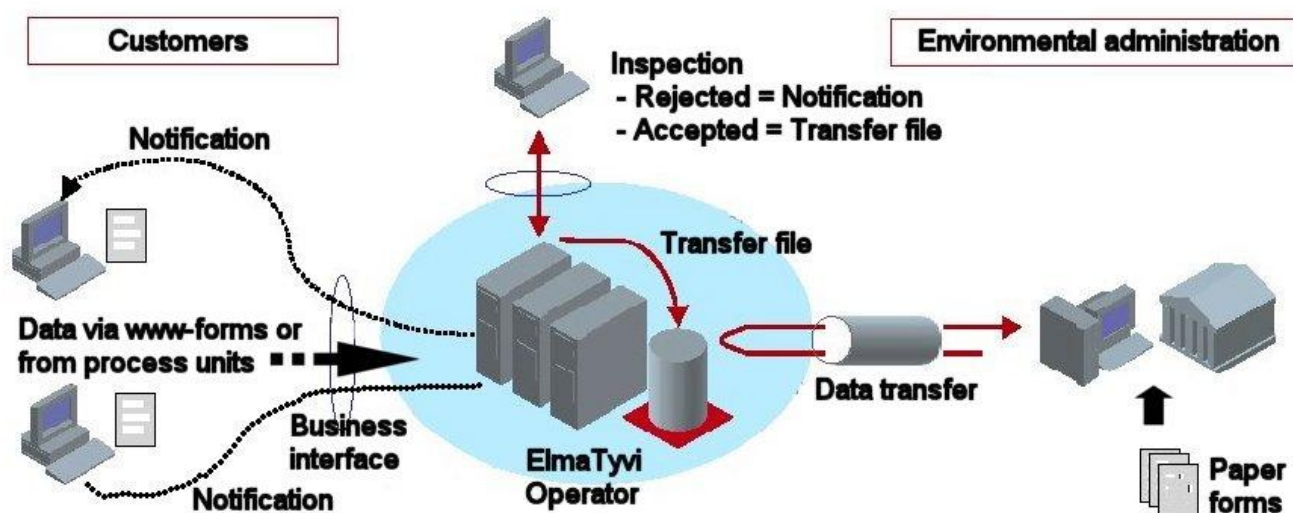
### Reporting options for the operators

The operators may submit the emission reports to the supervising authorities either as hard copies or electronically by email or through the Internet (Figure 2). Larger industrial installations have developed reporting systems which are based on direct information flow from the plant information systems to the supervising authority. The emission data are always checked by the supervising authority before recording into the VAHTI data system as described in Section 1.4. When the operator chooses to send the data over the Internet using a centralised data collection system<sup>14</sup> the data will be automatically checked for completeness and only the completed data will be sent to the authorities for checking of the substance.

<sup>13</sup> According to the Finnish Environmental Protection Act, Section 27.2, the Environmental Protection Register contains information about emission reports and monitoring connected to permits. The Centres for Economic Development, Transport and the Environment and municipal authorities are responsible for collecting the data from operators. The Finnish Parliament has approved additions to the Environmental Protection Act which stipulates *inter alia* that operators must submit reports on emissions to the authorities.

<sup>14</sup> The centralised data collection system TYVI is a consultant service used in various data collection procedures from the companies to the authorities, in addition to the environmental administration, such as the tax authority, customs and statistics.





**Figure 2.** Reporting options for the operators

Further information on the VAHTI Data System is available from Mr Markku Hietamäki, Ministry of the Environment (email: [firstname.surname@ymparisto.fi](mailto:firstname.surname@ymparisto.fi))

## ANNEX 3. Discussion of the default CO<sub>2</sub> emission factor for coal and its applicability to the Finnish inventory

### Problem statement

The current Finnish inventory uses the default emission factor 94.6 g CO<sub>2</sub>/MJ coal combusted (given originally as 25.8 g C/MJ coal). This default value can be found in Table 1-2, p. 1.6 of the workbook of both the IPCC Guidelines (IPCC 1995) and the IPCC Revised Guidelines (IPCC 1997). The factor can also be found in Table 3.3 of OECD/IEA (1991) and its original source appears to be Grubb (1989).

Table 3.3 gives a range of variation equal to  $\pm 3\%$ . The text states that the variation is between world regions and due to “differences among ranks of coal.” (OECD/IEA 1991, p. 64). The default emission factor also appears in Table B–1 of OECD/IEA (1991, p. 154). Given the information reported in that table, the factor seems to be a weighted average reflecting the market shares of hard and brown coals in North America in 1987. In that same table, the factor given for Europe is 3.1% higher, equal to 26.6 g C/MJ (97.5 g CO<sub>2</sub>/MJ).

This immediately raises the question regarding the appropriateness of the default factor for use in the Finnish inventory. For some reason, the default selected to the IPCC Guidelines was the one defined for North America. Is the distribution of coal combusted in Finland similar to that in North America? Are there differences between decades? Is it reasonable to assume that the 1987 markets in North America are similar to the 1990’s, or the current markets in Finland? Are there differences between individual years? What about trends over years?

### An alternative approach

We know from energy statistics that quantities of coal imported to Finland from different countries vary from year to year. We also know from literature that the carbon content, water content and calorific value vary depending on coal origin (Taipale 1996). These properties can be used to calculate an emission factor for coal.

If  $c$  is the carbon content of coal expressed as a mass fraction of carbon in dry matter [–],  $w$  is the water content of coal [–], and  $h$  is the net calorific value [MJ/kg], then the emission factor  $x$  [g/MJ] is

$$x = 1000 \frac{44.01}{12.01} \frac{c}{h} (1 - w),$$

where 44.01/12.01 is the ratio of the molecular masses of carbon dioxide and carbon. We assume that the above relation is valid for a given type of coal, where the type is determined by the country of origin of that coal. Now then, since coal from different countries of origin is being combusted in Finland, we would like to have an average emission factor, which reflects this fact. Moreover, since quantities of coal imported from different countries vary from year to year, we would also expect the emission factor to show annual variation. We model this variation by weighing emission factors calculated for each type of coal  $x_i$  by their share of total imports  $s_i$  in any given year  $t$ , thus yielding an average annual emission factor for that year

$$x_t = s_{1,t}x_1 + s_{2,t}x_2 + \dots + s_{n,t}x_n,$$

where it is understood that constant properties of a given type of coal over time are assumed.

### The data

We obtained data on coal imports by country of origin from Table 10.3 of energy statistics prepared by Statistics Finland. These data are available for 1990–2003, except for 1996 when the table was not prepared.

Data on properties of fuel combusted in Finland were obtained from Taipale (1996). This study reports results from measurements carried out mainly during the 1990’s. It gives water contents, carbon contents and net calorific values for coal of different origins. The statistics reported are the number of measurements,

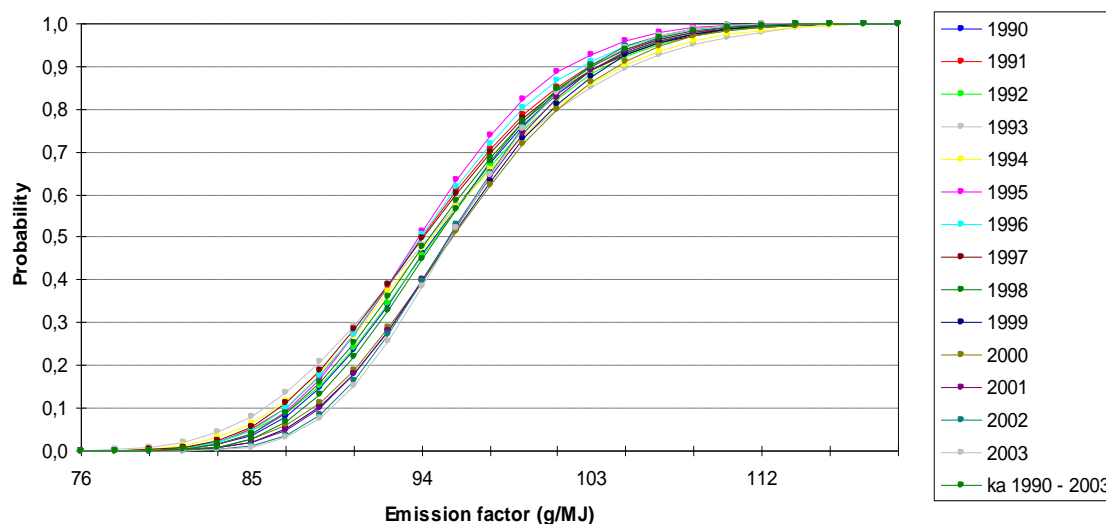
minimum, maximum and the mean. In case of the most important countries of coal origin, such as Poland and Russia, hundreds of measurements were available. This was the case for the net calorific value and water content. Measurements of carbon content were scarcer ranging from a few to tens of measurements, depending on the country of origin. For 13 countries or regions, the net calorific value and water content were not available. The carbon content was not available for 16 countries or regions. In all, the data consist of 23 countries or regions.

There is clearly a problem with the missing data. A first attempt was made by selecting values from literature to replace the missing data. Although the proportion of imports with the missing fuel property data was not greater than 1%-17%, depending on the year under consideration, this solution resulted in a correlation between the calculated emission factor and the proportion of missing data. The higher the proportion of missing data, the higher the calculated average emission factors.

The second attempt produced better results. An algorithm was constructed to select values at random from the available data to replace the missing values. The selection process was designed to give an equal probability of selection for any one value of fuel property. The sampling was done separately for each of the properties. Fuel properties for which data were available were modelled using triangular distributions, with min and max corresponding to the measured min and max, and the most likely value corresponding to the mean of all measurements. Import statistics were assumed relatively accurate. Imports were assumed to be normally distributed, means corresponding to the imported quantity and standard deviations equal to half of the unit used to report the data ( $1000 \text{ t}/2 = 500 \text{ t}$ ).

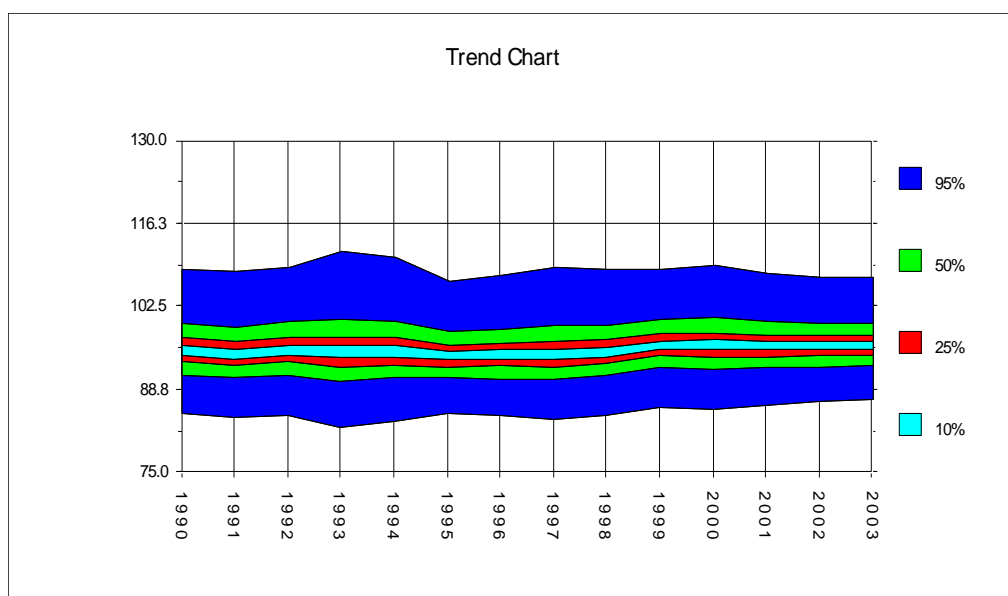
## Results and discussion

The simulation was designed to separate year-to-year variability from other uncertainties. Figure 1 shows a wide range of uncertainty in an individual year's emission factors and also that the years are clearly different from each other.



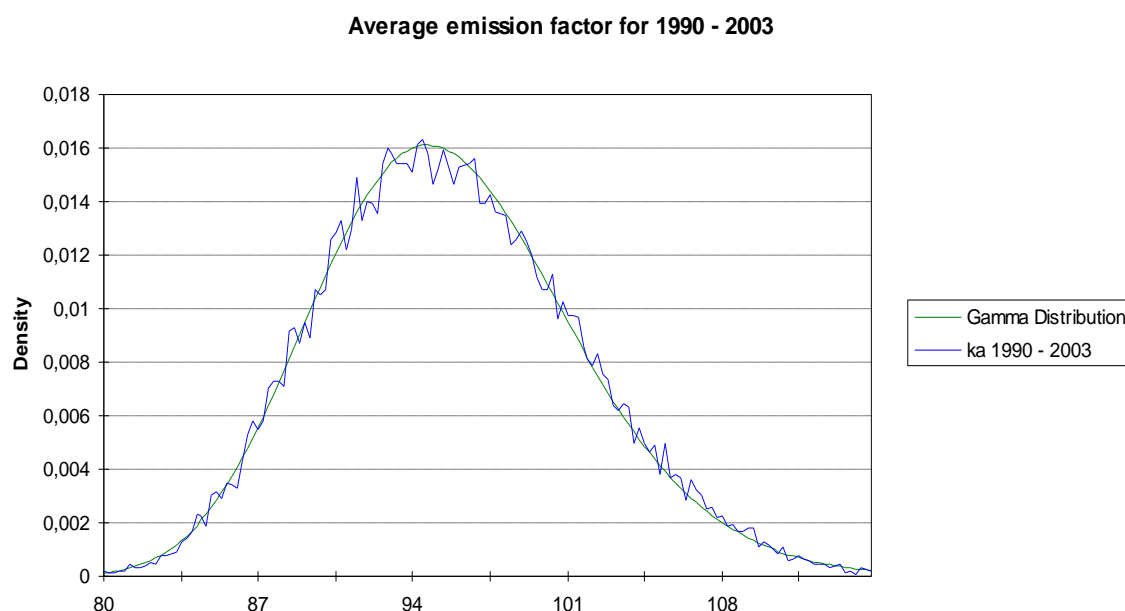
**Figure 1.** Uncertainty and year-to-year variability in the average coal emission factor

Figure 2 shows a combined view of uncertainty as a trend over time. The central value of the simulated average emission factor (the light blue area in Fig. 2) does not display a clear trend over time. The 1996 emission factor, the year for which import data were not available, was calculated simply as the average of the 1995 and 1997 emission factors.



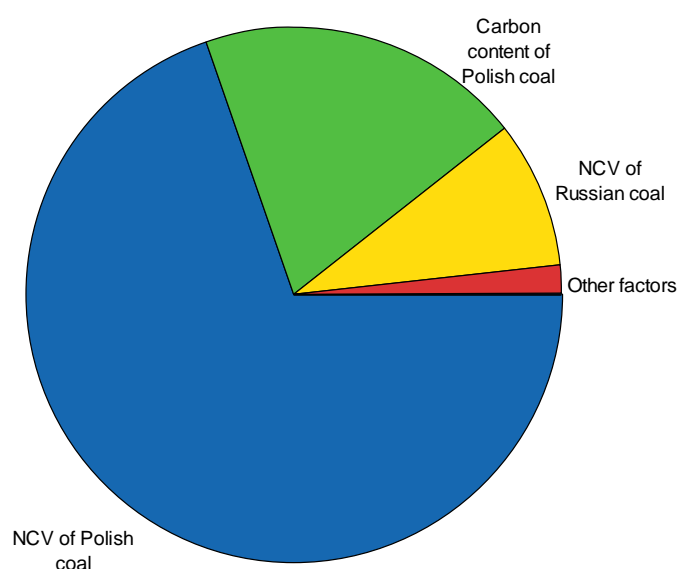
**Figure 2.** Uncertainty in the coal emission factor over time

Figure 3 displays a time average of the simulation results. Two observations are immediate: (i) the distribution is centred around a value which is not far from the default emission factor 94.6 g/MJ; (ii) the width of the distribution suggests a much larger uncertainty than the  $\pm 3\%$  given in the OECD/IEA (1991) for regional emission factors. Note, however, that this is in agreement with an example shown in that text for Greece, for which the national level of variation was found to be much wider (OECD/IEA, p. 155). The distribution in Figure 3 suggests an uncertainty around 12%-13%. It is much larger than the current uncertainty used for solid fuels in the inventory, which is 3%-5%.



**Figure 3.** An average coal emission factor for 1990-2003

Variance decomposition suggests that most of the uncertainty in the emission factor for 1990-2003 is due to a variable net calorific value of the Polish coal combusted in Finland (Fig. 4). The carbon content of Polish coal and the net calorific value of Russian coal are also important factors affecting uncertainty of the average emission factor. Other factors play a minor role in the overall uncertainty.



**Figure 4.** Variance decomposition of the average emission factor for 1990-2003

Summary statistics for the simulation are given in Table 10. Estimates of the means are 0.3%-2.2% larger than the current default emission factor used.

**Table 1.** Summary statistics for simulation (n = 30 000) of coal emission factors. All numbers have the unit of measurement g/MJ

Year	Mean	Sd	MCSE*	Quantiles		
				2.5%	50.0%	97.5%
1990	95.87	6.18	0.036	85.0	95.5	109.0
1991	95.27	6.27	0.036	84.3	94.8	108.7
1992	95.93	6.44	0.037	84.5	95.5	109.5
1993	95.75	7.55	0.044	82.6	95.2	112.0
1994	95.87	7.09	0.041	83.5	95.3	111.1
1995	94.92	5.68	0.033	84.9	94.6	106.9
1996	95.12	6.04	0.035	84.5	94.7	108.0
1997	95.32	6.51	0.038	84.0	94.8	109.3
1998	95.66	6.26	0.036	84.7	95.2	109.0
1999	96.69	5.92	0.034	86.1	96.4	109.0
2000	96.77	6.20	0.036	85.6	96.4	109.8
2001	96.54	5.71	0.033	86.3	96.2	108.5
2002	96.50	5.37	0.031	86.9	96.2	107.7
2003	96.66	5.29	0.031	87.3	96.3	107.8

\*Monte Carlo standard error of the mean,  $Sd/\sqrt{n}$ .

## ANNEX 4. Tier 1 Reference calculation based on National Energy Balances of 2012

### Energy Balance Sheet 2012, ktoe

	Coal	Crude oil & NGL	Petroleum products	Natural gas	Nuclear energy	Hydro & wind power	Peat fuel	Recycled fuels and others	Wood fuels	Electricity	District heat & heat pumps	Total
	1	2	3	4	5	6	7		8	9	10	11
Indigenous production	—	—	465	—	5 989	1 493	992	271	7 913	—	386	<b>17 509</b>
Recycled oil	—	—	22	—	—	—	—	598	—	—	—	<b>620</b>
Imports	2 655	11 226	4 832	3 005	—	—	22	12	62	1 641	—	<b>23 456</b>
Exports	-32	—	-7 646	—	—	—	-2	—	-36	-141	—	<b>-7 858</b>
International marine bunkers	—	—	-123	—	—	—	—	—	—	—	—	<b>-123</b>
Stock Changes	387	-99	290	—	—	—	555	—	—	—	—	<b>1 132</b>
<b>Total Primary Energy Supply</b>	<b>3 010</b>	<b>11 127</b>	<b>-2 161</b>	<b>3 006</b>	<b>5 989</b>	<b>1 493</b>	<b>1 567</b>	<b>880</b>	<b>7 939</b>	<b>1 500</b>	<b>386</b>	<b>34 736</b>
Statistical Difference	-32	-909	1 223	0	—	—	14	-15	0	0	0	<b>282</b>
Electricity generation	-717	—	-38	-27	-5 989	-1 493	-175	-48	-297	3 818	—	<b>-4 965</b>
Combined district heat and power	-1 222	—	-29	-1 142	—	—	-906	-173	-1 642	1 338	2 954	<b>-821</b>
Cogeneration electricity in industry	-15	—	-36	-192	—	—	-55	-135	-739	664	264	<b>-244</b>
District heat production	-141	—	-242	-397	—	—	-168	-128	-575	—	1 419	<b>-232</b>
Oil refinery	—	-12 036	11 740	—	—	—	—	—	—	—	—	<b>-296</b>
Coal transformation	-475	—	—	—	—	—	—	—	—	—	—	<b>-475</b>

	Coal	Crude oil & NGL	Petroleum products	Natural gas	Nuclear energy	Hydro & wind power	Peat fuel	Recycled fuels and others	Wood fuels	Electricity	District heat & heat pumps	Total
	1	2	3	4	5	6	7		8	9	10	11
Energy sectors's own consumption	-175	—	—	—	—	—	—	—	—	—	—	
Transmission and distributions losses	-42	—	-11	—	—	—	—	—	—	-250	-320	<b>-623</b>
<b>TFC (total final consumption)</b>	<b>255</b>	<b>—</b>	<b>8 001</b>	<b>1 249</b>	<b>—</b>	<b>—</b>	<b>249</b>	<b>130</b>	<b>4 967</b>	<b>7 069</b>	<b>4 703</b>	<b>26 622</b>
Industry	252	—	676	905	—	—	194	104	3 131	3 413	1 593	<b>10 383</b>
Transport	—	—	4 492	13	—	—	—	—	271	63	—	<b>4 839</b>
Residential	0	—	470	33	—	—	5	0	1 334	1 912	2 019	<b>5 773</b>
Agriculture	3	—	463	4	—	—	47	0	148	147	14	<b>827</b>
Commerce and public services	—	—	287	34	—	—	3	0	83	1 534	1 076	<b>3 017</b>
Other consumption	—	—	309	—	—	—	—	26	—	0	—	<b>335</b>
Non-energy use Blast furnace oil (subtracted from TFC industry)	—	—	1 189	259	—	—	—	0	—	—	—	<b>1 448</b>
			115									

## Energy Balance Sheet 2012, TJ

	Coal	Crude oil & NGL	Petroleum products	Natural gas	Nuclear energy	Hydro & wind power	Peat fuel	Recycled fuels and others	Wood fuels	Electricity	Heat sold & heat pumps	Total
	1	2	3	4	5	6	7		8	9	10	11
Indigenous production	–	–	19 471	–	250 767	62 489	41 541	11 327	331 298	–	16 175	<b>733 067</b>
Recycled oil	–	–	904	16	–	–	–	25 023	–	–	–	<b>25 943</b>
Imports	111 157	470 020	202 325	125 821	–	–	929	502	2 583	68 720	–	<b>982 058</b>
Exports	-1 348	0	-320 129	–	–	–	-91	–	-1 497	-5 922	–	<b>-328 986</b>
International marine bunkers	–	–	-5 169	–	–	–	–	–	–	–	–	<b>-5 169</b>
Stock Changes	16 210	-4 154	12 122	–	–	–	23 230	–	–	–	–	<b>47 408</b>
<b>Total Primary Energy Supply</b>	<b>126 019</b>	<b>465 866</b>	<b>-90 476</b>	<b>125 835</b>	<b>250 767</b>	<b>62 489</b>	<b>65 610</b>	<b>36 851</b>	<b>332 384</b>	<b>62 798</b>	<b>16 175</b>	<b>1 454 319</b>
Statistical Difference	-1 326	-38 050	51 204	0	–	–	606	-633	0	4	0	<b>11 804</b>
Electricity generation	-30 032	–	-1 580	-1 112	-250 767	-62 489	-7 323	-2 001	-12 429	159 851	–	<b>-207 881</b>
Combined district heat and power	-51 165	–	-1 195	-47 804	–	–	-37 946	-7 237	-68 757	56 038	123 675	<b>-34 390</b>
Cogeneration electricity in industry	-629	–	-1 492	-8 024	–	–	-2 293	-5 659	-30 959	27 781	11 039	<b>-10 236</b>
District heat production	-5 907	–	-10 151	-16 621	–	–	-7 020	-5 379	-24 065	–	59 423	<b>-9 719</b>
Oil refinery	–	-503 917	491 534	–	–	–	–	–	–	–	–	<b>-12 383</b>
Coal transformation	-19 872	–	–	–	–	–	–	–	–	–	–	<b>-19 872</b>
Energy sectors's own consumption	-7 318											<b>-7 318</b>
Transmission and distributions losses	-1 748	–	-440	–	–	–	–	–	–	-10 487	-13 418	<b>-26 093</b>



	Coal	Crude oil & NGL	Petroleum products	Natural gas	Nuclear energy	Hydro & wind power	Peat fuel	Recycled fuels and others	Wood fuels	Electricity	Heat sold & heat pumps	Total
	1	2	3	4	5	6	7		8	9	10	11
<b>TFC (total final consumption)</b>	<b>10 675</b>	–	<b>334 996</b>	<b>52 275</b>	–	–	<b>10 423</b>	<b>5 438</b>	<b>207 945</b>	<b>295 978</b>	<b>196 894</b>	<b>1 114 623</b>
Industry	10 536	–	28 303	37 899	–	–	8 131	4 366	131 104	142 880	66 697	<b>434 735</b>
Transport	–	–	188 085	548	–	–	–	0	11 330	2 653	–	<b>202 616</b>
Residential	15	–	19 672	1 391	–	–	202	0	55 833	80 064	84 541	<b>241 717</b>
Agriculture	124	–	19 378	186	–	–	1 970	0	6 205	6 170	590	<b>34 623</b>
Commerce and public services	–	–	12 024	1 405	–	–	121	0	3 473	64 210	45 066	<b>126 299</b>
Other consumption	–	–	12 934	–	–	–	–	1 072	–	0	–	<b>14 006</b>
Non-energy use	–	–	49 782	10 846	–	–	–	–	–	–	–	<b>60 628</b>
Blast furnace oil (subtracted from TFC industry)			4 820									

## Energy Balance Sheet 2012, TJ

Comparison to CRF categories:							CRF2014_v1.5			
Data from energy balance	Coal	Oil products	Natural gas	Peat	Recycled fuels and other	Wood fuels.	Total excluding biomass	Total Including biomass	Sector totals excl. biomass	Difference CRF/EB
Transformation (CRF 1.A 1)	87 732	27 240	73 561	54 580	20 276	136 210	253 252	399 599	263 770	4,2%
Industry (CRF 1.A 2)	10 536	28 303	37 899	8 131	4 366	131 104	87 051	220 338	105 550	21.2%
Transport (CRF 1.A 3)	—	188 085	548	—	0	11 330	188 633	199 963	169 934	-9.9%
Commerce and public services (CRF 1.A 4a)	—	12 024	1 405	121	0	3 473	13 550	17 023	13 944	2.9%
Residential (CRF 1.A 4b)	15	19 672	1 391	202	0	55 833	21 279	77 113	19 624	-7.8%
Agriculture (CRF 1.A 4c)	124	19 378	186	1 970	0	6 205	21 657	27 862	19 766	-8.7%
Other (CRF 1.A 5)	—	12 934	—	—	1 072	—	13 470	14 006	20 096	49.2%
Totals by fuel	98 407	307 636	114 989	65 004	25 713	344 155	598 892	955 904		
Aviation bunkers correction		-25 800								
Totals	98 407	281 836	114 989	77 860		357 012	573 092	930 104	612 684	6.9%
	Solid fuels	Liquid fuels	Gaseous fuels	Other		Biomass				
CRF totals by fuel	99 791	318 532	114 736	79 624		350 380	612 684	963 064		
difference CRF/EB	1.4%	13.0%	-0.2%	2.3%		-1.9%	6.9%	3.5%		

## Energy Balance Sheet 2012, Gg CO<sub>2</sub>

	Coal	Crude oil & NGL	Petroleum products	Natural gas	Nuclear energy	Hydro & wind power	Peat fuel	Recycled fuels and others	Wood fuels	Electricity	District heat & heat pumps	Total (fossil & peat)	Total (incl. biomass)
	1	2	3	4	5	6	7		8	9	10	11	
Indigenous production	–	–	–	–	0	0	4 421	897	35 947	–	0	5 318	41 265
Recycled oil	–	–	65	1	–	–	–	1 982	–	–	–	2 048	2 048
Imports	11 093	34 167	14 507	6 891	–	–	–	–	280	0	–	66 657	66 937
Exports	-134	–	-22 953	–	–	–	-10	–	–	0	–	-23 097	-23 097
International marine bunkers	–	–	-371	–	–	–	–	–	–	–	–	-371	-371
Stock Changes	1 618	-302	869	–	–	–	2 472	–	–	–	–	4 657	4 657
<b>Total Primary Energy Supply</b>	<b>12 576</b>	<b>33 865</b>	<b>-7 883</b>	<b>6 891</b>	<b>0</b>	<b>0</b>	<b>6 884</b>	<b>2 879</b>	<b>36 227</b>	<b>0</b>	<b>0</b>	<b>55 212</b>	<b>91 439</b>
Statistical Difference	–	–	3 671	0	–	–	–	–	–	–	–	3 671	3 671
Electricity generation	2 997	–	113	61	0	0	779	158	1 349	0	–	4 109	5 457
Combined district heat and power	5 106	–	86	2 618	–	–	4 038	573	7 460	0	0	12 421	19 881
Cogeneration electricity in industry	63	–	107	439	–	–	244	448	3 359	0	–	1 301	4 661
District heat production	589	–	728	910	–	–	747	426	2 611	–	0	3 401	6 012
Oil refinery	–	36 631	-35 243	–	–	–	–	–	–	–	–	1 388	1 388
Coal transformation	1 983	–	–	–	–	–	–	–	–	–	–	1 983	1 983
Energy sectors's own consumption	730	–	–	–	–	–	–	–	–	–	–	730	730
Transmission and distributions losses	174	–	32	–	–	–	–	–	–	0	0	206	206

	Coal	Crude oil & NGL	Petroleum products	Natural gas	Nuclear energy	Hydro & wind power	Peat fuel	Recycled fuels and others	Wood fuels	Electricity	District heat & heat pumps	Total (fossil & peat)	Total (incl. biomass)
	1	2	3	4	5	6	7		8	9	10	11	
<b>TFC (total final consumption)</b>	<b>1 053</b>	<b>–</b>	<b>20 104</b>	<b>2 269</b>	<b>–</b>	<b>–</b>	<b>1 109</b>	<b>431</b>	<b>22 231</b>	<b>0</b>	<b>0</b>	<b>24 535</b>	<b>47 197</b>
Industry	1 051	–	2 029	2 076	–	–	865	346	14 225	0	0	6 022	20 593
Transport	–	–	13 486	30	–	–	–	–	897	–	–	13 516	14 413
Residential	1	–	1 410	76	–	–	21	0	6 058	0	0	1 510	7 568
Agriculture	–	–	1 389	10	–	–	210	0	673	0	0	1 609	2 282
Commerce and public services	–	–	862	77	–	–	13	0	377	0	0	952	1 329
Other consumption	–	–	927	–	–	–	–	85	–	0	–	927	1 012
Non-energy use	–	–	3 569	594	–	–	–	–	–	–	–	4 163	4 163
Total CO <sub>2</sub> emissions (excluding non-energy use)	10 538		22 558	6 297			6 918	2 036	37 010			48 092	87 516
CO <sub>2</sub> emission factor. g/MJ	100.8	73.1	72.1	55.04	0.00	0.00	107.5	80.0*	109.6	0.00	0.00		
Oxidation factor	0.99	0.995	0.995	0.995	0.00	0.00	0.99	0.99	0.99	0.00	0.00		

\* estimation

## Energy Balance Sheet 2012, Gg CO<sub>2</sub>

Comparison to CRF categories:							CRF2014_v1.5			
Data from energy balance	Coal	Oil products	Natural gas	Peat	Recycled fuels and other	Wood fuels.	Total excluding biomass	Total Including biomass	Sector totals excl. biomass	Difference CRF/EB
Transformation (CRF 1.A 1)	9 485	2 454	4 029	5 809	1 606	14 779	21 776	38 161	20 353	-6.5%
Industry (CRF 1.A 2)	1 051	2 029	2 076	865	346	14 225	6 022	20 593	8 200	36.2%
Transport (CRF 1.A 3)	—	13 486	30	—	0	897	13 516	14 413	12 471	-7.7%
Commerce and public services (CRF 1.A 4a)	—	862	77	13	0	377	952	1 329	1 016	6.7%
Residential (CRF 1.A 4b)	1	1 410	76	21	0	6 058	1 510	7 568	1 429	-5.4%
Agriculture (CRF 1.A 4c)	—	1 389	10	210	0	673	1 609	2 282	1 510	-6.2%
Other (CRF 1.A 5)	—	927	—	—	85	—	927	1 012	1 377	48.4%
Totals by fuel	10 538	22 558	6 297	6 918	2 036	37 010	48 348	85 358		
Aviation bunkers correction		-1 889								
Totals	10 538	20 669	6 297	7 936		38 028	45 441	83 470	46 356	2.0%
CRF totals by fuel	9 958	22 592	6 284	7 522		37 266	46 356	83 622		
difference CRF/EB	-5.5%	9.3%	-0.2%	-5.2%		-2.0%	2.0%	0.2%		

## ANNEX 5. Assessment of completeness and (potential) sources and sinks of greenhouse gas emissions and removals excluded

Completeness of the Finnish inventory is evaluated by sectors in the tables below. The completeness is estimated by the gases (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, F-gases, NMVOC) and emission categories according to the detailed CRF-classification.

### Abbreviations used in tables:

X - included in the inventory

C - confidential business information

IE - included elsewhere

NA - not applicable

NE - not estimated

NO - not occurring in Finland

### Energy, Fuel combustion (CRF 1.A)

Greenhouse gas source and sink categories	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Explanation, -if not estimated -if included elsewhere	Notes
<b>1.A. Fuel combustion activities</b>					
<b>1. Energy industries</b>					
a. Public Electricity and Heat Production	X	X	X		
b. Petroleum Refining	X	X	X		
c. Manufacture of Solid Fuels and Other Energy Industries	X	X	X		
<b>2. Manufacturing Industries and Construction</b>					
a. Iron and Steel	X	X	X		
b. Non-Ferrous Metals	X	X	X		
c. Chemicals	X	X	X		
d. Pulp, Paper and Print	X	X	X		
e. Food Processing, Beverages and Tobacco	X	X	X		
f. Other:					
Construction	X	X	X		
Other non-specified	X	X	X		
Transferred CO <sub>2</sub>	X	NO	NO		Negative (sink)

Greenhouse gas source and sink categories	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Explanation, -if not estimated -if included elsewhere	Notes
<b>3. Transport</b>					
a. Civil Aviation	X	X	X		
b. Road Transportation	X	X	X		
c. Railways	X	X	X		
d. Navigation	X	X	X		
e. Other Transportation Other off-road machinery	X	X	X		
<b>4. Other Sectors</b>					
a. Commercial/Institutional	X	X	X		
b. Residential	X	X	X		
c. Agriculture/Forestry/ Fisheries	X	X	X		
<b>5. Other</b>					
a. Stationary					
Other non-specified	X	X	X		
Fuels from non-energy use	X	X	X		
Indirect N <sub>2</sub> O emissions from NO <sub>x</sub>	NO	NO	X		
b. Mobile	X	X	X		

### **Energy, Fugitive emissions (CRF 1.B)**

Greenhouse gas source and sink categories	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Explanation, -if not estimated -if included elsewhere	Notes
<b>1.B Fugitive emissions from fuels</b>					
<b>1. Solid fuels</b>					
a. Coal Mining	NO	NO	NO		
b. Solid Fuel Transformation	NO	NO	NO		
c. Other	NO	NO	NO		
<b>2. Oil and Natural Gas</b>					
a. Oil	X	X	NO		
b. Natural Gas	X	X			

Greenhouse gas source and sink categories	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Explanation, -if not estimated -if included elsewhere	Notes
c. Venting and Flaring	X	X	X		
d. Other Other non-specified	X	NO	NO		

## **Industrial Processes (CRF 2)**

Greenhouse gas source and sink categories	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Explanation, -if not estimated -if included elsewhere	Notes
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### **2. Industrial Processes**

#### **A. Mineral Products**

1. Cement Production	X			Indirect CO <sub>2</sub> emissions are included in 2.A 6 Road paving.	
2. Lime Production	X				
3. Limestone and Dolomite Use	X				
4. Soda Ash Production and Use	X				
5. Asphalt Roofing	IE				
6. Road Paving with Asphalt	X				
7. Other Glass production	X	NO	NO		

#### **B. Chemical Industry**

1. Ammonia Production	X	NO	NO		No ammonia production in Finland after 1992.
2. Nitric Acid Production			X		
3. Adipic Acid Production	NO		NO		
4. Carbide Production	NO	NO			
5. Other Hydrogen Production	X	NO	NO		*Ethylene is produced in Finland, but emitted CH <sub>4</sub> is used as fuel in the ovens of oil refinery.
Chemicals Production	X	NO	NO		
Phosphoric Acid Production	X	NO	NO		
5. Other Carbon black	NO	NA*	NO		
Ethylene					
Dichloroethylene					
Styrene					
Methanol					
Other non-specified					



Greenhouse gas source and sink categories	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Explanation, -if not estimated -if included elsewhere	Notes
<b>C. Metal Production</b>					
1. Iron and Steel Production	X	X		Emissions from integrated ferrochromium and stainless steel plant have been allocated to 2.C 1 Iron and steel production.	Includes emissions from integrated ferrochromium and stainless steel plant.
2. Ferroalloys Production	IE	NO			
3. Aluminium Production	NO	NO			
4. SF <sub>6</sub> Used in Aluminium and Magnesium Foundries	NO	NO			
5. Other Non-ferrous metals	X	NO	NO	Only indirect CO <sub>2</sub> emissions from NMVOC emissions	
<b>D. Other Production</b>					
1. Pulp and Paper	NO				
2. Food and Drink	NO				
<b>G. Other</b>	NO				

**F-gases (CRF 2.F)**

Greenhouse gas source and sink categories	HFC <sub>s</sub>	PFC <sub>s</sub>	SF <sub>6</sub>	Explanation, -if not estimated -if included elsewhere	Notes
<b>2. Industrial Processes</b>					
<b>E. Production of Halocarbons and SF<sub>6</sub></b>					
1. By-product Emissions	NO	NO	NO		
Production of HCFC-22	NO	NO	NO		
Other	NO	NO	NO		
<b>F. Consumption of Halocarbons and SF<sub>6</sub></b>					
1. Refrigeration and Air Conditioning Equipment	X	X	NO		
2. Foam Blowing	X	NO	NO		Excl. one component foam.
3. Fire Extinguishers	X, C	NO	NO		Reported grouped with other confidential data.
4. Aerosols/ Metered Dose Inhalers	X	NO	NO		Incl. one component foam.
5. Solvents	NO	NO	NO		
6. Other applications using ODS substitutes	NO	NO	NO		

Greenhouse gas source and sink categories	HFCs	PFCs	SF <sub>6</sub>	Explanation, -if not estimated -if included elsewhere	Notes
7. Semiconductor Manufacture	C, NA, NO	C, NA, NO	C, NA		Reported grouped with other confidential data.
8. Electrical Equipment	NO	NO	X		The activity data is confidential.
9. Other	X	X	X		Confidential information grouped together as one "source category": HFC-23 from refrigeration and air-conditioning; HFC-23, PFCs, and SF <sub>6</sub> from semiconductor manufacturing; HFCs from fixed fire protection equipment; SF <sub>6</sub> from shoes; SF <sub>6</sub> from magnesium die-casting; SF <sub>6</sub> from research.

### **Solvent and other product use (CRF 3)**

The evaluation of CRF category CRF 3 (Solvent and other product use) covers also the NMVOC emissions.

Greenhouse gas source and sink categories	CO <sub>2</sub>	NMVOC	N <sub>2</sub> O	Explanation, -if not estimated -if included elsewhere	Notes
<b>3. Solvent and Other Product Use</b>					
<b>A. Paint Application</b>	X	X			
<b>B. Degreasing and Dry Cleaning</b>	X	X	NO		
<b>C. Chemical Products, Manufacture and Processing</b>	X	X			
<b>D. Other</b>					
1. Use of N <sub>2</sub> O for Anaesthesia			X		Includes all uses of N <sub>2</sub> O in Finland.
2. N <sub>2</sub> O from Fire Extinguishers			IE	Included in Use of N <sub>2</sub> O for Anaesthesia	
3. N <sub>2</sub> O from Aerosol Cans			IE	Included in Use of N <sub>2</sub> O for Anaesthesia	
4. Other Use of N <sub>2</sub> O			IE	Included in Use of N <sub>2</sub> O for Anaesthesia	
5. Other (as specified in table 3.A-D)					
Wood preservation	X	X	NO		
Printing industry	X	X	NO		
Other non-specified	NO	NO	NO		
Use of pesticides	X	X	NO		
Glass wool induction	X	X	NO		
Mineral wool induction	X	X	NO		
Domestic solvent use	X	X	NO		Car care products included.
Fat, edible and non edible oil extraction	NO	X	NO		Biological origin, no fossil CO <sub>2</sub>

**Agriculture (CRF 4)**

Greenhouse gas source and sink categories	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Explanation, -if not estimated -if included elsewhere	Notes	
4. Agriculture						
A. Enteric fermentation						
1.Cattle		X		See 'Other'		
Dairy Cattle		X				
Non-Dairy Cattle		IE				
2.Buffalo		NO				
3.Sheep		X		No methodology available		
4.Goats		X				
5.Camels and Lamas		NO				
6.Horses		X				
7.Mules and Asses		NO				
8.Swine		X				
9.Poultry		NE				
10.Other		X		Suckler cows, heifers, bulls, calves, reindeer, fur animals		
B. Manure Management						
1.Cattle		X	X	See 'Other'		
Dairy Cattle		X	X			
Non-Dairy Cattle		IE	IE			
2.Buffalo		NO	NO			
3.Sheep		X	X			
4.Goats		X	X			
5.Camels and Lamas		NO	NO			
6. Horses		X	X			
7.Mules and Asses		NO	NO			

Greenhouse gas source and sink categories	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Explanation, -if not estimated -if included elsewhere	Notes
8.Swine		IE	IE	See 'Other'	
9.Poultry		X	X		
10. Other		X	X		Suckler cows, heifers, bulls calves, reindeer, fur animals, reindeer, ponies, fattening pigs, weaned pigs, boars, sows, piglets
11.Anaerobic Lagoons		NO	NO		
12.Liquid Systems		X	X		
13. Daily spread		NO	NO		
14.Solid Storage and Dry Lot		X	X		
15.Other AWMS		X	X		Deep litter
<b>C. Rice Cultivation</b>	NO				
<b>D. Agricultural Soils</b>					
1. Direct Soil Emissions		NE	X	No methodology available for CH <sub>4</sub> (GPG LULUCF 2003, p.3.8.3)	
2.Pasture, range and paddock manure			X		
3.Indirect Emissions		NE	X	No methodology available for CH <sub>4</sub>	
4.Other Other non-specified Municipal sewage sludge applied on fields			X		
<b>E. Prescribed Burning of Savannas</b>	NO				
<b>F. Field Burning of Agricultural Residues</b>					
1.Cereals		X	X		
2.Pulse		NO	NO		
3.Tubers and Roots		NO	NO		
4.Sugar Cane		NO	NO		
5.Other		NO	NO		

Greenhouse gas source and sink categories	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Explanation, -if not estimated -if included elsewhere	Notes
G. Other	NO				

### **Land Use Land Use Change and Forestry (CRF 5)**

Greenhouse gas source and sink categories	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Explanation, -if not estimated -if included elsewhere	Notes
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#### **5. Land use, Land use change and Forestry**

##### **A. Forest land**

##### **1. Forest land remaining forest land**

Carbon stock change in living biomass	X				
Net carbon stock change in dead organic matter	IE			Net carbon stock change in DOM is included in SOM	See NIR 7.2.3.1
Net carbon stock change in soils	X				

##### **2. Land converted to forest land**

Carbon stock change in living biomass	X, IE, NO			Losses in tree biomass is included in the gains. The method to estimate carbon stock change in this category gives an estimate for a net carbon stock change.	See NIR 7.2.3.2
Net carbon stock change in dead organic matter	IE, NO			Net carbon stock change in DOM is included in SOM	See NIR 7.2.3.2
Net carbon stock change in soils	X, NO				

##### **B. Cropland**

1. Cropland remaining cropland	X	NA	NA		Non-CO <sub>2</sub> emissions included under agriculture CRF 4.D
2. Land converted to cropland	X	NA	X		

##### **C. Grassland**

1. Grassland remaining grassland	X	NA	NA		Non-CO <sub>2</sub> emissions included under agriculture CRF 4.D
2. Land converted to grassland	X	NA	NA		

Greenhouse gas source and sink categories	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Explanation, -if not estimated -if included elsewhere	Notes
<b>D. Wetlands</b>					
1. Wetlands remaining wetlands	NE			Parties do not have to report categories presented in appendices of GPG LULUCF 2003 (Appendix: 3a.3 Wetlands remaining wetlands).	
2. Land converted to wetlands (include peat extraction areas)					
Carbon stock change in living biomass	X, NE, NO			NE: Method under development.	See NIR 7.5.2 and 7.2.3
Net carbon stock change in dead organic matter	X, NE, NO			Parties do not have to report carbon stock changes in this pool according to GPG LULUCF 2003	
Net carbon stock change in soils	X, NE, NO			NE: At the moment there is no data and no IPCC method to estimate carbon stock changes in these categories	
<b>E. Settlements</b>					
1. Settlements remaining settlements	NE			Parties do not have to report categories presented in appendices of GPG LULUCF 2003 (Appendix: 3a.4 Settlements).	
2. Land converted to settlements	X, NE				
				NE: No data available for biomass gains in this category.	See NIR 7.6.2.2
<b>F. Other land</b>					
1. Other land remaining other land	NE			Parties do not have to report categories presented in appendices of GPG LULUCF 2003 No methodology currently available	
2. Land converted to other land	NA, NO				

Greenhouse gas source and sink categories	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Explanation, -if not estimated -if included elsewhere	Notes
<b>G. Other</b>					
Harvested wood products	X				
<b>Information items:</b>					
Forest land converted to other land use categories	IE	IE,NE	IE, NE	CO <sub>2</sub> , IE: in other categories 5.B.2.1 to 5.F.2.1 CH <sub>4</sub> , N <sub>2</sub> O NE: No reliable methodology to estimate CH <sub>4</sub> and N <sub>2</sub> O emissions. CH <sub>4</sub> ,IE: Area transferred from forest land to peat extraction is reported under category 5(II). N <sub>2</sub> O, IE: Area transferred from forest land to peat extraction is reported under category 5(II) and conversion to cropland under category 5 (III).	
Grassland converted to other land use categories	NE	NE	NE	No activity data available to calculate this.	
<b>5 (I) Direct N<sub>2</sub>O emissions from N fertilisation</b>			X		
<b>5(II) Non-CO<sub>2</sub> emissions from drainage of soils</b>		X,NE	X, NE	N <sub>2</sub> O emissions from Forest land, N <sub>2</sub> O and CH <sub>4</sub> emissions from Wetlands (peat extraction areas) and CH <sub>4</sub> emissions from lands converted to inland waters are reported. N <sub>2</sub> O and CH <sub>4</sub> emissions from other Wetlands and CH <sub>4</sub> from Forest land are not reported due to that no reliable methodology is currently available and, inadequate activity data. Parties do not have to report categories presented in appendices of GPG LULUCF 2003 (Appendix: 3.a.2)	See NIR 7.5, 7.8.2
<b>5(III) N<sub>2</sub>O emissions from disturbance associated with land-use conversion to cropland</b>			X		
<b>5(IV) CO<sub>2</sub> emissions from agricultural lime application</b>	X				

Greenhouse gas source and sink categories	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Explanation, -if not estimated -if included elsewhere	Notes
5(V) Biomass Burning	X, IE, NE	X, IE, NE	X, IE, NE	X: Emissions from biomass burning on forest lands is reported IE: Emissions from wildfires on wetlands and other lands are reported under forest land category 5.A.1. NE: Emissions from biomass burning on other land use categories are not reported.	See NIR 7.8.5.1

### **Waste (CRF 6)**

Greenhouse gas source and sink categories	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Explanation, -if not estimated -if included elsewhere	Notes
6. Waste					
A. Solid Waste Disposal on Land					
1. Managed Waste Disposal on Land	NO	X		Unmanaged waste disposal, which occurred in early 1990's, is included under managed waste disposal.	
2. Unmanaged Waste Disposal Sites	NO	IE/NO			
3. Other	NO	X			
Municipal sludge Industrial sludge Industrial solid waste Construction and demolition waste					
B. Wastewater Handling					
1.Industrial Wastewater		X	NE	No IPCC methodologies for N <sub>2</sub> O available.	
2.Domestic and Commercial Wastewater					N <sub>2</sub> O from human sewage is estimated partly by the means of population and partly by the means of N input (measured values)
Domestic and commercial		X	NE	No IPCC methodologies for N <sub>2</sub> O from domestic and commercial wastewater available.	
Human sewage		NA	X		
3.Other		NO	X		National emission source
N input from Fish Farming					
N input from industrial wastewater					
C. Waste Incineration	IE	IE	IE	Waste incineration without energy recovery is nearly zero. Waste incineration with and without energy recovery are included in the calculations of the energy sector (CRF 1.A.).	
D. Other					
Compost production	NO	X	X		



## **Land Use, Land-Use Change and Forestry Activities under the Kyoto Protocol (CRF 5(KP))**

Greenhouse gas source and sink categories	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Explanation, -if not estimated -if included elsewhere	Notes
<b>5(KP) Land use, land-use change and forestry activities under the Kyoto Protocol</b>					
<b>5(KP-I) Carbon stock changes and net CO<sub>2</sub> emissions and removals</b>					
A.1.1 Afforestation and reforestation				Biomass: The method used for tree biomass estimation produces a combined estimate for gains and losses.	In NIR the description of the method is in Sections 11.3.1.1 and 7.2.3.1 and 7.2.3.2
above ground biomass	X, IE				
below ground biomass	X, IE				
litter	IE			Litter and dead wood (DOM): C-stock changes in these pools for mineral soils are estimated using the Yasso07 model that produces a combined estimate	
dead wood	IE			DOM and soil organic matter (SOM)	
soil	X				
A.2 Deforestation				Gains in biomass is not estimated for all deforested areas because there is no data available to estimate biomass growth.	In NIR the description of the method is in Sections 11.3.1.1 and 7.2.3.1 and 7.2.3.2
above ground biomass	X, NE, NO, NA				
below ground biomass	X, IE, NE, NO, NA				
litter	IE, NO			Litter: if IE is reported, litter is included in SOM or in energy sector as peat combustion.	
dead wood	X, IE			Dead wood: if IE is reported, litter is included in SOM.	
soil	X, NA				
B.1 Forest management				Litter and dead wood (DOM): C-stock changes in these pools for mineral soils are estimated using the Yasso07 model that produces a combined estimate	In NIR the description of the method is in Sections 11.3.1.1 and 7.2.3.1 and 7.2.3.2
above ground biomass	X				
below ground biomass	X				
litter	IE				
dead wood	IE				
soil	X				
<b>5(KP-II)1. Direct N<sub>2</sub>O emissions from N fertilisation</b>					
A.1.1 Afforestation and reforestation			NO		
B.1 Forest management			X		

Greenhouse gas source and sink categories	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	Explanation, -if not estimated -if included elsewhere	Notes
5(KP-II)2. N <sub>2</sub> O emissions from drainage of soils					
A.1.1 Afforestation and reforestation			X		Emissions reported in CRF table 5(KP-II)5 Biomass burning, because in table 5(KP-II)2 there is no place for AR emissions. By doing this way the emissions are accounted correctly in Accounting table. See NIR Section 11.3.1 See NIR Section 11.3.1
B.1 Forest management			X		
5(KP-II)3. D. N <sub>2</sub> O emissions from disturbance associated with land-use conversion to cropland					
A.2 Deforestation			X		
5(KP-II)4. Carbon emissions from lime application					
A.1.1 Afforestation and reforestation	NO				
A.2 Deforestation	X				
B.1 Forest management	NO				
5(KP-II)5. GHG emissions from biomass burning					
A.1.1 Afforestation and reforestation	X, NO	X, NO	X, NO		
A.2 Deforestation	NO, IE	NO, IE	NO, IE	Controlled burnings in areas converted to cropland or grassland are rare in Finland. Possible emissions are allocated to Agriculture sector.	
B.1 Forest management	X, IE	X	X	CO <sub>2</sub> emissions from controlled burning are included in CSC in living biomass in FM. Biomass burned in controlled burning is mainly cutting residues and thus included in losses in living biomass.	

## *ANNEX 6. Uncertainty analysis*

Annex 6 provides the mandatory reporting table for uncertainty analysis. For this submission, Finland reports both Tier 1 and Tier 2 uncertainty analyses. Tier 2 analysis was based on Monte Carlo simulation, and it was prepared in accordance with IPCC methodology (IPCC 2000, 2003 and 2006). The results of tier 2 analysis are reported according to the table 3.3. of 2006 IPCC Guidelines, an tier 1 analysis in table 6.1 of GPG 2003.

Analysis tables with numerical results are here below, detailed supplementary information can be found in UA-KCA\_FIN-2014-2012-v1.5.xlsx, and UA-KCA\_KP-FIN-2014-2012-v1.5.xlsx for this data.

Uncertainty analysis was re-evaluated in 2013 and the emissions in uncertainty analysis are now aggregated mainly to the 3rd category level. In energy sector CRF fuel types are also considered, and in Tier 2 level analysis subgrouping goes down to detailed fuel types. For this submission only minor changes were done in the uncertainty analysis parameterization, and they were in f-gases uncertainty estimation.

**Table 1.** Tier 2 uncertainty analysis. Unit of emissions is Gg CO<sub>2</sub> equivalent

Category	CFR fuel	Gas	Emissions/ removals 1990	Emissions/ removals 2012	Activity data uncertainty 2012		Emission factor/ implied EF uncertainty 2012		Uncertainty in emissions 2012		Uncertainty share 2012	Category trend 1990-2012	Uncertainty in trend 2012	
			Gg CO <sub>2</sub> -eq	Gg CO <sub>2</sub> -eq	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %			(-) %	(+) %
1A1 Energy Industries	Liquid	CO <sub>2</sub>	2 838.0	2 431.6	1 %	1 %	2 %	2 %	3 %	3 %	0.06 %	-14 %	5 %	5 %
1A1 Energy Industries	Liquid	CH <sub>4</sub>	1.0	1.0	1 %	1 %	32 %	32 %	32 %	32 %	0.00 %	3 %	31 %	49 %
1A1 Energy Industries	Liquid	N <sub>2</sub> O	24.9	26.7	1 %	1 %	33 %	33 %	33 %	33 %	0.01 %	7 %	12 %	18 %
1A1 Energy Industries	Solid	CO <sub>2</sub>	9 640.1	7 709.3	1 %	1 %	1 %	1 %	1 %	1 %	0.10 %	-20 %	3 %	4 %
1A1 Energy Industries	Solid	CH <sub>4</sub>	2.3	1.9	1 %	1 %	57 %	57 %	57 %	57 %	0.00 %	-15 %	2 %	4 %
1A1 Energy Industries	Solid	N <sub>2</sub> O	43.4	52.0	1 %	1 %	58 %	58 %	58 %	58 %	0.03 %	20 %	3 %	4 %
1A1 Energy Industries	Gaseous	CO <sub>2</sub>	2 623.1	4 434.2	1 %	1 %	0 %	0 %	1 %	1 %	0.04 %	69 %	3 %	3 %
1A1 Energy Industries	Gaseous	CH <sub>4</sub>	1.0	1.9	1 %	1 %	50 %	50 %	50 %	50 %	0.00 %	81 %	11 %	8 %
1A1 Energy Industries	Gaseous	N <sub>2</sub> O	15.6	27.4	1 %	1 %	47 %	47 %	47 %	47 %	0.01 %	75 %	4 %	4 %
1A1 Energy Industries	Biomass	CH <sub>4</sub>	1.5	11.0	3 %	3 %	59 %	60 %	59 %	60 %	0.01 %	627 %	96 %	132 %
1A1 Energy Industries	Biomass	N <sub>2</sub> O	3.1	118.1	3 %	3 %	59 %	59 %	59 %	60 %	0.06 %	3744 %	508 %	707 %
1A1 Energy Industries	Other	CO <sub>2</sub>	3 950.0	5 796.3	2 %	2 %	2 %	2 %	3 %	3 %	0.15 %	47 %	9 %	10 %
1A1 Energy Industries	Other	CH <sub>4</sub>	2.5	5.9	2 %	2 %	53 %	54 %	53 %	54 %	0.00 %	139 %	21 %	48 %
1A1 Energy Industries	Other	N <sub>2</sub> O	34.6	83.1	2 %	2 %	53 %	54 %	53 %	54 %	0.04 %	140 %	21 %	49 %
1A2 Manufacturing industries and construction	Liquid	CO <sub>2</sub>	4 552.0	3 023.0	5 %	5 %	1 %	1 %	6 %	6 %	0.15 %	-34 %	5 %	6 %
1A2 Manufacturing industries and construction	Liquid	CH <sub>4</sub>	2.5	2.4	5 %	5 %	29 %	29 %	29 %	31 %	0.00 %	-5 %	18 %	22 %
1A2 Manufacturing industries and construction	Liquid	N <sub>2</sub> O	36.9	25.2	5 %	5 %	30 %	55 %	30 %	55 %	0.01 %	-32 %	14 %	19 %
1A2 Manufacturing industries and construction	Solid	CO <sub>2</sub>	4 842.8	2 237.9	2 %	2 %	4 %	4 %	4 %	4 %	0.08 %	-54 %	2 %	2 %
1A2 Manufacturing industries and construction	Solid	CH <sub>4</sub>	1.4	0.4	2 %	2 %	27 %	28 %	27 %	28 %	0.00 %	-70 %	8 %	11 %
1A2 Manufacturing industries and construction	Solid	N <sub>2</sub> O	46.7	9.9	2 %	2 %	28 %	28 %	28 %	28 %	0.00 %	-79 %	5 %	7 %
1A2 Manufacturing industries and construction	Gaseous	CO <sub>2</sub>	2 189.8	1 453.3	2 %	2 %	0 %	0 %	2 %	2 %	0.02 %	-34 %	2 %	2 %
1A2 Manufacturing industries and construction	Gaseous	CH <sub>4</sub>	1.0	0.6	2 %	2 %	50 %	50 %	50 %	50 %	0.00 %	-42 %	5 %	4 %
1A2 Manufacturing industries and construction	Gaseous	N <sub>2</sub> O	15.3	10.6	2 %	2 %	47 %	47 %	47 %	47 %	0.00 %	-31 %	3 %	3 %
1A2 Manufacturing industries and construction	Biomass	CH <sub>4</sub>	6.8	11.7	2 %	2 %	33 %	33 %	33 %	33 %	0.00 %	72 %	50 %	76 %
1A2 Manufacturing industries and construction	Biomass	N <sub>2</sub> O	56.5	76.3	2 %	2 %	41 %	41 %	41 %	41 %	0.03 %	35 %	11 %	10 %
1A2 Manufacturing industries and construction	Other	CO <sub>2</sub>	1 597.7	1 514.9	2 %	2 %	2 %	2 %	3 %	3 %	0.04 %	-5 %	7 %	8 %
1A2 Manufacturing industries and construction	Other	CH <sub>4</sub>	1.1	1.0	2 %	2 %	39 %	39 %	39 %	39 %	0.00 %	-10 %	19 %	19 %
1A2 Manufacturing industries and construction	Other	N <sub>2</sub> O	17.0	14.6	2 %	2 %	38 %	39 %	38 %	39 %	0.01 %	-14 %	15 %	20 %

Category	CFR fuel	Gas	Emissions/ removals 1990	Emissions/ removals 2012	Activity data uncertainty 2012		Emission factor/ implied EF uncertainty 2012		Uncertainty in emissions 2012		Uncertainty share 2012	Category trend 1990-2012	Uncertainty in trend 2012	
			Gg CO2-eq	Gg CO2-eq	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %			(-) %	(+) %
1A3a Civil aviation	Liquid	CO2	385.1	203.5	20 %	20 %	2 %	2 %	20 %	20 %	0.04 %	-47 %	11 %	12 %
1A3a Civil aviation	Liquid	CH4	0.3	0.2	20 %	20 %	98 %	99 %	98 %	104 %	0.00 %	-38 %	13 %	15 %
1A3a Civil aviation	Liquid	N2O	4.9	2.8	20 %	20 %	70 %	150 %	70 %	153 %	0.00 %	-43 %	12 %	13 %
1A3b Road transportation	Diesel oil	CO2	4 923.5	6 913.0	1 %	1 %	2 %	1 %	2 %	2 %	0.11 %	40 %	2 %	2 %
1A3b Road transportation	Diesel oil	CH4	11.5	4.4	1 %	1 %	50 %	51 %	50 %	51 %	0.00 %	-62 %	1 %	1 %
1A3b Road transportation	Diesel oil	N2O	68.1	110.1	1 %	1 %	70 %	152 %	70 %	151 %	0.15 %	62 %	2 %	2 %
1A3b Road transportation	Gasoline	CO2	5 882.5	4 129.8	2 %	2 %	2 %	2 %	3 %	3 %	0.10 %	-30 %	2 %	3 %
1A3b Road transportation	Gasoline	CH4	77.9	16.3	2 %	2 %	35 %	35 %	35 %	35 %	0.01 %	-79 %	5 %	12 %
1A3b Road transportation	Gasoline	N2O	91.8	40.5	2 %	2 %	63 %	132 %	63 %	132 %	0.05 %	-56 %	29 %	111 %
1A3b Road transportation	Gaseous	CO2	0.0	8.9	3 %	3 %	0 %	1 %	3 %	3 %	0.00 %			
1A3b Road transportation	Gaseous	CH4	0.0	2.1	3 %	3 %	50 %	50 %	50 %	50 %	0.00 %			
1A3b Road transportation	Gaseous	N2O	0.0	0.0	3 %	3 %	70 %	149 %	70 %	149 %	0.00 %			
1A3b Road transportation	Biomass	CH4	0.0	1.6	1 %	1 %	71 %	72 %	71 %	72 %	0.00 %			
1A3b Road transportation	Biomass	N2O	0.0	10.8	1 %	1 %	60 %	117 %	60 %	117 %	0.01 %			
1A3c Railways	Liquid	CO2	191.1	98.7	5 %	5 %	1 %	2 %	5 %	5 %	0.00 %	-48 %	4 %	4 %
1A3c Railways	Liquid	CH4	0.2	0.1	5 %	5 %	50 %	50 %	50 %	51 %	0.00 %	-52 %	3 %	3 %
1A3c Railways	Liquid	N2O	1.5	0.8	5 %	5 %	70 %	154 %	70 %	154 %	0.00 %	-46 %	4 %	4 %
1A3d Navigation	Liquid	CO2	441.3	483.9	5 %	6 %	1 %	1 %	6 %	6 %	0.02 %	10 %	8 %	9 %
1A3d Navigation	Liquid	CH4	4.6	2.5	5 %	6 %	81 %	82 %	81 %	82 %	0.00 %	-45 %	10 %	31 %
1A3d Navigation	Liquid	N2O	2.9	3.8	5 %	6 %	64 %	113 %	64 %	114 %	0.00 %	31 %	65 %	62 %
1A3e Other transportation (off-road vehicles and other machinery)	Liquid	CO2	659.9	633.3	15 %	15 %	1 %	1 %	15 %	15 %	0.08 %	-4 %	22 %	32 %
1A3e Other transportation (off-road vehicles and other machinery)	Liquid	CH4	5.0	6.2	15 %	15 %	46 %	50 %	48 %	57 %	0.00 %	25 %	40 %	56 %
1A3e Other transportation (off-road vehicles and other machinery)	Liquid	N2O	4.7	4.3	15 %	15 %	58 %	112 %	59 %	114 %	0.00 %	-8 %	22 %	37 %
1A3e Other transportation (off-road vehicles and other machinery)	Biomass	CH4	0.0	0.5	9 %	9 %	45 %	45 %	45 %	47 %	0.00 %			
1A3e Other transportation (off-road vehicles and other machinery)	Biomass	N2O	0.0	0.2	9 %	9 %	43 %	70 %	44 %	71 %	0.00 %			

Category	CFR fuel	Gas	Emissions/ removals 1990	Emissions/ removals 2012	Activity data uncertainty 2012		Emission factor/ implied EF uncertainty 2012		Uncertainty in emissions 2012		Uncertainty share 2012	Category trend 1990-2012	Uncertainty in trend 2012	
			Gg CO2-eq	Gg CO2-eq	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %			(-) %	(+) %
1A4 Other sectors	Liquid	CO2	6 634.6	3 523.6	7 %	7 %	1 %	1 %	7 %	7 %	0.22 %	-47 %	6 %	7 %
1A4 Other sectors	Liquid	CH4	17.8	9.8	7 %	7 %	34 %	34 %	34 %	35 %	0.00 %	-45 %	22 %	39 %
1A4 Other sectors	Liquid	N2O	55.3	29.3	7 %	7 %	38 %	41 %	38 %	43 %	0.01 %	-47 %	21 %	35 %
1A4 Other sectors	Solid	CO2	46.5	10.9	9 %	9 %	1 %	1 %	9 %	9 %	0.00 %	-77 %	4 %	5 %
1A4 Other sectors	Solid	CH4	2.3	0.1	9 %	9 %	69 %	74 %	69 %	75 %	0.00 %	-96 %	3 %	13 %
1A4 Other sectors	Solid	N2O	0.6	0.1	9 %	9 %	43 %	43 %	43 %	44 %	0.00 %	-81 %	9 %	15 %
1A4 Other sectors	Gaseous	CO2	104.0	184.1	3 %	3 %	0 %	0 %	3 %	3 %	0.01 %	77 %	12 %	13 %
1A4 Other sectors	Gaseous	CH4	0.2	0.2	3 %	3 %	52 %	51 %	52 %	52 %	0.00 %	-7 %	47 %	97 %
1A4 Other sectors	Gaseous	N2O	0.6	1.0	3 %	3 %	34 %	34 %	34 %	34 %	0.00 %	76 %	32 %	34 %
1A4 Other sectors	Biomass	CH4	161.3	243.9	9 %	9 %	69 %	134 %	70 %	134 %	0.29 %	51 %	26 %	25 %
1A4 Other sectors	Biomass	N2O	27.8	40.6	9 %	9 %	61 %	128 %	61 %	129 %	0.05 %	46 %	24 %	27 %
1A4 Other sectors	Other	CO2	121.9	238.8	9 %	9 %	2 %	2 %	9 %	9 %	0.02 %	96 %	34 %	47 %
1A4 Other sectors	Other	CH4	1.2	2.4	9 %	9 %	43 %	42 %	44 %	44 %	0.00 %	96 %	91 %	141 %
1A4 Other sectors	Other	N2O	1.5	2.9	9 %	9 %	61 %	128 %	62 %	129 %	0.00 %	94 %	108 %	157 %
1A5a Indirect N2O emissions from NOx	Non-fuel	N2O	439.4	218.4					62 %	62 %	0.12 %	-50 %	33 %	94 %
1A5a Non-specified emissions of fuels from non-energy use	Liquid	CO2	207.5	59.3	20 %	20 %	5 %	5 %	20 %	21 %	0.01 %	-71 %	7 %	10 %
1A5a Non-specified emissions of fuels from non-energy use	Liquid	CH4	0.2	0.1	20 %	20 %	60 %	60 %	61 %	66 %	0.00 %	-71 %	19 %	54 %
1A5a Non-specified emissions of fuels from non-energy use	Liquid	N2O	1.8	0.5	20 %	20 %	59 %	60 %	60 %	67 %	0.00 %	-71 %	19 %	52 %
1A5a Other non-specified	Liquid	CO2	985.7	894.6	20 %	20 %	2 %	2 %	20 %	21 %	0.16 %	-9 %	27 %	47 %
1A5a Other non-specified	Liquid	CH4	2.5	2.1	20 %	20 %	49 %	50 %	51 %	60 %	0.00 %	-16 %	48 %	106 %
1A5a Other non-specified	Liquid	N2O	7.7	6.6	20 %	20 %	46 %	47 %	48 %	56 %	0.00 %	-15 %	46 %	99 %
1A5a Other non-specified	Solid	CO2	1.2	0.0							0.00 %	-100 %		
1A5a Other non-specified	Solid	CH4	0.0	0.0							0.00 %	-100 %		
1A5a Other non-specified	Solid	N2O	0.0	0.0							0.00 %	-100 %		
1A5a Other non-specified	Gaseous	CO2	53.4	203.0	38 %	38 %	0 %	1 %	38 %	38 %	0.07 %	280 %	3657 %	3304 %
1A5a Other non-specified	Gaseous	CH4	0.1	0.2	38 %	38 %	61 %	60 %	65 %	79 %	0.00 %	278 %	4023 %	4076 %
1A5a Other non-specified	Gaseous	N2O	0.3	1.1	38 %	38 %	60 %	60 %	65 %	79 %	0.00 %	280 %	4053 %	4011 %
1A5a Other non-specified	Biomass	CH4	0.2	1.0	10 %	10 %	59 %	59 %	60 %	62 %	0.00 %	401 %	321 %	881 %
1A5a Other non-specified	Biomass	N2O	0.2	0.3	10 %	10 %	53 %	54 %	53 %	55 %	0.00 %	28 %	76 %	222 %
1A5a Other non-specified	Other	CO2	24.0	0.0							0.00 %	-100 %		
1A5a Other non-specified	Other	CH4	0.2	0.0							0.00 %	-100 %		
1A5a Other non-specified	Other	N2O	0.1	0.0							0.00 %	-100 %		
1A5b Mobile	Liquid	CO2	58.0	204.1	22 %	21 %	2 %	2 %	22 %	21 %	0.04 %	252 %	160 %	788 %
1A5b Mobile	Liquid	CH4	0.1	0.2	22 %	22 %	42 %	41 %	44 %	49 %	0.00 %	252 %	200 %	755 %
1A5b Mobile	Liquid	N2O	0.6	2.6	22 %	21 %	64 %	134 %	65 %	140 %	0.00 %	336 %	262 %	1649 %
1A5b Mobile	Biomass	CH4	0.0	0.0	50 %	50 %	70 %	151 %	76 %	171 %	0.00 %			
1A5b Mobile	Biomass	N2O	0.0	0.0	50 %	50 %	70 %	152 %	76 %	172 %	0.00 %			

Category	CFR fuel	Gas	Emissions/ removals 1990	Emissions/ removals 2012	Activity data uncertainty 2012		Emission factor/ implied EF uncertainty 2012		Uncertainty in emissions 2012		Uncertainty share 2012	Category trend 1990-2012	Uncertainty in trend 2012	
			Gg CO2-eq	Gg CO2-eq	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %			(-) %	(+) %
1B2a Oil - refining/storage	Non-fuel	CO2	1.0	1.4	90 %	90 %	25 %	25 %	90 %	99 %	0.00 %	38 %	143 %	576 %
1B2a Oil - refining/storage	Non-fuel	CH4	7.6	10.6	90 %	90 %	90 %	90 %	102 %	159 %	0.01 %	38 %	144 %	580 %
1B2bT Natural gas - transmission	Non-fuel	CO2	0.5	0.6	5 %	5 %	25 %	25 %	26 %	26 %	0.00 %	38 %	9 %	10 %
1B2bT Natural gas - transmission	Non-fuel	CH4	3.6	4.9	5 %	5 %	0 %	0 %	5 %	5 %	0.00 %	38 %	9 %	10 %
1B2bD Natural gas - distribution	Non-fuel	CO2	0.0	2.9	3 %	3 %	25 %	25 %	25 %	25 %	0.00 %			
1B2bD Natural gas - distribution	Non-fuel	CH4	0.0	22.1	3 %	3 %	0 %	0 %	3 %	3 %	0.00 %			
1B2c Venting and flaring	Non-fuel	CO2	121.9	100.5					40 %	40 %	0.04 %	-18 %	37 %	60 %
1B2c Venting and flaring	Non-fuel	CH4	0.0	0.0					49 %	50 %	0.00 %	35 %	73 %	163 %
1B2c Venting and flaring	Non-fuel	N2O	0.7	1.0					50 %	49 %	0.00 %	36 %	74 %	162 %
1B2d Other (CO2 from NMVOC)	Non-fuel	CO2	95.5	28.0	99 %	99 %	20 %	20 %	99 %	105 %	0.03 %	-71 %	57 %	170 %
2A1 Cement production		CO2	733.6	499.6	2 %	2 %	5 %	5 %	5 %	5 %	0.02 %	-32 %	2 %	2 %
2A2 Lime production		CO2	382.6	402.9	2 %	2 %	3 %	3 %	4 %	4 %	0.01 %	5 %	5 %	5 %
2A3 Limestone and dolomite use		CO2	98.2	238.6	5 %	5 %	3 %	3 %	6 %	6 %	0.01 %	143 %	20 %	22 %
2A4 Soda ash production and use		CO2	12.9	21.0	5 %	5 %	3 %	3 %	6 %	6 %	0.00 %	63 %	11 %	12 %
2A6 Road paving with asphalt		CO2	21.2	1.7	85 %	86 %	20 %	20 %	85 %	92 %	0.00 %	-92 %	7 %	32 %
2A7 Other (glass production)		CO2	20.9	1.6	5 %	5 %	3 %	3 %	6 %	6 %	0.00 %	-92 %	1 %	1 %
2B1 Ammonia production		CO2	44.0	0.0							0.00 %	-100 %		
2B2 Nitric acid production		N2O	1 655.7	166.4	3 %	3 %	15 %	15 %	15 %	15 %	0.02 %	-90 %	23 %	51 %
2B5f Chemicals production		CO2	24.4	7.5	100 %	100 %	20 %	20 %	100 %	105 %	0.01 %	-69 %	56 %	176 %
2B5g Hydrogen		CO2	57.9	676.5	5 %	5 %	3 %	3 %	6 %	6 %	0.04 %	1068 %	127 %	151 %
2B5i Phosphoric Acid Production		CO2	24.5	42.4					7 %	7 %	0.00 %	73 %	25 %	33 %
2C1 Iron and steel production		CO2	1 935.2	2 277.8					6 %	6 %	0.13 %	18 %	27 %	47 %
2C1 Iron and steel production		CH4	5.1	9.2	3 %	3 %	20 %	20 %	20 %	20 %	0.00 %	81 %	8 %	8 %
2C5 Other (non-ferrous metals)		CO2	0.4	0.3	100 %	100 %	20 %	20 %	100 %	105 %	0.00 %	-27 %	133 %	407 %
2F1 Refrigeration and air conditioning equipment		HFC	0.0	861.0					14 %	14 %	0.11 %	6833594 %	4487670 %	35574288 %
2F1 Refrigeration and air conditioning equipment		PFC	0.0	0.4					22 %	22 %	0.00 %			
2F2 Foam blowing		HFC	0.0	13.2					11 %	11 %	0.00 %			
2F4 Aerosols/metered dose inhalers		HFC	0.0	48.4					27 %	27 %	0.01 %			
2F8 Electrical equipment		SF6	107.1	7.2					53 %	53 %	0.00 %	-93 %	16 %	37 %
2F9 Other (grouped confidential data)		HFC	0.0	2.9					14 %	14 %	0.00 %	57635 %	161316 %	299650 %
2F9 Other (grouped confidential data)		PFC	0.1	1.5					20 %	20 %	0.00 %	2021 %	5081 %	10550 %
2F9 Other (grouped confidential data)		SF6	7.9	29.6					19 %	19 %	0.01 %	277 %	1002 %	1934 %
3 Solvent and other product use		CO2	115.9	39.8	61 %	61 %	7 %	7 %	61 %	62 %	0.02 %	-66 %	23 %	68 %
3 Solvent and other product use		N2O	62.0	26.2	10 %	10 %	0 %	0 %	10 %	10 %	0.00 %	-58 %	10 %	19 %

Category	CFR fuel	Gas	Emissions/ removals 1990	Emissions/ removals 2012	Activity data uncertainty 2012		Emission factor/ implied EF uncertainty 2012		Uncertainty in emissions 2012		Uncertainty share 2012	Category trend 1990-2012	Uncertainty in trend 2012	
			Gg CO <sub>2</sub> -eq	Gg CO <sub>2</sub> -eq	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %			(-) %	(+) %
4A Enteric fermentation		CH <sub>4</sub>	1 831.9	1 544.1					25 %	25 %	0.35 %	-16 %	4 %	4 %
4B Manure management		CH <sub>4</sub>	202.5	250.8					12 %	12 %	0.03 %	24 %	19 %	23 %
4B Manure management		N <sub>2</sub> O	486.7	415.6					43 %	66 %	0.25 %	-15 %	28 %	42 %
4D1 Direct soil emissions		N <sub>2</sub> O	3 068.9	2 727.8					71 %	117 %	2.86 %	-11 %	47 %	104 %
4D2 Pasture, range and paddock manure		N <sub>2</sub> O	190.5	185.7					70 %	200 %	0.33 %	-3 %	58 %	142 %
4D3 Indirect emissions		N <sub>2</sub> O	766.8	583.5					80 %	302 %	1.57 %	-24 %	68 %	84 %
4F Field burning of agricultural residues		CH <sub>4</sub>	1.9	0.4					46 %	55 %	0.00 %	-79 %	6 %	9 %
4F Field burning of agricultural residues		N <sub>2</sub> O	0.6	0.1					38 %	44 %	0.00 %	-79 %	5 %	7 %
6A Solid waste disposal on land		CH <sub>4</sub>	3 635.3	1 737.1					30 %	30 %	0.47 %	-52 %	7 %	6 %
6B1 Industrial wastewater		CH <sub>4</sub>	22.2	17.3	10 %	10 %	71 %	99 %	72 %	100 %	0.02 %	-22 %	12 %	16 %
6B2 Domestic and commercial wastewater		CH <sub>4</sub>	131.3	96.9	6 %	6 %	30 %	28 %	31 %	28 %	0.03 %	-26 %	13 %	15 %
6B2 Domestic and commercial wastewater		N <sub>2</sub> O	105.3	78.3	6 %	6 %	94 %	370 %	94 %	368 %	0.26 %	-26 %	5 %	6 %
6B3a Other (N input from fish farming)		N <sub>2</sub> O	8.3	3.0	10 %	10 %	94 %	370 %	94 %	371 %	0.01 %	-64 %	5 %	6 %
6B3b Other (N input from industrial wastewater)		N <sub>2</sub> O	30.2	17.8	7 %	7 %	94 %	370 %	94 %	367 %	0.06 %	-41 %	5 %	5 %
6D Other (compost production)		CH <sub>4</sub>	21.6	58.3	20 %	20 %	72 %	73 %	72 %	77 %	0.04 %	170 %	133 %	300 %
6D Other (compost production)		N <sub>2</sub> O	20.4	59.1	20 %	20 %	73 %	86 %	73 %	89 %	0.05 %	189 %	146 %	217 %
5A1 Forest Land remaining Forest Land		CO <sub>2</sub>	-23 111.0	-38 321.4					25 %	25 %	8.70 %	66 %	69 %	229 %
5A2 Land converted to Forest Land		CO <sub>2</sub>	130.7	- 116.1					222 %	220 %	0.23 %	-189 %	780 %	916 %
5B1 Cropland remaining Cropland		CO <sub>2</sub>	4 716.1	5 448.1					80 %	78 %	3.87 %	16 %	9 %	49 %
5B2 Land converted to Cropland		CO <sub>2</sub>	627.5	1 295.9					72 %	73 %	0.85 %	107 %	38 %	75 %
5C1 Grassland remaining Grassland		CO <sub>2</sub>	868.5	326.8					200 %	204 %	0.59 %	-62 %	180 %	41 %
5C2 Land converted to Grassland		CO <sub>2</sub>	- 117.6	- 9.8					#####	#####	0.30 %	-92 %	840 %	888 %
5D2 Land converted to Wetlands		CO <sub>2</sub>	1 310.8	1 753.1					28 %	28 %	0.44 %	34 %	46 %	72 %
5E2 Land converted to Settlements		CO <sub>2</sub>	929.4	906.4					62 %	61 %	0.50 %	-2 %	64 %	181 %
5G Other (Harvested Wood Products)		CO <sub>2</sub>	- 945.6	1 287.5					25 %	25 %	0.29 %	-236 %	59 %	41 %
5(i) Direct N <sub>2</sub> O emissions from N fertilization		N <sub>2</sub> O	27.0	14.9	0.1	0.1	76 %	138 %	76 %	139 %	0.02 %	-45 %	7 %	8 %
5(ii) Non-CO <sub>2</sub> emissions from drainage of soils and wetlands		CH <sub>4</sub>	41.5	56.6					30 %	30 %	0.02 %	36 %	49 %	77 %
5(ii) Non-CO <sub>2</sub> emissions from drainage of soils and wetlands		N <sub>2</sub> O	1 215.2	1 297.7					30 %	30 %	0.35 %	7 %	38 %	59 %
5(iii) N <sub>2</sub> O emissions from disturbance associated with land-use conversion		N <sub>2</sub> O	6.9	12.3	0.2	0.1	50 %	50 %	51 %	54 %	0.01 %	78 %	99 %	224 %
5(iv) CO <sub>2</sub> emissions from agricultural lime application		CO <sub>2</sub>	617.9	194.2	0.2	0.2	7 %	3 %	20 %	21 %	0.04 %	-69 %	8 %	10 %
5(v) Biomass Burning		CO <sub>2</sub>	3.4	0.9	0.1	0.1	69 %	70 %	70 %	72 %	0.00 %	-75 %	18 %	62 %
5(v) Biomass Burning		CH <sub>4</sub>	4.0	0.4	0.1	0.1	70 %	70 %	71 %	72 %	0.00 %	-90 %	8 %	26 %
5(v) Biomass Burning		N <sub>2</sub> O	0.4	0.0	0.1	0.1	69 %	70 %	70 %	72 %	0.00 %	-90 %	8 %	26 %

Notes: When uncertainties are estimated for emissions/removals directly (not for AD and EF), the columns for AD and EF/IEF uncertainty are left blank. When year 2011 emissions/removals are zero, all uncertainty columns are left blank. When either 1990 or 2011 emissions are zero, trend uncertainty columns are left blank.



**Table 2.** Tier 1 uncertainty analysis excluding LULUCF sector. Unit of emissions is Gg CO<sub>2</sub> equivalent

Category	CFR fuel	Gas	Emissions/ removals 1990 Gg CO <sub>2</sub> -eq	Emissions/ removals 2012 Gg CO <sub>2</sub> -eq	AD uncertainty 2012 ± %	EF/IEF uncertainty 2012 ± %	Combined uncertainty 2012 ± %	Uncertainty share 2012 ± %	Combined trend uncertainty ± %
1.A.1. Energy Industries	Liquid	CO <sub>2</sub>	2 838.0	2 431.6	1 %	2 %	3 %	0.11 %	0.060 %
1.A.1. Energy Industries	Liquid	CH <sub>4</sub>	1.0	1.0	1 %	32 %	32 %	0.001 %	0.000 %
1.A.1. Energy Industries	Liquid	N <sub>2</sub> O	24.9	26.7	1 %	33 %	33 %	0.015 %	0.002 %
1.A.1. Energy Industries	Solid	CO <sub>2</sub>	9 640.1	7 709.3	1 %	1 %	1 %	0.17 %	0.15 %
1.A.1. Energy Industries	Solid	CH <sub>4</sub>	2.3	1.9	1 %	57 %	57 %	0.002 %	0.000 %
1.A.1. Energy Industries	Solid	N <sub>2</sub> O	43.4	52.0	1 %	58 %	58 %	0.050 %	0.012 %
1.A.1. Energy Industries	Gaseous	CO <sub>2</sub>	2 623.1	4 434.2	1 %	0 %	1 %	0.067 %	0.074 %
1.A.1. Energy Industries	Gaseous	CH <sub>4</sub>	1.0	1.9	1 %	50 %	50 %	0.002 %	0.001 %
1.A.1. Energy Industries	Gaseous	N <sub>2</sub> O	15.6	27.4	1 %	47 %	47 %	0.021 %	0.009 %
1.A.1. Energy Industries	Biomass	CH <sub>4</sub>	1.5	11.0	3 %	60 %	60 %	0.011 %	0.008 %
1.A.1. Energy Industries	Biomass	N <sub>2</sub> O	3.1	118.1	3 %	59 %	60 %	0.12 %	0.098 %
1.A.1. Energy Industries	Other	CO <sub>2</sub>	3 950.0	5 796.3	2 %	2 %	3 %	0.27 %	0.23 %
1.A.1. Energy Industries	Other	CH <sub>4</sub>	2.5	5.9	2 %	54 %	54 %	0.005 %	0.003 %
1.A.1. Energy Industries	Other	N <sub>2</sub> O	34.6	83.1	2 %	54 %	54 %	0.073 %	0.041 %
1.A.2 Manufacturing Industries and Construction	Liquid	CO <sub>2</sub>	4 552.0	3 023.0	5 %	1 %	5 %	0.26 %	0.31 %
1.A.2 Manufacturing Industries and Construction	Liquid	CH <sub>4</sub>	2.5	2.4	5 %	29 %	30 %	0.001 %	0.000 %
1.A.2 Manufacturing Industries and Construction	Liquid	N <sub>2</sub> O	36.9	25.2	5 %	55 %	55 %	0.023 %	0.006 %
1.A.2 Manufacturing Industries and Construction	Solid	CO <sub>2</sub>	4 842.8	2 237.9	2 %	4 %	4 %	0.15 %	0.12 %
1.A.2 Manufacturing Industries and Construction	Solid	CH <sub>4</sub>	1.4	0.4	2 %	28 %	28 %	0.000 %	0.000 %
1.A.2 Manufacturing Industries and Construction	Solid	N <sub>2</sub> O	46.7	9.9	2 %	28 %	28 %	0.005 %	0.012 %
1.A.2 Manufacturing Industries and Construction	Gaseous	CO <sub>2</sub>	2 189.8	1 453.3	2 %	0 %	2 %	0.041 %	0.049 %
1.A.2 Manufacturing Industries and Construction	Gaseous	CH <sub>4</sub>	1.0	0.6	2 %	50 %	50 %	0.000 %	0.000 %
1.A.2 Manufacturing Industries and Construction	Gaseous	N <sub>2</sub> O	15.3	10.6	2 %	47 %	47 %	0.008 %	0.002 %
1.A.2 Manufacturing Industries and Construction	Biomass	CH <sub>4</sub>	6.8	11.7	2 %	33 %	34 %	0.006 %	0.003 %
1.A.2 Manufacturing Industries and Construction	Biomass	N <sub>2</sub> O	56.5	76.3	2 %	41 %	41 %	0.051 %	0.016 %
1.A.2 Manufacturing Industries and Construction	Other	CO <sub>2</sub>	1 597.7	1 514.9	2 %	2 %	3 %	0.074 %	0.053 %
1.A.2 Manufacturing Industries and Construction	Other	CH <sub>4</sub>	1.1	1.0	2 %	39 %	39 %	0.001 %	0.000 %
1.A.2 Manufacturing Industries and Construction	Other	N <sub>2</sub> O	17.0	14.6	2 %	39 %	39 %	0.009 %	0.001 %

Category	CFR fuel	Gas	Emissions/ removals 1990 Gg CO2-eq	Emissions/ removals 2012 Gg CO2-eq	AD uncertainty 2012 ± %	EF/IEF uncertainty 2012 ± %	Combined uncertainty 2012 ± %	Uncertainty share 2012 ± %	Combined trend uncertainty ± %
1.A.3.a. Civil Aviation	Liquid	CO2	385.1	203.5	20 %	2 %	20 %	0.067 %	0.082 %
1.A.3.a. Civil Aviation	Liquid	CH4	0.3	0.2	20 %	99 %	101 %	0.000 %	0.000 %
1.A.3.a. Civil Aviation	Liquid	N2O	4.9	2.8	20 %	150 %	152 %	0.007 %	0.003 %
1.A.3.b. Road Transportation	Liquid - diesel oil	CO2	4 923.5	6 913.0	1 %	2 %	2 %	0.21 %	0.15 %
1.A.3.b. Road Transportation	Liquid - diesel oil	CH4	11.5	4.4	1 %	51 %	51 %	0.004 %	0.004 %
1.A.3.b. Road Transportation	Liquid - diesel oil	N2O	68.1	110.1	1 %	152 %	152 %	0.27 %	0.11 %
1.A.3.b. Road Transportation	Liquid - gasoline	CO2	5 882.5	4 129.8	2 %	2 %	3 %	0.18 %	0.15 %
1.A.3.b. Road Transportation	Liquid - gasoline	CH4	77.9	16.3	2 %	35 %	35 %	0.009 %	0.026 %
1.A.3.b. Road Transportation	Liquid - gasoline	N2O	91.8	40.5	2 %	132 %	132 %	0.088 %	0.074 %
1.A.3.b. Road Transportation	Gaseous	CO2		8.9	3 %	1 %	3 %	0.000 %	0.001 %
1.A.3.b. Road Transportation	Gaseous	CH4		2.1	3 %	50 %	50 %	0.002 %	0.001 %
1.A.3.b. Road Transportation	Gaseous	N2O		0.0	3 %	149 %	149 %	0.000 %	0.000 %
1.A.3.b. Road Transportation	Biomass	CH4		1.6	1 %	72 %	72 %	0.002 %	0.002 %
1.A.3.b. Road Transportation	Biomass	N2O		10.8	1 %	117 %	117 %	0.021 %	0.018 %
1.A.3.c. Railways	Liquid	CO2	191.1	98.7	5 %	2 %	5 %	0.008 %	0.010 %
1.A.3.c. Railways	Liquid	CH4	0.2	0.1	5 %	50 %	50 %	0.000 %	0.000 %
1.A.3.c. Railways	Liquid	N2O	1.5	0.8	5 %	154 %	154 %	0.002 %	0.001 %
1.A.3.d. Navigation	Liquid	CO2	441.3	483.9	6 %	1 %	6 %	0.045 %	0.054 %
1.A.3.d. Navigation	Liquid	CH4	4.6	2.5	6 %	82 %	82 %	0.003 %	0.002 %
1.A.3.d. Navigation	Liquid	N2O	2.9	3.8	6 %	113 %	113 %	0.007 %	0.002 %
1.A.3.e. Other Transportation	Liquid	CO2	659.9	633.3	15 %	1 %	15 %	0.15 %	0.19 %
1.A.3.e. Other Transportation	Liquid	CH4	5.0	6.2	15 %	50 %	52 %	0.005 %	0.002 %
1.A.3.e. Other Transportation	Liquid	N2O	4.7	4.3	15 %	112 %	113 %	0.008 %	0.001 %
1.A.3.e. Other Transportation	Biomass	CH4		0.5	9 %	45 %	46 %	0.000 %	0.000 %
1.A.3.e. Other Transportation	Biomass	N2O		0.2	9 %	70 %	70 %	0.000 %	0.000 %

Category	CFR fuel	Gas	Emissions/ removals 1990 Gg CO2-eq	Emissions/ removals 2012 Gg CO2-eq	AD uncertainty 2012 ± %	EF/IEF uncertainty 2012 ± %	Combined uncertainty 2012 ± %	Uncertainty share 2012 ± %	Combined trend uncertainty ± %
1.A.4. Other Sectors	Liquid	CO2	6 634.6	3 523.6	7 %	1 %	7 %	0.41 %	0.49 %
1.A.4. Other Sectors	Liquid	CH4	17.8	9.8	7 %	34 %	35 %	0.006 %	0.003 %
1.A.4. Other Sectors	Liquid	N2O	55.3	29.3	7 %	41 %	42 %	0.020 %	0.012 %
1.A.4. Other Sectors	Solid	CO2	46.5	10.9	9 %	1 %	9 %	0.002 %	0.002 %
1.A.4. Other Sectors	Solid	CH4	2.3	0.1	9 %	74 %	75 %	0.000 %	0.002 %
1.A.4. Other Sectors	Solid	N2O	0.6	0.1	9 %	43 %	44 %	0.000 %	0.000 %
1.A.4. Other Sectors	Gaseous	CO2	104.0	184.1	3 %	0 %	3 %	0.010 %	0.013 %
1.A.4. Other Sectors	Gaseous	CH4	0.2	0.2	3 %	52 %	52 %	0.000 %	0.000 %
1.A.4. Other Sectors	Gaseous	N2O	0.6	1.0	3 %	34 %	34 %	0.001 %	0.000 %
1.A.4. Other Sectors	Biomass	CH4	161.3	243.9	9 %	134 %	134 %	0.54 %	0.20 %
1.A.4. Other Sectors	Biomass	N2O	27.8	40.6	9 %	128 %	128 %	0.085 %	0.031 %
1.A.4. Other Sectors	Other	CO2	121.9	238.8	9 %	2 %	9 %	0.035 %	0.042 %
1.A.4. Other Sectors	Other	CH4	1.2	2.4	9 %	43 %	44 %	0.002 %	0.001 %
1.A.4. Other Sectors	Other	N2O	1.5	2.9	9 %	128 %	128 %	0.006 %	0.003 %
1.A.5.a.1. Indirect N2O emissions from NOx		N2O	439.4	218.4	0 %	62 %	62 %	0.22 %	0.14 %
1.A.5.a.2. Non-specified emissions of Fuels from non-energy use	Liquid	CO2	207.5	59.3	20 %	5 %	21 %	0.020 %	0.025 %
1.A.5.a.2. Non-specified emissions of Fuels from non-energy use	Liquid	CH4	0.2	0.1	20 %	60 %	63 %	0.000 %	0.000 %
1.A.5.a.2. Non-specified emissions of Fuels from non-energy use	Liquid	N2O	1.8	0.5	20 %	60 %	63 %	0.001 %	0.001 %
1.A.5.a.3. Other non-specified	Liquid	CO2	985.7	894.6	20 %	2 %	20 %	0.30 %	0.36 %
1.A.5.a.3. Other non-specified	Liquid	CH4	2.5	2.1	20 %	50 %	54 %	0.002 %	0.001 %
1.A.5.a.3. Other non-specified	Liquid	N2O	7.7	6.6	20 %	47 %	51 %	0.006 %	0.003 %
1.A.5.a.3. Other non-specified	Solid	CO2	1.2		0 %	0 %	0 %		
1.A.5.a.3. Other non-specified	Solid	CH4	0.0		0 %	0 %	0 %		
1.A.5.a.3. Other non-specified	Solid	N2O	0.0		0 %	0 %	0 %		
1.A.5.a.3. Other non-specified	Gaseous	CO2	53.4	203.0	38 %	1 %	38 %	0.13 %	0.15 %
1.A.5.a.3. Other non-specified	Gaseous	CH4	0.1	0.2	38 %	61 %	72 %	0.000 %	0.000 %
1.A.5.a.3. Other non-specified	Gaseous	N2O	0.3	1.1	38 %	60 %	71 %	0.001 %	0.001 %
1.A.5.a.3. Other non-specified	Biomass	CH4	0.2	1.0	10 %	59 %	60 %	0.001 %	0.001 %
1.A.5.a.3. Other non-specified	Biomass	N2O	0.2	0.3	10 %	54 %	55 %	0.000 %	0.000 %
1.A.5.a.3. Other non-specified	Other	CO2	24.0		0 %	0 %	0 %		
1.A.5.a.3. Other non-specified	Other	CH4	0.2		0 %	0 %	0 %		
1.A.5.a.3. Other non-specified	Other	N2O	0.1		0 %	0 %	0 %		
1.A.5.b. Mobile	Liquid	CO2	58.0	204.1	22 %	2 %	22 %	0.073 %	0.089 %
1.A.5.b. Mobile	Liquid	CH4	0.1	0.2	22 %	42 %	47 %	0.000 %	0.000 %
1.A.5.b. Mobile	Liquid	N2O	0.6	2.6	22 %	134 %	136 %	0.006 %	0.004 %
1.A.5.b. Mobile	Biomass	CH4			50 %	151 %	159 %	0.000 %	
1.A.5.b. Mobile	Biomass	N2O		0.0	50 %	152 %	160 %	0.000 %	0.000 %

b)

Category	CFR fuel	Gas	Emissions/ removals 1990 Gg CO2-eq	Emissions/ removals 2012 Gg CO2-eq	AD uncertainty 2012 ± %	EF/IEF uncertainty 2012 ± %	Combined uncertainty 2012 ± %	Uncertainty share 2012 ± %	Combined trend uncertainty ± %	
1.B.2.a. Oil - Refining / Storage		CO2	1.0	1.4	90 %	25 %	93 %	0.002 %	0.002 %	
1.B.2.a. Oil - Refining / Storage		CH4	7.6	10.6	90 %	90 %	127 %	0.022 %	0.020 %	
1.B.2.b.3. Natural Gas - Transmission		CO2	0.5	0.6	5 %	25 %	26 %	0.000 %	0.000 %	
1.B.2.b.3. Natural Gas - Transmission		CH4	3.6	4.9	5 %	0 %	5 %	0.000 %	0.000 %	
1.B.2.b.4. Natural Gas - Distribution		CO2		2.9	3 %	25 %	25 %	0.001 %	0.001 %	
1.B.2.b.4. Natural Gas - Distribution		CH4		22.1	3 %	0 %	3 %	0.001 %	0.001 %	
1.B.2.c. Venting and Flaring		CO2	121.9	100.5	40 %	0 %	40 %	0.066 %	0.081 %	a)
1.B.2.c. Venting and Flaring		CH4	0.0	0.0	50 %	0 %	50 %	0.000 %	0.000 %	a)
1.B.2.c. Venting and Flaring		N2O	0.7	1.0	50 %	0 %	50 %	0.001 %	0.001 %	a)
1.B.2.d. Other (CO2 from NMVOC)		CO2	95.5	28.0	99 %	20 %	101 %	0.047 %	0.058 %	
2.A.1. Cement Production		CO2	733.6	499.6	2 %	5 %	5 %	0.044 %	0.022 %	
2.A.2. Lime Production		CO2	382.6	402.9	2 %	3 %	4 %	0.024 %	0.017 %	
2.A.3. Limestone and Dolomite Use		CO2	98.2	238.6	5 %	3 %	6 %	0.023 %	0.025 %	
2.A.4. Soda Ash Production and Use		CO2	12.9	21.0	5 %	3 %	6 %	0.002 %	0.002 %	
2.A.6. Road Paving with Asphalt (CO2 from NMVOC)		CO2	21.2	1.7	86 %	20 %	88 %	0.002 %	0.006 %	
2.A.7. Other (glass production)		CO2	20.9	1.6	5 %	3 %	6 %	0.000 %	0.001 %	
2.B.1. Ammonia Production		CO2	44.0		0 %	0 %	0 %			
2.B.2. Nitric Acid Production		N2O	1 655.7	166.4	3 %	15 %	15 %	0.042 %	0.27 %	
2.B.5.f. Chemicals production (CO2 from NMVOC)		CO2	24.4	7.5	100 %	20 %	102 %	0.013 %	0.016 %	
2.B.5.g. Hydrogen		CO2	57.9	676.5	5 %	3 %	6 %	0.066 %	0.074 %	
2.B.5.i. Phosphoric Acid Production		CO2	24.5	42.4	7 %	0 %	7 %	0.005 %	0.006 %	a)
2.C.1. Iron and Steel Production		CO2	1 935.2	2 277.8	6 %	0 %	6 %	0.24 %	0.30 %	a)
2.C.1. Iron and Steel Production		CH4	5.1	9.2	3 %	20 %	20 %	0.003 %	0.001 %	
2.C.5. Other (non-ferrous metals) (CO2 from NMVOC)		CO2	0.4	0.3	100 %	20 %	102 %	0.001 %	0.001 %	
2.F.1. Refrigeration and Air Conditioning Equipment		HFC	0.0	861.0	14 %	0 %	14 %	0.20 %	0.24 %	a)
2.F.1. Refrigeration and Air Conditioning Equipment		PFC		0.4	22 %	0 %	22 %	0.000 %	0.000 %	a)
2.F.2. Foam Blowing		HFC		13.2	11 %	0 %	11 %	0.002 %	0.003 %	a)
2.F.4. Aerosols/ Metered Dose Inhalers		HFC		48.4	27 %	0 %	27 %	0.022 %	0.026 %	a)
2.F.8. Electrical Equipment		SF6	107.1	7.2	53 %	0 %	53 %	0.006 %	0.008 %	a)
2.F.9. Other (grouped confidential data)		HFC	0.0	2.9	14 %	0 %	14 %	0.001 %	0.001 %	a)
2.F.9. Other (grouped confidential data)		PFC	0.1	1.5	20 %	0 %	20 %	0.000 %	0.001 %	a)
2.F.9. Other (grouped confidential data)		SF6	7.9	29.6	19 %	0 %	19 %	0.009 %	0.011 %	a)
3. Solvent and Other Product Use		CO2	115.9	39.8	61 %	7 %	61 %	0.040 %	0.049 %	
3. Solvent and Other Product Use		N2O	62.0	26.2	10 %	0 %	10 %	0.004 %	0.005 %	

Category	CFR fuel	Gas	Emissions/ removals 1990 Gg CO2-eq	Emissions/ removals 2012 Gg CO2-eq	AD uncertainty 2012 ± %	EF/IEF uncertainty 2012 ± %	Combined uncertainty 2012 ± %	Uncertainty share 2012 ± %	Combined trend uncertainty ± %	
4.A. Enteric Fermentation		CH4	1 831.9	1 544.1	0 %	25 %	25 %	0.64 %	0.016 %	b)
4.B. Manure Management		CH4	202.5	250.8	12 %	0 %	12 %	0.049 %	0.061 %	a)
4.B. Manure Management		N2O	486.7	415.6	66 %	0 %	66 %	0.45 %	0.55 %	a)
4.D.1. Direct Soil Emissions		N2O	3 068.9	2 727.8	117 %	0 %	117 %	5.2 %	6.4 %	a)
4.D.2. Pasture, Range and Paddock Manure		N2O	190.5	185.7	200 %	0 %	200 %	0.61 %	0.75 %	a)
4.D.3. Indirect Emissions		N2O	766.8	583.5	302 %	0 %	302 %	2.9 %	3.5 %	a)
4.F. Field Burning of Agricultural Residues		CH4	1.9	0.4	55 %	0 %	55 %	0.000 %	0.000 %	a)
4.F. Field Burning of Agricultural Residues		N2O	0.6	0.1	44 %	0 %	44 %	0.000 %	0.000 %	a)
6.A. Solid Waste Disposal on Land		CH4	3 635.3	1 737.1	0 %	30 %	30 %	0.86 %	0.60 %	b)
6.B.1. Industrial Wastewater		CH4	22.2	17.3	10 %	99 %	99 %	0.028 %	0.004 %	
6.B.2. Domestic and Commercial Wastewater		CH4	131.3	96.9	6 %	30 %	31 %	0.049 %	0.014 %	
6.B.2. Domestic and Commercial Wastewater		N2O	105.3	78.3	6 %	370 %	371 %	0.48 %	0.069 %	
6.B.3.a. Other (N input from fish farming)		N2O	8.3	3.0	7 %	370 %	371 %	0.018 %	0.022 %	
6.B.3.b. Other (N input from industrial wastewater)		N2O	30.2	17.8	10 %	370 %	371 %	0.11 %	0.044 %	
6.D. Other (compost production)		CH4	21.6	58.3	20 %	73 %	75 %	0.072 %	0.047 %	
6.D. Other (compost production)		N2O	20.4	59.1	20 %	86 %	88 %	0.085 %	0.056 %	
a) When uncertainties are estimated for the total emission and emissions <b>are not</b> correlated (correlation < 90%) across years, uncertainty in emissions is entered in the column for <b>AD</b> uncertainty (IPCC GPG page 6.17)										
b) When uncertainties are estimated for the total emission and emissions <b>are</b> correlated (correlation > 90%) across years, uncertainty in emissions is entered in the column for <b>EF</b> uncertainty (IPCC GPG page 6.17)										

**Table 3.** Tier 1 uncertainty analysis including LULUCF sector. Unit of emissions is Gg CO<sub>2</sub> equivalent

Category	CFR fuel	Gas	Emissions/ removals 1990 Gg CO <sub>2</sub> -eq	Emissions/ removals 2012 Gg CO <sub>2</sub> -eq	AD uncertainty 2012 ± %	EF/IEF uncertainty 2012 ± %	Combined uncertainty 2012 ± %	Uncertainty share 2012 ± %	Combined trend uncertainty ± %
1.A.1. Energy Industries	Liquid	CO <sub>2</sub>	2 838.0	2 431.6	1 %	2 %	3 %	0.18 %	0.080 %
1.A.1. Energy Industries	Liquid	CH <sub>4</sub>	1.0	1.0	1 %	32 %	32 %	0.001 %	0.000 %
1.A.1. Energy Industries	Liquid	N <sub>2</sub> O	24.9	26.7	1 %	33 %	33 %	0.025 %	0.007 %
1.A.1. Energy Industries	Solid	CO <sub>2</sub>	9 640.1	7 709.3	1 %	1 %	1 %	0.30 %	0.19 %
1.A.1. Energy Industries	Solid	CH <sub>4</sub>	2.3	1.9	1 %	57 %	57 %	0.003 %	0.001 %
1.A.1. Energy Industries	Solid	N <sub>2</sub> O	43.4	52.0	1 %	58 %	58 %	0.086 %	0.026 %
1.A.1. Energy Industries	Gaseous	CO <sub>2</sub>	2 623.1	4 434.2	1 %	0 %	1 %	0.12 %	0.093 %
1.A.1. Energy Industries	Gaseous	CH <sub>4</sub>	1.0	1.9	1 %	50 %	50 %	0.003 %	0.001 %
1.A.1. Energy Industries	Gaseous	N <sub>2</sub> O	15.6	27.4	1 %	47 %	47 %	0.037 %	0.015 %
1.A.1. Energy Industries	Biomass	CH <sub>4</sub>	1.5	11.0	3 %	60 %	60 %	0.019 %	0.011 %
1.A.1. Energy Industries	Biomass	N <sub>2</sub> O	3.1	118.1	3 %	59 %	60 %	0.20 %	0.12 %
1.A.1. Energy Industries	Other	CO <sub>2</sub>	3 950.0	5 796.3	2 %	2 %	3 %	0.46 %	0.30 %
1.A.1. Energy Industries	Other	CH <sub>4</sub>	2.5	5.9	2 %	54 %	54 %	0.009 %	0.004 %
1.A.1. Energy Industries	Other	N <sub>2</sub> O	34.6	83.1	2 %	54 %	54 %	0.13 %	0.059 %
1.A.2 Manufacturing Industries and Construction	Liquid	CO <sub>2</sub>	4 552.0	3 023.0	5 %	1 %	5 %	0.45 %	0.38 %
1.A.2 Manufacturing Industries and Construction	Liquid	CH <sub>4</sub>	2.5	2.4	5 %	29 %	30 %	0.002 %	0.001 %
1.A.2 Manufacturing Industries and Construction	Liquid	N <sub>2</sub> O	36.9	25.2	5 %	55 %	55 %	0.039 %	0.004 %
1.A.2 Manufacturing Industries and Construction	Solid	CO <sub>2</sub>	4 842.8	2 237.9	2 %	4 %	4 %	0.25 %	0.098 %
1.A.2 Manufacturing Industries and Construction	Solid	CH <sub>4</sub>	1.4	0.4	2 %	28 %	28 %	0.000 %	0.000 %
1.A.2 Manufacturing Industries and Construction	Solid	N <sub>2</sub> O	46.7	9.9	2 %	28 %	28 %	0.008 %	0.010 %
1.A.2 Manufacturing Industries and Construction	Gaseous	CO <sub>2</sub>	2 189.8	1 453.3	2 %	0 %	2 %	0.071 %	0.060 %
1.A.2 Manufacturing Industries and Construction	Gaseous	CH <sub>4</sub>	1.0	0.6	2 %	50 %	50 %	0.001 %	0.000 %
1.A.2 Manufacturing Industries and Construction	Gaseous	N <sub>2</sub> O	15.3	10.6	2 %	47 %	47 %	0.014 %	0.001 %
1.A.2 Manufacturing Industries and Construction	Biomass	CH <sub>4</sub>	6.8	11.7	2 %	33 %	34 %	0.011 %	0.004 %
1.A.2 Manufacturing Industries and Construction	Biomass	N <sub>2</sub> O	56.5	76.3	2 %	41 %	41 %	0.089 %	0.030 %
1.A.2 Manufacturing Industries and Construction	Other	CO <sub>2</sub>	1 597.7	1 514.9	2 %	2 %	3 %	0.13 %	0.070 %
1.A.2 Manufacturing Industries and Construction	Other	CH <sub>4</sub>	1.1	1.0	2 %	39 %	39 %	0.001 %	0.000 %
1.A.2 Manufacturing Industries and Construction	Other	N <sub>2</sub> O	17.0	14.6	2 %	39 %	39 %	0.016 %	0.003 %

Category	CFR fuel	Gas	Emissions/ removals 1990 Gg CO2-eq	Emissions/ removals 2012 Gg CO2-eq	AD uncertainty 2012 ± %	EF/IEF uncertainty 2012 ± %	Combined uncertainty 2012 ± %	Uncertainty share 2012 ± %	Combined trend uncertainty ± %
1.A.3.a. Civil Aviation	Liquid	CO2	385.1	203.5	20 %	2 %	20 %	0.12 %	0.10 %
1.A.3.a. Civil Aviation	Liquid	CH4	0.3	0.2	20 %	99 %	101 %	0.000 %	0.000 %
1.A.3.a. Civil Aviation	Liquid	N2O	4.9	2.8	20 %	150 %	152 %	0.012 %	0.002 %
1.A.3.b. Road Transportation	Liquid - diesel oil	CO2	4 923.5	6 913.0	1 %	2 %	2 %	0.36 %	0.20 %
1.A.3.b. Road Transportation	Liquid - diesel oil	CH4	11.5	4.4	1 %	51 %	51 %	0.006 %	0.002 %
1.A.3.b. Road Transportation	Liquid - diesel oil	N2O	68.1	110.1	1 %	152 %	152 %	0.48 %	0.18 %
1.A.3.b. Road Transportation	Liquid - gasoline	CO2	5 882.5	4 129.8	2 %	2 %	3 %	0.31 %	0.19 %
1.A.3.b. Road Transportation	Liquid - gasoline	CH4	77.9	16.3	2 %	35 %	35 %	0.016 %	0.020 %
1.A.3.b. Road Transportation	Liquid - gasoline	N2O	91.8	40.5	2 %	132 %	132 %	0.15 %	0.038 %
1.A.3.b. Road Transportation	Gaseous	CO2		8.9	3 %	1 %	3 %	0.001 %	0.001 %
1.A.3.b. Road Transportation	Gaseous	CH4		2.1	3 %	50 %	50 %	0.003 %	0.002 %
1.A.3.b. Road Transportation	Gaseous	N2O		0.0	3 %	149 %	149 %	0.000 %	0.000 %
1.A.3.b. Road Transportation	Biomass	CH4		1.6	1 %	72 %	72 %	0.003 %	0.002 %
1.A.3.b. Road Transportation	Biomass	N2O		10.8	1 %	117 %	117 %	0.036 %	0.022 %
1.A.3.c. Railways	Liquid	CO2	191.1	98.7	5 %	2 %	5 %	0.015 %	0.012 %
1.A.3.c. Railways	Liquid	CH4	0.2	0.1	5 %	50 %	50 %	0.000 %	0.000 %
1.A.3.c. Railways	Liquid	N2O	1.5	0.8	5 %	154 %	154 %	0.004 %	0.000 %
1.A.3.d. Navigation	Liquid	CO2	441.3	483.9	6 %	1 %	6 %	0.077 %	0.067 %
1.A.3.d. Navigation	Liquid	CH4	4.6	2.5	6 %	82 %	82 %	0.006 %	0.001 %
1.A.3.d. Navigation	Liquid	N2O	2.9	3.8	6 %	113 %	113 %	0.012 %	0.004 %
1.A.3.e. Other Transportation	Liquid	CO2	659.9	633.3	15 %	1 %	15 %	0.26 %	0.23 %
1.A.3.e. Other Transportation	Liquid	CH4	5.0	6.2	15 %	50 %	52 %	0.009 %	0.004 %
1.A.3.e. Other Transportation	Liquid	N2O	4.7	4.3	15 %	112 %	113 %	0.014 %	0.003 %
1.A.3.e. Other Transportation	Biomass	CH4		0.5	9 %	45 %	46 %	0.001 %	0.000 %
1.A.3.e. Other Transportation	Biomass	N2O		0.2	9 %	70 %	70 %	0.000 %	0.000 %

Category	CFR fuel	Gas	Emissions/ removals 1990 Gg CO2-eq	Emissions/ removals 2012 Gg CO2-eq	AD uncertainty 2012 ± %	EF uncertainty 2012 ± %	Combined uncertainty 2012 ± %	Uncertainty share 2012 ± %	Combined trend uncertainty ± %
1.A.4. Other Sectors	Liquid	CO2	6 634.6	3 523.6	7 %	1 %	7 %	0.70 %	0.61 %
1.A.4. Other Sectors	Liquid	CH4	17.8	9.8	7 %	34 %	35 %	0.010 %	0.002 %
1.A.4. Other Sectors	Liquid	N2O	55.3	29.3	7 %	41 %	42 %	0.035 %	0.006 %
1.A.4. Other Sectors	Solid	CO2	46.5	10.9	9 %	1 %	9 %	0.003 %	0.003 %
1.A.4. Other Sectors	Solid	CH4	2.3	0.1	9 %	74 %	75 %	0.000 %	0.002 %
1.A.4. Other Sectors	Solid	N2O	0.6	0.1	9 %	43 %	44 %	0.000 %	0.000 %
1.A.4. Other Sectors	Gaseous	CO2	104.0	184.1	3 %	0 %	3 %	0.018 %	0.016 %
1.A.4. Other Sectors	Gaseous	CH4	0.2	0.2	3 %	52 %	52 %	0.000 %	0.000 %
1.A.4. Other Sectors	Gaseous	N2O	0.6	1.0	3 %	34 %	34 %	0.001 %	0.000 %
1.A.4. Other Sectors	Biomass	CH4	161.3	243.9	9 %	134 %	134 %	0.93 %	0.34 %
1.A.4. Other Sectors	Biomass	N2O	27.8	40.6	9 %	128 %	128 %	0.15 %	0.053 %
1.A.4. Other Sectors	Other	CO2	121.9	238.8	9 %	2 %	9 %	0.061 %	0.053 %
1.A.4. Other Sectors	Other	CH4	1.2	2.4	9 %	43 %	44 %	0.003 %	0.001 %
1.A.4. Other Sectors	Other	N2O	1.5	2.9	9 %	128 %	128 %	0.010 %	0.004 %
1.A.5.a.1. Indirect N2O emissions from NOx		N2O	439.4	218.4	0 %	62 %	62 %	0.39 %	0.059 %
1.A.5.a.2. Non-specified emissions of Fuels from non-energy use	Liquid	CO2	207.5	59.3	20 %	5 %	21 %	0.035 %	0.030 %
1.A.5.a.2. Non-specified emissions of Fuels from non-energy use	Liquid	CH4	0.2	0.1	20 %	60 %	63 %	0.000 %	0.000 %
1.A.5.a.2. Non-specified emissions of Fuels from non-energy use	Liquid	N2O	1.8	0.5	20 %	60 %	63 %	0.001 %	0.001 %
1.A.5.a.3. Other non-specified	Liquid	CO2	985.7	894.6	20 %	2 %	20 %	0.51 %	0.45 %
1.A.5.a.3. Other non-specified	Liquid	CH4	2.5	2.1	20 %	50 %	54 %	0.003 %	0.001 %
1.A.5.a.3. Other non-specified	Liquid	N2O	7.7	6.6	20 %	47 %	51 %	0.010 %	0.004 %
1.A.5.a.3. Other non-specified	Solid	CO2	1.2		0 %	0 %	0 %		
1.A.5.a.3. Other non-specified	Solid	CH4	0.0		0 %	0 %	0 %		
1.A.5.a.3. Other non-specified	Solid	N2O	0.0		0 %	0 %	0 %		
1.A.5.a.3. Other non-specified	Gaseous	CO2	53.4	203.0	38 %	1 %	38 %	0.22 %	0.19 %
1.A.5.a.3. Other non-specified	Gaseous	CH4	0.1	0.2	38 %	61 %	72 %	0.000 %	0.000 %
1.A.5.a.3. Other non-specified	Gaseous	N2O	0.3	1.1	38 %	60 %	71 %	0.002 %	0.001 %
1.A.5.a.3. Other non-specified	Biomass	CH4	0.2	1.0	10 %	59 %	60 %	0.002 %	0.001 %
1.A.5.a.3. Other non-specified	Biomass	N2O	0.2	0.3	10 %	54 %	55 %	0.000 %	0.000 %
1.A.5.a.3. Other non-specified	Other	CO2	24.0		0 %	0 %	0 %		
1.A.5.a.3. Other non-specified	Other	CH4	0.2		0 %	0 %	0 %		
1.A.5.a.3. Other non-specified	Other	N2O	0.1		0 %	0 %	0 %		
1.A.5.b. Mobile	Liquid	CO2	58.0	204.1	22 %	2 %	22 %	0.13 %	0.11 %
1.A.5.b. Mobile	Liquid	CH4	0.1	0.2	22 %	42 %	47 %	0.000 %	0.000 %
1.A.5.b. Mobile	Liquid	N2O	0.6	2.6	22 %	134 %	136 %	0.010 %	0.006 %
1.A.5.b. Mobile	Biomass	CH4			50 %	151 %	159 %	0.000 %	0.000 %
1.A.5.b. Mobile	Biomass	N2O		0.0	50 %	152 %	160 %	0.000 %	0.000 %

b)



Category	CFR fuel	Gas	Emissions/ removals 1990 Gg CO <sub>2</sub> -eq	Emissions/ removals 2012 Gg CO <sub>2</sub> -eq	AD uncertainty 2012 ± %	EF/IEF uncertainty 2012 ± %	Combined uncertainty 2012 ± %	Uncertainty share 2012 ± %	Combined trend uncertainty ± %	
1.B.2.a. Oil - Refining / Storage		CO <sub>2</sub>	1.0	1.4	90 %	25 %	93 %	0.004 %	0.003 %	
1.B.2.a. Oil - Refining / Storage		CH <sub>4</sub>	7.6	10.6	90 %	90 %	127 %	0.038 %	0.025 %	
1.B.2.b.3. Natural Gas - Transmission		CO <sub>2</sub>	0.5	0.6	5 %	25 %	26 %	0.000 %	0.000 %	
1.B.2.b.3. Natural Gas - Transmission		CH <sub>4</sub>	3.6	4.9	5 %	0 %	5 %	0.001 %	0.001 %	
1.B.2.b.4. Natural Gas - Distribution		CO <sub>2</sub>		2.9	3 %	25 %	25 %	0.002 %	0.001 %	
1.B.2.b.4. Natural Gas - Distribution		CH <sub>4</sub>		22.1	3 %	0 %	3 %	0.002 %	0.002 %	
1.B.2.c. Venting and Flaring		CO <sub>2</sub>	121.9	100.5	40 %	0 %	40 %	0.11 %	0.10 %	a)
1.B.2.c. Venting and Flaring		CH <sub>4</sub>	0.0	0.0	50 %	0 %	50 %	0.000 %	0.000 %	a)
1.B.2.c. Venting and Flaring		N <sub>2</sub> O	0.7	1.0	50 %	0 %	50 %	0.001 %	0.001 %	a)
1.B.2.d. Other (CO <sub>2</sub> from NMVOC)		CO <sub>2</sub>	95.5	28.0	99 %	20 %	101 %	0.081 %	0.070 %	
2.A.1. Cement Production		CO <sub>2</sub>	733.6	499.6	2 %	5 %	5 %	0.077 %	0.025 %	
2.A.2. Lime Production		CO <sub>2</sub>	382.6	402.9	2 %	3 %	4 %	0.042 %	0.022 %	
2.A.3. Limestone and Dolomite Use		CO <sub>2</sub>	98.2	238.6	5 %	3 %	6 %	0.040 %	0.031 %	
2.A.4. Soda Ash Production and Use		CO <sub>2</sub>	12.9	21.0	5 %	3 %	6 %	0.003 %	0.003 %	
2.A.6. Road Paving with Asphalt (CO <sub>2</sub> from NMVOC)		CO <sub>2</sub>	21.2	1.7	86 %	20 %	88 %	0.004 %	0.005 %	
2.A.7. Other (glass production)		CO <sub>2</sub>	20.9	1.6	5 %	3 %	6 %	0.000 %	0.001 %	
2.B.1. Ammonia Production		CO <sub>2</sub>	44.0		0 %	0 %	0 %			
2.B.2. Nitric Acid Production		N <sub>2</sub> O	1 655.7	166.4	3 %	15 %	15 %	0.073 %	0.23 %	
2.B.5.f. Chemicals production (CO <sub>2</sub> from NMVOC)		CO <sub>2</sub>	24.4	7.5	100 %	20 %	102 %	0.022 %	0.019 %	
2.B.5.g. Hydrogen		CO <sub>2</sub>	57.9	676.5	5 %	3 %	6 %	0.11 %	0.092 %	
2.B.5.i. Phosphoric Acid Production		CO <sub>2</sub>	24.5	42.4	7 %	0 %	7 %	0.008 %	0.007 %	a)
2.C.1. Iron and Steel Production		CO <sub>2</sub>	1 935.2	2 277.8	6 %	0 %	6 %	0.42 %	0.37 %	a)
2.C.1. Iron and Steel Production		CH <sub>4</sub>	5.1	9.2	3 %	20 %	20 %	0.005 %	0.002 %	
2.C.5. Other (non-ferrous metals) (CO <sub>2</sub> from NMVOC)		CO <sub>2</sub>	0.4	0.3	100 %	20 %	102 %	0.001 %	0.001 %	
2.F.1. Refrigeration and Air Conditioning Equipment		HFC	0.0	861.0	14 %	0 %	14 %	0.34 %	0.30 %	a)
2.F.1. Refrigeration and Air Conditioning Equipment		PFC		0.4	22 %	0 %	22 %	0.000 %	0.000 %	a)
2.F.2. Foam Blowing		HFC		13.2	11 %	0 %	11 %	0.004 %	0.004 %	a)
2.F.4. Aerosols/ Metered Dose Inhalers		HFC		48.4	27 %	0 %	27 %	0.037 %	0.033 %	a)
2.F.8. Electrical Equipment		SF <sub>6</sub>	107.1	7.2	53 %	0 %	53 %	0.011 %	0.010 %	a)
2.F.9. Other (grouped confidential data)		HFC	0.0	2.9	14 %	0 %	14 %	0.001 %	0.001 %	a)
2.F.9. Other (grouped confidential data)		PFC	0.1	1.5	20 %	0 %	20 %	0.001 %	0.001 %	a)
2.F.9. Other (grouped confidential data)		SF <sub>6</sub>	7.9	29.6	19 %	0 %	19 %	0.016 %	0.014 %	a)
3. Solvent and Other Product Use		CO <sub>2</sub>	115.9	39.8	61 %	7 %	61 %	0.070 %	0.061 %	
3. Solvent and Other Product Use		N <sub>2</sub> O	62.0	26.2	10 %	0 %	10 %	0.007 %	0.007 %	

Category	CFR fuel	Gas	Emissions/ removals 1990 Gg CO <sub>2</sub> -eq	Emissions/ removals 2012 Gg CO <sub>2</sub> -eq	AD uncertainty 2012 ± %	EF/IEF uncertainty 2012 ± %	Combined uncertainty 2012 ± %	Uncertainty share 2012 ± %	Combined trend uncertainty ± %	
4.A. Enteric Fermentation		CH <sub>4</sub>	1 831.9	1 544.1	0 %	25 %	25 %	1.1 %	0.18 %	b)
4.B. Manure Management		CH <sub>4</sub>	202.5	250.8	12 %	0 %	12 %	0.086 %	0.075 %	a)
4.B. Manure Management		N <sub>2</sub> O	486.7	415.6	66 %	0 %	66 %	0.79 %	0.69 %	a)
4.D.1. Direct Soil Emissions		N <sub>2</sub> O	3 068.9	2 727.8	117 %	0 %	117 %	9.1 %	8.0 %	a)
4.D.2. Pasture, Range and Paddock Manure		N <sub>2</sub> O	190.5	185.7	200 %	0 %	200 %	1.1 %	0.93 %	a)
4.D.3. Indirect Emissions		N <sub>2</sub> O	766.8	583.5	302 %	0 %	302 %	5.0 %	4.4 %	a)
4.F. Field Burning of Agricultural Residues		CH <sub>4</sub>	1.9	0.4	55 %	0 %	55 %	0.001 %	0.001 %	a)
4.F. Field Burning of Agricultural Residues		N <sub>2</sub> O	0.6	0.1	44 %	0 %	44 %	0.000 %	0.000 %	a)
6.A. Solid Waste Disposal on Land		CH <sub>4</sub>	3 635.3	1 737.1	0 %	30 %	30 %	1.5 %	0.27 %	b)
6.B.1. Industrial Wastewater		CH <sub>4</sub>	22.2	17.3	10 %	99 %	99 %	0.049 %	0.007 %	
6.B.2. Domestic and Commercial Wastewater		CH <sub>4</sub>	131.3	96.9	6 %	30 %	31 %	0.086 %	0.018 %	
6.B.2. Domestic and Commercial Wastewater		N <sub>2</sub> O	105.3	78.3	6 %	370 %	371 %	0.83 %	0.086 %	
6.B.3.a. Other (N input from fish farming)		N <sub>2</sub> O	8.3	3.0	7 %	370 %	371 %	0.032 %	0.014 %	
6.B.3.b. Other (N input from industrial wastewater)		N <sub>2</sub> O	30.2	17.8	10 %	370 %	371 %	0.19 %	0.007 %	
6.D. Other (compost production)		CH <sub>4</sub>	21.6	58.3	20 %	73 %	75 %	0.13 %	0.065 %	
6.D. Other (compost production)		N <sub>2</sub> O	20.4	59.1	20 %	86 %	88 %	0.15 %	0.076 %	
5.A.1. Forest Land remaining Forest Land		CO <sub>2</sub>	-23 111.0	-38 321.4	25 %	0 %	25 %	-28 %	24 %	a)
5.A.2. Land converted to Forest Land		CO <sub>2</sub>	130.7	- 116.1	222 %	0 %	222 %	-0.73 %	0.64 %	a)
5.B.1. Cropland remaining Cropland		CO <sub>2</sub>	4 716.1	5 448.1	80 %	0 %	80 %	12 %	11 %	a)
5.B.2. Land converted to Cropland		CO <sub>2</sub>	627.5	1 295.9	73 %	0 %	73 %	2.7 %	2.4 %	a)
5.C.1. Grassland remaining Grassland		CO <sub>2</sub>	868.5	326.8	204 %	0 %	204 %	1.9 %	1.7 %	a)
5.C.2. Land converted to Grassland		CO <sub>2</sub>	- 117.6	- 9.8	3421 %	0 %	3421 %	-0.95 %	0.84 %	a)
5.D.2. Land converted to Wetlands		CO <sub>2</sub>	1 310.8	1 753.1	28 %	0 %	28 %	1.4 %	1.2 %	a)
5.E.2. Land converted to Settlements		CO <sub>2</sub>	929.4	906.4	62 %	0 %	62 %	1.6 %	1.4 %	a)
5.G. Other (Harvested Wood Products)		CO <sub>2</sub>	- 945.6	1 287.5	25 %	0 %	25 %	0.91 %	0.80 %	a)
5.I Direct N <sub>2</sub> O emissions from N fertilization		N <sub>2</sub> O	27.0	14.9	10 %	138 %	139 %	0.059 %	0.006 %	
5.II Non-CO <sub>2</sub> emissions from drainage of soils and wetlands		CH <sub>4</sub>	41.5	56.6	30 %	0 %	30 %	0.049 %	0.043 %	a)
5.II Non-CO <sub>2</sub> emissions from drainage of soils and wetlands		N <sub>2</sub> O	1 215.2	1 297.7	30 %	0 %	30 %	1.1 %	0.98 %	a)
5.III N <sub>2</sub> O emissions from disturbance associated with land-use conversion to cropland		N <sub>2</sub> O	6.9	12.3	15 %	50 %	52 %	0.018 %	0.008 %	
5.IV CO <sub>2</sub> emissions from agricultural lime application		CO <sub>2</sub>	617.9	194.2	20 %	7 %	21 %	0.12 %	0.100 %	
5.V Biomass Burning		CO <sub>2</sub>	3.4	0.9	10 %	70 %	71 %	0.002 %	0.002 %	
5.V Biomass Burning		CH <sub>4</sub>	4.0	0.4	10 %	70 %	71 %	0.001 %	0.003 %	
5.V Biomass Burning		N <sub>2</sub> O	0.4	0.0	10 %	70 %	71 %	0.000 %	0.000 %	
a) When uncertainties are estimated for the total emission and emissions <b>are not</b> correlated (correlation < 90%) across years, uncertainty in emissions is entered in the column for <b>AD</b> uncertainty (IPCC GPG page 6.17)										
b) When uncertainties are estimated for the total emission and emissions <b>are</b> correlated (correlation > 90%) across years, uncertainty in emissions is entered in the column for <b>EF</b> uncertainty (IPCC GPG page 6.17)										

## *ANNEX 7. Additional information to be considered as part of the annual inventory submission and the supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol or other useful reference information*

### *Legal entities authorised to participate in the mechanisms under Articles 6, 12 and 17 of the Kyoto Protocol*

<b>Legal entity</b>	<b>Reason for authorization</b>
Adven Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Ahlstrom Glassfibre Oy	Operators (companies with legally binding emission ceilings under the EU ETS)
Ahlstrom Tampere Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Altia Oyj	Operator (company with a legally binding emission ceiling under the EU ETS)
Avilon Fibres Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Boliden Kokkola Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Borealis Polymers Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Climate Opportunity Fund Ky	Authorisation for CDM and JI projects
Corenso United Oy Ltd	Operator (company with a legally binding emission ceiling under the EU ETS)
Danske Bank Oyj	Authorization from the Ministry of the environment
E.ON Kainuu Oy	Authorisation from the Ministry of the Environment
Ekokem Oy Ab	Operator (company with a legally binding emission ceiling under the EU ETS)
Elenia Lämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
EM Finance Oy	Authorisation from the Ministry of the Environment
Energiakolmio Oy	Authorisation from the Ministry of the Environment
Enocell Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
EPV Energia Oy	Authorisation from the Ministry of the Environment
ER-Saha Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Etelä-Savon Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
FC Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
FC Power Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Finavia Oyj	Operator (company with a legally binding emission ceiling under the EU ETS)
Fine Carbon Fund Ky	Authorisation for CDM and JI projects
Fine Post-2012 Carbon Fund Ky	Authorisation for CDM and JI projects
Fingrid Oyj	Operator (company with a legally binding emission ceiling under the EU ETS)
Finnsementti Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Fortum Markets Oy	Authorisation from the Ministry of the Environment
Fortum Oyj	Authorisation for CDM and JI projects
Fortum Power and Heat Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Gasum Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
GreenStream Network Oyj	Authorisation from the Ministry of the Environment
Haapajärven Lämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Haminan Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Hankkija Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Haukiputaan Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Helsingin Energia	Operator (company with a legally binding emission ceiling under the EU ETS)
Helsingin ja Uudenmaan Sairaanhoidopiiri	Operator (company with a legally binding emission ceiling under the EU ETS)
Hyvinkään Lämpövoima	Operator (company with a legally binding emission ceiling under the EU ETS)
Hämeenkyrön Voima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Imatran Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Imatran Lämpö	Operator (company with a legally binding emission ceiling under the EU ETS)
Isojoen Lämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
J.M. Huber Finland Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Jakobstads Energiverk	Operator (company with a legally binding emission ceiling under the EU ETS)
Juankosken Biolämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Juho Thermal Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Junnikkala Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Jyväskylän Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)

Legal entity	Reason for authorization
Jyväskylän Energiantuotanto Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Jyväskylän Voima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Järvi-Suomen Voima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Kainuun Voima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Kajaanin Lämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Kannuksen Kaukolämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Kanteleen Voima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Karstulan Lämpöverkko Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Kauhavan Kaukolämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Kaukaan Voima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Keitele Energy Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Kemijärven Kaukolämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Kemin Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Keramia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Keravan Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Keravan Lämpövoima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Keskusosuuskunta Oulun Seudun Sähkö	Operator (company with a legally binding emission ceiling under the EU ETS)
Keuruun Lämpövoima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Kokkolan Energia	Operator (company with a legally binding emission ceiling under the EU ETS)
Kokkolan Voima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Koskisen Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Kotkamills Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Kotkan Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Kraftnät Åland Ab	Operator (company with a legally binding emission ceiling under the EU ETS)
KSS Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
KSS Lämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Kuhmon Lämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Kumpuniemen Voima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Kuopion Energia	Operator (company with a legally binding emission ceiling under the EU ETS)
Kuopion Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Kuusamon energia- ja vesiosuuskunta	Operator (company with a legally binding emission ceiling under the EU ETS)
Kuusamon Juusto Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Kymin Voima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Kymppivoima Hankinta Oy	Authorisation from the Ministry of the Environment
Laanilan Voima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Lahti Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Laitilan Lämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Lappeenrannan Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Lapuan Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Liedon Lämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Liikelaitos Salon Kaukolämpö	Operator (company with a legally binding emission ceiling under the EU ETS)
Lohjan Biolämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Loimaan Kaukolämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Luvian Saha Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Lämpö Oy Juurakkotuli	Operator (company with a legally binding emission ceiling under the EU ETS)
Mariehamns Bioenergi Ab	Operator (company with a legally binding emission ceiling under the EU ETS)
Mariehamns Energi ab	Operator (company with a legally binding emission ceiling under the EU ETS)
Metso Fabrics Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Metsä Board Kemi Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Metsä Board Oyj	Operator (company with a legally binding emission ceiling under the EU ETS)
Metsä Fibre Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Metsä Tissue Oyj	Operator (company with a legally binding emission ceiling under the EU ETS)
Metsäliitto Osuuskunta	Operator (company with a legally binding emission ceiling under the EU ETS)
Momentive Specialty Chemicals Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Mondi Lohja Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Mondo Minerals B.V. Suomen sivuliike	Operator (company with a legally binding emission ceiling under the EU ETS)
Mussalon Voima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Muuramen Lämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Myllykoski Paper Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Myllyvoima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Mäntän Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Neste Oil Oyj	Operator (company with a legally binding emission ceiling under the EU ETS)

Legal entity	Reason for authorization
Nivalan Kaukolämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Nordea Pankki Suomi Oy	Approval and authorisation from the Ministry of the Environment
Nordic Carbon Fund Ky	Authorisation for CDM and JI projects
Nordkalk Oyj Abp	Operator (company with a legally binding emission ceiling under the EU ETS)
Nurmeksen Lämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Nurmijärven Sähkö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Oulun Energia	Operator (company with a legally binding emission ceiling under the EU ETS)
Outokummun Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Outokumpu Chrome Oy and Outokumpu Stainless Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Outokumpu Oyj	Approval and authorisation from the Ministry of the Environment
Ovako Imatra Oy Ab	Operator (company with a legally binding emission ceiling under the EU ETS)
Oy Alholmens Kraft Ab	Operator (company with a legally binding emission ceiling under the EU ETS)
Oy Kokkola Power Ab	Operator (company with a legally binding emission ceiling under the EU ETS)
Oy Perhonjoki Ab	Operator (company with a legally binding emission ceiling under the EU ETS)
Oy Turku Energia Åbo Energi Ab	Operator (company with a legally binding emission ceiling under the EU ETS)
Paimion Lämpökeskus Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Pankaboard Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Pansion Lämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Paroc Oy Ab	Operator (company with a legally binding emission ceiling under the EU ETS)
Pohjola Pankki Oyj	Approval and authorisation from the Ministry of the Environment
Pohjolan Voima Oy	Approval and authorisation from the Ministry of the Environment
Pori Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Porin Prosessivoima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Porvoon Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Premium Board Finland Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Punkavoima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Puulaakson Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
PVO-Huippuvoima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
PVO-Lämpövoima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Pölkky Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Raisionkaaren Teollisuuspuisto Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Rauman Biovoima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Rauman Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Raunion Saha Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Rovaniemen Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Rovaniemen koulutuskuntayhtymä	Operator (company with a legally binding emission ceiling under the EU ETS)
Ruukki Metals Oy	Operator (company with a legally binding emission ceiling under the EU ETS), authorisation for CSM and JI projects
Saint-Gobain Rakennustuotteet Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Saint-Gobain Weber Oy Ab	Operator (company with a legally binding emission ceiling under the EU ETS)
Salon Energiantuotanto Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Sappi Finland Operations Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Sarlin Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Savon Sellu Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Savon Voima Oyj	Operator (company with a legally binding emission ceiling under the EU ETS)
SCA Tissue Finland Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Seinäjoen Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
SMA Mineral Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Sonoco-Alcore Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Stora Enso Oyj/Financial Services	Operator (company with a legally binding emission ceiling under the EU ETS)
Stora Enso Publication Papers Oy Ltd	Operator (company with a legally binding emission ceiling under the EU ETS)
Stora Enso Wood Products Oy Ltd	Operator (company with a legally binding emission ceiling under the EU ETS)
Sucros Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Suomen Sokeri Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Suomen Teollisuuden Energiapalvelut STEP Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Suomussalmen kunta	Operator (company with a legally binding emission ceiling under the EU ETS)
Suur-Savon Sähkö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Taivalkosken Voima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Tammisaaren Energia	Operator (company with a legally binding emission ceiling under the EU ETS)
Tampereen Energiantuotanto Oy	Operator (company with a legally binding emission ceiling under the EU ETS)

Legal entity	Reason for authorization
Teollisuuden Voima Oyj	Operator (company with a legally binding emission ceiling under the EU ETS)
Tervakoski Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Tornion Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Tornion Voima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Turun Seudun Energiatuotanto Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
UPM-Kymmene Oyj	Operator (company with a legally binding emission ceiling under the EU ETS)
UPM-Kymmene Wood Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Vaasan Sähkö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Valkeakosken Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Vantaan Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Vapo Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Varissuon Lämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Varkauden Aluelämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Wärtsilä Finland Oyj	Authorisation for CDM and JI projects
Vaskiluodon Voima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Vatajankosken Sähkö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Veljet Kuusisto Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Versowood Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Wienerberger Oy Ab	Operator (company with a legally binding emission ceiling under the EU ETS)
Viitasaaren Lämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
VS Lämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Yara Suomi Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Ylivieskan Tiili Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Äänevoima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)