

GREENHOUSE GAS EMISSIONS IN FINLAND  
1990-2013

*National Inventory Report*

*2015 submission*

*30 October 2015*

# PREFACE

This submission is made to meet the reporting requirements for national greenhouse gas inventories under the UNFCCC (UNFCCC 2013) and EU regulation 525/2013 on a mechanism for monitoring and reporting greenhouse gas emissions and for reporting other information at national and Union level relevant to climate change (EU MMR). The submission contains also supplementary information to be included in the national inventory submission in accordance with the requirements under the Kyoto Protocol. However, as the CRF Reporter is not yet functional to allow for provision of emissions/removals under Article 3, paragraph without errors, the information provided under the Kyoto Protocol should be considered only as additional information, not a formal national submission under the Kyoto Protocol. There is one exception to this, the information provided on the accounting of Kyoto Protocol units relevant to the first commitment period can be used, as necessary, in the assessment of the fulfilment of the commitments under the first commitment period.

The 2015 national inventory submission contains the following parts:

- Part 1 Finland's national greenhouse gas emission inventory report (NIR) prepared using the UNFCCC reporting guidelines (UNFCCC 2013) and the guidelines for the preparation of the information required under Article 7, paragraph 1 in the Annex to Decision 15/CMP.1 and Annex II to Decision 2/CMP.8 of the Kyoto Protocol. Other relevant decisions under the Kyoto Protocol (19/CMP.1, 2/CMP.7, 4/CMP.7 and 6/CMP.9) are also followed.
- Part 2 CRF (Common Reporting Format) data tables showing Finland's greenhouse gas emissions for the years 1990-2013 excluding KP-LULUCF data tables. The CFR tables were compiled using UNFCCC CRF Reporter Inventory software (version 5.10.1).
- 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, 31.12.2014, and transfers of the units during 2014.

Statistics Finland (Pia Forsell, Kari Grönfors, Timo Kareinen, Päivi Lindh, Sini Niinistö, Riitta Pipatti, Kai Skoglund), The Natural Resources Institute Finland<sup>1</sup> (Markus Haakana, Jaakko Heikkinen, Juha Heikkinen, Tuula Larmola, Aleksi Lehtonen, Paula Ollila, Jari Perttunen, Sanna Pitkänen, Kristiina Regina, Tarja Tuomainen, Sointu Virkkala), the Finnish Environment Institute (Tommi Forsberg, Johanna Mikkola-Pusa, Jouko Petäjä, Kristina Saarinen), VTT Technical Research Centre of Finland Ltd (Heidi Auvinen, Jenni Eckhardt, Kari Mäkelä), Finavia (Mikko Viinikainen, Johanna Kara), the Energy Authority (Jouko Hepola, Jonna Makkonen, Johanna Pakkala), the Ministry of Employment and the Economy (Juhani Tirkkonen), and the Ministry of Foreign Affairs of Finland (Matti Nummelin, Johanna Pietikäinen) have made the inventory calculations and/or provided the descriptions of the methodologies and other information.

Statistics Finland is the national entity with the overall responsibility for the compilation and finalisation of inventory reports and their submission to the UNFCCC Secretariat and the European Commission. Statistics Finland approves the inventory submissions to the EU, UNFCCC and the Kyoto Protocol independently.

Information under the EU MMR (EU 525/2013) is included in relevant chapters of the NIR and Annex 9 and information under the EU decision on accounting rules for greenhouse gas emissions and removals from activities relating to land use, land-use change and forestry (529/2013/EU) is included in Annex 10.

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

The contact person at Statistics Finland is:

Dr Riitta Pipatti,

PB 6 A, FIN-00022 Statistics Finland

tel. + 358-29-551 3543, email [riitta.pipatti@stat.fi](mailto:riitta.pipatti@stat.fi)

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<sup>1</sup> The Natural Resources Institute Finland (Luke) comprises former MTT Agrifood Research Finland, the Finnish Forest Research Institute, the Finnish Game and Fisheries Research Institute and the Information Centre of the Ministry of Agriculture and Forestry started its operations 1 January 2015.

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# 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 (hereafter referred to as EU MMR). This regulation encompasses also reporting to fulfil the EU Effort Sharing Decision (406/2009/EC) and the EU LULUCF Decision (529/2013/EU). The implementation of the EU MMR is further specified in the Commission Implementing Regulation (EU) No 749/2014 and the Commission Delegated Regulation (EU) No 666/2014. This report aims at fulfilling the reporting commitments related greenhouse gas emission inventories 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. The Climate Law (609/2015) enforces Statistics Finland's role as the national entity responsible for Finland national greenhouse gas inventory. 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 MMR. Besides Statistics Finland, the Finnish Environment Institute and the Natural Resources Institute Finland 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 Ltd). In Finland the national system, as intended in the Kyoto Protocol (Article 5.1), is based, besides laws and 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 MMR. A description of the National Greenhouse Gas Inventory System including the institutional arrangements in Finland is provided in Section 1.2. Changes in Finland's national system/institutional arrangement are reported in Chapter 13 of this report.

This report also includes supplementary information in accordance with Article 7, paragraph 1, of the Kyoto Protocol. The required information is consistent with relevant decisions and guidelines under Article 7, paragraph 1 and includes information on Finland's assigned amount for the second commitment period, corresponding emissions and removals (see Chapter 2), 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) for the first commitment period that are part of Finland's inventory submission. The information on the accounting of Kyoto units is provided for both the first and the second commitment period. This supplementary information under the Kyoto Protocol should be considered as additional information only, as this submission is an official submission under the UNFCCC only.

## *ES.2 Summary of national emission and removal-related trends*

In 2013, Finland's greenhouse gas emissions totalled 63.1 million tonnes of carbon dioxide equivalent (Mt CO<sub>2</sub> eq.). The total emissions in 2013 were approximately 12% (8.3 Mt) below the 1990 emissions level. Compared to 2012, the emissions increased by approximately 1%.

A summary of the Finnish national emissions and removals for 1990-2013 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 2013, which was on level with the previous year. The share of renewable energy of total energy consumption decreased in 2013 and stood at 31 per cent. The biggest decline was seen in the use of hydro power; the availability of hydro power declined in the Nordic countries in 2013 and the production of hydro power decreased by 24% in Finland. The use of forest chippings rose to a new record level in 2013, and 5% more was used than in 2012. The use of fossil fuels went up by 2% from the year before. Of fossil fuels, the use of natural gas fell by 7% and the use of peat by 12% from 2012. The consumption of coal (including hard coal, coke, and blast furnace and coke oven gas) increased by 23% (Energy supply and consumption, Statistics Finland).

Total electricity consumption went down by 1% and amounted to 84 TWh in 2013. Of total electricity consumption, 81% was covered by domestic production and 19% by net imports of electricity from the Nordic countries and Russia. Net imports of electricity declined by 10% from the year before as the water situation in the Nordic countries was worse than in 2012 (Energy supply and consumption, Statistics Finland).

Emissions in the industrial processes and product use sector increased between 1993 and 2008 to a level over 40% higher than the base year emissions<sup>2</sup>, but decreased over 20% compared to 2008 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 but during 2010-2013 emissions have been 14-23% lower than the peak value in 2008. 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 and product use sector. The growth in HFC emissions has contributed with an almost equal amount to the increase of the emissions in this sector.

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 1990-2013 as the removals in the sector exceeded the emissions. The net removals in the sector were 20.4 Mt CO<sub>2</sub> eq. in 2013 and have decreased with 27% since the previous year and increased by 29% since 1990. 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.

Indirect CO<sub>2</sub> emissions have decreased 69% since 1990, main reason is that industry has reduced the use of solvent chemicals.

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<sup>2</sup> Finland's base year under the UNFCCC is 1990. Under the Kyoto Protocol the base year is 1990, except for fluorinated gases (HFCs, PFCs, SF<sub>6</sub> and NF<sub>3</sub>) for which the base year is 1995. Under the EU Effort Sharing Decision, the base year is 2005 (relates only to emissions not included in the EU Emissions Trading Scheme). Unless otherwise specified, references to the base year in this report refer always to 1990.

**Table ES.2-1** Finnish greenhouse gas emissions and removals (Mt CO<sub>2</sub> equivalent). The base year refers to 1990 which is Finland base year under the UNFCCC.

<b>Sector</b>	<b>Base year</b>	<b>1990</b>	<b>1995</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>	<b>2013</b>
Energy	53.6	53.6	55.4	53.9	59.1	61.7	69.3	65.4	53.6	64.8	62.7	54.4	52.4	60.0	52.9	47.6	48.4
Industrial processes and product use <sup>1</sup>	5.3	5.3	4.8	5.2	5.2	5.1	5.4	5.7	5.6	5.6	6.0	6.3	4.6	4.7	4.7	4.5	4.4
F- gases	0.1	0.1	0.1	0.6	0.6	0.7	0.7	0.7	0.9	1.0	1.2	1.4	1.5	1.8	1.6	1.5	1.6
Agriculture	7.5	7.5	6.8	6.4	6.4	6.6	6.4	6.4	6.4	6.4	6.3	6.4	6.4	6.5	6.3	6.3	6.3
Waste	4.7	4.7	4.6	3.9	3.7	3.4	3.2	3.1	2.8	2.9	2.8	2.7	2.6	2.6	2.5	2.5	2.3
Indirect CO <sub>2</sub> -emissions <sup>2</sup>	0.3	0.3	0.2	0.2	0.2	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
<b>TOTAL (exl. LULUCF<sup>3</sup>)</b>	<b>71.3</b>	<b>71.3</b>	<b>71.8</b>	<b>70.1</b>	<b>75.3</b>	<b>77.7</b>	<b>85.1</b>	<b>81.3</b>	<b>69.5</b>	<b>80.7</b>	<b>79.1</b>	<b>71.2</b>	<b>67.5</b>	<b>75.8</b>	<b>68.1</b>	<b>62.4</b>	<b>63.1</b>
<b>TOTAL (exl. LULUCF and Indirect CO<sub>2</sub> emissions)</b>	<b>71.1</b>	<b>71.1</b>	<b>71.6</b>	<b>70.0</b>	<b>75.1</b>	<b>77.5</b>	<b>85.0</b>	<b>81.2</b>	<b>69.3</b>	<b>80.6</b>	<b>79.0</b>	<b>71.1</b>	<b>67.4</b>	<b>75.7</b>	<b>68.0</b>	<b>62.4</b>	<b>63.0</b>
LULUCF <sup>3</sup>	NA	-15.8	-15.5	-24.5	-26.2	-26.6	-27.2	-28.6	-29.6	-35.9	-28.1	-26.9	-39.4	-26.7	-26.2	-27.9	-20.4

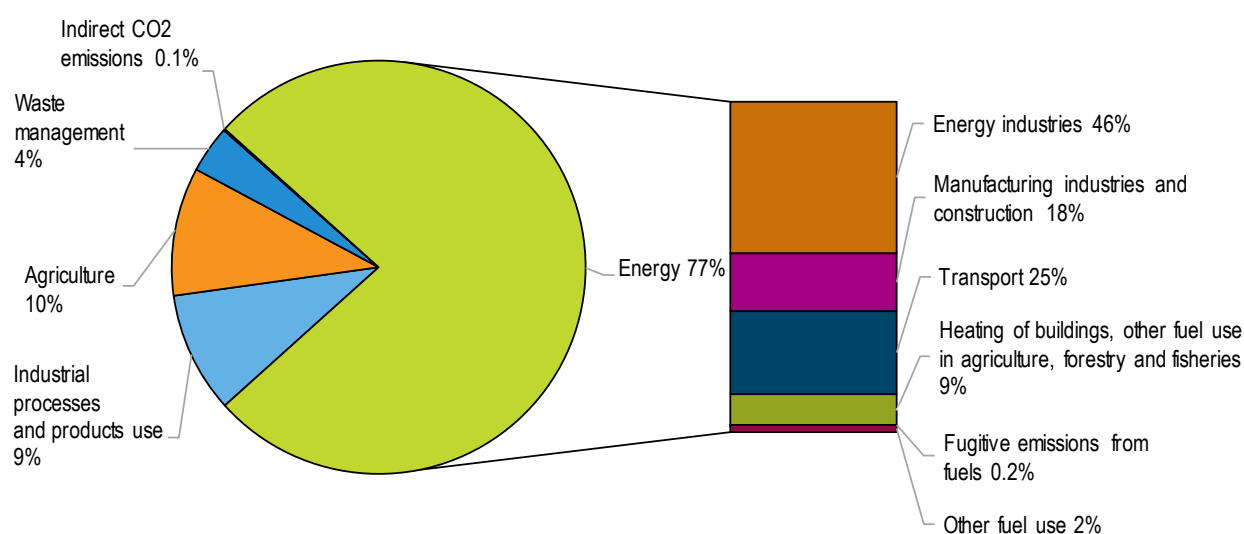
<sup>1</sup>excluding F-gases<sup>2</sup>indirect CO<sub>2</sub>-emissions from NMVOC and CH<sub>4</sub> from energy, industrial processes and product use<sup>3</sup>Land use, land-use change and forestry

(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 and Product Use (CRF 2) Agriculture (CRF 3), Land Use, Land Use Change and Forestry (LULUCF) (CRF 4), and Waste (CRF 5). In addition, Finland reports indirect CO<sub>2</sub> emissions due to atmospheric oxidation of CH<sub>4</sub> and NMVOCs. National totals are presented with and without indirect CO<sub>2</sub> consistent with the UNFCCC reporting guidelines. Finland considers the national totals with indirect CO<sub>2</sub> emissions as the national totals to be used in assessing compliance with the emission reduction commitments under the Kyoto Protocol.

The composition of Finnish greenhouse gas emissions in 2013 is presented in Figure ES.3-1.



**Figure ES.3-1** The composition of Finnish greenhouse gas emissions in 2013 (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 77% share of the total emissions in 2013, being 48.4 Mt 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. Total consumption of energy in Finland amounted to 1.37 million terajoules (TJ) in 2013, which was on level with the previous year.

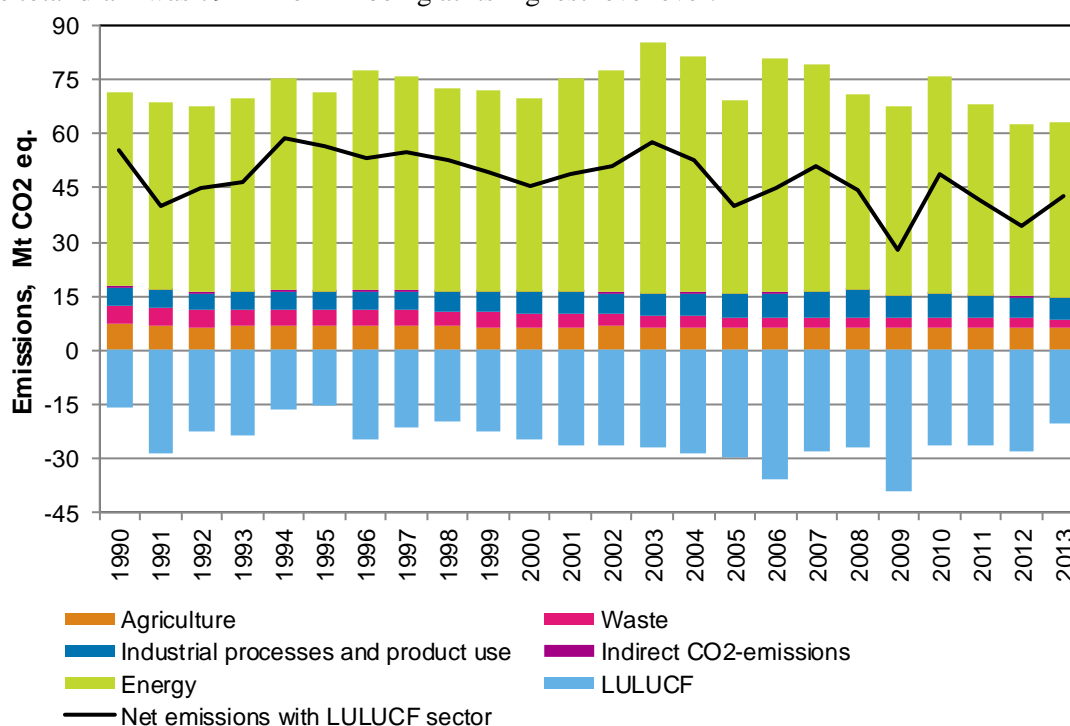
Agriculture is the second most significant source of greenhouse gas emissions in Finland. In 2013, agricultural emissions accounted for 10% (6.3 Mt CO<sub>2</sub> eq.) of total emissions. The total emissions from agriculture have a decreasing trend. The annual emissions have reduced by 15% since 1990 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 and product use (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 9% (6.0 Mt CO<sub>2</sub> eq.) of total greenhouse gas emissions in Finland in 2013, being the third largest source of greenhouse gas emissions. Emissions have increased by 11% (0.6 Mt CO<sub>2</sub> eq.) since 1990. Their share from the total greenhouse gas emissions has varied from 7 to 11 % of total emissions during the reporting period. The fluctuation in the emissions from industrial processes and product use is largely consistent with the economic trend, even if the factors influencing the emissions are more diverse.

The waste sector accounted for 4% (2.3 Mt CO<sub>2</sub> eq.) of total Finnish greenhouse gas emissions in 2013. 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 50% 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 indirect CO<sub>2</sub> emissions from atmospheric oxidation of CH<sub>4</sub> and NMVOCs to the Finnish greenhouse gas emissions is small, about 0.1% of the total greenhouse gas emissions in Finland.

The LULUCF sector is a net sink in Finland. The net sink has varied from approximately 20% to 60% of the annual emissions from the other sectors during 1990-2013. The most important components of the forest sink are the increment of growing stock and the harvest removals. The growth has increased since 1990 from 78 million m<sup>3</sup> to 104 million m<sup>3</sup>. Between years there is less fluctuation in the growth contrary to the harvest rates. In 2013, the total drain was 79 million m<sup>3</sup> being at its highest level ever.



**Figure ES.3-2** Greenhouse gas emissions and removals in Finland by reporting sector (Mt CO<sub>2</sub> eq.) and net CO<sub>2</sub> equivalent emissions (emissions plus removals). Emissions are positive and removals negative quantities

## *ES.4 Summary of emissions and removals related to Finland's quantified emission reduction commitment for the second commitment period of the Kyoto Protocol*

The European Union (EU) and its Member States, and Iceland have agreed (agreement under Article 4 of the Kyoto Protocol) to fulfil jointly their quantified emission limitation and reduction commitment (QELRC) for the second commitment period of the Kyoto Protocol. The joint QELRC is a reduction in the total emissions of 20 per cent compared to the emissions in the base year or period during the period 2013 – 2020.

The respective emission level allocation of the parties to the agreement are determined as follows:

- The joint assigned amount of the Parties of the agreement (EU, its Member States and Iceland) is calculated as the sum of the base or period year emissions for the EU Member States and Iceland in accordance with Article 3, paragraphs 7bis, 8 and 8bis.
- The emission levels allocated to the Member States are based on their annual emission allocations under the EU Effort Sharing Decision (406/2009/EC) as determined in the Commission decisions 2013/162/EU and 2013/634/EU.
- For Member States, for which land-use change and forestry constituted a net source in 1990, the aggregated anthropogenic CO<sub>2</sub> eq emissions by sources minus removals by sinks in 1990 from land-use change (deforestation), are added to allocated emission levels. The allocated emission levels constitute the assigned amounts for the Member States for the second commitment period.
- The assigned amount of a Member State covers the emissions from the non-emission trading sector (non-ETS) calculated as the total national emissions without LULUCF minus the national emissions in EU Emission trading sector for that Member State. Under the Article 4 agreement, the Member States are responsible for meeting their national emissions limitations/reductions for the non-ETS sector and for their accounted emissions/removals related to the Kyoto Protocol LULUCF activities in accordance with the rules set out in decision 2/CMP.7.
- The emission level allocated to Iceland is 15,327,217 tonnes CO<sub>2</sub> eq and is based on the agreement between the EU, its Member States and Iceland and equal Iceland's assigned amount for the second commitment period.
- The emission level allocated to the EU is equal to the joint assigned amount minus the sum of the emissions levels of the Member States and Iceland and equal to EU's assigned amount. The EU's responsibilities cover the emissions from the ETS sectors including also CO<sub>2</sub> emissions of domestic aviation for all member states.

The agreement and the respective emission levels allocated to each of the parties to the agreement will be described in detail in Finland's report to facilitate the calculation of the assigned amount for the second commitment period of the Kyoto Protocol.

For Finland, the allocated emission level for the period 2013 – 2020 is equal to 240,544,599 tonnes carbon dioxide equivalents (CO<sub>2</sub> eq). This amount will constitute Finland's assigned amount for the second commitment period.

Finland's assigned amount covers the emissions from the non-emission trading sector (non-ETS) calculated as the total national emissions without LULUCF minus the national verified emissions of installations in EU Emission trading sector. The quantity of CO<sub>2</sub> emissions of the inventory category '1.A.3.A civil aviation' is considered equal to zero when determining the annual non-ETS emissions as these emissions are covered by the EU emissions trading system for aviation. In addition to non-ETS emissions, Finland is responsible for the emissions/removals related to the Kyoto Protocol LULUCF activities in accordance with the accounting rules set out in decision 2/CMP.7 and the related information and elections described in Finland's report to facilitate the calculation of the assigned amount for the second commitment period of the Kyoto Protocol .

Finland's total national emissions without LULUCF were 63,069,302 tonnes CO<sub>2</sub> eq in 2013 and 62,877,112 tonnes CO<sub>2</sub> eq without CO<sub>2</sub> emissions from civil aviation (1.A.3a). The corresponding verified ETS emissions

were 31,496,743 tonnes CO<sub>2</sub> eq. Hence the non-ETS sector in 2013 were 31,380,369 tonnes of CO<sub>2</sub> eq (see also Table ES.4-2 and Annex 9). These emissions represent 13 per of Finland's assigned amount.

Reporting and accounting of LULUCF activities during the second commitment period (2013 – 2020) of the Kyoto Protocol is addressed in detail in Finland's report to facilitate the calculation of the assigned amount and Chapter 11 of this report. Under Article 3, paragraph 3, Finland reports and accounts for emissions and removals from afforestation (A), reforestation (R) and deforestation (D) activities, and under Article 3, paragraph 4, emissions and removals from forest management (FM). Reporting and accounting of these activities is mandatory for the second commitment period. Finland has not elected any voluntary Kyoto Protocol LULUCF activities for the second commitment period. The accounting of all activities under Article 3, paragraphs 3 and 4 will be for the entire commitment period. The emissions/removals from ARD are added to or subtracted from the assigned amount in full whereas the net emissions/removals from FM are subtracted from the FM reference level (FMRL) before the addition/subtraction. Also, additions to the assigned amount resulting from FM shall not exceed 3.5 per of the base year emissions (FM cap).

Net emissions from ARD activities in 2013 were 2,375,953 tonnes CO<sub>2</sub> eq., and net removals from FM activity were –46,052,936 tonnes CO<sub>2</sub> eq. (Table ES.4-1). Finland's FM reference level is –19,300,000 tonnes CO<sub>2</sub> eq and the technical correction to it based on this submission is –11,020,000 tonnes CO<sub>2</sub> eq. This means that the net removals from FM exceed the reference level including the technical correction with –15,732,936 tonnes CO<sub>2</sub> eq. The FM cap (3.5 per of the base year emissions) is -19,971,700 tonnes CO<sub>2</sub> eq for the whole commitment period. In total the KP LULUCF accounting based on the emissions and removals in 2013 would result in a net addition of units to the assigned amount of -13,356,983 tonnes CO<sub>2</sub> eq.

**Table ES.4-1** Emissions and removals (tonnes CO<sub>2</sub> eq.) in 2013 resulting from activities under Article 3.3 and 3.4 of Kyoto Protocol

	2013	2014	2015	2016	2017	2018	2019	2020	Total
<b>A. Article 3.3 activities</b>									
A.1. Afforestation/reforestation	-541 588								<b>-541 588</b>
A.2. Deforestation	2 917 540								<b>2 917 540</b>
<b>B. Article 3.4 activities</b>									
B.1. Forest management	-46 052 936								<b>-46 052 936</b>
B.2. Cropland management (if elected)	NA								NA
B.3. Grazing land management (if elected)	NA								NA
B.4. Revegetation (if elected)	NA								NA
B.5. Wetland drainage and rewetting (if elected)	NA								NA

**Table ES.4-2** Summary of emissions (+) and removals (-) in tonnes CO<sub>2</sub> eq in the year 2013 relevant for accounting under the second commitment period of the Kyoto Protocol.

<b>Finland's assigned amount</b>	<b>240 544 599</b>
Total national emissions	63 069 302
ETS emissions without aviation	31 496 743
CO <sub>2</sub> emissions from aviation	192 190
<b>Non-ETS emissions<sup>1)</sup></b>	<b>31 380 369</b>
<b>Article 3.3 net emissions</b>	<b>2 375 953</b>
Article 3.4 net removals (FM)	-46 052 936
Finland's FMRL	-19 300 000
Technical correction to the FMRL	-11 020 000
<b>FM net removals minus FMRL and the technical correction</b>	<b>-15 732 936</b>
Article 3.4 cap	-19 971 700
<b>Estimate of net additions to the assigned amount from Article 3.3 and 3.4<sup>2)3)</sup></b>	<b>13 356 983</b>

- 1) The emissions Finland's is responsible for in the joint fulfilment by the EU, its Member States and Iceland
- 2) Finland has chosen end of commitment period accounting for Articles 3.3 and 3.4
- 3) Sum of ADR net emissions and FM net removals minus FMRL and the technical correction (the sign has been changed to positive to indicate that this amount will be added to the assigned amount)

# 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 EU MMR guides the greenhouse gas inventory reporting by the Member States (MS) of the European Union (EU) to the Commission. This regulation builds on the reporting requirements of the UNFCCC and its Kyoto Protocol, but includes also many Union specific requirements, including provisions for annual quality checks and a review of the submission. The MSs submit their inventories to the Commission with annual deadlines for submission 15 January (preliminary data) and 15 March (final data).

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), sulphur hexafluoride (SF<sub>6</sub>) and nitrogen trifluoride (NF<sub>3</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. Finland's national total emissions include the indirect CO<sub>2</sub> emissions, but are presented with and without indirect CO<sub>2</sub>. The indirect CO<sub>2</sub> emissions have been separately estimated for fugitive emissions in the Energy sector and sources in the Industrial Processes and Other Product Use sector consistent with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Indirect N<sub>2</sub>O emission resulting from deposition of nitrogen due to emissions of nitrogen oxides (NO<sub>x</sub>) and ammonia (NH<sub>3</sub>) are estimated but only indirect N<sub>2</sub>O emissions from agricultural sources are included in the national total emissions consistent with the UNFCCC reporting guidelines in the Annex to Decision 24/CP.19 (UNFCCC 2013).

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 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 Common Reporting Format (CRF) tables which are part of the inventory submission. In the NIR the data is presented for a limited set of years consistent with the UNFCCC reporting guidelines.

The structure of this NIR follows the UNFCCC reporting guidelines (UNFCCC 2013).

## 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>3</sup>.* Finland's emissions during the first commitment period decreased almost five per cent compared to the emissions in 1990.

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 and Product Use, Agriculture, Land use, Land-use change and Forestry and Waste) and for all years from the base year to the most recent year. The preparation and reporting of the Finnish inventory is guided by the UNFCCC reporting guidelines (UNFCCC 2013 implementing the 2006 IPCC Guidelines for National Greenhouse Gas inventories (hereafter referred to as *2006 IPCC Guidelines*). For the reporting of the emissions and removals from the KP LULUCF activities, also the methodological guidance in the 2013 Supplementary Methods and Good Practice guidance arising from the Kyoto Protocol (hereafter referred to as *IPCC KP Supplement*) is followed. Finland has not elected the KP LULUCF activity *Wetland Drainage and Rewetting*. Therefore Finland has not used the 2013 Supplement to the 2006 IPCC guidelines for National Greenhouse Gas Inventories: Wetlands (hereafter referred to as *IPCC Wetlands Supplement*) in the inventory preparation except in a few cases, where the IPCC Wetlands Supplement has been used as a reference when updating national emission factors for drained organic soils in both the Agriculture and LULUCF sectors.

The EU MMR requires reporting of information on annual emission inventories and 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

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<sup>3</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.

(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 Effort Sharing Decision.

## 1.2 Description of the national inventory arrangements

The national inventory arrangements in Finland are described below. The descriptions take into account requirements for reporting on national inventory systems under the Kyoto Protocol and the EU MMR as well as for reporting on the national inventory arrangements consistent with in paragraph 20 – 27 in the UNFCCC reporting guidelines.

### 1.2.1 Institutional, legal and procedural arrangements

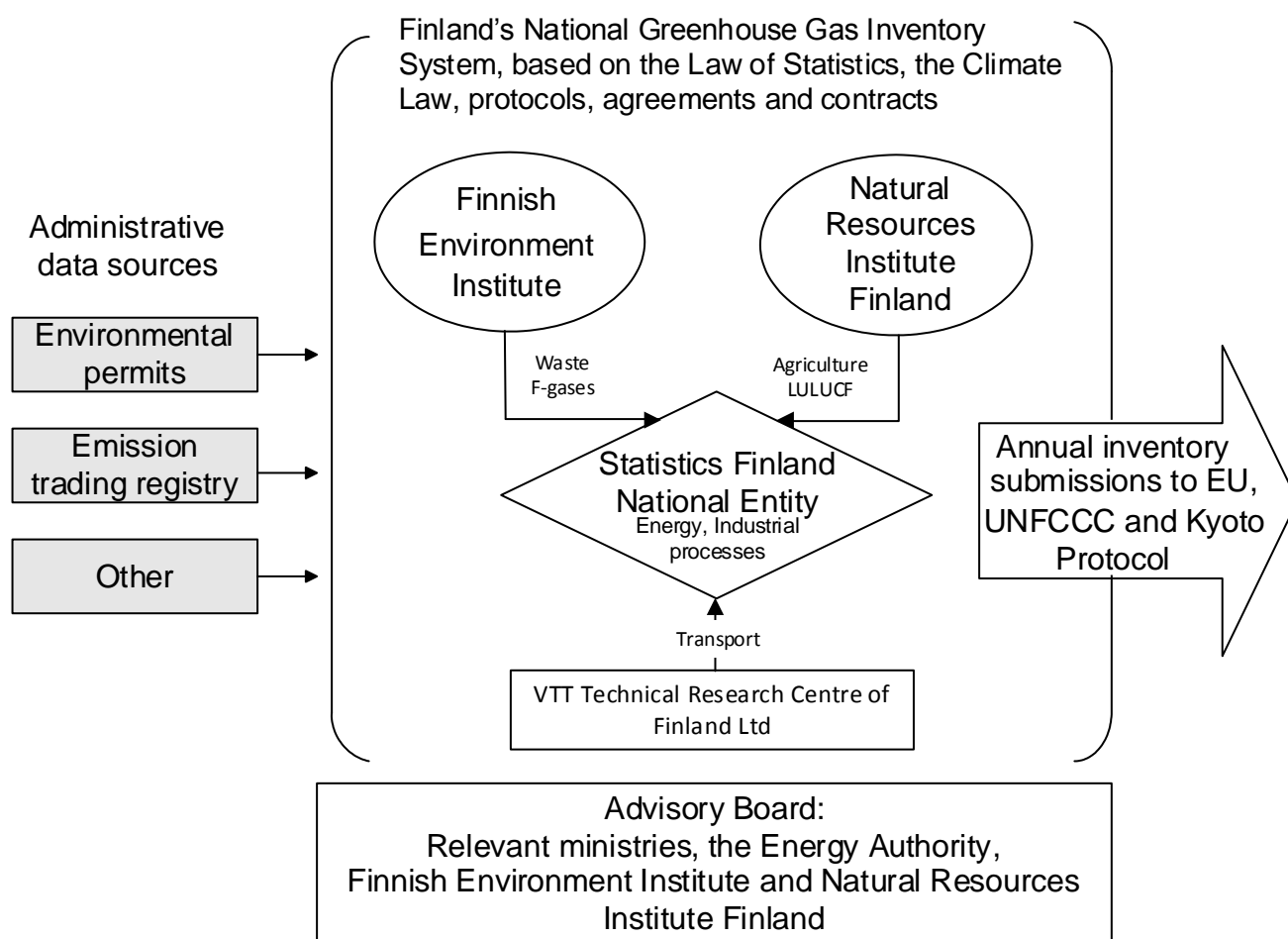
According to the Government resolution of 30 January 2003 on the organisation of climate policy activities of Government authorities, Statistics Finland<sup>4</sup> assumed the responsibilities of the national entity for Finland's greenhouse gas inventory from the beginning of 2005. In 2015, the role of Statistics Finland as the national entity was enforced through the adoption of the Climate Law (609/2015).

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 laws and regulations concerning Statistics Finland, on agreements between the inventory unit and expert organisations on the production of emission and removal estimates as well as related documentation. Statistics Finland has also agreements on cooperation and support to the expert organisations participating in Finland's national system with relevant 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 (see Section 1.2.3). The national system for the greenhouse gas inventory in Finland is presented in Figure 1.2-1 below<sup>5</sup>. Changes in national system since the previous submission are addressed in Chapter 13.

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<sup>4</sup> Contact information: : Dr Riitta Pipatti,  
PB 6 A, FIN-00022 Statistics Finland  
tel. + 358-29-551 3543  
email [riitta.pipatti@stat.fi](mailto:riitta.pipatti@stat.fi)  
[http://tilastokeskus.fi/org/yhteystiedot/index\\_en.html](http://tilastokeskus.fi/org/yhteystiedot/index_en.html)

<sup>5</sup> The detailed description of the National Greenhouse Gas Inventory System can be download at:  
<http://stat.fi/greenhousegases>



**Figure 1.2-1.** The National System for the Greenhouse Gas Inventory in Finland (LULUCF = Land use, land use change and forestry)

#### 1.2.1.1 Statistics Finland as the national entity 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 entity for the greenhouse gas inventory, the Statistics Finland Act (48/1992 and its amendment 901/2002) and the Statistics Act (280/2004 and its amendment 361/2013) 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 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. 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 and the EU Commission, co-ordinates participation in the review of the inventory, and publishes and archives the inventory results.

Statistics Finland has access to data collected for administrative purposes. Hence by law, Statistics Finland has access to data collected under the EU ETS, regulation on fluorinated gases, the European EPRTTR registry and energy statistics regulation. Access to EU ETS data is also ensured through the agreement between Statistics Finland and the Energy Authority. The EU ETS data and data collected under energy statistics regulation are significant data sources and used both directly and/or for verification in inventory compilation. The use of the EPRTTR and data collected under the regulation on fluorinated greenhouse gases have a much more limited role in the inventory preparation.

Statistics Finland approves the inventory before the submissions to the UNFCCC and EU. The draft inventory submission to the EU 15 January is presented to the advisory board, and before submitting the final inventory to UNFCCC 15 April, the national inventory report is sent to the inter-ministerial network on climate policy issues for comments.

### 1.2.1.2 Responsibilities of expert organisations

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

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. Finavia continues to support Statistics Finland in the task by providing Statistics Finland with expert advice (the calculations are described in Section 3.2.5.3).

The agreements between Statistics Finland and the expert organisations define the division of responsibilities (sectors/categories covered) and tasks related to uncertainty and key category analysis, QA/QC and reviews. They also specify the procedures and schedules for the annual inventory process co-ordinated by Statistics Finland. The responsibilities to estimate and report emissions/removals from different sectors/categories of the different expert organisations are based on established practices for the preparation and compilation of the greenhouse gas emission inventory. The scope of these responsibilities by expert organisation is presented in Table 1.2-1.

**Table 1.2-1** Responsibility areas by expert organisation

Area		Organisations
CRF 1.A.	Stationary sources - fuel combustion in point sources, such as power plants, heating boilers, industrial combustion plants and processes	Statistics Finland
CRF 1.A.	Mobile sources (transport and off-road machinery)	Statistics Finland, VTT Technical Research Centre of Finland Ltd (as a purchased service)
CRF 1.A.	Other fuel combustion (agriculture, households, services, public sector, etc.)	Statistics Finland
CRF 1.B.	Fugitive emissions from energy production and distribution	Statistics Finland
CRF 2.	Emissions from industrial processes and product use	Statistics Finland
CRF 2.	Emissions of F-gases	Finnish Environment Institute
CRF 3.	Emissions from agriculture	Natural Resources Institute Finland (Luke)
CRF 4.	Emissions from land use, land-use change and forestry	Natural Resources Institute Finland
CRF 5.	Emissions from waste	Finnish Environment Institute
Indirect CO <sub>2</sub>	Non-methane volatile organic compounds, NMVOC	Finnish Environment Institute
KP	Activities under Article 3, paragraphs 3 and 4 of the Kyoto Protocol (ARD and FM)	Natural Resources Institute Finland

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 and verification process of the inventory.

### *1.2.1.3 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 contents, 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 and the biennial reports under the UNFCCC. Separate agreements have been made on the division of responsibilities and co-operation between Statistics Finland and the ministries.

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 international emissions trading under 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 was updated in 2010.

Finland's registry and changes to it since the previous inventory submission are described in Chapter 14.

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.

## *1.2.2 Overview of inventory planning, preparation and management*

The inventory planning, preparation and management process is described in the next Section (1.2.3) together with the quality management process. The quality control and quality assurance elements are integrated into the inventory production system. This means that all stages of the inventory process, planning, preparation and management, include relevant quality management processes.

### *1.2.3 Quality assurance, quality control and verification plan*

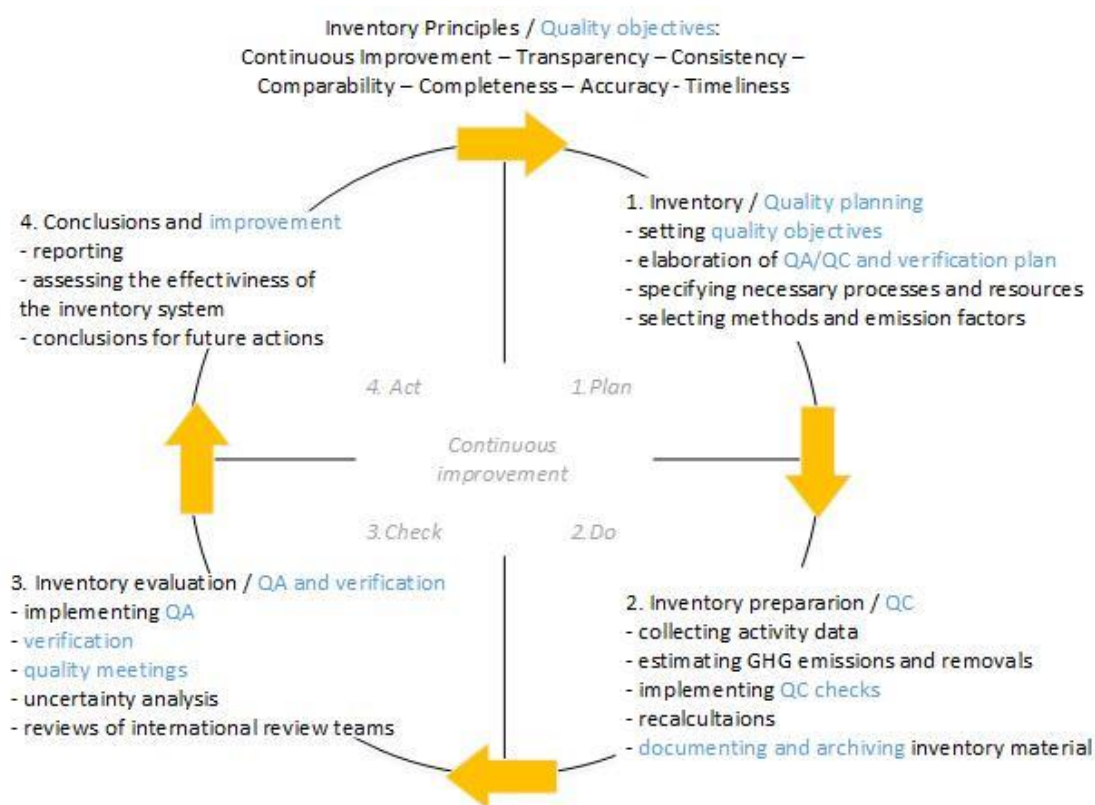
This section presents the quality management including quality objectives and the QA/QC and verification plan for the Finnish greenhouse gas inventory at the national inventory level. Category-specific QA/QC details are discussed in the relevant sections of this NIR.

### 1.2.3.1 Quality management

The objective of Finland's GHG inventory system is to produce high-quality GHG inventories which 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 in conjunction with the inventory process (Figure 1.2-2). 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.

Inventory process consists of four main stages: planning, preparation, evaluation and improvement (PDCA cycle) and aims to continuous improvement. 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 1.2-2** Inventory and QA/QC process of the inventory

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) and verification process and elaborates the QA/QC and verification plan (Section 1.2.3.2). 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 and verification procedures.

Issues related to QA/QC and verification 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 and sectoral CRF tables (See Section 1.3.2).

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. 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.

Also, 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)).

### 1.2.3.2 QA/QC and verification plan and quality objectives (Plan)

The inventory planning stage includes the setting of quality objectives and elaboration of the QA/QC and verification 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 (Table 1.2-2) 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.

**Table 1.2-2.** The quality objectives regarding all calculation sectors for the inventory

Quality objectives	
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	
1.6. Verification of the inventory meet the requirements	
1.7. Known uncertainties of the inventory are taken into consideration when planning the improvement needs	
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 and category-specific QA/QC and verification procedures regarding all sectors are set in the QA/QC plan. This is a document 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 and category-specific inventory QC checks, information on quality assurance and verification, schedules and responsible parties. The QA/QC form addresses the actions to be taken in each stage of the inventory preparation. Sectoral experts fill in the form the QA/QC and verification procedures performed, and results of the procedures. Discussions in the bilateral quality meetings are based on information documented on these forms. 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 category-specific QC checklists. These lists are included in the internal documentation of the calculations.

#### *1.2.3.3 Quality control procedures (Do)*

The general and category-specific QC procedures are performed by the experts during inventory calculation and compilation according to the QA/QC and verification plan.

The QC procedures used in Finland's GHG inventory comply with the 2006 IPCC Guidelines. General inventory QC checks (2006 IPCC Guidelines, Vol 1, Chapter 6, Table 6.1) 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 reviews of the 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 and verification form for each category, which provides a record of the procedures performed. Results of the completed QC checks are recorded in the internal documents of the calculations and archived in the expert organisations. Key findings are summarised in the category-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 as much as possible to ensure consistency between CRF Tables and the NIR. This is continuously improved in order to avoid any discrepancies.

#### *1.2.3.4 Quality assurance (Check)*

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 and external audits, peer reviews and UNFCCC and EU inventory reviews.

Under the EU MMR, Finland compares annually greenhouse gas inventory data with data reported under the UN ECE (air pollutant data), the EU ETS and energy statistics (see the Energy Chapter and Annex 9). In addition, the European environmental Agency (EEA) performs QA/QC of EU Member States' submissions under the EU MMR (e.g. completeness checks, consistency checks and comparisons across Member States). These checks and comparisons produce valuable information for correction of potential errors and deficiencies. The information is taken into account before Finland submits its final annual inventory to the UNFCCC.

### *Basic review of the draft submission*

A basic review of the draft GHG emission and removal estimates and the draft report 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.

### *Internal and external audits*

An annual in-depth-review of the inventory is done mainly in conjunction with the bilateral quality meetings. 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 required QA and verification procedures according to the QA/QC and verification 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 QA/QC plan, category-specific QC/QA and verification if relevant, review feedback, structure and transparency of the reporting (NIR and CRF tables), improvement needs and plans, and functioning of the national inventory system (e.g. resources for inventory preparation). 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. As a result of the quality meetings held in 2015, for example, some quality assurance or verification possibilities were identified for specific sectors and the NIR descriptions were improved based on documentation in the QA/QC forms and feedback from the UNFCCC review.

Category-specific internal audits 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 category-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 timing of 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.

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 2011 two internal audits were carried out, one in mobile sources and another in the 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 were audited in order to assess the transparency of the instructions. The audit confirmed that the instructions were adequate for the inventory preparation but 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 3.2.4.6). However, due to the implementation of the 2006 IPCC Guidelines, including renewal of the data handling and calculation processes for the Energy sector in 2014-2016, the earliest timing for the audits is estimated to be in 2017. The resources for these audits need to be confirmed.

### *Peer reviews*

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. More information on peer review activities that have been undertaken are described in the category-specific chapters.

Peer reviews may also be bilateral collaboration. For example, the Finnish and Swedish, and occasionally also other Nordic countries, GHG inventory teams have met periodically to exchange information, experiences and views relating to the preparation on the national GHG inventories. In 2015 Nordic greenhouse gas inventory experts meeting, which included participants from Finland, Sweden, Norway and Denmark, was held in Helsinki. In this meeting several issues concerning the inventory were discussed. It was decided to further continue co-operation in order to get input to the QA and verification of inventory data and to create a network for sharing information.

This collaboration also provides opportunities for bilateral peer reviews. 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 soil carbon. The project results have increased confidence in the reported carbon stock changes. In 2012 - 2014, the collaboration meetings (Finland, Sweden and Norway) 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, comparison of emission factors and other parameters as well reporting on the Kyoto Protocol LULUCF activities during the second commitment period.

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. Technical reviews to verify the annual emissions under the ESD will be conducted under the EU MMR also for the inventory submissions in 2015 – 2022.

#### *1.2.3.5 Verification (Check)*

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 category-specific chapters.

#### *1.2.3.6 Improvement of the inventory, including the process for recalculations (Act)*

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 as well as UNFCCC and EU review feedback and uncertainty analysis where relevant. In addition, the inventory unit and experts performing the inventory calculations follow the development of the sector. When technologies and practices change, or new activity or research data become available, they evaluate the need for improvements and recalculations to improve the inventory.

Finland's inventory system has a special procedure for the consideration and approval of the recalculations. If sectoral experts identify any needs for recalculations they contact inventory unit and provide comparison calculations and solid justification for the recalculation. The methodological changes are then communicated to the advisory board for evaluation, and approved by the inventory unit before adopted into the production.

As a part of the inventory improvement also the QA/QC and verification plan is checked and updated annually based on results received from the previous inventory round. In the implementation of the improvements, resources are prioritized based on the significance of the sources where needed. The results of the key category analysis are taken into account in assessing the significance.

#### *1.2.3.7 Treatment of confidentiality issues*

The treatment of confidential information in GHG inventory is based on national<sup>6</sup> and international<sup>7</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 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.

### *1.2.4 Changes in the national inventory arrangements since previous annual greenhouse gas inventory submission*

Changes in national inventory arrangements since the previous annual inventory submission are described in Chapter 13.

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<sup>6</sup> Statistics Act 280/2004

<sup>7</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

## 1.3 *Inventory preparation, and data collection, processing and storage*

### 1.3.1 *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 2015 submission contains estimates for the calendar year 2013.

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 agreements with Statistics Finland (Table 1.2-1) and according to the UNFCCC reporting 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. Under the EU MMR, 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 and commitments.

The preparation schedules of the 2015 inventory submissions to the EU and UNFCCC have been exceptional. Due to the delay in the provision of a functional CRF Reporter all submissions have been delayed significantly.

Data collection and processing of each category are described in category-specific chapters. In addition, data sources used are described in Section 1.4.

### 1.3.2 *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. Due to the complexity of some of the methods used in the inventory preparation, the replication of inventory calculations will in some cases require in addition to the documentation, access to the model and support by experts familiar their use. Documentation also stands as evidence of the compliance and functionality of the national system. 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):
  - the description of Finland's national system
  - agreements with expert organisations participating in the inventory preparation
  - other agreements
  - quality plan and related documents e.g. documentation of the annual bilateral quality meetings
2. The annual inventory process documents by reporting sector, which are produced, updated and archived in the expert organisations responsible for the sectors, 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
- reference for country-specific data and methods
- the CRF Reporter databases, the set of CRF tables and the National Inventory Report (NIR)
- review reports and other relevant material related the review
- 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. 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 in 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.

#### *Energy and Industrial Processes and Product Use*

The Energy (except transportation) and Industrial Processes and Product Use sector (except F-gases and indirect CO<sub>2</sub> emissions from 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 Ltd
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 Ltd 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 indirect CO<sub>2</sub> emissions from 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 the Natural Resources Institute Finland (Luke). 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 Luke. Datainfo is updated annually.

### *LULUCF*

The archiving of LULUCF sector and KP-LULUCF:

1. Original National Forest Inventory data (NFI) are archived in the Natural Resources Institute Finland (Luke). 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 Luke.
3. All activity data, calculation procedures, results and reports are stored at Luke. 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 .xml and MS Excel files in the network drives and in an external disc drive. Paper copies of referred articles and literature are archived at Luke.

### *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.

## 1.4 Brief general description of the methodologies (including tiers used) and data sources used

The methodologies used for the Finnish greenhouse gas inventory are consistent with 2006 IPCC guidelines and the IPCC KP Supplement. Detailed descriptions of the methodologies used can be found as sector specific from Chapters 3 to 9 and 11.

**Table 1.4-1** Reported emissions, calculation methods and type of emission factors used in the Finnish inventory

CRF	Source	Stock change reported	Emissions reported	Method	Emission factor
1. Energy					
1.A Fuel combustion					
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, D, PS
			CH <sub>4</sub>	Tier 3, CS, M	CS, D
			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, OTH	CS
			CH <sub>4</sub>	Tier 1, Tier 3, CS, M, OTH	CS, D
			N <sub>2</sub> O	Tier 1, Tier 3, CS, M, OTH	CS, D
1.A.4	Other Sectors		CO <sub>2</sub>	Tier 1, Tier 3, M, CS	CS, D
			CH <sub>4</sub>	Tier 1, Tier 3, M, CS	CS, D
			N <sub>2</sub> O	Tier 1, Tier 3, M, CS	CS, D
1.A.5	Other		CO <sub>2</sub>	Tier 1	CS
			CH <sub>4</sub>	Tier 1	CS
			N <sub>2</sub> O	Tier 1	CS
1.B Fugitive emissions from fuels					
1.B.2	Oil and natural gas and other emissions from energy production		CO <sub>2</sub>	CS	CS
			CH <sub>4</sub>	Tier 2, Tier 1, CS	CS, PS, D
			N <sub>2</sub> O	CS	CS
2. Industrial processes and product use					
2.A Mineral industry					
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	Glass production		CO <sub>2</sub>	Tier 3	CS
2.A.4	Other process uses of carbonates				
	- Ceramics		CO <sub>2</sub>	Tier 2	CS
	- Other uses of Soda Ash		CO <sub>2</sub>	Tier 2	CS
	- Other		CO <sub>2</sub>	Tier 2	CS
2.B Chemical industry					
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 and 3	PS
2.B.6	Titanium Dioxide Production		IE (2.A.4)	NA	NA

CRF	Source	Stock change reported	Emissions reported	Method	Emission factor
2.B.10	Other				
	- Phosphoric acid Production		CO <sub>2</sub>	CS	PS
	- Hydrogen Production		CO <sub>2</sub>	Tier 2	CS
	- Limestone and dolomite use		CO <sub>2</sub>	Tier 2	CS
<b>2.C Metal industry</b>					
2.C.1	Iron and Steel Production				
	- Steel		CO <sub>2</sub>	Tier 3, CS	CS
	- Limestone and dolomite use		CO <sub>2</sub>	Tier 2	CS
	- Pig iron		IE (Steel)		
	- Sinter		IE (Steel)		
	- Other: Coke		CH <sub>4</sub>	Tier 1	D
2.C.2	Ferroalloys Production		IE (2.C.1)	Tier 3, CS	CS
2.C.4	Magnesium production		IE (2.H.3)	CS	NA
2.C.6	Zinc Production		IE (2.C.7)	Tier 2	CS
2.C.7	Other		CO <sub>2</sub>	Tier 2	CS
<b>2.D Non-energy products from fuels and solvent use</b>					
2.D.1	Lubricant use		CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O	Tier 1	CS
2.D.2	Paraffin waxes use		CO <sub>2</sub>	Tier 1	D
2.D.3	Other				
	- Other; Use of urea-based catalysts		CO <sub>2</sub>	Tier 1	D
<b>2.E Electronics industry</b>					
2.E.1	Integrated circuit or semiconductor		IE (2.H.3)	Other, Tier 2a	D
<b>2.F Product uses as substitutes for ODS</b>					
2.F.1	Refrigeration and air conditioning equipment		HFC, PFC	Tier 2	D / CS/ NA
2.F.2	Foam blowing and use of foam products		HFC	Tier 2	D
2.F.3	Fire protection		IE (2.H.3)	Other	NA
2.F.4	Technical aerosols, one-component polyurethane foam, tear gas and metered dose inhalers		HFC	Tier 2	D
<b>2.G Other product manufacture and use</b>					
2.G.1	Electrical Equipment		SF <sub>6</sub>	Tier 2	CS
2.G.3	N <sub>2</sub> O from Product uses		N <sub>2</sub> O	CS (Tier 2)	CS
<b>2.H Other</b>					
2.H.3	Grouped confidential data of halocarbons and SF <sub>6</sub>		SF <sub>6</sub> , HFCs, PFCs	Tier 1, Tier 2, Other	D
<b>3. Agriculture</b>					
<b>3.A Enteric fermentation</b>					
3.A.1	Cattle				
	- Dairy Cattle		CH <sub>4</sub>	Tier 2	CS
	- Non-Dairy Cattle		CH <sub>4</sub>	Tier 2	CS

CRF	Source	Stock change reported	Emissions reported	Method	Emission factor
3.A.2	Sheep		CH <sub>4</sub>	CS	CS
3.A.3	Swine		CH <sub>4</sub>	CS	CS
3.A.4	Other livestock				
	- Goats		CH <sub>4</sub>	Tier 1	D
	- Horses		CH <sub>4</sub>	Tier 1	D
	- Poultry		NE <sup>1)</sup>	NA	NA
	- Reindeers		CH <sub>4</sub>	CS	CS
	- Fur-bearing animals		CH <sub>4</sub>	Tier 1	OTH
<b>3.B Manure management</b>					
3.B.1	Cattle				
	- Dairy Cattle		CH <sub>4</sub>	Tier 2	CS
			N <sub>2</sub> O	Tier 2	D
	- Non-Dairy Cattle		CH <sub>4</sub>	Tier 2	CS
			N <sub>2</sub> O	Tier 2	D
3.B.2	Sheep		CH <sub>4</sub>	Tier 2	CS
			N <sub>2</sub> O	Tier 2	D
3.B.3	Swine		CH <sub>4</sub>	Tier 2	CS
			N <sub>2</sub> O	Tier 2	D
3.B.4	Other livestock				
	- Poultry		CH <sub>4</sub>	Tier 2	CS
			N <sub>2</sub> O	Tier 2	D
	- Horses		CH <sub>4</sub>	Tier 2	CS
			N <sub>2</sub> O	Tier 2	D
	- Goats		CH <sub>4</sub>	Tier 2	CS
			N <sub>2</sub> O	Tier 2	D
	- Fur animals		CH <sub>4</sub>	Tier 2	CS
			N <sub>2</sub> O	Tier 2	D
	- Reindeer		CH <sub>4</sub>	Tier 2	CS
			N <sub>2</sub> O	Tier 2	D
	Liquid system		N <sub>2</sub> O	T2	D
	Solid storage and dry lot		N <sub>2</sub> O	T2	D
	Pasture, range, and paddock <sup>1</sup>		N <sub>2</sub> O	IE	IE
<b>3.D Agricultural soils</b>					
3.D a	<u>Direct Soil Emissions</u>				
	- Synthetic Fertilisers		N <sub>2</sub> O	Tier 1	D
	- Animal Manure Applied to Soils		N <sub>2</sub> O	Tier 1	D
	- Municipal Sewage Sludge Applied to Soils		N <sub>2</sub> O	Tier 1	D
	- Pasture, Range and Paddock Manure		N <sub>2</sub> O	Tier 1	D
	- Crop Residue		N <sub>2</sub> O	Tier 1	D
	- Mineralization associated with loss of soil organic matter (mineral soils)		N <sub>2</sub> O	Tier 2	D, CS
	- Cultivation of Histosols				
3.D b	<u>Indirect Emissions</u>				
	- Atmospheric Deposition		N <sub>2</sub> O	Tier 1	D
	- Nitrogen Leaching and Run-off		N <sub>2</sub> O	Tier 1	D
<b>3.F Field burning of agricultural residues</b>					
3.F.1	Cereals		CH <sub>4</sub> , N <sub>2</sub> O	D	D
3.F.2	Pulses		NO	NA	NA

CRF	Source	Stock change reported	Emissions reported	Method	Emission factor
	3.F.3 Tubers and roots		NO	NA	NA
	3.F.4 Sugar cane		NO	NA	NA
	3.F.5 Other		NO	NA	NA
	<b>3.G Liming</b>				
	3.G.1 Liming		CO <sub>2</sub>	Tier 1	D
	<b>3.H Urea application</b>				
	3.H.1 Urea application		CO <sub>2</sub>	Tier 1	D
	<b>4. Land-use, land-use change and forestry</b>				
	<b>4.A Forest land (remaining, converted)</b>				
	Living biomass	carbon/ CO <sub>2</sub>		Tier 3	CS
	DOM, SOM (mineral and organic soils)	carbon/ CO <sub>2</sub>		Tier 3, Tier 2	CS
	<b>4.B Cropland (remaining, converted)</b>				
	Living biomass	carbon/ CO <sub>2</sub>		Tier 3	CS, D
	DOM, SOM (mineral and organic soils)	carbon/ CO <sub>2</sub>		Tier 3, Tier 2	CS, D
	<b>4.C Grassland (remaining, converted)</b>				
	Living biomass	carbon/ CO <sub>2</sub>		Tier 3	CS, D
	DOM, SOM (mineral and organic soils)	carbon/ CO <sub>2</sub>		Tier 3, Tier 2	CS, D
	<b>4.D Wetlands (remaining, converted)</b>				
	Peat extraction areas: living biomass	carbon/ CO <sub>2</sub>		Tier 3	CS
	Peat extraction areas: DOM, SOM	carbon/ CO <sub>2</sub>		Tier 2	CS
	Flooded land: living biomass	carbon/ CO <sub>2</sub>		Tier 3	CS
	Flooded land: DOM, SOM	carbon/ CO <sub>2</sub>		Tier 1	CS, D
	Other wetlands: SOM	carbon/ CO <sub>2</sub>		Tier 2	CS
	<b>4.E Settlements (converted)</b>				
	Living biomass	carbon/ CO <sub>2</sub>		Tier 3	CS
	DOM, SOM	carbon/ CO <sub>2</sub>		Tier 2	CS
	<b>4.G Harvested Wood Products</b>	carbon/ CO <sub>2</sub>		Tier 2	D
	<b>4.(I) Direct N<sub>2</sub>O emissions from fertilisation</b>				
	Forest land		N <sub>2</sub> O	Tier 1	D
	<b>4.(II) Non-CO<sub>2</sub> emissions from drainage and rewetting and other management of organic and mineral soils</b>				
	Wetlands: Peat extraction areas		CH <sub>4</sub> , N <sub>2</sub> O	Tier 2	CS
	Wetlands: Flooded land		CH <sub>4</sub>	Tier 1	D
	Other Wetlands		CH <sub>4</sub> , N <sub>2</sub> O	Tier 2	CS
	Forest land: Drained organic forest soils		CH <sub>4</sub> , N <sub>2</sub> O	Tier 2, Tier 1	CS, D
	<b>4.(III) Direct non-CO<sub>2</sub> emissions from N mineralisation/immobilisation</b>				
	Settlements, Cropland, Grassland		N <sub>2</sub> O	Tier 1	CS, D
	<b>4.(IV) N<sub>2</sub>O emissions from N leaching and runoff</b>				
	Land converted to Cropland and Grassland		N <sub>2</sub> O	Tier 1	D
	<b>4.(V) Biomass burning</b>				

CRF	Source	Stock change reported	Emissions reported	Method	Emission factor
	Forest land		CO <sub>2</sub> , CH <sub>4</sub> , NO <sub>2</sub> , NO <sub>x</sub> , CO	Tier 2	CS, D
<b>5.Waste</b>					
<b>5.A Solid waste disposal</b>					
5.A.1	Managed Waste Disposal		CH <sub>4</sub>	Tier 2	CS, D
5.A.2	Unmanaged Waste Disposal Sites		IE, NO	NA	NA
<b>5.B Biological treatment of solid waste</b>					
5.B.1	Composting				
	- Municipal solid waste		CH <sub>4</sub> , N <sub>2</sub> O	Tier 1	D
	- Municipal sludge		CH <sub>4</sub> , N <sub>2</sub> O	Tier 1	D
	- Industrial sludge		CH <sub>4</sub> , N <sub>2</sub> O	Tier 1	D
	- Industrial solid waste, constr. waste		CH <sub>4</sub> , N <sub>2</sub> O	Tier 1	D
5.B.2	Anaerobic digestion at biogas facilities				
	- Municipal solid waste		CH <sub>4</sub>	Tier 1	D
	- Municipal sludge		CH <sub>4</sub>	Tier 1	D
	- Industrial sludge		CH <sub>4</sub>	Tier 1	D
	- Industrial solid waste, constr. waste		CH <sub>4</sub>	Tier 1	D
<b>5.D Wastewater treatment and discharge</b>					
5.D.1	Domestic Wastewater		CH <sub>4</sub> N <sub>2</sub> O	CS, Tier 2 CS, Tier 1	CS, D D
5.D.2	Industrial Wastewater		CH <sub>4</sub> N <sub>2</sub> O	CS, Tier 2 CS	CS, D D
5.D.3	Other (Fish Farming)		N <sub>2</sub> O	CS	D

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 and Product Use 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 categories, Agriculture and LULUCF sectors necessitate the use of more complicated equations and models. Table 1.4-2 summarises the most important data sources used in the inventory.

**Table 1.4-2** 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, Eurocontrol Energy Authority (ETS emission data)
1.B Fugitive Emissions	VAHTI system Energy Statistics, Yearbook (Statistics Finland) Individual companies
2. (I) Industrial Processes and Product Use	Energy Authority (ETS emission data) Industrial statistics database VAHTI system Individual production plants

Sector	Main data sources
2. (II) Industrial Processes and Product Use (F-gases)	Surveys of the Finnish Environment Institute
3. Agriculture	Matilda database of the Ministry of Agriculture and Forestry Yearbook of Farm Statistics Finnish Trotting and Breeding Association Natural Resources Institute Finland (Luke) Finnish Environment Institute (SYKE) Published literature
4. LULUCF	NFI (National Forest Inventory) Finnish Statistical Yearbook of Forestry Yearbook of Farm Statistics Published literature National Land Survey of Finland
5. Waste	VAHTI system The Finnish Biogas Plant Register Water and Sewage Works Register Register for Industrial Water Pollution Control
Indirect CO <sub>2</sub> emissions	VAHTI system ULTIKA/ULJAS, import statistics of Finland Association of Finnish Paint Industry Individual companies Published literature

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 6.

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 linked to the 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.

In 2012, the EU ETS was extended to cover emissions from aviation covering internal flights within the EU as well as flights to and from the EU. Trafi (Finnish Transport Safety Agency) is the national authority for emissions trading in aviation in Finland.

During the period 2013–2020, the EU ETS was again extended to cover all installations (not only combustion installations) with thermal input of more than 20 MW and some new industrial sources, such as N<sub>2</sub>O emissions nitric acid production. During this period, the emission allowances are mainly actioned. An EU ETS operator can apply also for free emission allowances from the Ministry of Employment and the Economy depending on their industrial branch consistent with the decision 2011/278/EU. 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*

The national key categories for the base year and the latest reported inventory year were identified using Approach 1 and trend assessment provided in the CRF Reporter software. An Approach 2 identification and consideration of qualitative criteria will be added in the inventory by the next submission. 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 1.6). The goal is to screen the long list of category-gas combinations (over 200 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.

### *1.5.1 KP-LULUCF activities*

The results of the key category analysis for KP LULUCF activities for the inventory year 2013 are included in the separate CRF Tables. Carbon stock changes under ARD and FM and CH<sub>4</sub> and N<sub>2</sub>O emissions from drainage of soils are identified as key sources for the KP-LULUCF activities (Table 1.5-1). Identification of the associated category as a key category in the UNFCCC inventory is used as a criterion for the identification of key categories for KP-LULUCF.

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

Category	Gas	Level		Trend
		Base year	Year 2013	
1.A.1. Energy Industries	Liquid	CO2	Yes	Yes
1.A.1. Energy Industries	Solid	CO2	Yes	Yes
1.A.1. Energy Industries	Gaseous	CO2	Yes	Yes
1.A.1. Energy Industries	Other fossil	CO2	Yes	Yes
1.A.1. Energy Industries	Peat	CO2	Yes	Yes
1.A.1. Energy Industries	Biomass	N2O		Yes
1.A.2 Manufacturing Industries and Construction	Liquid	CO2	Yes	Yes
1.A.2 Manufacturing Industries and Construction	Solid	CO2	Yes	Yes
1.A.2 Manufacturing Industries and Construction	Gaseous	CO2	Yes	Yes
1.A.2 Manufacturing Industries and Construction	Other fossil	CO2	Yes	Yes
1.A.2 Manufacturing Industries and Construction	Peat	CO2	Yes	Yes
1.A.3.b. Road Transportation		CO2	Yes	Yes
1.A.3.c. Railways		CO2		Yes
1.A.3.d. Domestic Navigation	Liquid	CO2	Yes	Yes
1.A.4. Other Sectors	Liquid	CO2	Yes	Yes
1.A.4. Other Sectors	Peat	CO2		Yes
1.A.4. Other Sectors	Biomass	CH4	Yes	Yes
1.A.5. Other	Liquid	CO2	Yes	Yes
1.A.5. Other	Gaseous	CO2		Yes
2.A.1. Cement Production		CO2	Yes	Yes
2.A.2. Lime Production		CO2		Yes
2.A.4. Other Process Uses of Carbonates		CO2		Yes
2.B.2. Nitric Acid Production		N2O	Yes	Yes
2.B.10. Other		CO2		Yes
2.C.1. Iron and Steel Production		CO2	Yes	Yes
2.D. Non-energy Products from Fuels and Solvent Use		CO2		Yes
2.F.1. Refrigeration and Air Conditioning	Agg. F-gases		Yes	Yes
3.A. Enteric Fermentation		CH4	Yes	Yes
3.B. Manure Management		CH4		Yes
3.B. Manure Management		N2O		Yes
3.D.1. Direct N2O Emissions From Managed Soils		N2O	Yes	Yes
3.D.2. Indirect N2O Emissions From Managed Soils		N2O	Yes	Yes
3.G. Liming		CO2	Yes	Yes
4.A.1. Forest Land Remaining Forest Land		CO2	Yes	Yes
4.A.2. Land Converted to Forest Land		CO2		Yes
4.B.1. Cropland Remaining Cropland		CO2	Yes	Yes
4.B.2. Land Converted to Cropland		CO2	Yes	Yes
4.C.1. Grassland Remaining Grassland		CO2	Yes	
4.D.1.1. Peat Extraction Remaining Peat Extraction		CO2	Yes	Yes
4.D.1.3. Other Wetlands Remaining Other Wetlands		CO2		Yes
4.D.2. Land converted to Wetlands		CO2		Yes
4.E.2. Land converted to Settlements		CO2	Yes	Yes
4.G. Harvested Wood Products		CO2	Yes	Yes
4(II). Drainage and rewetting and other management of soils		CH4	Yes	Yes
4(II). Drainage and rewetting and other management of soils		N2O	Yes	Yes
5.A. Solid Waste Disposal		CH4	Yes	Yes

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

Key category	Gas	Criteria used for key category identification
		<i>Associated category in UNFCCC inventory is key</i>
Article 3.3 Afforestation / Reforestation	CO2	4A2 Land converted to Forest Land
	CH4	4(ii) Drainage, rewetting and other management of organic and mineral soils
	N2O	4(ii) Drainage, rewetting and other management of organic and mineral soils
Article 3.3 Deforestation	CO2	4B2 Land converted to Cropland
	CO2	4D2. Land converted to Wetlands
	CO2	4E2. Land converted to Settlements
	CH4	4(ii) Drainage, rewetting and other management of organic and mineral soils
	N2O	4(ii) Drainage, rewetting and other management of organic and mineral soils
Article 3.4 Forest Management	CO2	4A1 Forest Land remaining Forest Land
	CH4	4(ii) Drainage, rewetting and other management of organic and mineral soils
	N2O	4(ii) Drainage, rewetting and other management of organic and mineral soils

## *1.6 General uncertainty evaluation, including data on the overall uncertainty for the inventory totals*

This section provides an overview of the uncertainty analysis for the Finnish inventory. For the 2013 submission, the Approach 1 and Approach 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 both Approach 1 and Approach 2 uncertainty analysis annually. The Approach 2 analysis is based on Monte Carlo simulation, and it is 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 prioritise inventory improvement by using them in association with the key category analysis.

The main methodologies used by sector and changes are summarised 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.

In the industrial processes and product use 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 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 Institute using Monte Carlo analysis directly in the calculation sheets. Uncertainty distributions were fitted to results and included in the overall inventory uncertainty model.

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.

In the LULUCF sector, most of the uncertainties were based on uncertainty analyses carried out by Luke (for example for Forest land remaining forest land, separately for biomass, mineral and organic soils), in these cases emission uncertainties were used in the overall inventory uncertainty model. Whereas for the remaining categories uncertainties were estimated based on AD and EF/IEF uncertainties.

In the waste sector, the uncertainties were estimated based on AD and EF/IEF uncertainties in the overall inventory uncertainty model.

Uncertainties in KP-LULUCF activities were also included in the Approach 2 uncertainty model of inventory. 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 Approach 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 Approach 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 Approach 2 table in Annex 6. Similarly, the emission uncertainty was used in those cases in Approach 1 calculation following IPCC GPG.

Table 1.6-1 shows the uncertainties (for CO<sub>2</sub>-eq emissions/removals) for the 2013 level and trend (percentage change from 1990) estimated with Approach 1 and Approach 2 methods for this submission. Both uncertainties

for UNFCCC sectors and for KP activities are shown. For UNFCCC sectors Approach 1 and 2 gave quite similar results for 2013, owing to the use of the same input data. Small differences were caused by the fact that asymmetry of uncertainties cannot be taken into account in Approach 1; however, as the majority of emission is from sources with symmetrical distributions, the results of Approach 1 and 2 are quite close to each other. The similarity of results of Approach 1 and 2 confirm that both methods to combine uncertainties were applied correctly. The differences of Approach 1 and 2 estimates of trend uncertainty were larger. This is due to the fact that in Approach 1 method, when uncertainties are available only for emissions (not for AD and EF separately) the estimates of 1990 and 2013 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 Approach 1 is somewhat overestimated.

**Table 1.6-1** Inventory uncertainties for level and trend (percentage change from 1990)

Uncertainty estimate	Level uncertainty 2013		Trend uncertainty 2013	
	Approach 2	Approach 1	Approach 2	Approach 1
	%	%	%	%
<b>Total UNFCCC, without LULUCF</b>	-4 .. +7	±6	-6 .. +7	±10
<b>Total UNFCCC, with LULUCF</b>	-26 .. +34	±34	-23 .. +30	±52
01 indirect emissions	-14 .. +14	±14	-3 .. +4	±6
1 Energy	-1 .. +1	±1	-2 .. +2	±1
2 Industrial processes and product use	-4 .. +4	±4	-27 .. +51	±7
4. Agriculture	-34 .. +62	±58	-37 .. +59	±76
5. LULUCF	-50 .. +66	±69	-377 .. +455	±125
6. Waste	-35 .. +42	±38	-21 .. +49	±18
<b>KP-LULUCF</b>				
KP 3.3. ARD	-78 .. +78			
AR	-60 .. +60			
D	-63 .. +62			
KP 3.4. FM	-32 .. +31			
FM without HWP	-40 .. +40			
HWP	-50 .. +50			

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 1.6-2 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 1.6-2** 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
	-4 ... +7% -26 ... +34%	-6 ... +7% -23 ... +30%	Approach 2	NIR 2015	Without LULUCF With LULUCF

## *1.7 General assessment of completeness*

### *1.7.1 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, SF<sub>6</sub> and NF<sub>3</sub>), NMVOC, NO<sub>x</sub>, CO and SO<sub>2</sub>.

Finland has provided a list of sources in Table 2 in Annex 5 for which estimates are not provided because they are judged as insignificant. The level of the emissions from these sources is estimated to be below 0.05 per cent of the national total greenhouse gas emissions (for more details, see Annex 5).

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.

### *1.7.2 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.

### *1.7.3 Completeness by timely coverage*

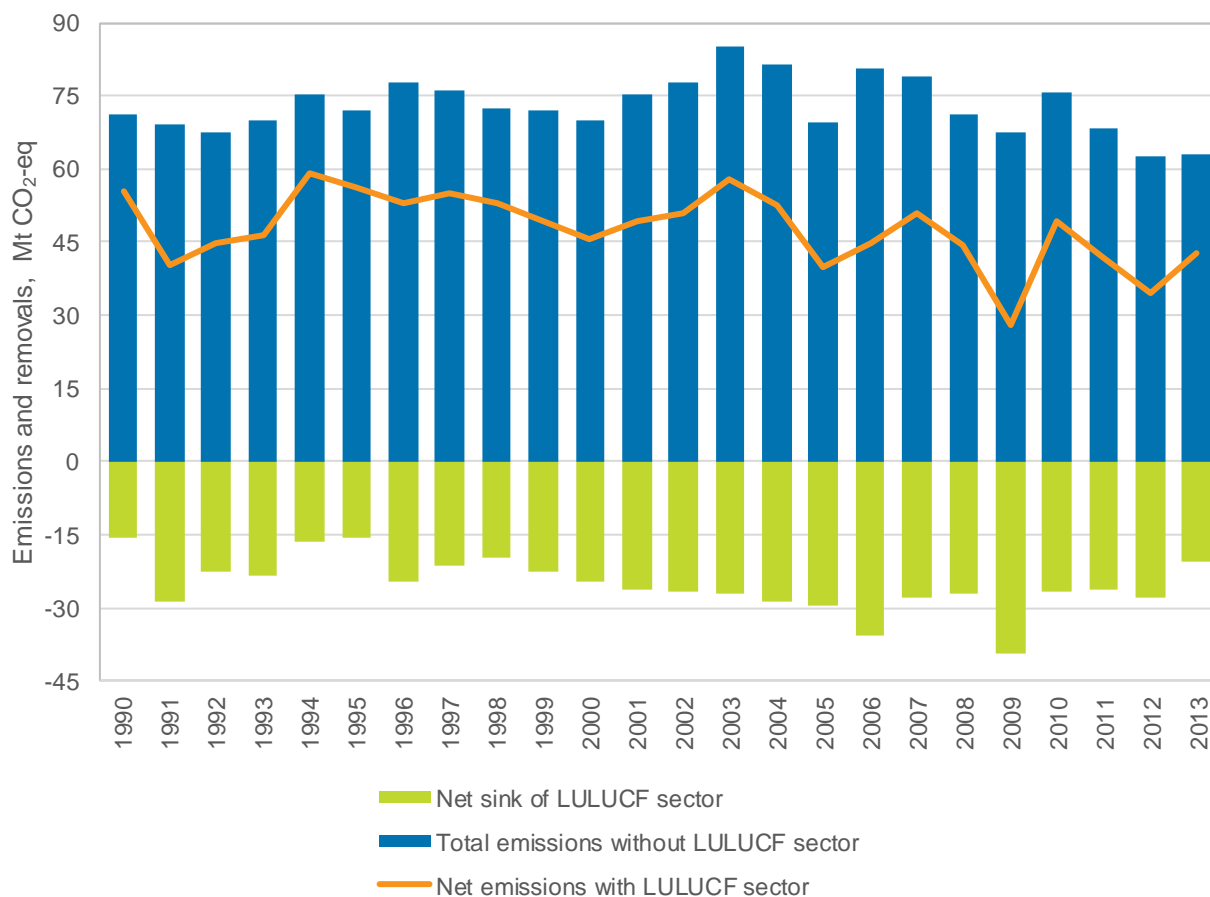
A complete set of CRF tables are provided for all years and the estimates are calculated in a consistent manner.

## 2 TRENDS IN GREENHOUSE GAS EMISSIONS

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

In 2013, Finland's greenhouse gas emissions totalled 63.1 million tonnes of carbon dioxide equivalent (Mt CO<sub>2</sub> eq.). The total emissions in 2013 were approximately 12% (8.3 Mt) below the 1990 emissions level. Compared to 2012, the emissions increased by approximately 1%.

The energy sector is the most significant source of greenhouse gas emissions in Finland and therefore the key driver behind the trend. Energy related emissions vary much in Finland, mainly according to the economic trend, the energy supply structure and climate conditions. More detailed trend descriptions by sector can be found in category-specific sections of this NIR and in Section 2.2. Figure 2.1-1 shows a time series of CO<sub>2</sub> equivalent emissions with and without the net removals in LULUCF sector in Finland during 1990–2013. 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** Total national CO<sub>2</sub> equivalent emissions with and without the net removals in LULUCF sector in Finland (Mt CO<sub>2</sub> eq.)

**Table 2.1-1** Total greenhouse gas emissions in Mt CO<sub>2</sub> eq. and indexed for the years 1990-2013 (index 1990=100)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
CO <sub>2</sub> with LULUCF <sup>1</sup>	38.6	40.1	30.1	33.8	35.8	42.8	37.7	24.8	29.9	36.0	29.2	13.9	34.9	28.3	21.1	29.2
CO <sub>2</sub> without LULUCF	57.2	58.3	57.3	62.5	65.0	72.6	68.9	56.9	68.3	66.5	58.5	55.6	63.8	56.7	51.2	51.8
CH <sub>4</sub> with LULUCF	9.29	8.93	8.01	7.84	7.60	7.36	7.15	6.87	6.92	6.75	6.56	6.45	6.47	6.23	6.19	6.05
CH <sub>4</sub> without LULUCF	7.75	7.47	6.66	6.52	6.30	6.09	5.91	5.66	5.73	5.59	5.46	5.41	5.49	5.31	5.27	5.13
N <sub>2</sub> O with LULUCF	7.60	7.25	6.90	6.85	6.96	7.07	7.13	7.20	7.01	7.07	7.20	6.34	5.94	5.80	5.77	5.83
N <sub>2</sub> O without LULUCF	6.34	5.99	5.63	5.58	5.68	5.79	5.85	5.93	5.73	5.80	5.92	5.07	4.68	4.54	4.52	4.57
HFCs	0.000	0.027	0.559	0.592	0.634	0.636	0.689	0.895	0.911	1.150	1.339	1.426	1.820	1.588	1.477	1.557
PFCs	0.000	0.000	0.013	0.023	0.017	0.018	0.014	0.016	0.019	0.010	0.014	0.011	0.001	0.002	0.005	0.006
SF <sub>6</sub>	0.052	0.037	0.026	0.026	0.025	0.026	0.024	0.022	0.028	0.019	0.027	0.027	0.022	0.024	0.022	0.031
NF <sub>3</sub>	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
<b>Total emissions with LULUCF<sup>1</sup></b>	<b>55.5</b>	<b>56.4</b>	<b>45.6</b>	<b>49.1</b>	<b>51.0</b>	<b>58.0</b>	<b>52.7</b>	<b>39.8</b>	<b>44.8</b>	<b>51.0</b>	<b>44.3</b>	<b>28.1</b>	<b>49.1</b>	<b>41.9</b>	<b>34.6</b>	<b>42.7</b>
<b>Total emissions<sup>1</sup></b>	<b>71.3</b>	<b>71.8</b>	<b>70.1</b>	<b>75.3</b>	<b>77.7</b>	<b>85.1</b>	<b>81.3</b>	<b>69.5</b>	<b>80.7</b>	<b>79.1</b>	<b>71.2</b>	<b>67.5</b>	<b>75.8</b>	<b>68.1</b>	<b>62.4</b>	<b>63.1</b>

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<b>Index (1990=100)</b>																
CO <sub>2</sub> without LULUCF <sup>1</sup>	100	102	100	109	114	127	120	100	119	116	102	97	112	99	89	91
CH <sub>4</sub> without LULUCF	100	96	86	84	81	79	76	73	74	72	71	70	71	69	68	66
N <sub>2</sub> O without LULUCF	100	94	89	88	90	91	92	93	90	91	93	80	74	72	71	72
Total (group of three)	100	101	98	105	108	119	113	96	112	109	98	93	104	93	86	86
F-gases	100	122	1136	1215	1282	1289	1379	1771	1816	2237	2617	2777	3496	3061	2853	3024
<b>Total (without LULUCF)<sup>1</sup></b>	<b>100</b>	<b>101</b>	<b>98</b>	<b>106</b>	<b>109</b>	<b>119</b>	<b>114</b>	<b>97</b>	<b>113</b>	<b>111</b>	<b>100</b>	<b>95</b>	<b>106</b>	<b>96</b>	<b>88</b>	<b>88</b>

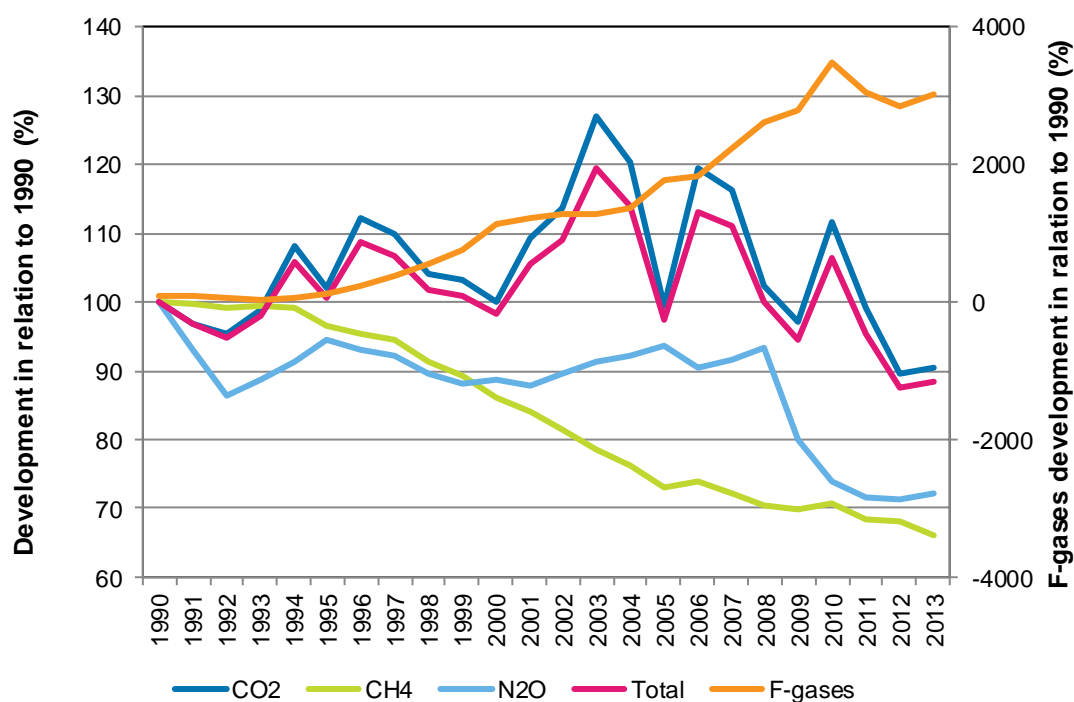
<sup>1</sup> including indirect CO<sub>2</sub>-emissions from NMVOC and CH<sub>4</sub> from energy, industrial processes and product use

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 80% to 85%. In absolute terms, CO<sub>2</sub> emissions have decreased 5.4 Mt (i.e. 10%) since 1990. Around 91% of all CO<sub>2</sub> emissions originate from the Energy sector in 2013. 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.

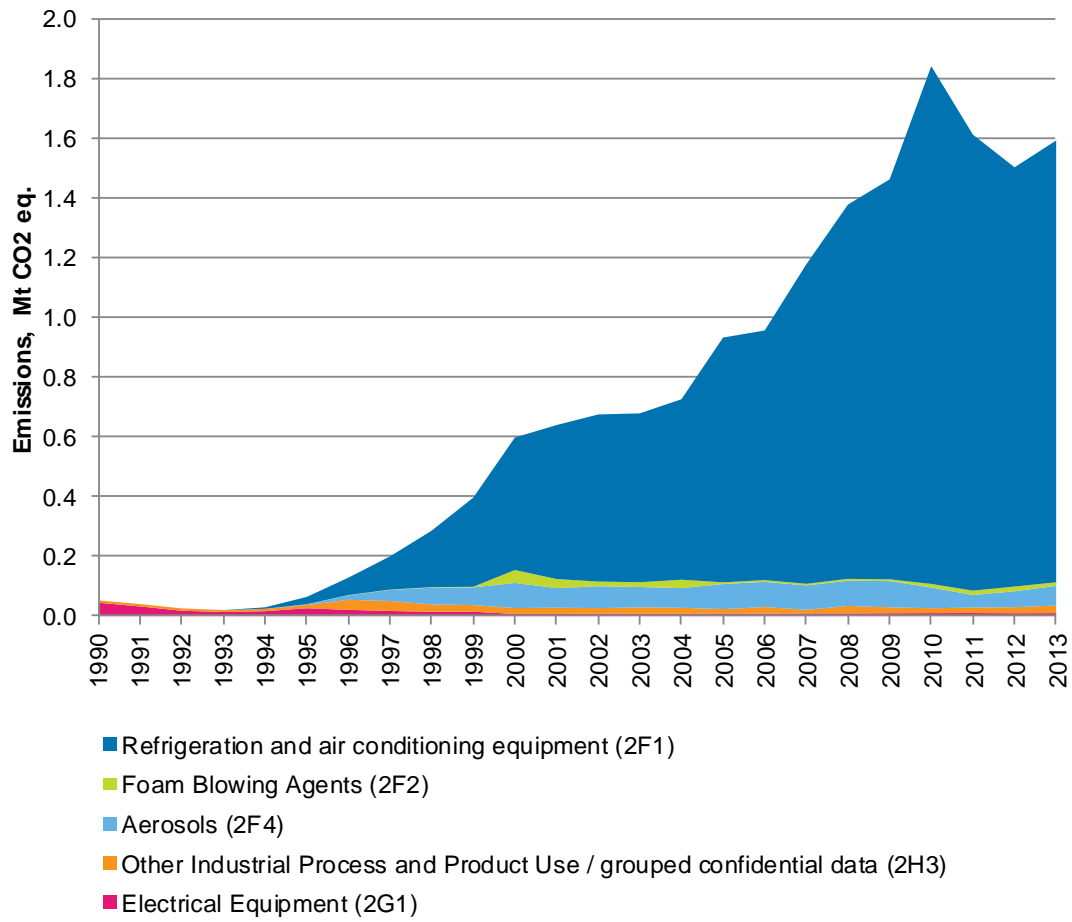
Correspondingly, emissions of nitrous oxide (N<sub>2</sub>O) have also decreased by 28%; the biggest decline occurred 2009 when the implementation a N<sub>2</sub>O abatement technology in nitric acid production reduced emissions significantly. Another reason for the decrease of the emission is the reduced nitrogen fertilisation of agricultural fields.

The development of emissions of greenhouse gases (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O and F-gases) relative to the 1990 level is presented in Figure 2.1-2.



**Figure 2.1-2** 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 thirtyfold during 1990-2013. A key driver behind the trend has been the substitution of ozone depleting substances (ODS) by F-gases in many applications. In Table 2.1-1 the development of emissions of F-gases during 1990-2013 is presented by gas category and in Figure 2.1-3 by subcategory (Mt CO<sub>2</sub> eq.).



**Figure 2.1-3** Emissions of F-gases by subcategory (Mt CO<sub>2</sub> eq.)

## 2.2 Description and interpretation of emission trends by sector

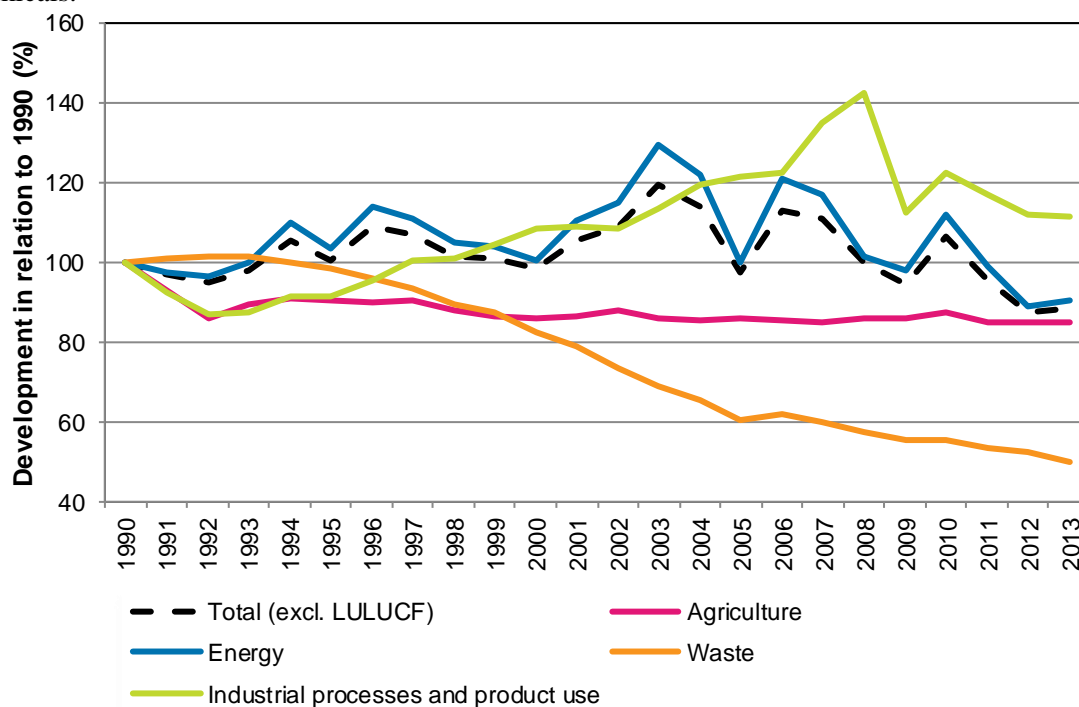
Figure 2.2-1 and Table 2.2-1 provide an overview of the development of the CO<sub>2</sub> equivalent emissions by IPCC source sector. The Energy sector is the most significant source of greenhouse gas emissions in Finland and energy-related CO<sub>2</sub> emissions vary much from year to year, mainly following the economic trend, the structure of the energy supply and climatic conditions. In 2013 emissions from energy sector totalled 48.4 Mt and were 10% below the level in 1990.

Emissions of industrial processes and product use were 6.0 Mt in 2013 and have increased by 11% (0.6 Mt CO<sub>2</sub> eq.) compared to 1990. Sectors emissions increased between 1993 and 2008 to a level almost 40 per cent higher than in 1990, 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.

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 1990-2013 as the removals in the sector exceeded the emissions. Most of the removals in the LULUCF sector came from tree biomass; that is to say the annual tree biomass growth has been higher than the removed biomass. 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.

Indirect CO<sub>2</sub> emissions have decreased 69% since 1990, main reason is that industry has reduced use of solvent chemicals.



**Figure 2.2-1** Relative development of greenhouse gas emissions by main category relative to the 1990 level (1990=100%)

**Table 2.2-1** Summary of emission trend by category (unit Mt CO<sub>2</sub> eq.)

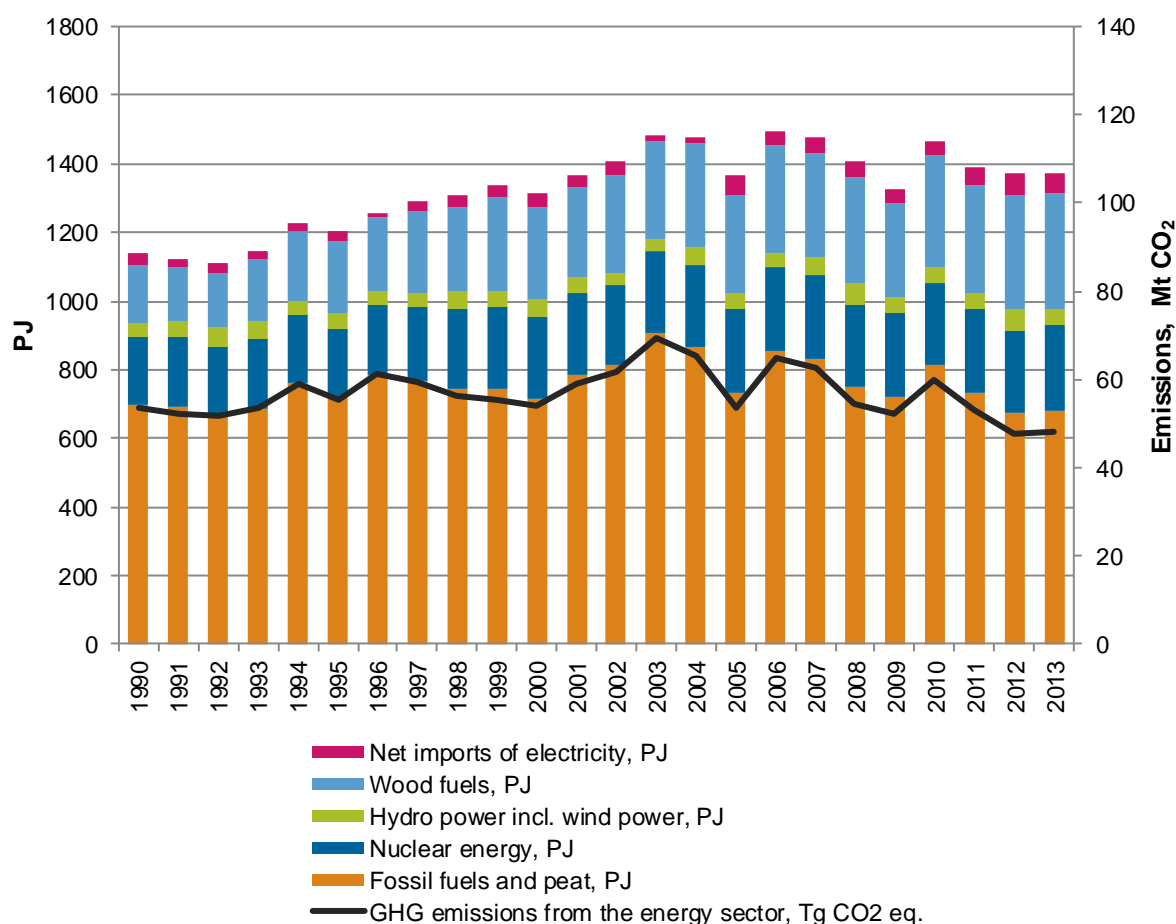
IPCC sector	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<b>1. Energy</b>	<b>53.6</b>	<b>55.4</b>	<b>53.9</b>	<b>59.1</b>	<b>61.7</b>	<b>69.3</b>	<b>65.4</b>	<b>53.6</b>	<b>64.8</b>	<b>62.7</b>	<b>54.4</b>	<b>52.4</b>	<b>60.0</b>	<b>52.9</b>	<b>47.6</b>	<b>48.4</b>
A Fuel combustion total	53.5	55.2	53.8	59.0	61.6	69.2	65.3	53.5	64.6	62.5	54.3	52.2	59.9	52.8	47.5	48.2
1. Energy industries	19.0	24.0	22.3	27.5	30.3	37.3	33.2	22.0	32.8	30.8	24.3	25.4	30.6	24.8	20.7	22.1
2. Manufacturing industries and construction	13.7	12.4	12.2	11.8	11.5	11.8	11.9	11.6	11.9	11.7	11.1	8.7	10.2	9.9	8.7	8.7
3. Transport	12.1	11.3	12.1	12.2	12.4	12.6	12.9	12.9	13.1	13.4	12.8	12.2	12.7	12.5	12.2	12.1
4. Other sectors	7.6	6.1	5.8	6.1	6.0	5.9	5.9	5.5	5.4	5.3	4.8	4.8	5.1	4.4	4.7	4.4
5. Other	1.14	1.30	1.32	1.44	1.42	1.46	1.32	1.41	1.41	1.28	1.28	1.22	1.30	1.15	1.16	1.03
B Fugitive emissions from fuels	0.12	0.17	0.12	0.13	0.13	0.13	0.12	0.14	0.12	0.14	0.15	0.13	0.14	0.13	0.14	0.12
<b>2. Industrial processes and product use</b>	<b>5.4</b>	<b>4.9</b>	<b>5.8</b>	<b>5.8</b>	<b>5.8</b>	<b>6.1</b>	<b>6.4</b>	<b>6.5</b>	<b>6.6</b>	<b>7.2</b>	<b>7.6</b>	<b>6.0</b>	<b>6.6</b>	<b>6.3</b>	<b>6.0</b>	<b>6.0</b>
A. Mineral industry	1.18	0.83	1.03	1.04	1.04	1.09	1.17	1.15	1.22	1.24	1.20	0.87	1.12	1.22	1.08	1.03
B. Chemical industry	1.86	1.67	1.59	1.53	1.60	1.67	1.77	1.85	1.75	2.12	2.33	1.59	1.04	0.95	0.99	1.12
C. Metal industry	1.98	2.08	2.39	2.44	2.32	2.48	2.57	2.40	2.47	2.49	2.55	1.97	2.44	2.38	2.29	2.09
D. Non-energy Products from Fuels and Solvent Use	0.22	0.19	0.14	0.14	0.14	0.12	0.11	0.10	0.11	0.13	0.13	0.10	0.09	0.08	0.08	0.10
F. Product Uses as Substitutes for ODS	0.00	0.03	0.57	0.61	0.65	0.65	0.70	0.91	0.93	1.16	1.35	1.43	1.82	1.59	1.47	1.56
G. Other Product Manufacture and Use	0.11	0.09	0.06	0.06	0.06	0.05	0.05	0.06	0.05	0.05	0.05	0.04	0.04	0.04	0.04	0.04
H. Other Industrial Process and Product Use	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.02	0.01	0.03	0.02	0.02	0.02	0.02	0.03
<b>3. Agriculture</b>	<b>7.5</b>	<b>6.8</b>	<b>6.4</b>	<b>6.4</b>	<b>6.6</b>	<b>6.4</b>	<b>6.4</b>	<b>6.4</b>	<b>6.4</b>	<b>6.3</b>	<b>6.4</b>	<b>6.4</b>	<b>6.5</b>	<b>6.3</b>	<b>6.3</b>	<b>6.3</b>
A. Enteric fermentation	2.43	2.14	2.11	2.09	2.12	2.09	2.08	2.06	2.07	2.05	2.03	2.05	2.10	2.08	2.06	2.06
B. Manure management	0.65	0.64	0.66	0.65	0.68	0.70	0.71	0.72	0.72	0.72	0.71	0.73	0.74	0.73	0.73	0.74
D. Agricultural soils	3.76	3.58	3.30	3.28	3.33	3.33	3.33	3.34	3.27	3.30	3.37	3.32	3.43	3.36	3.32	3.34
F. Field burning of agricultural residues	0.004	0.003	0.004	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.002	0.002	0.002	0.003
G. Liming	0.62	0.39	0.33	0.39	0.42	0.28	0.25	0.26	0.30	0.25	0.29	0.31	0.25	0.18	0.19	0.19
H. Urea application	0.0007	0.0002	0.0002	0.0003	0.0003	0.0003	0.0003	0.0003	0.0005	0.0008	0.0005	0.0004	0.0004	0.0007	0.0004	0.0003
<b>4. Land-use, land-use change and forestry</b>	<b>-15.8</b>	<b>-15.5</b>	<b>-24.5</b>	<b>-26.2</b>	<b>-26.7</b>	<b>-27.2</b>	<b>-28.6</b>	<b>-29.6</b>	<b>-35.9</b>	<b>-28.2</b>	<b>-26.9</b>	<b>-39.4</b>	<b>-26.7</b>	<b>-26.2</b>	<b>-27.9</b>	<b>-20.4</b>
A. Forest Land	-20.4	-19.7	-26.4	-31.0	-31.6	-31.7	-33.0	-37.9	-41.9	-32.8	-35.5	-50.6	-34.1	-33.0	-35.0	-26.4
B. Cropland	5.48	6.50	5.87	6.20	6.56	6.68	6.78	6.46	6.89	6.48	6.56	6.45	6.74	6.40	6.52	6.44
C. Grassland	0.86	0.75	0.71	0.72	0.71	0.72	0.78	0.83	0.84	0.83	0.81	0.75	0.68	0.62	0.62	0.61
D. Wetlands	1.56	1.76	1.89	2.11	2.15	2.08	1.96	2.21	2.50	2.22	2.36	2.46	2.41	2.35	2.27	2.40
E. Settlements	0.99	1.24	1.53	1.74	1.76	1.82	2.05	2.10	1.98	2.05	1.93	1.72	1.50	1.26	1.11	0.96
G. Harvested Wood Products	-4.31	-6.07	-8.16	-5.92	-6.20	-6.77	-7.16	-3.40	-6.21	-6.91	-3.11	-0.20	-3.91	-3.87	-3.39	-4.36
<b>5. Waste</b>	<b>4.7</b>	<b>4.6</b>	<b>3.9</b>	<b>3.7</b>	<b>3.4</b>	<b>3.2</b>	<b>3.1</b>	<b>2.8</b>	<b>2.9</b>	<b>2.8</b>	<b>2.7</b>	<b>2.6</b>	<b>2.6</b>	<b>2.5</b>	<b>2.5</b>	<b>2.3</b>
A. Solid Waste Disposal	4.3	4.2	3.5	3.3	3.1	2.9	2.7	2.4	2.5	2.4	2.3	2.2	2.2	2.1	2.1	2.0
B. Biological Treatment of Solid Waste	0.05	0.08	0.10	0.11	0.11	0.12	0.12	0.14	0.14	0.15	0.14	0.14	0.14	0.15	0.13	0.13
D. Wastewater Treatment and Discharge	0.30	0.28	0.26	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.24	0.25	0.25	0.26	0.25
<b>6. 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>Indirect CO<sub>2</sub>-emissions</b>	<b>0.26</b>	<b>0.20</b>	<b>0.15</b>	<b>0.15</b>	<b>0.14</b>	<b>0.14</b>	<b>0.13</b>	<b>0.12</b>	<b>0.12</b>	<b>0.12</b>	<b>0.11</b>	<b>0.09</b>	<b>0.10</b>	<b>0.09</b>	<b>0.08</b>	<b>0.08</b>
<b>National total emissions with LULUCF<sup>1</sup></b>	<b>55.5</b>	<b>56.4</b>	<b>45.6</b>	<b>49.1</b>	<b>51.0</b>	<b>58.0</b>	<b>52.7</b>	<b>39.8</b>	<b>44.8</b>	<b>51.0</b>	<b>44.3</b>	<b>28.1</b>	<b>49.1</b>	<b>41.9</b>	<b>34.6</b>	<b>42.7</b>
<b>NATIONAL TOTAL EMISSIONS<sup>1</sup></b>	<b>71.3</b>	<b>71.8</b>	<b>70.1</b>	<b>75.3</b>	<b>77.7</b>	<b>85.1</b>	<b>81.3</b>	<b>69.5</b>	<b>80.7</b>	<b>79.1</b>	<b>71.2</b>	<b>67.5</b>	<b>75.8</b>	<b>68.1</b>	<b>62.4</b>	<b>63.1</b>

<sup>1</sup> including indirect CO<sub>2</sub>-emissions from NMVOC and CH<sub>4</sub> from energy, industrial processes and product use

## 2.2.1 Energy

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. 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 2013, the energy sector's emissions were about 10% below the 1990 level. 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 46% of the total emissions in the energy sector in 2013. Emissions from the energy industries were 16% higher in 2013 than in 1990.



**Figure 2.2-2** Development of total energy consumption by energy source (PJ) and the energy sector's greenhouse gas emissions (Mt CO<sub>2</sub> eq.) in Finland (GHG Inventory and Energy Statistics, Yearbook)

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 2.2-2). Total consumption of energy in Finland amounted to 1.37 million terajoules (TJ) in 2013, which was on level with the previous year. Final consumption of energy went up by one per cent in industry and energy consumption in households decreased by six per cent. Energy consumption of transport was on level with the previous year.

The share of renewable energy of total energy consumption decreased in 2013 and stood at 31 per cent. The biggest decline was seen in the use of hydro power; the availability of hydro power declined in the Nordic countries in 2013 and the production of hydro power decreased by 24% in Finland. The use of forest chippings rose to a new record level in 2013, and 5% more was used than in 2012. EU targets for renewable energy are calculated relative to total final energy consumption; calculated in this manner, the share of renewable energy was 35% in Finland in 2013 based on preliminary data. Finland's target for the share of renewable energy is 38% of final energy consumption in 2020 (Energy supply and consumption, Statistics Finland).

The use of fossil fuels went up by 2% from the year before. Of fossil fuels, the use of natural gas fell by 7% and the use of peat by 12% from 2012. The consumption of coal (including hard coal, coke, and blast furnace and coke oven gas) increased by 23%. (Energy supply and consumption, Statistics Finland).

Total electricity consumption went down by 1% and amounted to 84 TWh in 2013. Of total electricity consumption, 81% was covered by domestic production and 19% by net imports of electricity from the Nordic countries and Russia (Figure 2.2-3). Net imports of electricity declined by 10% from the year before as the water situation in the Nordic countries was worse than in 2012 (Energy supply and consumption, Statistics Finland).

The production of electricity in Finland amounted to 68.3 TWh in 2013. The production grew by 1% from the previous year. Altogether 36% 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. 33% of the production of electricity was covered with nuclear power, 26% with fossil fuels and 4% with peat. The amount of electricity produced with fossil fuels and peat increased by 24% from the previous year, as the amount produced with hard coal went up by 50%. The increased production of condensing electricity raised the use of hard coal (Production of electricity and heat, Statistics Finland).

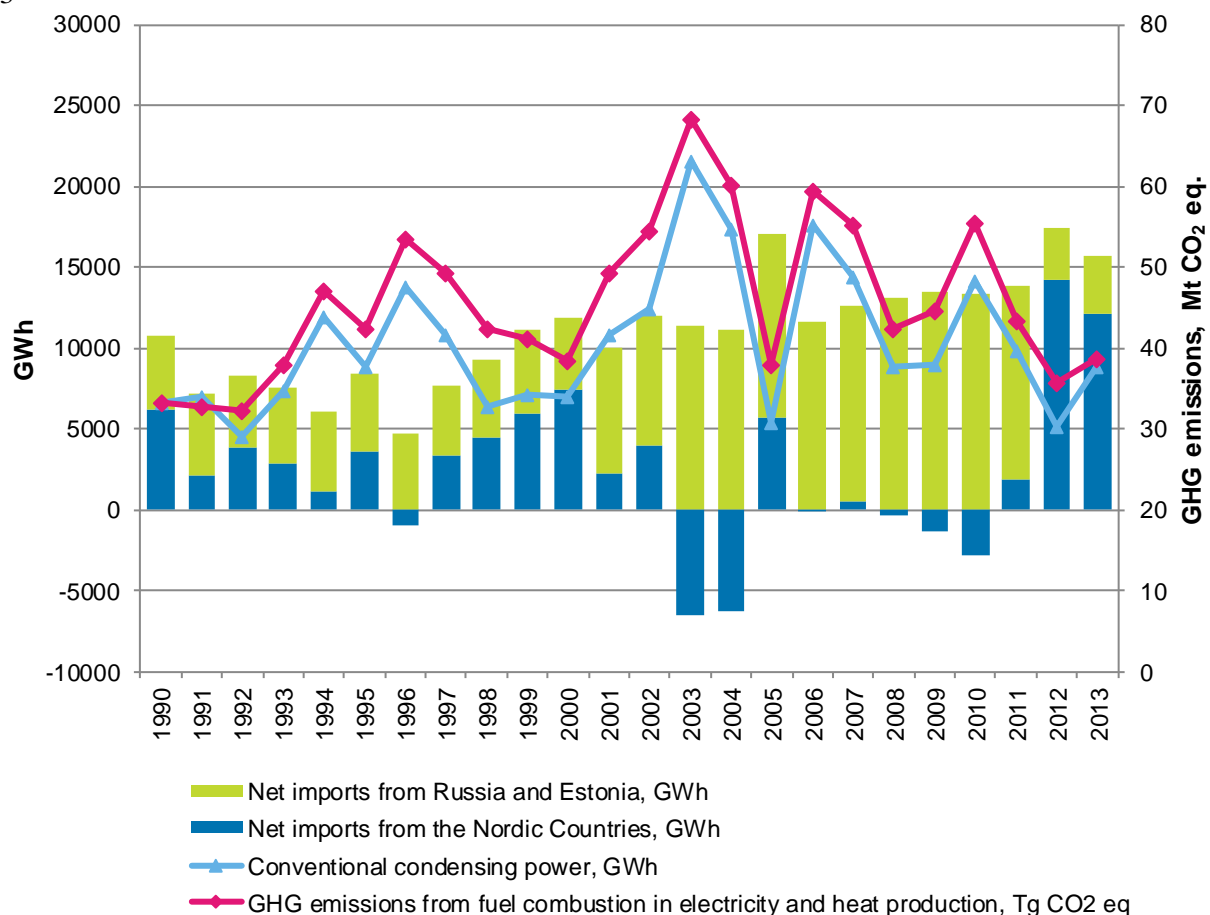
The production of district heat amounted to 34.5 TWh in 2013. The production decreased by 7% from the previous year. The need for the heating energy of buildings decreased due to the warmer weather than in the year before. According to the Finnish Meteorological Institute, heating degree days fell in all reference localities by at least five per cent from the previous year. Around 50% of district heat was produced with fossil fuels, whose use fell, however, by 11 per cent from one year ago. The use of renewable fuels in the production of district heat grew by 6% from the year before. District heat was produced most with wood fuels, hard coal and natural gas (Production of electricity and heat, Statistics Finland).

The production of industrial heat was 52.2 TWh in 2013. The production went down by 1% from the year before. The economic development of manufacturing weakened, so the use of industrial heat remained at a low level as in previous years. Over 70% 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)

Manufacturing industries and construction produce much energy themselves. Their share of the energy-related emissions was around 18% in 2013. 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 were in 2013 at the same level than in 1990. 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 3.2.5). Emissions were at the highest level in 2007, they were 11% above the level of 1990. The worldwide economic downturn that began 2008 decreased the kilometrage of all transport modes. The share of transportation of energy-related emissions was one fourth in 2013.

Emissions from the residential sector have decreased by 47% and from commercial sectors by 53% compared with the 1990 levels. The decrease is mainly due to substitution of direct oil heating with district heating and electricity.



**Figure 2.2-3** 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)

## 2.2.2 Industrial processes and product use

Emissions of industrial processes and product use have increased by 11% (0.6 Mt CO<sub>2</sub> eq.) from 1990 to 2013. 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 13% from 1990 to 2013, reasons are increased production of steel, hydrogen and use of limestone and dolomite. Methane emissions have decreased by 64%. Nitrous oxide emissions have fluctuated during the period 1990 to 2013; 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 1.4 Mt CO<sub>2</sub> eq. (86%).

The F-gas emissions are about thirtyfold 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 1.5 Mt 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.

## 2.2.3 Agriculture

Agricultural emissions have decreased by 15% (1.1 Mt CO<sub>2</sub> eq.) over the period 1990-2013. 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 42% 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 11% 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.

## 2.2.4 LULUCF

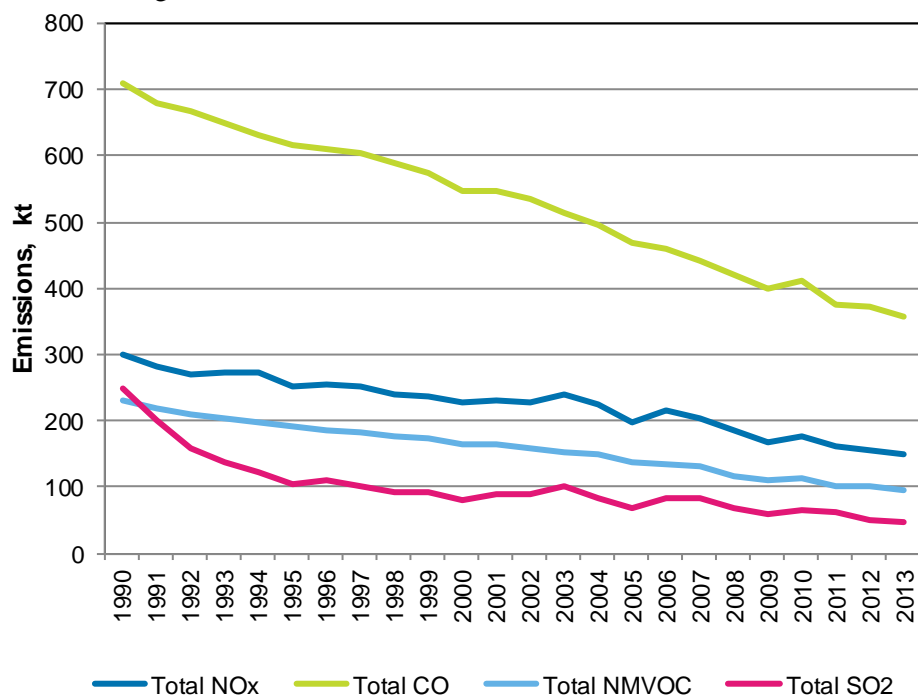
The sink of the LULUCF sector has varied from approximately 22% to 58% of the annual emissions from other sectors during 1990-2013. The determining factor is the balance of tree biomass growth and losses in Forest Land category. The increment of growing stock has increased 34% since 1990. Economic situation and the international market of forest industry products have brought about the amount of domestic commercial roundwood removals and caused the inter-annual fluctuation in the sink. The global economic downturn had a considerable negative effect on demand for forest-based industry products in 2009. In 2013, a slight economic upturn increased the demand of wood and forest industry products; commercial roundwood removals were at its highest level ever and produced a total drain of 79 million m<sup>3</sup> (Finnish Statistical Yearbook of Forestry 2014). Emissions from other land-use categories has been more stable. Emissions from drained organic soils have a slight increasing trend in croplands and wetlands.

## 2.2.5 Waste

Emissions from the waste sector have declined quite constantly since 1990. The decrease of 2.3 Mt 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.

## 2.3 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 2.3-1 and Table 2.3-1.



**Figure 2.3-1** Indirect greenhouse gas and sulphur dioxide emissions, kt

**Nitrogen oxides (NO<sub>x</sub>)** were generated in the energy, industrial, agriculture and LULUCF sectors. The energy sector is the most significant source, 97% of emissions are energy related. Emissions have decreased by 50% compared to 1990 and were 150 kt in 2013. The biggest decrease, 66%, has happened in the transport category due to the implementation of catalytic converters to cars and these emissions were 35% of the total emissions in 2013. Energy industries as well as manufacturing industries and construction generated both 25% of the emissions.

**Carbon monoxide (CO)** emissions, total 358 kt in 2013, originated almost exclusively in the energy sector, where transport generated 26% and other sectors (including small-scale combustion and off-road machinery) 58% of the total emissions. Total carbon monoxide emissions have decreased by 50% compared to 1990 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 94 kt in 2013. In all, 73% of the total emissions were generated in the energy sector, 26% originated from industrial processes and product use. Total NMVOC emissions have decreased by 59% from 1990 to 2013, the greatest decline has taken place in industrial processes and product use sector, where emissions decreased by 67%.

The **sulphur dioxide (SO<sub>2</sub>)** emissions totalled 48 kt in 2013 out of which 76% originated in the energy sector, where energy industries generated 50% of the total emissions and manufacturing industries and construction 17%. Sulphur dioxide emissions have totally decreased 81% from 1990, reasons for that are increased use of less sulphur containing fuels and sulphur abatement technology in energy production.

**Table 2.3-1** Trends of NO<sub>x</sub>, CO, NMVOC and SO<sub>2</sub> emissions in different sources, kt

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<b>Total nitrogen oxides</b>	<b>299</b>	<b>252</b>	<b>228</b>	<b>231</b>	<b>229</b>	<b>239</b>	<b>226</b>	<b>198</b>	<b>214</b>	<b>203</b>	<b>186</b>	<b>166</b>	<b>177</b>	<b>163</b>	<b>154</b>	<b>150</b>
- energy	294	247	224	227	225	234	221	194	210	199	181	162	172	159	150	146
- industry and product use	1.8	1.6	1.6	1.5	1.6	2.0	2.1	1.9	2.2	2.1	2.3	2.7	2.1	1.9	2.0	2.0
- agriculture	3.5	3.0	2.6	2.6	2.5	2.5	2.4	2.3	2.3	2.3	2.5	2.1	2.4	2.3	2.1	2.1
- LULUCF	0.05	0.02	0.01	0.03	0.03	0.02	0.01	0.02	0.03	0.01	0.02	0.01	0.01	0.02	0.01	0.01
<b>Total carbon monoxides</b>	<b>709</b>	<b>616</b>	<b>548</b>	<b>548</b>	<b>534</b>	<b>514</b>	<b>495</b>	<b>469</b>	<b>458</b>	<b>441</b>	<b>420</b>	<b>398</b>	<b>411</b>	<b>375</b>	<b>372</b>	<b>358</b>
- energy	704	613	544	544	530	510	492	466	456	438	417	395	409	373	370	355
- agriculture	4.2	3.4	3.7	3.2	3.3	3.1	3.1	3.0	2.7	3.0	2.9	2.8	1.9	2.3	2.2	2.8
- LULUCF	1.7	0.8	0.3	1.1	1.1	0.8	0.2	0.6	1.0	0.4	0.6	0.5	0.3	0.7	0.2	0.4
<b>Total NMVOCs</b>	<b>230</b>	<b>193</b>	<b>166</b>	<b>166</b>	<b>160</b>	<b>154</b>	<b>150</b>	<b>138</b>	<b>135</b>	<b>130</b>	<b>118</b>	<b>110</b>	<b>113</b>	<b>102</b>	<b>100</b>	<b>94</b>
- energy	154	138	120	121	117	113	108	101	97	91	84	80	83	73	74	69
- industry and product use	76	54	45	45	42	40	41	37	38	38	34	30	29	28	26	25
- waste	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	0.5	0.5	0.4
<b>Total sulphur oxides</b>	<b>250</b>	<b>105</b>	<b>81</b>	<b>90</b>	<b>89</b>	<b>102</b>	<b>84</b>	<b>69</b>	<b>84</b>	<b>82</b>	<b>67</b>	<b>59</b>	<b>67</b>	<b>61</b>	<b>52</b>	<b>48</b>
- energy	188	84	65	75	74	88	72	55	67	65	50	46	53	47	39	36
- industry and product use	62	21	16	15	15	14	13	14	17	18	17	13	14	14	13	11

## 2.4 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 2.4-1. The completeness of the reporting is also addressed in Annex 5.

**Table 2.4-1** Activity coverage and other information relating to activities under Article 3.3 and 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	HWP	Fertilisation	Drained, rewetted and other soils	Nitrogen mineralisation in mineral soils	Indirect N <sub>2</sub> O emissions from managed soils	Biomass burning					
											CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O			
					Min.	Org.	N <sub>2</sub> O	CH <sub>4</sub>	N <sub>2</sub> O	N <sub>2</sub> O	N <sub>2</sub> O	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O		
Article 3.3 activities	Afforestation and reforestation	R	R	IE	IE	R	R	IE	R	R	R	R	R	R	R	
	Deforestation	R	R	IE	R, IE	R	R	IE, IO	IE	R	R	R	R	R	R	
Article 3.4 activities	Forest management	R	R	IE	IE	R	R	R	R	R	R	R	R	R	R	
	Cropland management	NA	NA	NA	NA	NA	NA		NA		NA		NA	NA	NA	
	Grazing land management															
	Revegetation	NA	NA	NA	NA	NA	NA		NA	NA	NA		NA	NA	NA	
	Wetland drainage and rewetting	NA	NA	NA	NA	NA	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), IO (instantaneous oxidation)

Net emissions from ARD in 2013 were 2.4 Mt CO<sub>2</sub> eq. and from FM 46.1 Mt CO<sub>2</sub> eq. (Table 2.4-2). Area reported under AR in 2013 is 168 kha, under D 355 kha and under FM 21,722 kha.

**Table 2.4-2** Emissions and removals resulting from activities under Article 3.3 and 3.4 of Kyoto Protocol in 2013

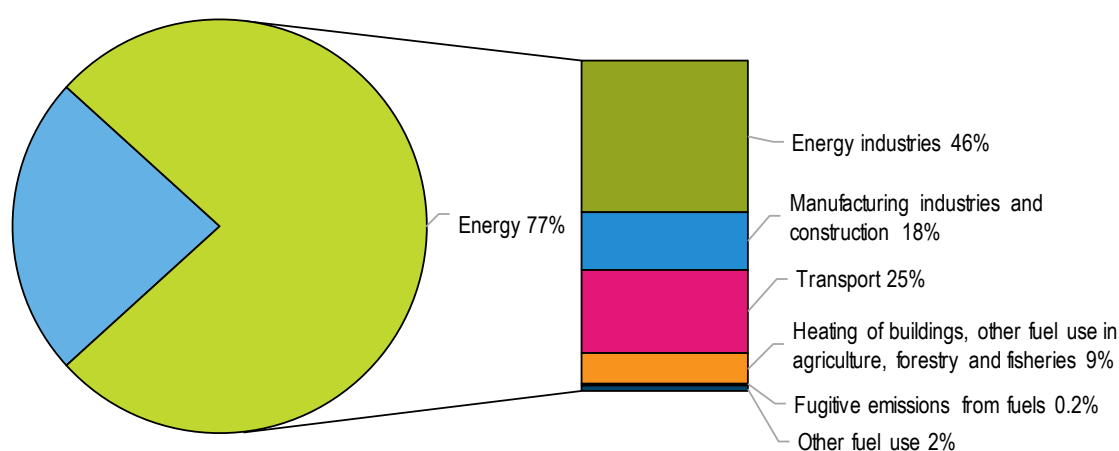
GREENHOUSE GAS SOURCE AND SINK ACTIVITIES	Net CO <sub>2</sub> emissions/removals	CH <sub>4</sub>	N <sub>2</sub> O	Net CO <sub>2</sub> equivalent emissions/removals
			(kt)	
<b>A. Article 3.3 activities</b>				2,375.95295
A.1. Afforestation and reforestation <sup>(6)</sup>	-570.04	0.20	0.08	-541.58753
A.2. Deforestation	2,857.30	0.60	0.15	2,917.54048
<b>B. Article 3.4 activities</b>				<b>-46,052.94</b>
B.1. Forest management	-47,998.02	33.42	3.72	-46,052.94
B.2. Cropland management (if elected)	NA	NA	NA	NA
B.3. Grazing land management (if elected)	NA	NA	NA	NA
B.4. Revegetation (if elected)	NA	NA	NA	NA
B.5. Wetland drainage and rewetting (if elected)	NA	NA	NA	NA

## 3 ENERGY (CRF 1)

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

#### 3.1.1 Description

The energy sector is the main source of greenhouse gas emissions in Finland. In 2013, the sector contributed 77% to total national emissions, totalling 48.4 million tonnes of carbon dioxide equivalent (Mt 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 2013. Due to independent rounding, the sums do not add up

Emissions from the energy sector are divided into three main categories: emissions from fossil fuel combustion (CRF 1.A), fugitive emissions from fuels (CRF 1.B) and CO<sub>2</sub> transport and storage (CRF 1.C). 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 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. Indirect CO<sub>2</sub> emissions from NMVOC and CH<sub>4</sub> from energy sector are included to the total greenhouse gas emissions but not included in energy sector emissions (See Chapter 9). General assessment of completeness can be found in Section 1.7 and a more detailed assessment is included in Annex 5.

Consistent with the UNFCCC guidelines, the emissions from energy sector are divided into subcategories presented in Table 3.1-1. Table also includes methods and type of emission factors used in the Finnish inventory.

**Table 3.1-1** Reported emissions, calculation methods and type of emission factors for the energy sector in the Finnish inventory (M= model, CS = country specific, D= default, PS= plant specific)

CRF	Source	Emissions reported	Method	Emission factor
1A Fuel combustion				
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, D, PS
		CH <sub>4</sub>	Tier 3, CS, M	CS, D
		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, OTH	CS
		CH <sub>4</sub>	Tier 1, Tier 3, CS, M, OTH	CS, D
		N <sub>2</sub> O	Tier 1, Tier 3, CS, M, OTH	CS, D
1.A.4	Other Sectors	CO <sub>2</sub>	Tier 1, Tier 3, M, CS	CS, D
		CH <sub>4</sub>	Tier 1, Tier 3, M, CS	CS, D
		N <sub>2</sub> O	Tier 1, Tier 3, M, CS	CS, D
1.A.5	Other	CO <sub>2</sub>	Tier 1	CS
		CH <sub>4</sub>	Tier 1	CS
		N <sub>2</sub> O	Tier 1	CS
1B Fugitive emissions from fuels				
1.B.1	Solid fuels	NA	NA	NA
1.B.2	Oil and natural gas and other emissions from energy production	CO <sub>2</sub>	CS	CS, D
		CH <sub>4</sub>	Tier2, Tier 1, CS	CS, PS, D
		N <sub>2</sub> O	CS	CS
1C CO <sub>2</sub> Transport and storage				
1.C.2	Injection and storage	NA	NA	NA

### 3.1.2 Quantitative overview

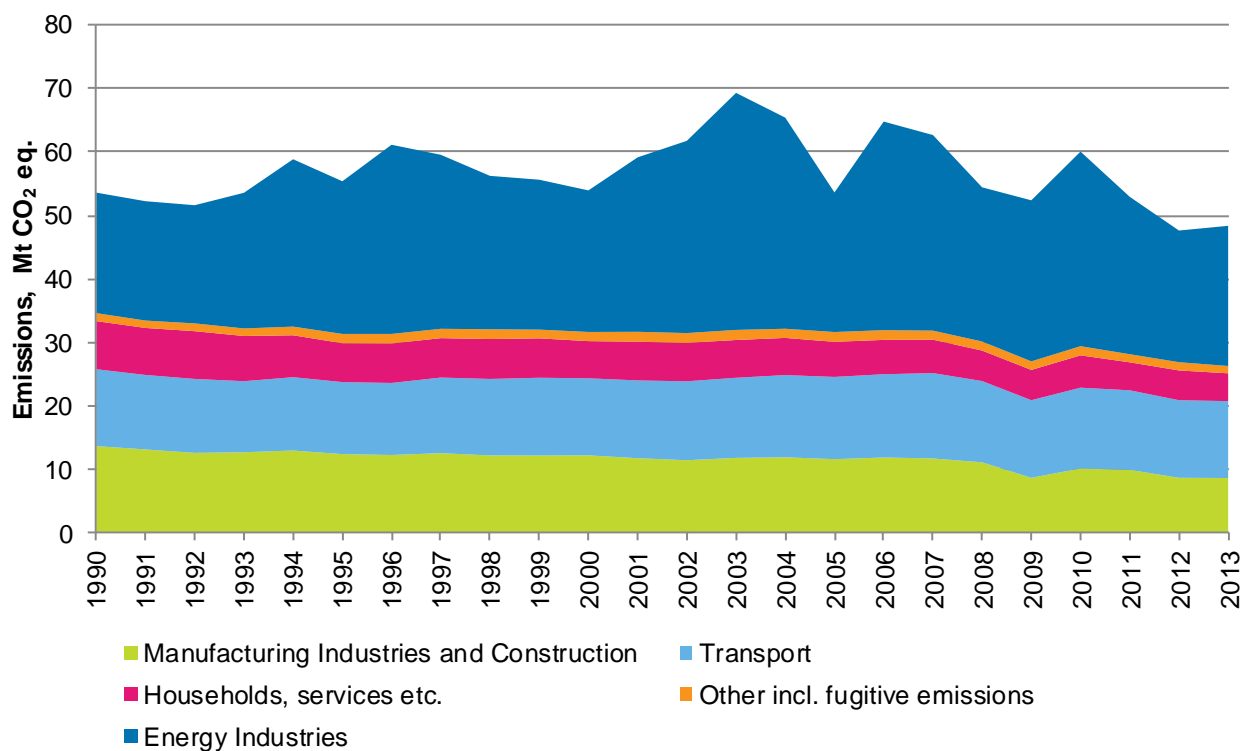
Energy-related CO<sub>2</sub> emissions vary much from year to year (Table 3.1-2, Figure 3.1-2), mainly following the economic trend, the structure of the energy supply and climatic conditions. Compared with 1990, the emissions in the energy sector in 2013 were about 10% lower. The main contributors to the descent are lower emissions in the manufacturing industries and construction with approximately 37% reduction and household, services etc. with around 42% reduction in emissions relative to 1990. Emissions from energy industry have increased 16% compared to 1990. In 2013 emissions from transport were approximately at the same level as in 1990. During the most recent years, the emissions from these source categories have been fluctuating considerably. In 2013 the emissions in the energy sector were about 2% higher than year before. The trends are discussed in more detail in Chapter 2 and the category-specific sections in this chapter.

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

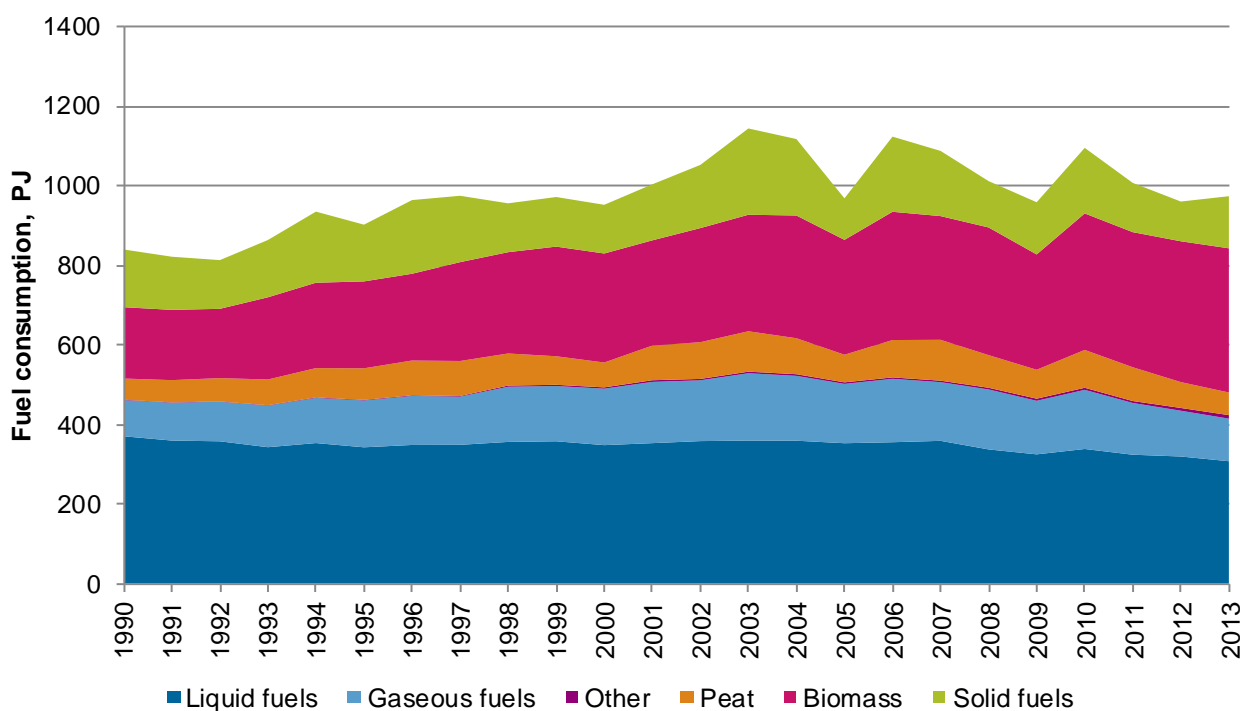
	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<b>Total energy</b>	<b>53.6</b>	<b>55.4</b>	<b>53.9</b>	<b>59.1</b>	<b>61.7</b>	<b>69.3</b>	<b>65.4</b>	<b>53.6</b>	<b>64.8</b>	<b>62.7</b>	<b>54.4</b>	<b>52.4</b>	<b>60.0</b>	<b>52.9</b>	<b>47.6</b>	<b>48.4</b>
Fuel combustion	53.5	55.2	53.8	59.0	61.6	69.2	65.3	53.5	64.6	62.5	54.3	52.2	59.9	52.8	47.5	48.2
CO <sub>2</sub>	52.6	54.3	52.9	58.0	60.6	68.1	64.2	52.5	63.6	61.5	53.3	51.3	58.8	51.8	46.5	47.3
CH <sub>4</sub>	0.37	0.35	0.33	0.36	0.37	0.37	0.36	0.35	0.36	0.36	0.38	0.38	0.42	0.37	0.39	0.37
N <sub>2</sub> O	0.54	0.58	0.60	0.64	0.66	0.69	0.67	0.59	0.65	0.64	0.60	0.56	0.65	0.61	0.58	0.58
Fugitive emissions from fuels	0.12	0.17	0.12	0.13	0.13	0.13	0.12	0.14	0.12	0.14	0.15	0.13	0.14	0.13	0.14	0.12
CO <sub>2</sub>	0.11	0.07	0.06	0.05	0.06	0.06	0.06	0.07	0.06	0.08	0.10	0.07	0.10	0.09	0.10	0.08
CH <sub>4</sub>	0.01	0.09	0.06	0.08	0.06	0.07	0.06	0.07	0.06	0.06	0.05	0.05	0.04	0.04	0.04	0.04
N <sub>2</sub> O	0.0007	0.0004	0.0004	0.0003	0.0004	0.0004	0.0005	0.0005	0.0005	0.0006	0.0007	0.0005	0.0006	0.0007	0.0009	0.0009

**Table 3.1-3** Emissions from fuel combustion and fugitive emissions from fuels in Finland (Mt CO<sub>2</sub> eq.)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<b>Total energy</b>	<b>53.6</b>	<b>55.4</b>	<b>53.9</b>	<b>59.1</b>	<b>61.7</b>	<b>69.3</b>	<b>65.4</b>	<b>53.6</b>	<b>64.8</b>	<b>62.7</b>	<b>54.4</b>	<b>52.4</b>	<b>60.0</b>	<b>52.9</b>	<b>47.6</b>	<b>48.4</b>
<b>Fuel combustion</b>	<b>53.5</b>	<b>55.2</b>	<b>53.8</b>	<b>59.0</b>	<b>61.6</b>	<b>69.2</b>	<b>65.3</b>	<b>53.5</b>	<b>64.6</b>	<b>62.5</b>	<b>54.3</b>	<b>52.2</b>	<b>59.9</b>	<b>52.8</b>	<b>47.5</b>	<b>48.2</b>
Energy industries	19.0	24.0	22.3	27.5	30.3	37.3	33.2	22.0	32.8	30.8	24.3	25.4	30.6	24.8	20.7	22.1
Manufacturing industries and construction	13.7	12.4	12.2	11.8	11.5	11.8	11.9	11.6	11.9	11.7	11.1	8.7	10.2	9.9	8.7	8.7
Transport	12.1	11.3	12.1	12.2	12.4	12.6	12.9	12.9	13.1	13.4	12.8	12.2	12.7	12.5	12.2	12.1
Other sectors	7.6	6.1	5.8	6.1	6.0	5.9	5.9	5.5	5.4	5.3	4.8	4.8	5.1	4.4	4.7	4.4
Other	1.1	1.3	1.3	1.4	1.4	1.5	1.3	1.4	1.4	1.3	1.3	1.2	1.3	1.2	1.2	1.0
<b>Fugitive emissions from fuels</b>	<b>0.12</b>	<b>0.17</b>	<b>0.12</b>	<b>0.13</b>	<b>0.13</b>	<b>0.13</b>	<b>0.12</b>	<b>0.14</b>	<b>0.12</b>	<b>0.14</b>	<b>0.15</b>	<b>0.13</b>	<b>0.14</b>	<b>0.13</b>	<b>0.14</b>	<b>0.12</b>
Oil refining	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
Natural gas	0.004	0.09	0.05	0.07	0.06	0.06	0.05	0.06	0.05	0.05	0.05	0.04	0.04	0.03	0.03	0.03
Flaring	0.11	0.07	0.06	0.05	0.06	0.06	0.06	0.07	0.06	0.08	0.10	0.08	0.10	0.09	0.10	0.08
Town gas	0.001	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO



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



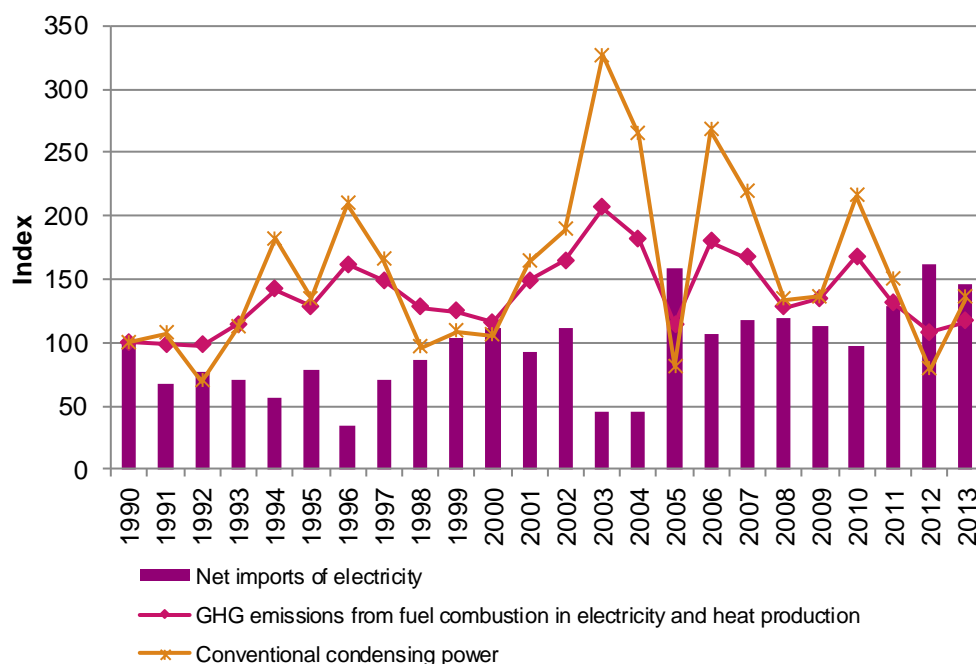
**Figure 3.1-3** Consumption of fuel types (PJ)

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

CO<sub>2</sub> emissions from fossil fuel combustion (47.3 Mt) accounted for 98% of the energy sector's total emissions and 75% of total greenhouse gas emissions in 2013.

The portion of N<sub>2</sub>O emissions from fuel combustion in 2013 was approximately 1%. N<sub>2</sub>O emissions come mainly from fluidised bed combustion and transport. CH<sub>4</sub> emissions from fuel combustion are 0.8% and are mainly due to the incomplete combustion of wood fuels (small-scale combustion).

The availability of hydropower in the Nordic electricity market influences significantly the electricity supply structure and hence the emissions (Figure 3.1-4). 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 Mt. The trends of emissions are mostly overwhelmed by the annual fluctuations. However, total emissions from fuel combustion increased by 2% from 2012, but these emissions are still 30% lower than the 2003 record level and 10% under the 1990 level.



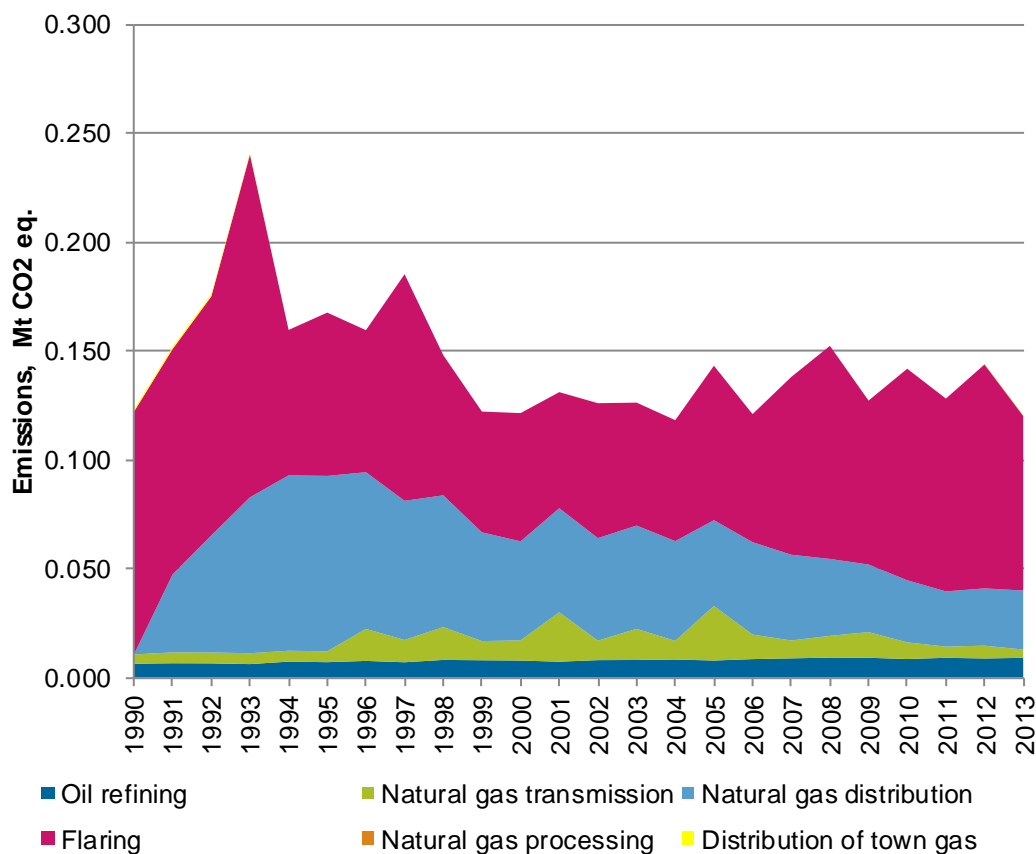
**Figure 3.1-4** Greenhouse gas emissions from fuel combustion in electricity and heat production, net imports of electricity and conventional condensing power indexed (index 1990=100) (Energy Statistics, Yearbook)

Fuel combustion by fuel (PJ) and related CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions for 1990-2013 are given in Appendix\_3b at the end of the Energy Chapter.

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

Fugitive emissions from fuels comprise only about 0.2% of total greenhouse gas emissions in Finland. Emissions were totally 0.12 Mt in 2013 and 0.12 Mt in 1990. These emissions have decreased by 2% since the 1990 level (Table 3.1-3 and Figure 3.1-5) due to decreased emissions in oil refining, especially in flaring. There were some disturbances in oil refineries and petrochemical industry in 1993 and 1997, which caused higher flaring emissions. Compared to the previous year emissions, the 2013 emissions are 16% lower.

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 Helsinki area network started gradually in 1991. The previously distributed town gas included only one per cent CH<sub>4</sub>, and these emissions are included in the inventory. Emissions of natural gas distribution were at its highest in 1994 and have halved since.



**Figure 3.1-5** Fugitive emissions from fuels by subcategory (Mt CO<sub>2</sub> eq.)

### 3.1.3 Key categories

Several emission sources in the energy combustion sector are key categories (Table 3.1-4).

**Table 3.1-4** Key categories in Energy sector in 2013 (Approach 1)

IPCC category	Gas	Identification criteria
1.A.1. Energy Industries - Liquid Fuels	CO <sub>2</sub>	L, T
1.A.1. Energy Industries - Solid Fuels	CO <sub>2</sub>	L, T
1.A.1. Energy Industries - Gaseous Fuels	CO <sub>2</sub>	L, T
1.A.1. Energy Industries - Other Fossil	CO <sub>2</sub>	L, T
1.A.1. Energy Industries - Peat	CO <sub>2</sub>	L, T
1.A.1. Energy Industries - Biomass	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 - Gaseous Fuels	CO <sub>2</sub>	L, T
1.A.2. Manufacturing Industries and Construction - Other Fossil	CO <sub>2</sub>	L, T
1.A.2. Manufacturing Industries and Construction - Peat	CO <sub>2</sub>	L, T
1.A.3.b. Road Transportation	CO <sub>2</sub>	L, T
1.A.3.c. Railways	CO <sub>2</sub>	T
1.A.3.d. Domestic Navigation - Liquid Fuels	CO <sub>2</sub>	L, T
1.A.4. Other Sectors - Liquid Fuels	CO <sub>2</sub>	L, T
1.A.4. Other Sectors - Peat	CO <sub>2</sub>	T
1.A.4. Other Sectors - Biomass	CH <sub>4</sub>	L, T
1.A.5. Other non-specified – Liquid Fuels	CO <sub>2</sub>	L, T
1.A.5. Other non-specified – Gaseous Fuels	CO <sub>2</sub>	T

### 3.1.4 Description of ILMARI calculation system

Calculations of all emissions from fuel combustion are made with the ILMARI calculation system developed at Statistics Finland. The current version of the ILMARI calculation system was developed in 2002. The calculation results of different subsystems, which calculate fugitive emissions and emissions from industrial processes and product use (excl. F-gases), are imported to ILMARI system before compiling of the CRF Tables.

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 6) makes it possible to take into account changes in the technology of combustion processes.

ILMARI combines three main types of activity source data of fuel combustion activities:

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.

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 3.1-6 and the production process of ILMARI and CRF 1 data tables is described in Table 3.1-6.

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 this verification check reveals 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. The more detailed QA/QC procedures of the subsectors of Energy sector are described in the corresponding chapters.

Calculation systems of mobile sources (LIPASTO) are described in detail in Section 3.2.5 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 2006 IPCC Guidelines. Therefore only selected parts of the results are taken to ILMARI. Most of the emission calculation of domestic transport and non-road machinery is done in the LIPASTO model of VTT Technical Research Centre of Finland Ltd. Statistics Finland calculates emissions of civil aviation based on information received from Eurocontrol.

Statistics Finland has decided the level of aggregation of transport data to be used in ILMARI, consistent with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and UNFCCC reporting guidelines, see Table 3.1-5. Emissions from categories 1.A.3bii, 1.A.3biii and 1.A.3biv are included in category 1.A.3bi as ILMARI system does not currently support reporting at more disaggregated level. The breakdown (and coverage, as mentioned above) of data published in the VTT Ltd LIPASTO website ([lipasto.vtt.fi/](http://lipasto.vtt.fi/)) are different from CRF categories, which must be noticed, when comparing the figures.

**Table 3.1-5** 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	1.A.3bi-iv Road transport - data taken from LIISA reported by fuel categories - emissions from categories 1A3bii, 1A3biii and 1A3biv are included in category 1A3bi as more disaggregated data is not available.
RAILI (railways) - includes emissions from fuels and electricity used in railway transport	1.A.3c Railways - only fuels and 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.4ciii
TYKO (non-road working machinery) - breakdown by machine type and fuel type (over 50 combinations)	Breakdown by following Off-road vehicles and other machinery categories (and fuel types) aggregated from TYKO: - 1.A.2gvii Manufacturing industry and construction - 1.A.4aii Commercial/institutional - 1.A.4bii Residential - 1.A.4cii Agriculture/forestry/ fisheries

**Table 3.1-6** Production process of ILMARI and CRF 1.A data tables

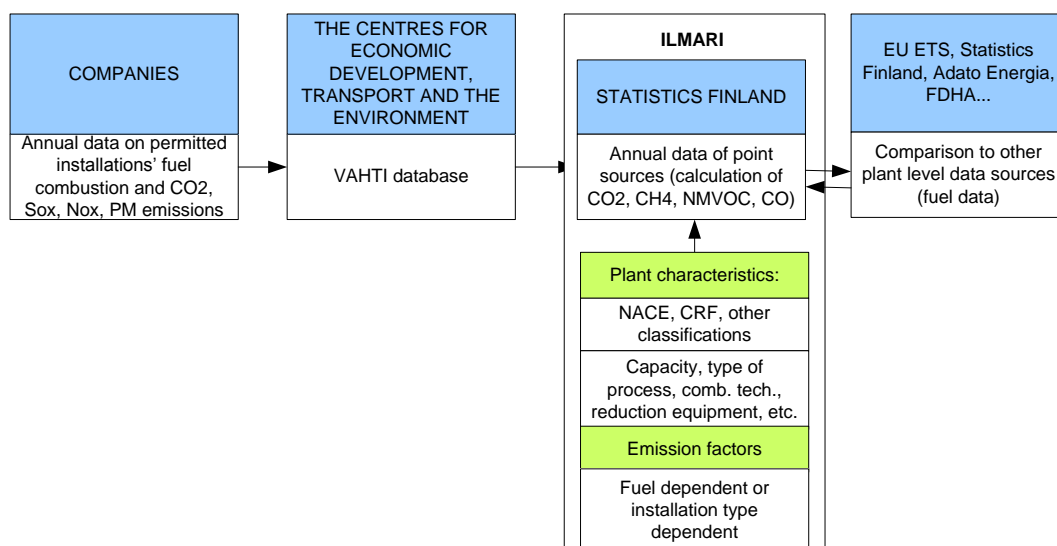
Production of CRF data tables for Energy sector	
1. VAHTI data input to ILMARI	Point source data input from database
Checks, corrections	Missing data (plants, fuels, emissions) Erroneous data Order of magnitude errors Quantity units Fuel codes
New data for plants	Technical data Classifications New emission factors
Comparison	Totals by plants Previous years' data Other plant level data Companies environmental reports
2. EU ETS data input to ILMARI	Point source data input for comparison and supplementation of VAHTI data
3. Lipasto data input to ILMARI	Manual input of transport and non-road machinery data
4. Energy Statistics data input to ILMARI	Manual input of heating fuels data and other fuel consumption data
5. Comparison to Energy Statistics	Totals and plant level data by fuel
6. Fugitive emissions input to ILMARI	Manual input from subsystem in which fugitive emissions are calculated
7. industrial processes and product use (excl. F-gases) data input to ILMARI	Manual input from subsystem in which emissions from industrial processes and product use (excl. F-gases) are calculated

## Production of CRF data tables for Energy sector

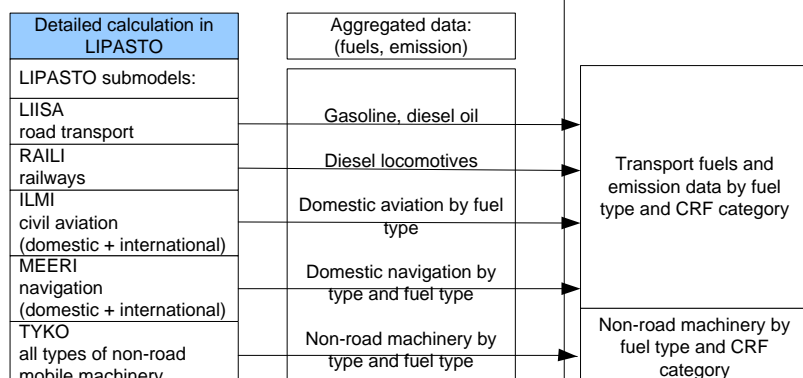
8. Final annual data sheet (output to ILMARI, stored in SAS time series database)	2 000 plants + 50 sectoral sources identification data, classifications, technical data, fuels, emission factors etc.
9. CRF query from SAS database (output to excel sheets)	SAS database functions
10. CRF time series in excel sheets	Manual cut and paste or linking to CRF Reporter excel import sheets

### Main data inputs of ILMARI

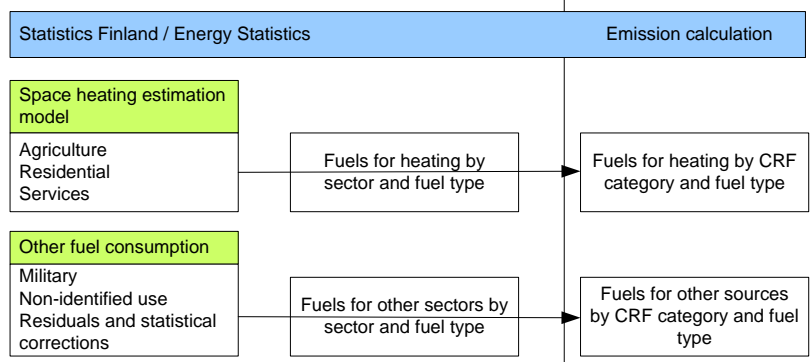
#### Point Sources



#### Transport and non-road machinery



#### Other emission sources

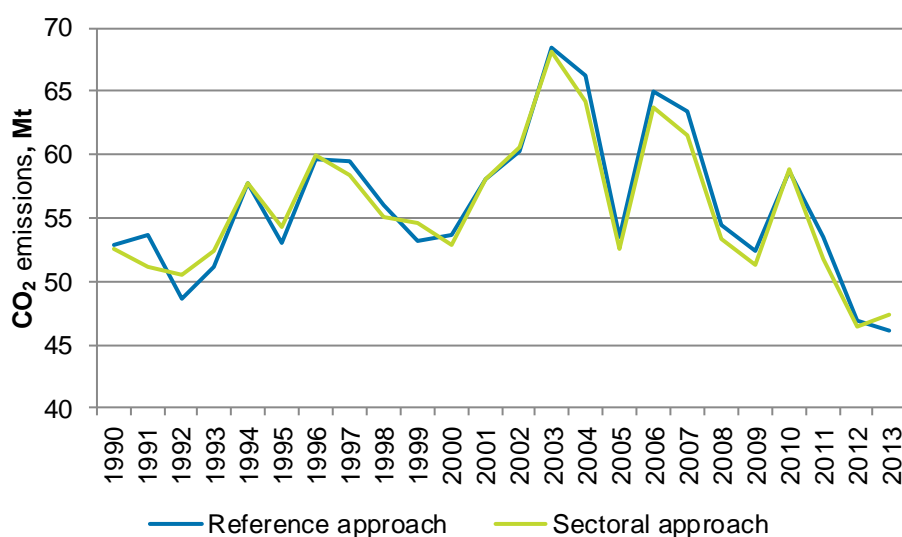


**Figure 3.1-6** Data sources of the ILMARI calculation system.

## 3.2 Fuel combustion activities (CRF 1.A)

### 3.2.1 Comparison of the sectoral approach with the 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.



**Figure 3.2-1** Carbon dioxide emissions of Reference and Sectoral Approach in Finland

The difference between the RA and SA was -2.6% for 2013 and 0.6% for 1990 (Figure 3.2-1).

The differences between the RA and SA are high especially in 1991-1993. No obvious reasons for these differences have been found, although some possible explanations were identified in the background data of a study by Torniainen (2006). The final conclusions on the reasons for differences cannot be made without further, resource demanding, investigations. Due to the resource demands for the task as well as the low significance of the issue, there are no plans to further investigate the reasons for the differences in the RA and SA for the years 1991 – 1993.

There are statistical differences in oil balances, which can be seen in the RA-SA comparison. As an example we could mention statistical differences of crude oil, which vary from -1,317 to +783 kt during 1990-1997. These figures alone correspond to several percentage differences in RA-SA comparison.

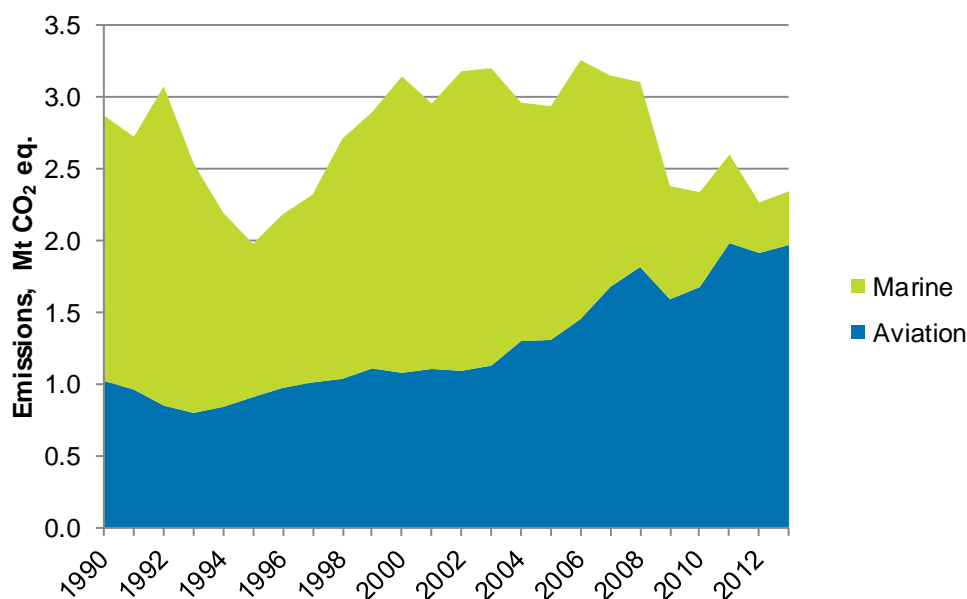
In recent years new challenges for the RA-SA comparison have emerged, when more biocomponents have been included in transport fuels. It is not always clear, whether these biocomponents and biogenic feedstocks are included in import and export data. This subject may become more important in coming years, because production and also import and export of transport biofuels are growing substantially in Finland.

The energy balance for the 2013 inventory is included in Annex 4.

### 3.2.2 International bunker fuels

International bunkers cover international aviation and navigation according to the IPCC Guidelines.

Emissions from international bunkers were 2.0 Mt CO<sub>2</sub> eq in aviation and 0.4 Mt CO<sub>2</sub> eq in navigation in 2013. The amount of emissions in international aviation has increased gradually for the whole time series except in the beginning of the decade when the trend was fluctuating (Figure 3.2-2). The most important reason for these fluctuations was 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 has disappeared due to Finland's EU membership and the common currency. However, during the most recent years refuelling in Finland has diminished.



**Figure 3.2-2** Emissions from international bunker, Mt CO<sub>2</sub> eq.

The emissions are calculated using the ILMARI calculation model of Statistics Finland (see closer Section 3.1.4). 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 3.2.5.3), 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 3.2.5.6). The fuel volumes of Åland correction (gasoil and residual fuel oil) are subtracted from bunkers and added to total domestic fuel consumption.

No uncertainty estimation for international bunkers has been carried out.

All bunker fuel quantities are taken directly from the Energy statistics. 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. Also the Åland-correction mentioned above causes some difference, because it has not been included in the IEA bunker fuel data. Until 2008 the difference has been less than 2 %, but in recent years it has become higher. In 2013 marine bunkers are 13% lower in CRF data than in IEA data. The actual figures have not grown substantially, but total navigation bunker sales have decreased due to market situation.

The bunker fuel figures reported in Sectoral background data for energy tables; Table 1.D 'International aviation and international navigation (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.

## *Recalculations*

Lubricant use in international shipping has been moved from the Energy to the IPPU sector due to the implementation of the 2006 IPCC Guidelines.

## *Sector-specific planned improvements*

There are no planned improvements in this category.

### *3.2.3 Feedstocks and non-energy use of fuels*

The emissions from the non-specified burning of feedstocks are calculated by a separate module in ILMARI. The ILMARI system includes point source (bottom-up) data on feedstock combustion in the petrochemical industry and these emissions are reported in corresponding subcategories of 1.A 2. These specified energy uses of feedstock are subtracted from the corresponding total amounts of feedstock. For the rest of the feedstock 100% of carbon is estimated to be stored in products (mainly plastics).

Residual fuel oil and coke oven gas coke is used as a feedstock in the metal industry and corresponding amount is subtracted from the reference approach. All (100%) of this carbon is estimated to be released as CO<sub>2</sub> during the process and emissions are reported in category 2.C 1 (see section 4.4.2). Natural gas is used as feedstock in the hydrogen production process and the carbon is subtracted from reference approach and emissions are reported in sector 2.B.10 (see section 4.3.5).

From the carbon of other oil products only carbon from paraffin waxes are estimated to oxidise and these emissions are reported in sector 2.D 2 (section 4.5.3). In the Finnish inventory lubricants contain waste oil as well as 2-stroke and 4-stroke oil. The ILMARI system includes point source (bottom-up) data also on waste oil combustion in different branches of industry, and these emissions are reported in corresponding subcategories of 1.A 2. 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 2.D 1 (section 4.5.2).

**Table 3.2-1** Reporting of carbon stored and emissions related to use of feedstock and lubricants (figures show approximate ranges for the latest years)

	Use in kt	kt CO <sub>2</sub>	Reported in inventory
Feedstock for metal industry	1200-1300	2000-2400	2.C 1; in RA subtracted from residual fuel oil and coke oven gas coke
Feedstock for hydrogen production	300-350 (1000 m <sup>3</sup> )	600-700	2.B 10; in RA subtracted from hydrogen production
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'
Lubricants			
Combustion of recycled waste oil	20-30	50-100	1.A.1 and 1.A.2
Non-specified consumption	30-50		
- of which, estimated combustion (2/3)	20-35	50-100	2.D 1
- stored carbon (in recycled lubricants)	10-15	30-50	RA carbon stored; subtracted from lubricants 'apparent consumption emissions'
Paraffin waxes			
combustion of candles	included in other oil	18-20	2.D 2; in RA subtracted from other oil

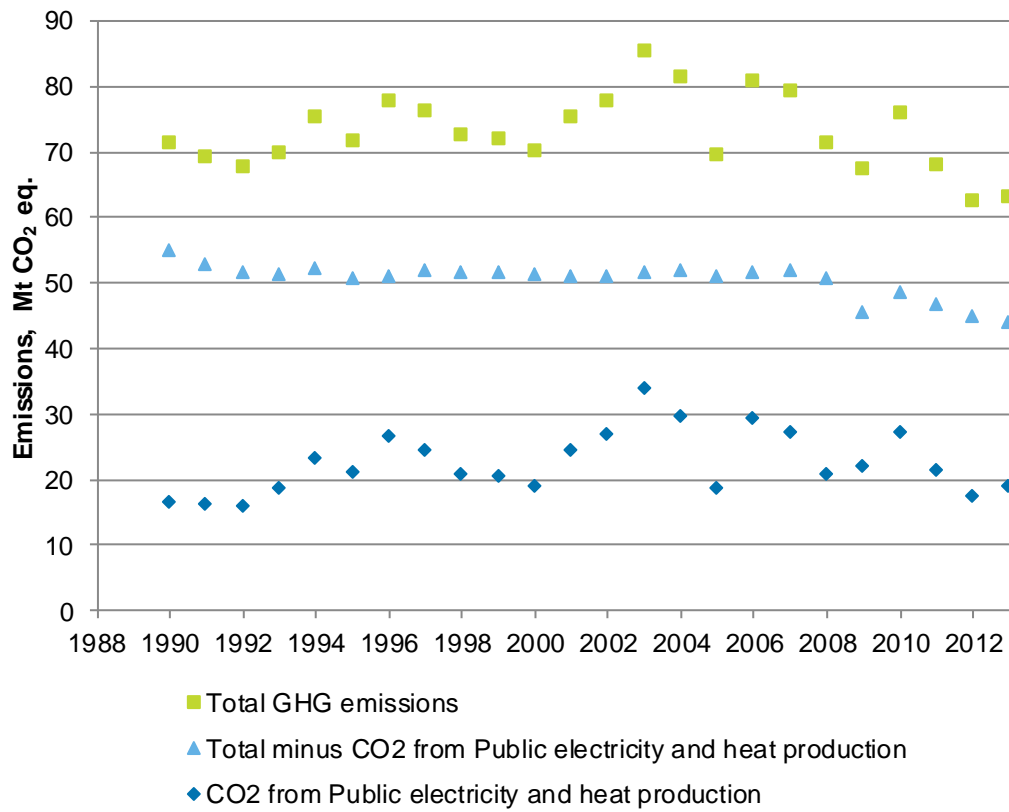
### 3.2.4 Energy industries and Manufacturing industries and Construction (CRF 1.A 1, CRF 1.A 2)

#### 3.2.4.1 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) as well as off-road vehicles and other machinery in manufacturing industry and construction. The emissions from Energy industries by relevant subcategory and gas in 1990–2013 are presented in Table 3.2-2 and emissions from Manufacturing industries and construction in Table 3.2-3. 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. The calculated amount of this stored CO<sub>2</sub> is subtracted from liquid fuels in subcategory 1.A 2d (See Section 3.4).

In 2013, the greenhouse gas emissions from Energy industries amounted to 22.1 Mt and Manufacturing industries and construction amounted to 8.7 Mt CO<sub>2</sub> eq. The share of energy industries was 46% of energy sector's total emissions. The corresponding share was 18% for manufacturing industries and construction. These two subsectors accounted together for 49% 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 3.2-3.



**Figure 3.2-3** 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 3.2-2** The emissions from Energy industries by relevant subcategory and gas (Mt CO<sub>2</sub> eq.)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<b>Energy industries</b>	<b>19.0</b>	<b>24.0</b>	<b>22.3</b>	<b>27.5</b>	<b>30.3</b>	<b>37.3</b>	<b>33.2</b>	<b>22.0</b>	<b>32.8</b>	<b>30.8</b>	<b>24.3</b>	<b>25.4</b>	<b>30.6</b>	<b>24.8</b>	<b>20.7</b>	<b>22.1</b>
<b>CO<sub>2</sub></b>	<b>18.8</b>	<b>23.8</b>	<b>22.1</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>24.0</b>	<b>25.0</b>	<b>30.3</b>	<b>24.4</b>	<b>20.4</b>	<b>21.7</b>
Public electricity and heat production	16.5	21.1	19.0	24.4	26.9	33.9	29.7	18.7	29.4	27.3	20.8	22.0	27.4	21.4	17.6	19.0
Petroleum refining	2.04	2.5	2.7	2.5	2.6	2.7	2.7	2.6	2.7	2.8	2.8	2.8	2.7	2.8	2.6	2.5
Manufacture of solid fuels and other energy industries	0.35	0.32	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	0.25
<b>CH<sub>4</sub></b>																
<b>Total</b>	<b>0.010</b>	<b>0.015</b>	<b>0.018</b>	<b>0.023</b>	<b>0.029</b>	<b>0.033</b>	<b>0.030</b>	<b>0.025</b>	<b>0.030</b>	<b>0.027</b>	<b>0.027</b>	<b>0.025</b>	<b>0.029</b>	<b>0.027</b>	<b>0.025</b>	<b>0.025</b>
<b>N<sub>2</sub>O</b>																
<b>Total</b>	<b>0.12</b>	<b>0.18</b>	<b>0.20</b>	<b>0.24</b>	<b>0.28</b>	<b>0.32</b>	<b>0.30</b>	<b>0.24</b>	<b>0.32</b>	<b>0.32</b>	<b>0.29</b>	<b>0.28</b>	<b>0.35</b>	<b>0.32</b>	<b>0.29</b>	<b>0.30</b>

**Table 3.2-3** The emissions from Manufacturing industries and construction by relevant subcategory and gas (Mt CO<sub>2</sub> eq.)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<b>Manufacturing industries and construction</b>	<b>13.7</b>	<b>12.4</b>	<b>12.2</b>	<b>11.8</b>	<b>11.5</b>	<b>11.8</b>	<b>11.9</b>	<b>11.6</b>	<b>11.9</b>	<b>11.7</b>	<b>11.1</b>	<b>8.7</b>	<b>10.2</b>	<b>9.9</b>	<b>8.7</b>	<b>8.7</b>
<b>CO<sub>2</sub></b>	<b>13.5</b>	<b>12.2</b>	<b>12.0</b>	<b>11.6</b>	<b>11.3</b>	<b>11.6</b>	<b>11.7</b>	<b>11.4</b>	<b>11.7</b>	<b>11.6</b>	<b>11.0</b>	<b>8.6</b>	<b>10.0</b>	<b>9.8</b>	<b>8.5</b>	<b>8.5</b>
Iron and steel	2.50	2.66	3.69	3.31	3.36	3.60	3.57	3.67	3.80	3.42	3.26	2.30	3.00	2.95	2.25	2.15
Non-ferrous metals	0.34	0.11	0.14	0.15	0.13	0.12	0.11	0.10	0.10	0.10	0.11	0.09	0.11	0.10	0.10	0.10
Chemicals	1.25	1.32	1.13	1.20	1.12	1.24	1.23	1.26	0.87	0.90	0.96	0.71	0.78	0.80	0.67	0.74
Pulp, paper and print	5.35	4.79	3.89	3.76	3.51	3.63	3.74	3.40	3.89	4.10	3.65	3.02	3.47	3.16	2.83	2.83
Food processing, beverages and tobacco	0.83	0.70	0.33	0.32	0.32	0.26	0.25	0.21	0.21	0.19	0.16	0.25	0.24	0.25	0.22	0.23
Non-metallic minerals	1.37	0.80	0.89	0.89	0.91	0.90	0.97	0.95	1.00	0.99	0.97	0.64	0.72	0.75	0.65	0.63
Other	1.87	1.86	1.97	1.96	1.93	1.89	1.86	1.84	1.86	1.87	1.86	1.56	1.69	1.77	1.82	1.82
<b>CH<sub>4</sub></b>																
<b>Total</b>	<b>0.016</b>	<b>0.018</b>	<b>0.019</b>	<b>0.018</b>	<b>0.017</b>	<b>0.017</b>	<b>0.018</b>	<b>0.017</b>	<b>0.018</b>	<b>0.018</b>	<b>0.017</b>	<b>0.014</b>	<b>0.018</b>	<b>0.021</b>	<b>0.020</b>	<b>0.021</b>
<b>N<sub>2</sub>O</b>																
<b>Total</b>	<b>0.17</b>	<b>0.16</b>	<b>0.18</b>	<b>0.18</b>	<b>0.17</b>	<b>0.17</b>	<b>0.18</b>	<b>0.16</b>	<b>0.16</b>	<b>0.15</b>	<b>0.14</b>	<b>0.12</b>	<b>0.13</b>	<b>0.13</b>	<b>0.13</b>	<b>0.13</b>

Fuel combustion CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions by fuels for 1990-2013 are given in Appendix\_3b at the end of the Energy Chapter.

### 3.2.4.2 Methodological issues

#### Methods

Emissions from fuel combustion in point sources are calculated with the ILMARI calculation system (See Section 3.1.4). All emissions within CRF 1.A 1 and 1.A 2 (except off-road vehicles and other machinery) 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>8</sup>, 2006 IPCC Guidelines) using detailed activity (fuel consumption) data and fuel-specific emission factors. For off-road vehicles and other machinery reported under CRF 1.A 2g vii see Section 3.2.5.7.

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, 2006 IPCC 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).

#### *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 3.2-4.

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<sup>8</sup> Bottom-up installation level activity and technology data; technology dependent non-CO<sub>2</sub> emission factors.

**Table 3.2-4** CO<sub>2</sub> emission factors, oxidation factors and net caloric values (NCV) by fuel

Fuels	Year	NCV	Unit	Emission factor g CO <sub>2</sub> /MJ	Oxidation factor	Source of emission factor
<b>Liquid fuels</b>						
Town gas	all	16.9	GJ/1000 m <sup>3</sup>	59.4	1	Neste 1993
Refinery gas (+ other gases)		49.4 (45-55)	GJ/t	49.6-60.8	1	Plant-specific
LPG (liquefied petroleum gas)	1990-2012	46.2	GJ/t	65	1	Neste/ET2004
LPG (liquefied petroleum gas)	2013	46.3	GJ/t	64.9	1	SF 2014
Naphtha		44.3	GJ/t	72.7	1	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	1	EE/2006 IPCC GL
Diesel oil (fossil part)	1990-2012	42.8	GJ/t	73.6	1	VTT/Liisa Model/Neste
Diesel oil (fossil part)	2013	43.0	GJ/t	73.3	1	SF 2014
Gasoil (light fuel oil, heating fuel oil) (fossil part)	1990-2012	42.7	GJ/t	74.1	1	Neste/EE
Gasoil (light fuel oil, heating fuel oil) (fossil part)	2013	42.9	GJ/t	73.8	1	SF 2014
Gasoil (for non-road use) (fossil part)	1990-2012	42.8	GJ/t	73.6	1	EE (same as diesel oil)
Gasoil (for non-road use) (fossil part)	2013	42.9	GJ/t	73.8	1	SF 2014
Residual fuel oil (RFO, heavy fuel oil), low sulphur	1990-2012	41.1	GJ/t	78.8	1	Neste/EE
Residual fuel oil (RFO, heavy fuel oil), low sulphur	2013	40.4	GJ/t	79.2	1	SF 2014
Residual fuel oil (RFO, heavy fuel oil), normal	1990-2012	40.5	GJ/t	78.8	1	Neste/EE
Residual fuel oil (RFO, heavy fuel oil), normal	2013	40.2	GJ/t	78.4	1	SF 2014
Other residual fuel oil (heavy bottom oil)		40.2	GJ/t	79.2	1	Neste/EE
Petroleum coke		33.5 (20-36)	GJ/t	97 (90-102)	1	Plant-specific
Recycled waste oil		41	GJ/t	78.8	1	EE (=RFO)
Other petroleum products		35 (30-47)	GJ/t	78.8 (65-78.8)	1	EE (=RFO)
<b>Solid fuels</b>						
Anthracite		33.5	GJ/t	98.3	0.99	2006 IPCC GL
Hard coal (bituminous)	1990-2004	25.2 (21-32)	GJ/t	94.6	0.99	StatFi 2005
Hard coal (bituminous)	2005-2007	24.9-25.3 (23-31)	GJ/t	93.7-94.0	0.99	EE
Hard coal (bituminous)	2008-2013	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	107	0.99	2006 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	1	Gasum 2005
Natural gas		36.2	GJ/1000 m <sup>3</sup>	55.19	1	Gasum 2014

Fuels	Year	NCV	Unit	Emission factor g CO <sub>2</sub> /MJ	Oxidation factor	Source of emission factor
<b>Biomass fuels</b>						
Motor gasoline (biogenic part)		26.95-32.4	GJ/t	62.4-71.1	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	1	Neste/EE
Gasoil (for non-road use) (biogenic part)		44.1	GJ/t	70.9-71.8	1	Neste/EE
Biogenic parts of MSW/REF etc.		5-33	GJ/t	91-110	1	EE2015
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 sludge, waste paper, stink gas, etc.)		3-37 20	GJ/t GJ/1000 m <sup>3</sup>	109.6 59	0.99	1996 IPCC GL, VTT2045, EE
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	1	EE
Hydrogen		10.8	GJ/1000 m <sup>3</sup>	0		
<b>Other fuels, peat</b>						
Peat (milled)		10.1 [9.6-9.6]	GJ/t	105.9 [107.9-107.5]	0.99	VTT 2003 [2012-2013:ETS]
Peat (sod peat)		12.3 [12.1-11,7]	GJ/t	102 [104-103.9]	0.99	VTT 2003 [2012-2013:ETS]
Peat (pellets and briquettes)		18.0	GJ/t	97	0.99	VTT 2003
<b>Other fuels, wastes etc. (fossil parts)</b>						
Mixed fuels* (REF, RDF, PDF)		3-30	GJ/t	80-110	0.99	StatFi 2004, ETS, EE2015
Mixed fuels* (MSW)		10	GJ/t	80	0.99	StatFi 2004, EE2015
Gasified solid waste*		13.3 (7-30)	GJ/1000 m <sup>3</sup>	59	0.99	EE
Demolition wood*		8-15	GJ/t	114	0.99	StatFi 2004, EE2015
Impregnated wood*		12	GJ/t	114	0.99	StatFi 2004, EE2015
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	91	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, EE2015: 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)

October 2015

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, 2014: personal communication (Nupponen, 2015)

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

Fortum 2002: Composition of kerosenes (Fortum, 2004)

VTT 2003: Vesterinen 2003

SF 2014: Results from the project by Statistics Finland in which CO<sub>2</sub> emission factors and NCVs of liquid fuels were checked and updated based on information and measurement data received from oil refineries and importers.

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 later in this section.

Appendix\_3b presents the shares of each fuel in the fuel combustion subsector.

Properties of liquid fuels were partially checked and updated in a project during 2014. Emission factors used in the inventory (prior to 2013) were based on information received from Neste between years 2004-2008. The first focus was on the checking whether the emission factors of major liquid fuels (motor gasoline, diesel oil, light fuel oil, heavy fuel oil, LPG) were still applicable. In the project measurement and market data of liquid fuels in the Finnish oil market was gathered and based on this data new average CO<sub>2</sub> emission factors and NCVs suitable to Finnish conditions were calculated for LPG, diesel oil, gas oil and low sulphur residual fuel oil. New CO<sub>2</sub> emission factors are used only for 2013. Previously used emission factors are still applicable until around 2008-2010 since the largest changes that effect on the properties of oil products (for example biocomponents, changes in production processes and oil markets) have happened since then. However years between 2008-2012 as also the properties of motor gasoline still needs further investigation and possibly recalculation.

In Finnish inventory Solid fuels include hard coal, coke and other fuels (BFG, coke oven gas) derived from coal. These coal-based fuels are originally imported. Until 2007 the national CO<sub>2</sub> EF for hard coal is based on a research study described in Annex 7. In this study 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. 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. The verified values taken from the EU ETS in 2008-2013 are considered to be accurate. For years 2004-2007 country-specific CO<sub>2</sub> EF was estimated using the annual average NVC taken from EU ETS data.

Peat is one of the main fuels in Finland and it is a domestic energy source. In stationary combustion it is the fourth largest fuel (after wood, hard coal and natural gas), representing typically 4-7% of Total primary energy supply (TPES) and 6-10% of combustible fuels. The share of peat is generally around half of the share of hard coal, but varies considerable, like the share of hard coal, too. Due to local weather conditions in peat production and storage areas in 2012 and again in 2013, 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 2013 NCV of milled peat was 6% lower and CO<sub>2</sub> EF was 1.5% higher than default. This has been taken into account using national annual values in 2013 calculation instead of national default values of milled peat and sod peat. These exceptional annual values are shown in square brackets in Table 3.2-4.

Properties of peat and hard coal are summarized in Table 3.2-5.

**Table 3.2-5** 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

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 applicable. However, the latest data received from Gasum (Nupponen, 2015) show, that the NCV and EF have started to change slightly. For 2013 the CO<sub>2</sub>EF was 55.19 g/MJ, as the default NCV was 36.2 MJ/m<sup>3</sup>n. Starting from 2013 data, these values are checked annually.

The calculation of mixed fuels has been changed in this submission. Each reported batch of mixed fuels has been split to fossil and biogenic part, using either a default share for each type of mixed fuel or plant specific values based on the ETS data. In certain cases the operators participating EU ETS are obliged to measure plant specific CO<sub>2</sub> emission factor for each fuel from 2008 on. Using this data, the share of fossil/non-fossil energy can be adjusted.

There are changes in refinery processes, which partly explain the declining trend in the CO<sub>2</sub> IEF of refinery gas from 2004 to 2005. The output palette of the refineries has been developed to get lighter products (gasoline, LPG, diesel oil) instead of heavy fuel oil which also led to much higher use of natural gas based in the plant. These clearly affect the properties of refinery gases, because releases of methane and hydrogen are also collected to fuel gas system. Plant-specific default NCV and CO<sub>2</sub> EF values for 1990-2004 (prior to EU ETS) are re-estimated using EU ETS 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 Ltd 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.

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. We are expecting some new results concerning emission factors for small combustion. The whole set will be checked during 2015-2016.

CH<sub>4</sub> and N<sub>2</sub>O emission factors by main category/fuel are presented in Table 3.2-6 and Table 3.2-7.

**Table 3.2-6** 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
Gas fired boiler	60 (> 80% gas) and 86 (50% - 80% gas)	All / <1	5
		All / >1	1
Soda recovery boiler	70 (> 80% black liquor)	All / <1	5
		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 (combined cycle power plant)	All / < 5	3
		All / > 5	1
Engines	141 (diesel power plant, oil) and 143 (diesel power plant, other liquid fuel)	Diesel / < 50	4
		Diesel / > 50	2
Gas engines	142 (natural gas fired engines) and 143 (biogas fired engines)	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

Type of installation	Main category	Combustion technique* / Fuel capacity, MW	Emission factor, mg/MJ
	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 3.2-7** 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
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>

## *Emission factors vs. implied emission factors of CH<sub>4</sub> and N<sub>2</sub>O*

In a bottom-up-system there are always some sub-sectors which consist of a very small number of plants. In a small set of plants (or actually plant - fuel combinations) there may be different technologies, which have different emission factors. The changes in annual operation of plants easily change the share of each fuel and each plant within the sub-category, which is immediately reflected in the implied emission factors. In the Finnish inventory this can be seen in many cases and we think that it is normal variation. We check these variations when data are imported to CRF reporter and study the reasons. The changes in individual plants are always confidential information, thus they cannot be reported in the NIR. It would also be totally frustrating to report all these change, because there are many of them in the time series.

This type of bottom-up system differs from the situation, where emission factors have been defined for sector-fuel combinations using top-down-estimates. It seems clear, that implied emission factors are more unstable in a bottom-up system.

### *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 6). 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 end-of-pipe 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:

- data from the emission trading system (by the Energy Authority)
- 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).

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 annually.

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 starting from 2005. 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, starting 2012.

## **Waste combustion**

Energy use of waste is increasing significantly in Finland in the near future. There are six waste incineration plants in operation in Finland at the moment, and two new plants are under construction. Waste incineration capacity will increase from the current 1 million t/a to about 1.5 million t/a by the end of 2016. 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/or biomass as primary fuel. The annual amount of waste co-incinerated about 400,000 – 500,000 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.

As described in the beginning of this section, in this submission waste derived fuels are for the first time split to fossil and biogenic parts. The split is done as expert estimate by StatFi (fuel data collection does not originally include this split). Fossil parts are included in “Other Fuels” and biogenic parts in ”Biomass”.

Fuel combustion totals by fuel (PJ) as well as greenhouse gas emissions by fuel for 1990-2013 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 3.2-8 and Table 3.2-9.

**Table 3.2-8** Fuel consumption in Energy industries (CRF 1.A 1) (PJ)

		1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Liquid fuels	Heavy fuel oil	16.0	21.1	19.3	19.5	21.2	21.6	17.3	16.5	17.6	16.3	13.4	15.7	17.0	11.8	10.8	6.8
	Light fuel oil	0.5	1.1	0.9	1.4	1.3	1.7	1.9	1.5	0.6	0.7	0.6	0.4	0.6	0.5	1.1	0.6
	Refinery gases	16.1	16.8	15.4	16.3	18.6	17.3	16.1	16.3	17.7	19.0	17.4	20.5	18.4	20.3	19.4	18.1
	Other liquid fuels	3.9	4.3	4.7	4.3	4.6	4.5	4.6	4.4	4.9	5.6	5.5	5.7	5.1	5.4	4.7	5.3
Solid fuels	Hard coal	99.2	105.9	88.0	109.6	128.4	186.1	161.2	73.2	159.3	137.2	89.4	111.1	139.3	98.8	79.9	110.8
	Other solid fuels	2.1	3.2	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	4.0
Gaseous fuels	Natural gas and other gaseous fuels	47.9	68.8	94.9	103.8	104.7	121.5	115.8	104.4	111.9	97.0	104.0	94.8	104.5	88.9	81.0	70.2
Biomass	Woodfuels	3.0	16.1	34.5	37.8	49.5	56.1	59.2	59.0	61.7	53.3	66.9	63.6	81.7	87.1	91.7	94.1
	Biogas	NO	0.1	0.1	0.1	0.2	0.3	0.3	1.0	0.8	1.0	1.1	0.9	0.4	0.3	0.3	0.3
	Other non-fossil fuels	NO	0.39	0.27	0.37	1.54	1.87	2.70	3.57	3.22	4.58	5.19	5.66	5.88	5.56	6.42	7.30
Peat	Peat	37.7	63.4	49.8	74.0	80.2	86.6	76.2	55.6	77.6	85.3	65.6	59.4	79.5	70.4	52.0	45.1
Other fuels	Mixed fuels and waste	0.01	0.43	1.43	2.13	1.08	1.29	1.54	1.53	1.01	1.38	1.73	2.35	2.22	2.09	3.06	3.45

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 3.2-9** Fuel consumption in Manufacturing industries and construction (CRF 1.A 2) (PJ)

		1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Liquid fuels	Heavy fuel oil	34.2	27.7	22.6	22.5	21.7	20.0	20.9	18.4	18.5	17.1	12.9	10.4	11.2	10.5	9.8	8.3
	Light fuel oil	17.5	17.0	19.2	19.3	19.4	19.3	19.1	19.2	19.3	20.1	20.2	16.4	18.3	19.3	19.9	20.0
	LPG	4.5	4.7	8.4	8.2	8.3	9.1	9.6	10.0	10.5	9.9	9.7	8.1	9.2	9.1	8.8	8.1
	Refinery gases	5.0	5.7	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	8.9
	Recycled waste oil	0.5	0.5	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	0.6
	Other liquid fuels	2.7	2.2	1.7	1.2	1.8	1.6	2.1	2.2	2.1	2.2	2.0	1.6	1.6	2.2	2.2	2.5
Solid fuels	Hard coal	28.4	16.4	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	3.4
	Coke	5.9	4.9	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	1.2
	Other solid fuels	9.0	11.9	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	11.5
Gaseous fuels	Natural gas and other gaseous fuels	39.9	43.1	39.8	41.3	39.4	38.7	39.8	36.4	38.8	42.5	39.8	32.2	35.9	33.8	27.0	29.9
Biomass	Woodfuels	42.1	43.9	51.0	47.1	39.6	39.9	44.2	38.8	41.3	38.4	38.3	34.1	34.8	34.9	37.8	41.1
	Black/sulphite liquor	87.4	111.1	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	140.7
	Biogas	0.1	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.4	0.8	1.2	1.4	1.4
	Other non-fossil fuels	1.3	1.5	2.1	2.1	1.8	2.1	2.1	2.2	2.7	2.4	2.7	3.6	3.9	3.6	3.9	4.4
Peat	Peat	14.1	14.9	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	9.4
Other fuels	Mixed fuels and waste	1.1	1.1	1.9	2.1	2.4	2.7	2.6	2.4	2.5	2.4	2.5	3.0	3.0	2.8	3.9	5.4

Other liquid fuels includes e.g. petroleum coke.

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

### 3.2.4.3 Uncertainties and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

Uncertainty in fuel combustion (CRF 1.A) in total was  $\pm 1\%$  in Finland in 2013.

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\_App\_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, the second period from 2008 and the third period from 2013. 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, peat, SRF and refinery gases.

In 2015 submission a new type of time series correction has been launched. Country specific default values for NCV and CO<sub>2</sub> EF (prior to measured ETS data) have been re-estimated using the data taken from EU ETS. This approach was taken for refinery gases (1990-2004) and hard coal (2005-2007).

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 2013 was chosen to be 2%. As described in Section 3.2.4.2 CO<sub>2</sub> EF for peat in 2012 and 2013 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 category (see Section 1.6). A detailed description of the methodology of the uncertainty will be available in submission 2014.

Minor inconsistencies in the earlier inventories caused by missing data of some plants, changing classifications, etc. are corrected annually. Overall, methodologies and data sources are 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 category and fuel category level.

#### 3.2.4.4 Category-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 1.2.3. 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 is held annually between the inventory unit and the sectoral expert.

#### *QC procedures*

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.

Checking of installations' combustion technology and other technical properties is performed continuously and minor corrections is done annually.

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

- ILMARI/VAHTI, installation data
- ETS, installation data (in some cases production site data)
- manufacturing industry fuel survey; local kind-of-activity-unit data
- electricity and heat 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. 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.

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 3.2-10.

**Table 3.2-10** The results of the point source QC procedures for 2013 data

	Number	Quantity	PJ
Fuel records total (corrected values)	3 211	49 589	687
Fuel records original	1 784	43 733	585
Non-corrected original	1 432	23 818	323
Imputed fuel records	1 457	8 841	106
TJ corrected	131	0	-4
Quantity corrected	35	-2 627	0
Quantity and TJ corrected	143	-1 525	-35
Fuel code corrected	65	259	-58
Total corrected records (net Quantity and PJ corrections)	1 779	5 855	-0,1

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.

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.

### QA procedures

During 2014 the comparison of different statistics of total amounts of sold oil products, including bioshares, to Finnish markets was started together with Energy Statistics, Finnish oil companies and Finnish Petroleum Federation. The work will continue in 2015 and as a result Statistical differences will most likely decrease.

In 2014 inventory unit together with energy statistics team visited in one Finnish steel production plant. During the visit the material flows and emission measurements of the plant were studied and compared to the inventory information. As a result a new fuel code was included to the Finnish fuel classification and as regards to classification Finnish response to IEA survey was slightly changed. Also, the assumptions behind the inventory calculations were checked and found suitable.

Nordic co-operation has occasionally been used as quality assurance tool. 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 at that time 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. In 2015, a Nordic greenhouse gas inventory experts meeting, which included participants from Finland, Sweden, Norway and Denmark, was held in Helsinki. In this meeting several issues concerning the energy sector were discussed. Also approaches and EFs were

compared. The topics discussed included confidentiality issues, the use of ETS data, the use of emission and oxidation factors, small scale combustion and road transport. It was decided to continue co-operation in order to get input to the QA and verification of inventory data and to create a network for sharing information.

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.

### *Verification*

Sectoral approach of Energy sector is annually compared to Reference approach and differences are explained (see Section 3.2.1).

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.

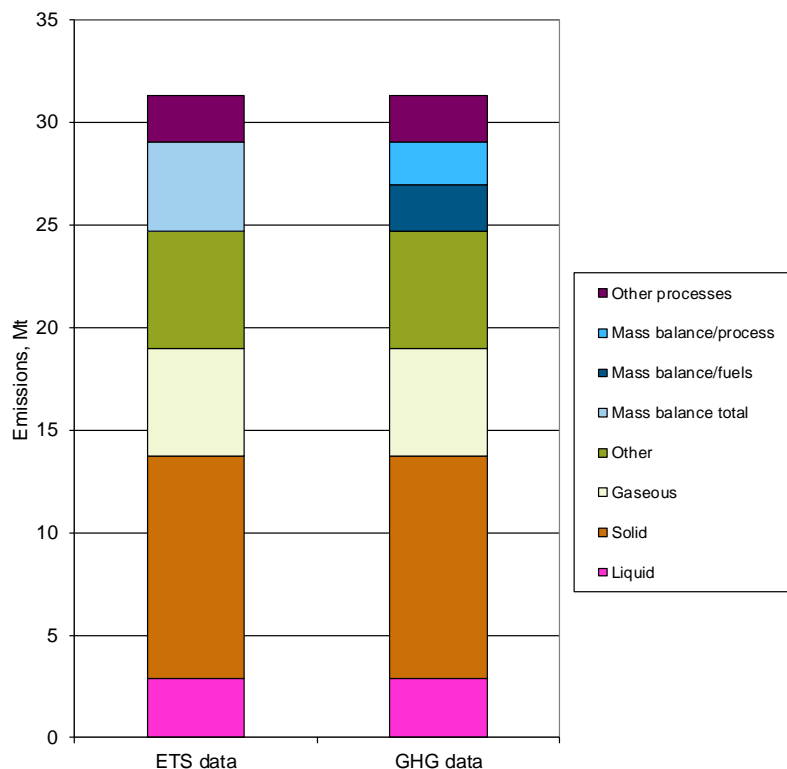
Finnish Environment Institute calculates the final data for the UNECE Air Pollutant inventories. The calculation system is separate from the GHG calculation system, but uses mostly the same basic data sources for calculation of emissions from fuel combustion. This independent calculation system is used 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. The thorough comparison between Air pollutant and GHG inventory in accordance with the EU Regulation 525/2013 is performed after 15 February and the differences are either corrected or accounted for by the 15 March submissions (Annex 9).

### **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 31.3 Mt in 2013. The corresponding amount taken from the GHG inventory data was 31.3 Mt. The calculation method of amount of transferred emission in the GHG data is explained in Section 3.4.1. The difference between the ETS and GHG data is 0.01 Mt, 0.02% of total ETS. There are more differences in the allocation of emissions to CRF categories, which can be seen in Figure 3.2-4. (Note: These results are based on the first calculations, and do not take into account the change in default oxidation factors, that was applied during the second round)

The most important difference is in the Iron and steel sector, which is almost totally allocated to Industrial Processes and Product Use 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 and Product Use. 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 and Product Use in the ETS.



**Figure 3.2-4** CO<sub>2</sub> emissions of ETS plants compared with the corresponding emissions reported in the greenhouse gas inventory in 2013. 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  $\pm 2\text{--}10\%$ ). 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 0.1% in 2013.

The change in default oxidation factor for liquid and gaseous fuels (due to 2006 GL) will introduce some more difference in the ETS and GHG data, but that will be studied later.

#### 3.2.4.5 Category-specific recalculations

Based on the recommendations by the ERT, time series of refinery gases were studied and some erroneous/unreliable activity, NCV and CO<sub>2</sub> emission factor data were discovered.

In one plant clearly unreliable activity data were corrected. Discussions with the plant staff (Ryypö, 2015) showed, that there are no reliable direct sources for revised activity data available for the early years (beginning of 1990's). The most reliable (and the only reliable) data for the whole time series are feedstock input data [ktonnes of feedstocks]. It was decided to use that data as a starting point to re-estimate the total production of refinery gases. Production of refinery gases in 1990-2004 was calculated as constant share from the feedstocks. The share was judged as the average from more reliable recent data (2005-2013).

For each plant, plant specific default NCVs and CO<sub>2</sub> EFs for 1990-2004 have been calculated as average from 2005-2013 ETS data. In one plant the changes in the input/output palettes (ranges) have been taken into account in the estimation of CO<sub>2</sub> EF. Therefore the CO<sub>2</sub> EF is slightly higher in 1990-2004 than in later years (the increased use of hydrogen and natural gas are expected to lower the CO<sub>2</sub> EF).

Time series consistency of CO<sub>2</sub> emission factor of hard coal for years 2004-2007 has been discussed in previous reviews. A new estimation method was applied to country-specific CO<sub>2</sub> EF for these years (2005-2007), where measured EFs were not available from the ETS. Annual average CO<sub>2</sub> EF was estimated using the annual average NCV and the correlation of NCV and CO<sub>2</sub> EF based on the ETS data 2008-2013. CO<sub>2</sub> EF was lowered from 94.6 to 93.3-94.0 t/TJ in 2005-2007. No change was made for 2004, because the uncertainty in the average NCV is judged to be somewhat higher than in later years.

Default CO<sub>2</sub>-emission factor for coke was changed from 108 to 107 t/TJ to follow 2006 IPCC Guidelines values.

Oxidation factors for liquid and gaseous fuels were changed from national default (0.995) to 2006 IPCC Guidelines value (1). For solid fuels default value 0.99 is still being used. The background for this decision was, that there are a small number of coal fired power plants, that measure the oxidation factor and report the values in ETS data. Based on these very few results we regard 0.99 as a good approximation for solid fuels (the same decision was applied to peat and wood fuels, which are allocated to other fuel categories).

Mixed fuels (MSW, SRF,..) were separated to fossil and biogenic part. In previous inventories the energy content of mixed fuels was reported totally in fossil category (Other fuels). CO<sub>2</sub> emissions were calculated using combined EF (fossil CO<sub>2</sub> / total energy). Now each fuel batch has been split to fossil and biogenic part and CO<sub>2</sub> and biogenic CO<sub>2</sub> emissions have been calculated separately. Due to this, 7,798 PJ of energy has been moved from Other fuels to Biomass. Corresponding amounts of CH<sub>4</sub> (25.8 t) and N<sub>2</sub>O (25.5 t) emissions have also been moved. In addition, the biogenic CO<sub>2</sub> emission have been increased by 823.9 kt (in previous inventories biogenic CO<sub>2</sub> from mixed fuels was not taken into account).

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. These corrections were made to take into account the latest updates in the Energy Statistics data.

#### 3.2.4.6 Category-specific planned improvements

The possibilities of reviewing Energy sector or part of it by an independent third party have been considered after the 2016 submission when 2006 IPCC Guidelines are fully in use and incorporated totally to the production processes of energy sector. 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.

Properties of liquid fuels were partially checked and updated in a project during 2014. New CO<sub>2</sub> emission factors for LPG, diesel oil, gas oil and low sulphur residual fuel oil are used only for 2013. Previously used emission factors are still applicable until around 2008-2010 since the largest changes that effect on the properties of oil products (for example biocomponents, changes in production processes and oil markets) have happened since then. However years between 2008-2012 as also the properties of motor gasoline still needs further investigation and possibly recalculation. One goal of the project is also to establish a plan for regular checking (e.g. annually or every 3/5 years) of these emission factors (annual monitoring?).

In the Finnish inventory default CO<sub>2</sub>-emission factors from 1996 IPCC Guidelines are still being used for most of woodfuels. Revising of the emission factors for woodfuels will be considered when more information is gathered from the stakeholders and the industry.

Possibility to provide disaggregated data on the most important fuels included in the other fuels categories will be considered further after the implementation of new data production system of energy sector in 2017.

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

#### 3.2.5.1 Category description

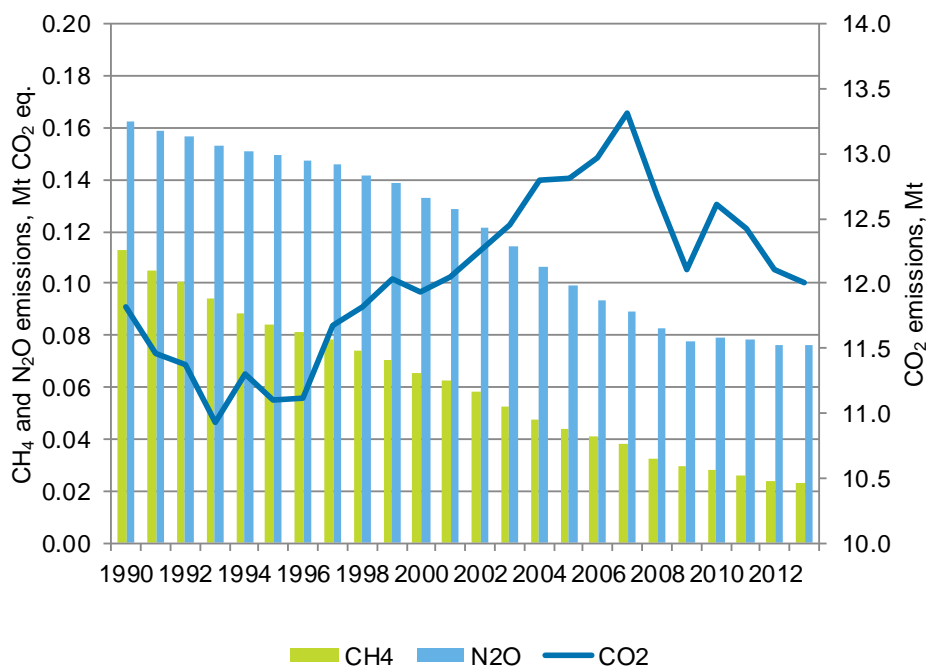
In 2013, the greenhouse gas emissions from transportation amounted to 12.1 Mt CO<sub>2</sub> equivalent. Compared to 2012 emissions declined 1% (0.11 Mt CO<sub>2</sub> eq.) in 2013. The share of the transport sector of the total greenhouse gas emissions is at similar level as in 1990, and it was approximately 17% (12.1 Mt CO<sub>2</sub>) in 1990 and 19% in 2013. 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 2013 compared to 2012 has stayed around stable due to the growing share of biofuels in road transport which restrains the otherwise growing emissions due to increasing kilometrage.

Emissions from Transport (CRF 1.A 3) include all domestic transport sectors: civil aviation, road transport, railways, domestic navigation and pipeline transportation (Table 3.2-11). The trend in the emissions of these categories is given in Figure 3.2-6 and in Table 3.2-12. In Figure 3.2-5 the emissions of the transport category are given by gas. Emissions from categories 1.A.3bii, 1.A.3biii and 1.A.3biv are included in category 1.A.3bi as ILMARI system (See Section 3.1.4) does not currently support reporting at more disaggregated level. Emissions from off-road vehicles and other machinery are reported in Manufacturing industries and construction (CRF 1.A.2) and Other sectors (CRF 1.A.4).

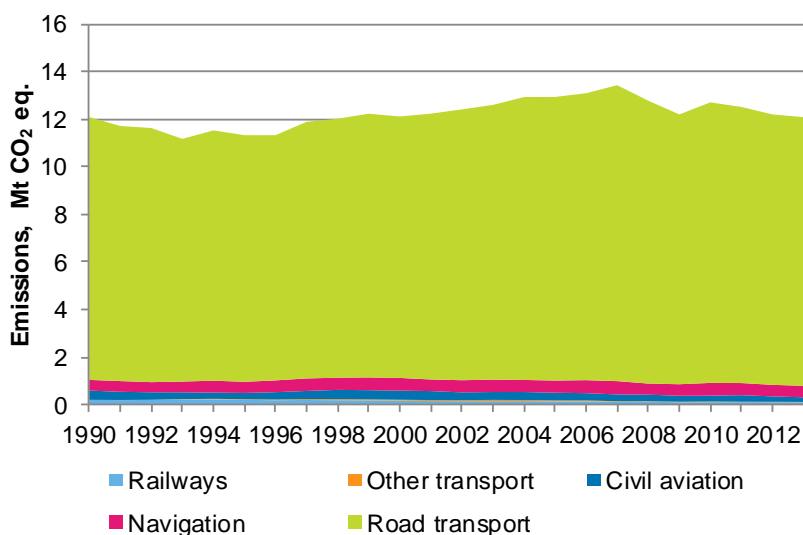
**Table 3.2-11** Reporting categories in the transport category

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.
bi-iv. Road Transport	Transport on roads by vehicles with combustion engines: cars, vans, buses, coaches, lorries, articulated vehicles, motorcycles and mopeds and minicars (quadricycles). Emissions from 1A3bi-iv are reported aggregated in 1A3bi.	Farm and forest tractors driving on roads are included in CRF 1.A.4ciii 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.4ciii.
e. Pipeline Transportation	Emissions from pipeline transportation is received from the VAHTI system	

Reporting category	Description	Remarks
Off-Road vehicles and other machinery	Non-road machinery and other vehicles from the TYKO model cover several types of machines, for example road maintenance tractors, forklifts, all-terrain vehicles and snowmobiles.	Off-Road vehicles and other machinery are reported in following CRF Categories: 1.A.2gvii Manufacturing industry and construction 1.A.4aii Commercial/institutional 1.A.4bii Residential 1.A.4cii Agriculture and forestry



**Figure 3.2-5** Emissions from transport sector by gas (Mt CO<sub>2</sub> eq.)



**Figure 3.2-6** Emissions from transport by subcategory (Mt CO<sub>2</sub> eq.)

Road transportation is the most important emission source in transport, covering over 94% of sector's emissions in 2013. The emission trends for each sub-category are discussed in corresponding sections.

### 3.2.5.2 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 Ltd.

The LIPASTO system is comprised of four sectoral submodels:

- road transport emissions model LIISA
- domestic navigation emissions model MEERI and
- railways emissions model RAILI
- non-road machinery model TYKO.

VTT is responsible for running the calculation models LIISA, MEERI, RAILI and TYKO. Finavia has estimated the emissions from aviation for the years 1990-2008. For 2009-2013, the aviation emissions were estimated based on simpler calculations (see Section 3.2.5.3). 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 the 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 3.2.2).

The fuel consumption in the transport sector in 1990-2013 can be seen in Table 3.2-13.

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 3.2-14 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 3.2-14. 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 in emission factors due to the fuel shift have been included in the transport emission calculation submodels.

#### *Bioshares of transport fuels*

Increasing amounts of biogenic additives or biofuels are mixed in transport fuels and some other liquid fuels (Table 3.2-15). Data sources, calculation methods and emission factors concerning the shares of biocomponents in transport fuels (bioshares) are described in sections dealing with the main consumption categories of these fuels: 3.2.5.4 (gasoline, diesel oil and biogas), 3.2.5.7 (non-road gasoil) and 3.2.6 (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 3.2-4 have been calculated using NCVs and

shares of different biocomponents in gasoline and diesel oil (see also Section 3.2.5.4). 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 3.2-12** Emissions from the Transport sector by subcategory (Mt CO<sub>2</sub> eq.)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<b>Total</b>	<b>12.1</b>	<b>11.3</b>	<b>12.1</b>	<b>12.2</b>	<b>12.4</b>	<b>12.6</b>	<b>12.9</b>	<b>12.9</b>	<b>13.1</b>	<b>13.4</b>	<b>12.8</b>	<b>12.2</b>	<b>12.7</b>	<b>12.5</b>	<b>12.2</b>	<b>12.1</b>
<b>CO<sub>2</sub></b>																
<b>3. Transport</b>	<b>11.8</b>	<b>11.1</b>	<b>11.9</b>	<b>12.1</b>	<b>12.2</b>	<b>12.4</b>	<b>12.8</b>	<b>12.8</b>	<b>13.0</b>	<b>13.3</b>	<b>12.7</b>	<b>12.1</b>	<b>12.6</b>	<b>12.4</b>	<b>12.1</b>	<b>12.0</b>
a. Civil aviation	0.39	0.26	0.38	0.37	0.32	0.33	0.33	0.32	0.30	0.28	0.27	0.25	0.24	0.27	0.22	0.19
b. Road transportation	10.8	10.2	10.8	11.0	11.2	11.4	11.8	11.8	12.0	12.3	11.8	11.3	11.7	11.5	11.3	11.2
c. Railways	0.19	0.19	0.16	0.14	0.14	0.14	0.14	0.13	0.13	0.11	0.12	0.09	0.10	0.10	0.10	0.09
d. Navigation	0.44	0.46	0.53	0.48	0.50	0.51	0.50	0.50	0.54	0.55	0.46	0.48	0.53	0.50	0.48	0.48
e. Other transportation	0.002	0.025	0.036	0.044	0.043	0.055	0.047	0.041	0.039	0.027	0.019	0.021	0.029	0.016	0.017	0.013
<b>CH<sub>4</sub></b>																
<b>3. Transport</b>	<b>0.113</b>	<b>0.084</b>	<b>0.065</b>	<b>0.063</b>	<b>0.058</b>	<b>0.053</b>	<b>0.048</b>	<b>0.044</b>	<b>0.041</b>	<b>0.038</b>	<b>0.033</b>	<b>0.030</b>	<b>0.028</b>	<b>0.026</b>	<b>0.024</b>	<b>0.023</b>
<b>N<sub>2</sub>O</b>																
<b>3. Transport</b>	<b>0.163</b>	<b>0.149</b>	<b>0.133</b>	<b>0.129</b>	<b>0.121</b>	<b>0.114</b>	<b>0.106</b>	<b>0.099</b>	<b>0.093</b>	<b>0.090</b>	<b>0.083</b>	<b>0.078</b>	<b>0.079</b>	<b>0.079</b>	<b>0.076</b>	<b>0.077</b>
a. Civil aviation	0.005	0.003	0.005	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.003	0.003	0.004	0.003	0.003
b. Road transportation	0.154	0.142	0.124	0.120	0.113	0.106	0.098	0.091	0.085	0.081	0.075	0.071	0.071	0.071	0.070	0.070
c. Railways	0.0015	0.0014	0.0010	0.0009	0.0008	0.0008	0.0008	0.0007	0.0007	0.0006	0.0006	0.0005	0.0005	0.0005	0.0005	0.0004
d. Navigation	0.0028	0.0029	0.0035	0.0031	0.0033	0.0034	0.0032	0.0033	0.0036	0.0037	0.0033	0.0034	0.0038	0.0037	0.0034	0.0034
e. Other transportation	0.0000	0.0001	0.0002	0.0002	0.0002	0.0003	0.0003	0.0002	0.0002	0.0001	0.0001	0.0001	0.0002	0.0001	0.0001	0.0001

**Table 3.2-13** Fuel consumption by fuel type in transport (PJ)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<b>Civil aviation</b>																
Aviation gasoline	0.11	0.08	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	0.03
Jet kerosene	5.15	3.51	5.11	5.02	4.36	4.41	4.49	4.34	4.08	3.80	3.69	3.37	3.28	3.66	3.04	2.60
<b>Road transportation</b>																
Gasoline	80.7	76.7	71.2	72.2	73.5	73.8	75.1	74.9	74.2	74.1	66.3	64.0	62.6	59.2	56.8	57.1
Diesel oil	66.9	62.1	76.5	78.1	79.8	81.9	85.5	86.2	88.9	94.3	94.6	89.6	97.0	98.0	97.1	96.3
Natural gas	NO	NO	0.05	0.06	0.11	0.13	0.12	0.11	0.15	0.16	0.17	0.21	0.20	0.16	0.16	0.11
Liquid biofuels	NO	NO	NO	NO	0.03	0.18	0.19	NO	0.03	0.08	2.94	5.43	5.75	8.16	8.03	9.18
Gaseous biofuels	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	0.039
<b>Railways</b>																
Gasoil	2.58	2.61	2.17	1.92	1.85	1.84	1.88	1.73	1.76	1.48	1.57	1.25	1.30	1.34	1.29	1.25
Liquid biofuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.012	0.021	0.025	0.009	0.001
<b>Navigation</b>																
Residual oil	1.56	1.79	2.23	1.69	1.94	2.12	1.82	1.74	1.84	1.96	1.61	1.70	1.74	1.85	1.64	1.23
Gasoil	2.52	2.44	2.82	2.76	2.81	2.78	2.92	3.09	3.37	3.41	2.58	2.66	3.19	3.19	2.99	3.26
Gasoline	1.80	1.88	1.94	1.93	1.96	1.92	1.92	1.92	1.99	2.00	1.56	1.54	1.62	1.22	1.25	1.39
Diesel oil	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.41	0.47	0.52	0.46	0.52	0.51
Liquid biofuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.06	0.11	0.15	0.16	0.13	0.10
<b>Other transportation</b>																
Natural gas	0.04	0.45	0.65	0.80	0.79	1.00	0.85	0.75	0.71	0.49	0.35	0.39	0.53	0.29	0.31	0.24

**Table 3.2-14** The allocation of diesel oil, heating gasoil and non-road gasoil; numbers include bioshares (PJ)

PJ (including bio-shares)		1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Road transportation	Diesel oil	66.9	62.1	76.5	78.1	79.8	81.9	85.5	86.2	88.9	94.3	95.1	92.0	99.6	102.5	101.4	102.7
Leisure boats		0.45	0.46	0.48	0.48	0.48	0.47	0.47	0.47	0.48	0.48	0.4	0.5	0.5	0.5	0.5	0.5
Domestic navigation	Non-road gasoil	4.45	4.11	4.24	4.09	4.16	4.14	4.11	4.20	4.57	4.56	4.15	4.25	4.77	4.76	4.53	4.86
Railway transport		2.58	2.61	2.17	1.92	1.85	1.84	1.88	1.73	1.76	1.48	1.57	1.26	1.32	1.37	1.30	1.26
Off-road vehicles and other machinery		29.39	28.33	30.36	30.60	30.74	30.76	30.74	30.82	30.80	31.48	31.78	27.61	29.64	30.73	31.88	31.48
Energy production, heating, industry	Light fuel oil (=heating gasoil)	68.89	63.17	59.26	61.77	60.13	59.33	57.91	53.30	50.56	47.71	41.75	41.85	44.98	37.10	39.59	36.01
Total gasoil + diesel oil		172.6	160.8	173.0	176.9	177.1	178.4	180.6	176.7	177.1	180.0	174.7	167.5	180.9	176.9	179.2	176.9

**Table 3.2-15** Amount of biocomponents of liquid fuels and avoided fossil CO<sub>2</sub>, 2002-2013 (TJ)

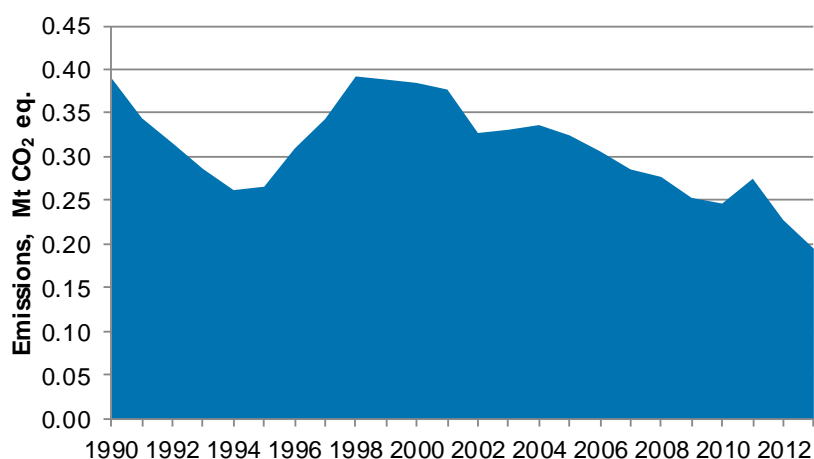
	Gasoline	Diesel oil	Non-road gasoil	Heating gasoil	Biogas	Avoided fossil CO <sub>2</sub> , kt
2002	33	NO	NO	NO	0.0	2
2003	176	NO	NO	NO	0.1	13
2004	186	NO	NO	NO	0.1	14
2005	NO	NO	NO	NO	0.1	0
2006	34	NO	NO	NO	0.1	3
2007	71	5	NO	NO	0.2	6
2008	2 704	437	NO	NO	0.3	229
2009	3 209	2 460	415	546	1	486
2010	3 401	2 614	929	715	2	561
2011	3 881	4 583	655	665	6	718
2012	4 034	4 334	245	248	15	650
2013	2 980	6 500	40	41	39	704

### 3.2.5.3 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 0.19 Mt CO<sub>2</sub> eq. in 2013. Emissions declined 14% compared to 2012. In 1990 emissions were 0.39 Mt CO<sub>2</sub> eq. See Figure 3.2-7 and Table 3.2-16.

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 2013.



**Figure 3.2-7** Emissions from domestic civil aviation (Mt CO<sub>2</sub> eq.)

**Table 3.2-16** Emissions, fuel consumption and number of flights or flight hours by fuel type in the Civil Aviation (1.A 3a) sector

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<b>Civil aviation, emissions, Mg CO<sub>2</sub> eq.</b>	0.39	0.27	0.38	0.38	0.33	0.33	0.34	0.32	0.31	0.29	0.28	0.25	0.25	0.27	0.23	0.19
<b>Aviation gasoline</b>																
Fuel consumption, PJ	0.110	0.079	0.079	0.065	0.053	0.054	0.045	0.039	0.050	0.048	0.046	0.043	0.043	0.041	0.031	0.025
Flight hours (general aviation)	97770	61365	60991	50644	41774	36000	35359	30160	38834	37362	36202	33581	33506	31806	24415	19852
<b>Jet kerosene</b>																
Fuel consumption, PJ	5.15	3.51	5.11	5.02	4.36	4.41	4.49	4.34	4.08	3.80	3.69	3.37	3.28	3.66	3.04	2.60
Number of flights (air transport)	70256	62599	76658	74066	66745	66876	67132	66509	68951	62458	63266	62282	56984	63358	55059	48358

## 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 3.2-8, Savola M. & Viinikainen M., 1995, in Finnish only). 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 submodel has been prepared by Finavia and the data have been fed to the ILMARI system (see Section 3.1.4).

For years 2009-2013, 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. For more information see Section 1.2.1.

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 Section 3.2.2).

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, and 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:

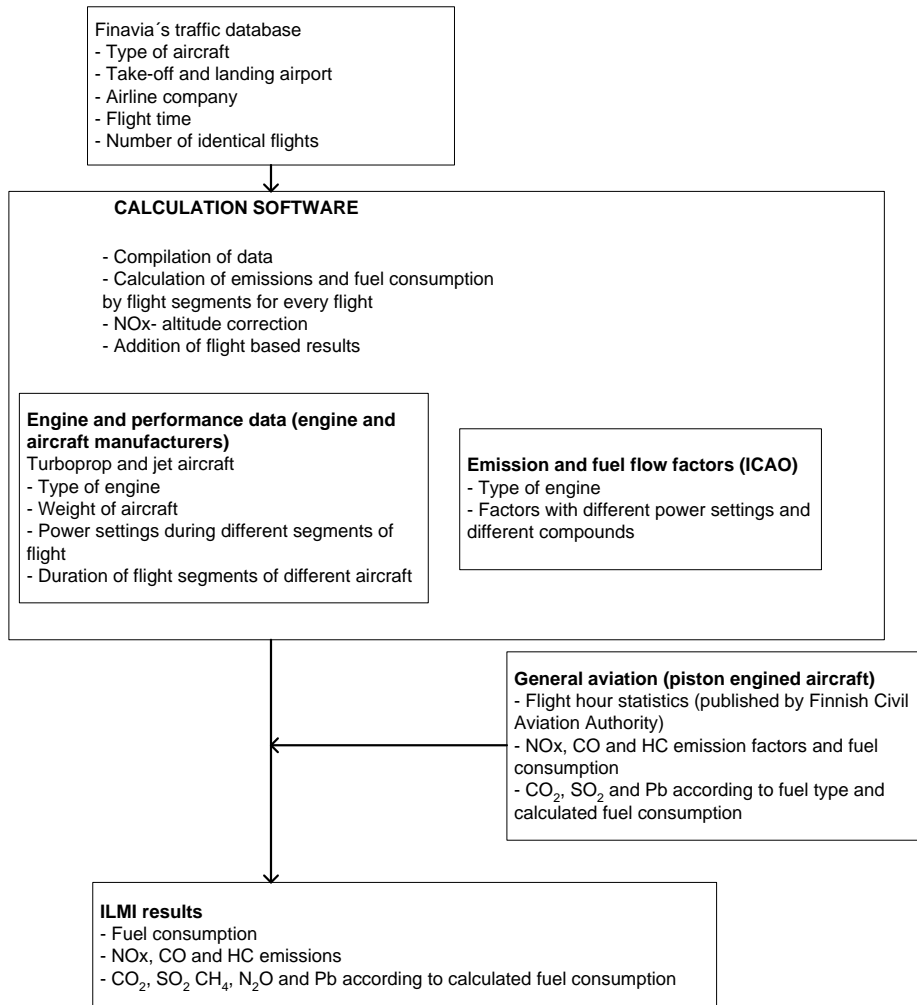
$$EMISSION\ per\ fs = EF\ per\ fs * FLIGHT\ TIME\ per\ fs * FF\ per\ fs * NUMBER\ OF\ ENGINES.$$

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 3.2-8** The ILMI calculation model

#### 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

### *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 3.2-4: jet fuel 73.2 g/MJ and aviation gasoline 71.3 g/MJ).

### *Uncertainties and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

A summary of the uncertainty analysis methodology used in the inventory is given in Section 1.6. Monte Carlo simulation has been used to combine the uncertainties of each calculation parameter in order to get the total uncertainty of the category.

The emissions estimate for the years 2009-2013 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 2009-2013, 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.

### *Category-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 overflight 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 3.2.2). 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).

### *Category-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 previous estimates were based on several data sources, which include partly contradictory data.

New time series including fuel data and emission data were received from Eurocontrol. Data on fuel consumption were directly taken from Eurocontrol data set. However, there are still some questions concerning emission CH<sub>4</sub> and N<sub>2</sub>O emission factors in this data set. Therefore average emission factors were taken from

previous year's calculations (ILMI model). The applicability of EFs based on Eurocontrol data set will be studied in the following submission.

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.

### *Category-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.

#### *3.2.5.4 Road transportation*

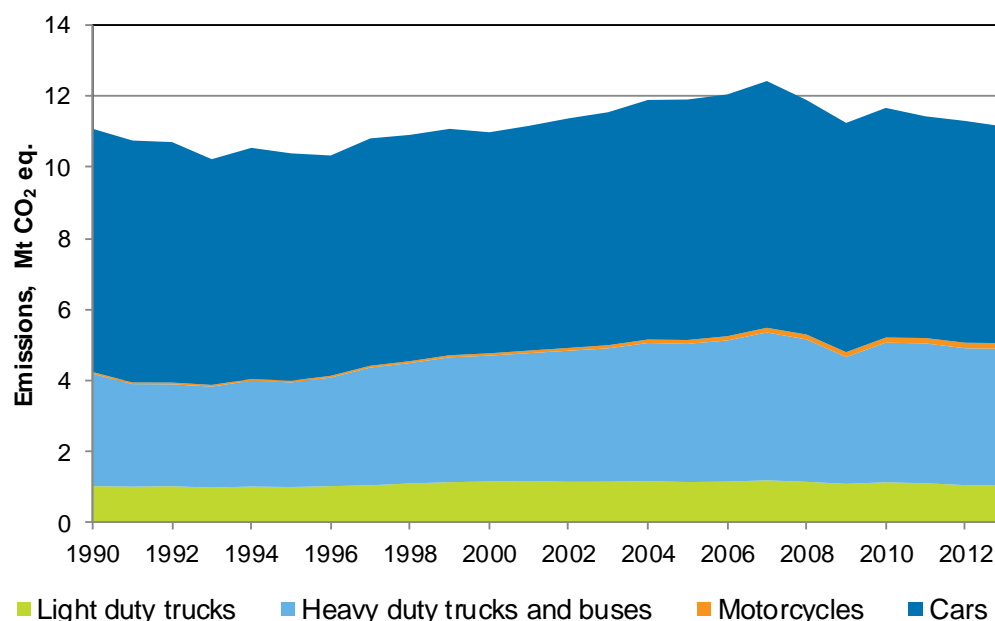
Road transportation (CRF 1.A 3b) covers all transportation on roads in Finland except farm and forest tractors driving occasionally on the roads or military vehicles. Types of vehicles with combustion engines are: cars, vans, buses and coaches, lorries and articulated vehicles, motorcycles and mopeds. Emissions from categories 1A3bii, 1A3biii and 1A3biv are included in category 1A3bi as ILMARI system (See section 3.1.4) does not currently support reporting at more disaggregated level.

Road transportation is the most important emission source in the Transport sector. The emissions of road transportation were 11.3 Mt (CO<sub>2</sub> eq.) in 2013; that was 94% of the sector's emissions and 18% of the total emissions. Compared to 2012 emissions declined 1%. Emissions were 11.1 Mt (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 3.2-9).

The main reason for emission growth is increased kilometrage. Fuel consumption per vehicle has stayed quite stable (see also Table 3.2-17). 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 2013 less than 1% of emissions in Road transportation.

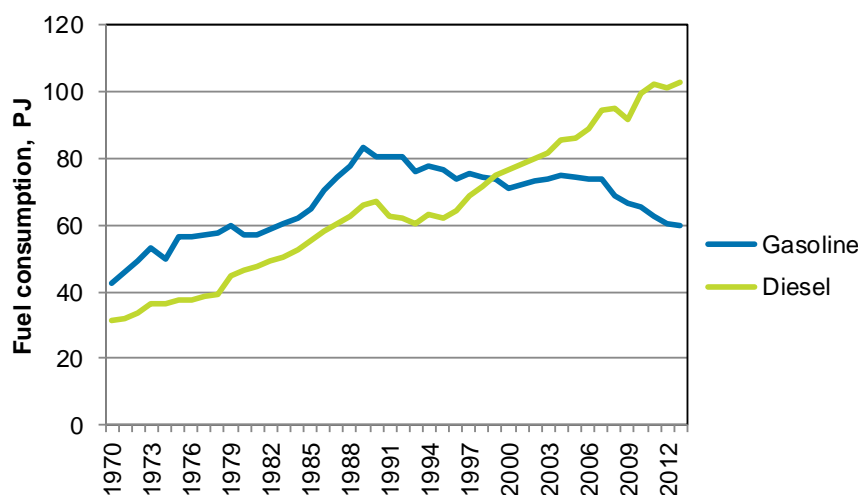
In 2008 the emissions deviated from the upward trend. The worldwide economic downturn that began 2008 decreased the emissions of all transport modes. At the same time, the change in Finland to CO<sub>2</sub> based taxation of cars has caused a transition from gasoline to diesel cars and lowered the specific 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 2013 compared to 2012 has continued downwards because of the prolonged economic downturn.



**Figure 3.2-9** Emissions from road transportation by types of vehicle (Mt CO<sub>2</sub> eq.) (The detailed transport calculation model LIPASTO of VTT Technical Research Centre of Finland Ltd)

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 3.2-10 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 3.2-10** Consumption of diesel oil and gasoline (including bioshares) in road transportation in the years 1970-2013 (Energy Statistics, Statistics Finland)

### 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 Ltd. 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 LIISA model has been totally renewed and the year 2013 is the first year calculated with the new model. Despite the renewal the calculation method is basically the same as in the old model. All emission factors have been checked and harmonised to comply with the 2006 IPCC Guidelines and EMEP/EEA 2013.

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 diesel oil in leisure boats. Hence the amount of fuels used for other purposes than road traffic is deducted from the total sales of fuels before the emission calculation (see under the paragraph Activity data). 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 quite small.

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). Finally, all emissions are summed up. The calculation model is described in Appendix\_3a at the end of Chapter 3.

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) 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 nation-wide 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 street types (main street, collector street, residential street, local plan road) based on information from traffic calculations in some cities.

Both public road and street mileage are divided according to the vehicle technology for every vehicle types: vehicles without catalytic converters, with catalytic converters, diesel, and gas (CNG). The division of kilometrage to vehicle types and technologies is done by a new ALIISA model, which is a vehicle fleet model and submodel to LIISA. The ALIISA model has 45 different vehicle types including gasoline, diesel, FFV (Flexible-fuel vehicle), ED95 (ethanol-diesel vehicle), gas, PHEV (plug-in hybrid electric vehicle), BEV (battery electric vehicle) and FCEV (fuel cell electric vehicle, hydrogen). Beside kilometrage the ALIISA model comprises data on vehicle sales, fleet, fuel consumption, biofuels, energy and CO<sub>2</sub> emissions. All this forecasted to the year 2050. The ALIISA model ensures that all foreseeable technologies can be included in the emission calculations. Furthermore, kilometrage is divided according to vehicle age (model year).

Motorcycle, moped and quadricycle kilometrage is specified in a separate model using the number of motorcycles, mopeds and quadricycles (from Statistics Finland) and estimation of yearly kilometrage of each vehicle 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 0 to 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 0 to Euro 3). Quadricycles (minicars) are diesel technology and emission standard is Euro 2.

For each automobile type, the cold driving emission and fuel consumption surplus is calculated according to the EMEP/EEA emission inventory guidebook 2013 (EMEP/EEA 2013)

### *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 59.8 PJ and in leisure boats and working machines 5.2 PJ (8.0% of total sales). Diesel fuel sales were 102.7 PJ of which use in leisure boats was 0.5 PJ (0.5% 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 3.2.5.7). Gasoline and diesel used in leisure boats are calculated with the MEERI model (See Section 3.2.5.6).

For modeling 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. 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 and vehicle fleet model ALIISA at VTT, street kilometrage systems of city of Helsinki and Espoo and population data of cities.

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

Road traffic kilometrage in Finland in 1990-2013 is presented in Table 3.2-17.

**Table 3.2-17** Road traffic kilometrage in Finland [Million km/a] (LIISA)

	Cars	Vans	Buses	Lorries	MC+Mopeds	Total
1990	35 757	3 593	660	2 780	467	43 257
1995	34 740	3 743	633	2 669	468	42 254
2000	38 698	4 266	596	3 009	607	47 177
2001	39 205	4 361	594	3 068	663	47 892
2002	39 651	4 452	600	3 232	733	48 667
2003	40 312	4 514	572	3 325	815	49 537
2004	40 660	4 591	594	3 389	902	50 136
2005	41 192	4 676	595	3 477	995	50 936
2006	41 259	4 779	595	3 561	1 107	51 302
2007	41 770	4 895	593	3 699	1 223	52 180
2008	41 102	4 945	606	3 767	1 299	51 718
2009	41 236	5 048	609	3 503	1 325	51 722
2010	40 990	5 136	611	3 727	1 384	51 849
2011	40 941	5 245	611	3 888	1 483	52 168
2012	40 359	5 298	616	3 901	1 518	51 691
2013	40 286	5 297	617	3 940	1 527	51 667

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 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, TAAE<sup>9</sup> and THxEE<sup>10</sup>
- biodiesel and synthetic biodiesel (mostly NEXBTL<sup>11</sup>-diesel)
- biogasoil mixed in the non-road gasoil (mostly NEXBTL-diesel)

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 2013 bioshares of gasoline and diesel oil were 4.6% and 6.3% 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 27%.

### *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 3.2-4). They differ slightly from those expressed in the IPCC guidelines. The emission factors are based on product analysis in Neste Oil laboratories and data from other oil product importers. Neste Oil is the leading company in oil product manufacturing in Finland (market shares for most important transport fuels vary between 50 and 100%). 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 3.2-4. 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 based on the EMEP/EEA 2013 report. Cold driving has been taken into account in defining the final factors.

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.

### *Uncertainties and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

A summary of the uncertainty analysis methodology used in the inventory is given in Section 1.6. Monte Carlo simulation has been used to combine the uncertainties of each calculation parameter in order to get the total uncertainty of the category.

<sup>9</sup> tertiary amyl ethyl ester

<sup>10</sup> tert-hexyl ethyl ether

<sup>11</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 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  $\pm 150\%$ .

There have been an inconsistency between kilometrage data and fuel sales. As the fuel sales is quite accurate there must be an error on kilometrage data. Also other studies have shown that the kilometrage data are wrong. As the CO<sub>2</sub> emission calculation is based on fuel sales the erroneous kilometrage data have affected only on CH<sub>4</sub> and N<sub>2</sub>O and other emissions that are based on kilometrage. This problem has now been solved when the kilometrage figures have been revised. Basic source for new kilometrage has been a study made by Statistics Finland (Statistics Finland 2010) where kilometrage were derived from odometer readings made in yearly inspections of vehicles. Based mainly on this study the kilometrage figures delivered originally by the Finnish Transport Agency have been changed by the following percentages.

**Table 3.2-18** Revision percentage of kilometrage for the year 2012

Vehicle type	Change, %
Cars	-12
Vans	18
Buses/coaches	1.3
lorries	23
Total	-7.5

### *Category-specific QA/QC and verification*

The quality management process and the QA/QC plan for the whole inventory are presented in Section 1.2.3. The QA/QC plan for the transport sector includes the QA/QC and verification measures based on 2006 IPCC Guidelines. 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 is held annually between the inventory unit and the sectoral expert.

During the renovation of the models several measures have been made to assure the quality.

- The year 2012 has been calculated both with the old and new models to see the effect of renovation
- CO<sub>2</sub> emissions have been calculated both in VTT and Statistics Finland
- Other gases have been compared to the data reported under the UNECE CLRTAP reporting by Finnish Environment Institute

International verifications have not yet been performed because figures produced according to the new guidelines and renovation have not yet been reported and there is no use to verify the old figures.

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.

Recalculations made for the year 2012 show the following emission amount differences between old and new LIISA models (Table 3.2-19). There are two main reasons that cause changes in the emission amounts; changes in kilometrage and changes in emission factors. The new models also include new vehicle technologies (FFV, gas, electric vehicles etc. as described in paragraph Methods) and for example urea additive AdBlue. As the CO<sub>2</sub> emissions are based on the fuel sales which are unchanged and CH<sub>4</sub> and N<sub>2</sub>O have only minor effect on GHG emission, the change in GHG emissions due to the renovation is small (-1%). Recalculations have been made for the whole time series 1990–2012 to ensure the time series' consistency.

**Table 3.2-19** Emission amount difference between old and new LIISA models.

2012	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO	NO <sub>x</sub>	SO <sub>2</sub>	HC
difference in %	1.3	-22	-55	-50	12	-5	-40

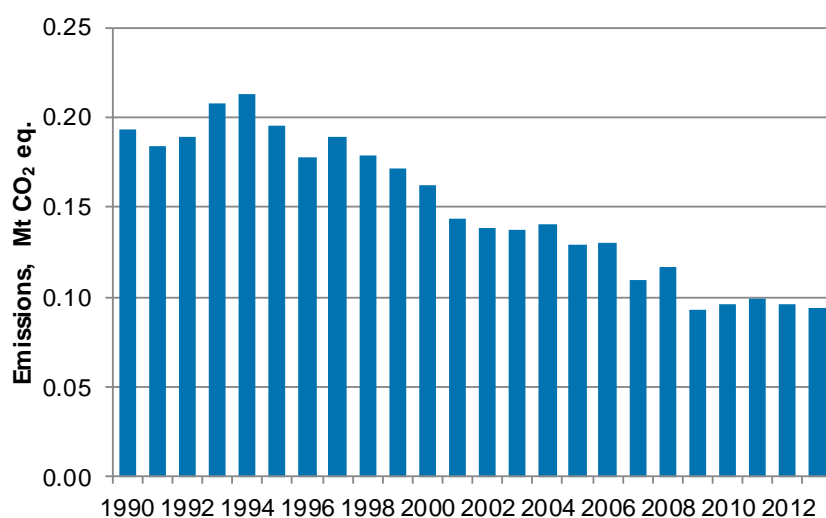
### Category-specific planned improvements

There are no category-specific planned improvements.

#### 3.2.5.5 Railway transportation

Emissions of railway transportation in Finland comprise railway transport operated by diesel locomotives. In 2013 electric locomotives ran 86% 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 2013 rail services accounted for over 28% of all freight carryings in Finland, which is considerably higher than the average for EU countries. In 2013 the volume of freight transport in Finland totalled 36.4 million tonnes, which is 3.0% more than in 2012 (Transport and Communications Statistical Yearbook for Finland, 2014).

Railway transportation is a minor emission source in the transport sector. The emissions of railway transportation were 0.09 Mt (CO<sub>2</sub> eq.) in 2013, it was less than 1% of the sector's emissions and emissions declined 3% compared to 2012. The emissions were 0.19 Mt (CO<sub>2</sub> eq.) in 1990 (Figure 3.2-11). 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. The recession still continued in 2013.



**Figure 3.2-11** Emissions from railway transportation (Mt CO<sub>2</sub> eq.)

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 Ltd. The RAILI model has been totally renewed and the year 2013 is the first year calculated with the new model. The calculation method is the same as in the old model. The emission factors of CH<sub>4</sub> and N<sub>2</sub>O have been harmonised to comply with the 2006 IPCC Guidelines and EMEP/EEA 2013.

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.

### Activity data

Activity data in RAILI model 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 five 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. 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.

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.

In the calculation of emissions from railway transportation terajoules (TJs) have been used as activity data. Fuel oil consumption in railway transportation in Finland is presented in Table 3.2-13.

### Emission factors and other parameters

The emission factors used in the calculation of emissions from Railway transportation are presented in Table 3.2-20. The emission factor of CH<sub>4</sub> is based on 2006 IPCC Guidelines and N<sub>2</sub>O on EMEP/EEA 2013. 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 3.2-4.

In 2013 0.1% 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. The same bioshare of gasoil has been used for all users.

**Table 3.2-20** Emission factors used in the calculation of emissions from Railway transportation (2006 IPCC Guidelines, EMEP/EEA 2013)

Fuel type	N <sub>2</sub> O emission factor g/kg fuel	CH <sub>4</sub> emission factor g/kg fuel
Gasoil	0.051	0.1785

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

A summary of the uncertainty analysis methodology used in the inventory is given in Section 1.6. Monte Carlo simulation has been used to combine the uncertainties of each calculation parameter in order to get the total uncertainty of the 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.

### *Category-specific QA/QC and verification*

The quality management process and the QA/QC plan for the whole inventory are presented in Section 1.2.3. The QA/QC plan for the transport sector includes the QA/QC and verification measures based on 2006 IPCC Guidelines. 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 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.

### *Category-specific recalculations*

Recalculations made for the year 2012 show the following differences between new and old RAILI models. The changes in CH<sub>4</sub> and N<sub>2</sub>O are due to the emission factor harmonisation with the other LIPASTO models and 2006 IPCC Guidelines. Recalculations have been made for the whole time series 1990 – 2012 to ensure the time series' consistency.

**Table 3.2-21** Difference between old and new RAILI models.

2012	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO	NO <sub>x</sub>	SO <sub>2</sub>	NM VOC
difference in %	0	7	-40	0	0	0	0

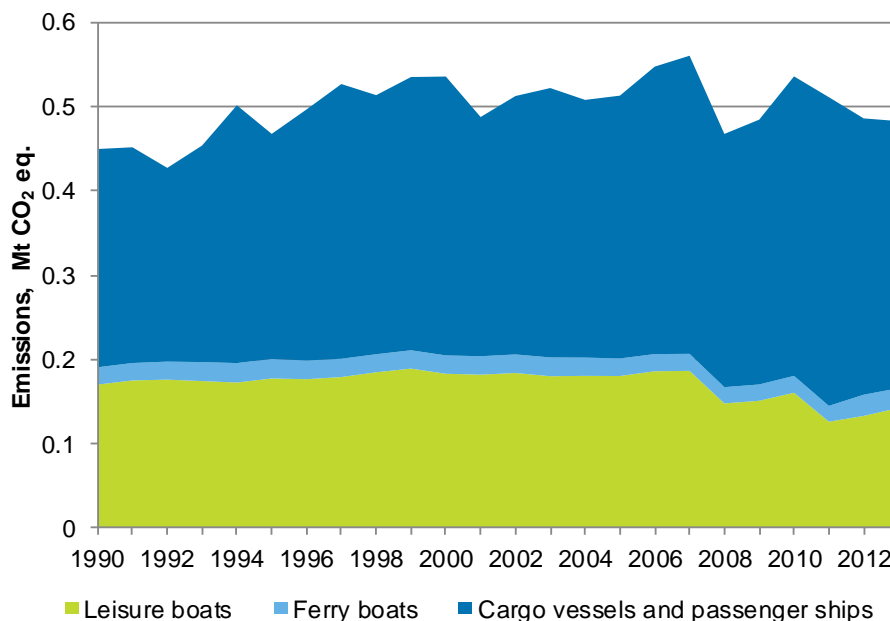
### *Category-specific planned improvements*

There are no category-specific planned improvements.

### 3.2.5.6 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 Transport category. The emissions of domestic navigation were 0.48 Mt (CO<sub>2</sub> eq.) in 2013, it was under 4% of the sector's emissions and emissions declined 1% compared to previous year. The emissions were 0.45 Mt (CO<sub>2</sub> eq.) in 1990. Emissions from domestic navigation by ship types are presented in Figure 3.2-12.



**Figure 3.2-12** Emissions from domestic navigation by ship types (Mt 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. 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 3.2-22.

### 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. Calculation methods are different depending on vehicle category. The methods are described under.

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). In the model there are 9 different ship types. Ships are further divided into different engine types (2-stroke and 4-stroke). These are further divided into different emission levels, at the moment from Tier 0 to Tier 2. Ships have 7 size categories.

Emissions are calculated according to the fuels ships are using: Heavy fuel oil (HFO), HFO + scrubber, Marine diesel oil / Marine gas oil (MDO/MGO), Diesel and Gas (LNG).

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).

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).

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

### *Activity data*

For MEERI model 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 3.2-22.

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.

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 for the whole time series for this register renovation have been done.

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.

Amount of used fuels (TJ) have been partly used as activity data to calculate emissions of domestic navigation.

**Table 3.2-22** 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
1995	2.35	0.12	0.10	1.39	1.27	0.31	0.58
2000	2.43	0.42	0.15	1.63	1.26	0.29	0.82
2001	2.41	0.37	0.14	1.37	1.26	0.29	0.54
2002	2.44	0.37	0.13	1.54	1.26	0.29	0.67
2003	2.39	0.40	0.13	1.29	1.26	0.30	1.06
2004	2.40	0.39	0.12	1.36	1.26	0.29	0.84
2005	2.40	0.47	0.12	1.24	1.26	0.28	0.98
2006	2.47	0.36	0.12	1.51	1.27	0.27	1.19
2007	2.48	0.39	0.12	1.68	1.27	0.27	1.16
2008	2.03	0.36	0.12	1.64	1.27	0.26	0.54
2009	2.10	0.36	0.12	1.52	1.27	0.26	0.86
2010	2.24	0.34	0.12	1.69	1.27	0.27	1.28
2011	1.78	0.45	0.12	1.89	1.27	0.26	1.11
2012	1.88	0.57	0.12	1.58	1.27	0.34	0.78
2013	2.00	0.64	0.12	1.29	1.27	0.31	0.85

### *Emission factors and other parameters*

The CO<sub>2</sub> emission factors are presented in Table 3.2-4.

In 2013 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 2006).

CO<sub>2</sub> emission factors are based on national figures (Table 3.2-4). They differ slightly from those expressed in the IPCC Guidelines. The difference is small.

The CH<sub>4</sub> and N<sub>2</sub>O emission factors for working boats, cruisers, ferryboats and leisure boats are based on the 2006 IPCC Guidelines and harmonised with the other LIPASTO models where the emission factors of the same fuels were used.

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 3.2-23.

**Table 3.2-23** Emission factors, net caloric values and densities used in the calculation of emissions from domestic navigation (IPCC 2006)

Fuel type	N <sub>2</sub> O emission factor g/kg fuel	CH <sub>4</sub> emission factor g/kg fuel
Gasoline	0.05	3.05
Gasoil	0.078	0.293
Heavy fuel oil HFO	0.073	0.273

Finnish Meteorological Institute has a world leading ship emission model STEAM, where the ship emission calculations are based on the data from AIS (Automatic Identification System) on the entire Baltic Sea. The detailed results of this model have been used to estimate characteristics of ships, auxiliary engines, speeds and fuel types.

### *Uncertainties and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

Monte Carlo simulation has been used to combine the uncertainties of each calculation parameter in order to get the total uncertainty of the 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  $\pm 10\%$ .

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.).

### *Category-specific QA/QC and verification*

The quality management process and the QA/QC plan for the whole inventory are presented in Section 1.2.3. The QA/QC plan for the transport sector includes the QC measures based on 2006 IPCC Guidelines. 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 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.

The above mentioned STEAM model results have been used to verify the emission calculation of MEERI model. Also ship emission experts from the Finnish Meteorological Institute have been used to verify the calculation methods of MEERI model.

### *Category-specific recalculations*

The year 2012 has been calculated both with old and new MEERI models. Comparison made for the year 2012 show the following differences in results between old and new MEERI models.

**Table 3.2-24** Differences between old and new MEERI models

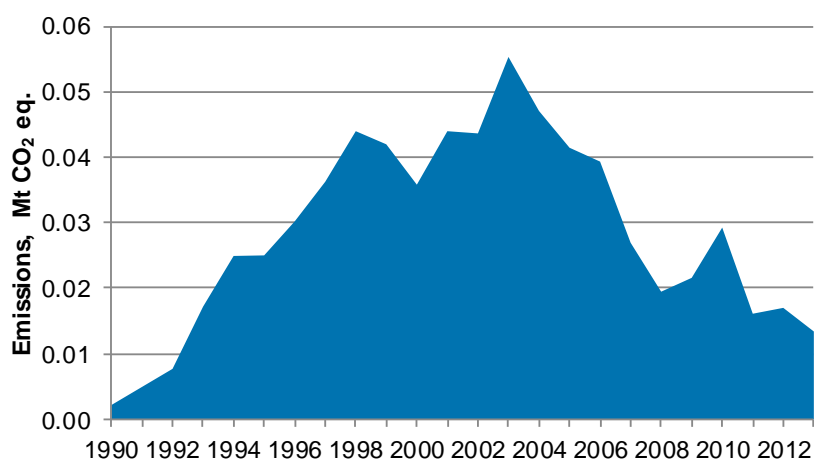
2012	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	CO	NO <sub>x</sub>	SO <sub>2</sub>	NM VOC
Difference in %	0	3	-8	2	-2	0	1

### *Category-specific planned improvements*

There are no category-specific planned improvements.

### 3.2.5.7 Other transportation

Emission sources of other transportation include pipeline transport. The emissions were 13 kt (CO<sub>2</sub> eq.) in 2013. Emissions declined 21% compared to 2012 but have increased over six-fold compared to 1990. Total emissions from pipeline transportation in 1990-2013 are presented in Mt CO<sub>2</sub> eq. in Figure 3.2-13.



**Figure 3.2-13** Emissions from pipeline transportation (Mt CO<sub>2</sub> eq.)

Emissions of off-road vehicles and other machinery are allocated to CRF categories 1.A 2gvii Manufacturing industry and Construction, 1.A 4aii Commercial/Institutional, 1.A 4bii Residential, and 1.A 4cii Agriculture/Forestry/Fisheries. Complete list of machine types included in each CRF category is presented in Table 3.2-26. The emissions from off-road vehicles and other machinery is based on TYKO model and amounted 2.6 Mt (CO<sub>2</sub> eq.) in 2013 altogether, it was four per cent of total greenhouse gas emissions. Emissions were approximately at the same level as in 2012 but have increased 7% compared to 1990. Total emissions from TYKO model by CRF categories in 1990-2013 are presented in Mt CO<sub>2</sub> eq. in Table 3.2-25.

Emission trend of off-road vehicles and other machinery 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 off-road vehicles and machinery at lowest level of the total time series. In 2010 the market began to recover and the use of these vehicles and other machinery increased. Prolonged economic downturn has again turned the trend downwards. The greatest increase was in off-road vehicles and other machinery using gasoil/diesel. The use of biofuels started in 2008 and in 2010 the use was doubled.

**Table 3.2-25** Greenhouse gas emissions from TYKO model by CRF categories (Mt CO<sub>2</sub> eq.)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<b>Off-road vehicles and other machinery</b>	<b>2.45</b>	<b>2.37</b>	<b>2.55</b>	<b>2.57</b>	<b>2.59</b>	<b>2.59</b>	<b>2.60</b>	<b>2.60</b>	<b>2.59</b>	<b>2.65</b>	<b>2.64</b>	<b>2.29</b>	<b>2.43</b>	<b>2.51</b>	<b>2.63</b>	<b>2.63</b>
1.A 2gvii Manufacturing and construction	1.17	1.14	1.26	1.28	1.29	1.29	1.29	1.30	1.32	1.37	1.39	1.12	1.25	1.34	1.39	1.39
1.A 4aii Commercial/Institutional	0.20	0.20	0.21	0.21	0.21	0.21	0.20	0.20	0.20	0.20	0.19	0.16	0.16	0.17	0.17	0.17
1.A 4bii Residential	0.14	0.16	0.18	0.18	0.18	0.18	0.19	0.19	0.20	0.20	0.20	0.19	0.19	0.20	0.21	0.21
1.A 4cii Agriculture/Forestry	0.94	0.88	0.91	0.90	0.91	0.91	0.91	0.91	0.87	0.87	0.86	0.82	0.82	0.80	0.86	0.85

### Methods

Emission data from pipeline transportation are received from VAHTI system (Annex 6).

The TYKO model from VTT Technical Research Centre of Finland Ltd estimates emissions and energy consumption of non-road machinery, which are reported in the Finnish inventory under sectors 1.A 2gvii Manufacturing industry and Construction, 1.A 4aii Commercial/Institutional, 1.A 4bii Residential, and 1.A 4cii 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 is made afterwards for the ILMARI system (see Section 3.1.4) 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 3.2-25.

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 emission factors of CH<sub>4</sub> and N<sub>2</sub>O have been harmonised to comply with the 2006 IPCC Guidelines and EMEP/EEA 2013.

### *Activity data*

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

**Table 3.2-26** Breakdown of different machine types in TYKO model to CRF subcategories

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

### *Emission factors and other parameters*

The CO<sub>2</sub> emission factors for off-road vehicles and other machinery are presented in Table 3.2-4. In 2013 bioshares of gasoline and gasoil oil were 4.6% and 0.1% respectively (calculated from TJ).

Other emission factors for off-road vehicles and other machinery in the TYKO model 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. The emission factors of CH<sub>4</sub> and N<sub>2</sub>O have been harmonised to comply with the 2006 IPCC Guidelines and EMEP/EEA 2013.

### *Uncertainties and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

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

### *Category-specific QA/QC and verification*

The quality management process and the QA/QC plan for the whole inventory are presented in Section 1.2.3. The QA/QC plan for the transport sector includes the QC measures based on 2006 IPCC Guidelines. 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 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)).

### *Category-specific recalculations*

All emission factors of the TYKO model were checked and harmonised to comply with the 2006 IPCC Guidelines and EMEP/EEA 2013 and also with the other LIPASTO models where the emission factors of the same fuels were used. Recalculations for the entire time series 1990 – 2012 have been made to ensure the time series' consistency.

Due to the implementation of the 2006 IPCC Guidelines off-road vehicles and other machinery in commercial, institutional and residential sectors were reallocated to 1.A 4 from 1.A 3e.

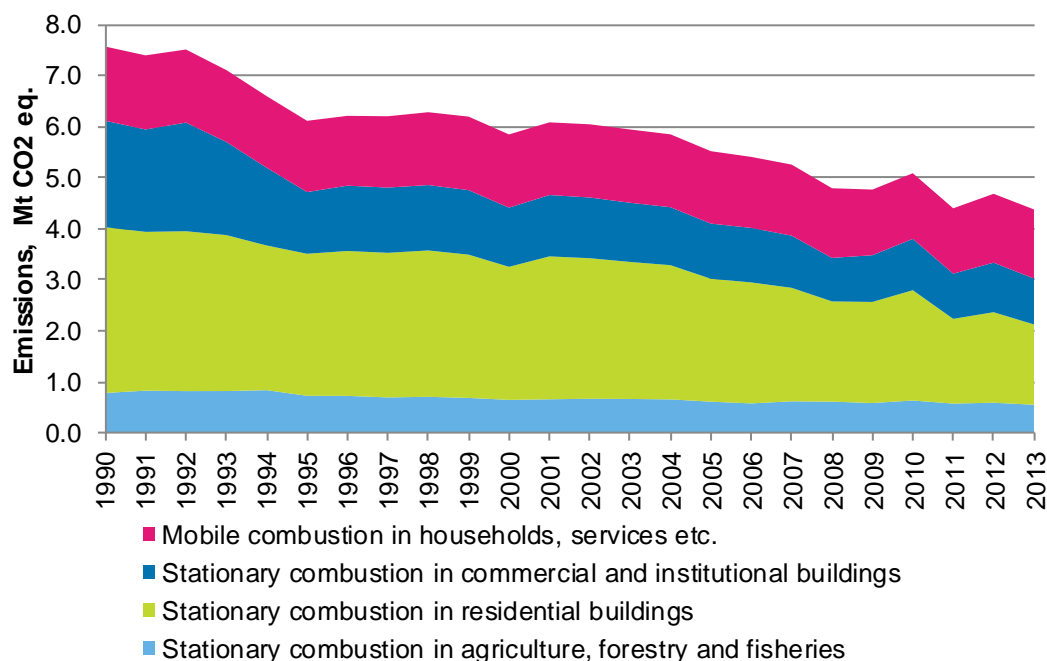
### *Category-specific planned improvements*

There are no category-specific planned improvements.

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

#### 3.2.6.1 Category description

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

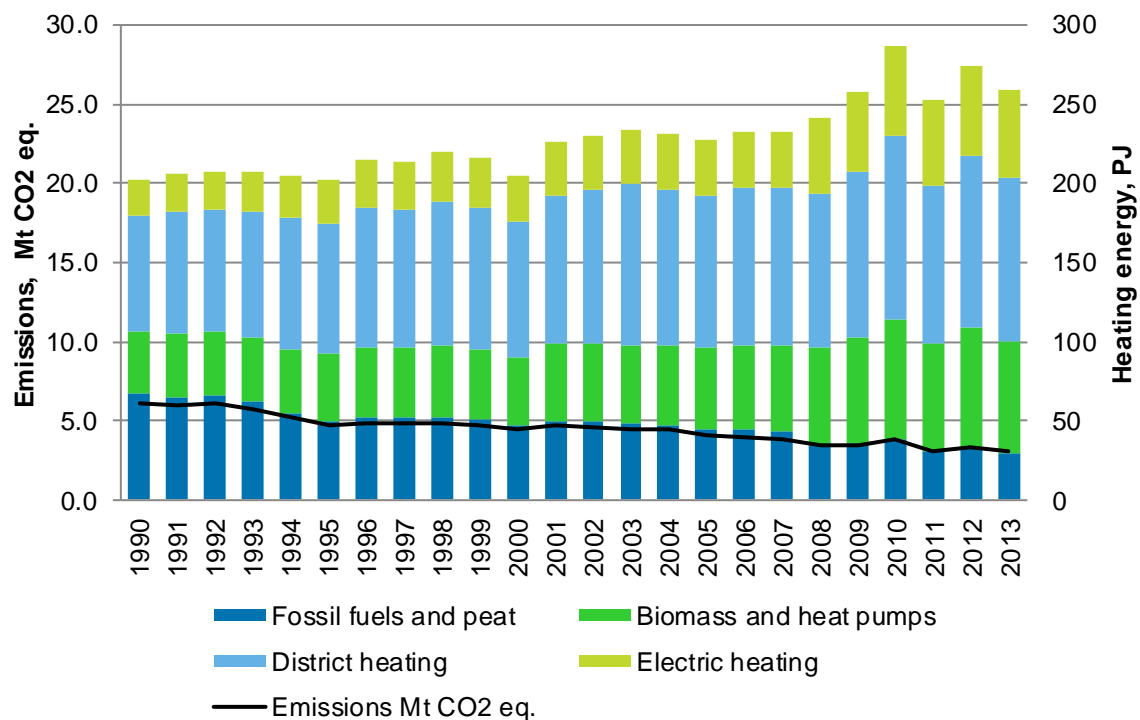


**Figure 3.2-14** Emissions from stationary and mobile sources in Other Sector (CRF 1.A 4)

The emissions of Other sectors were altogether 4.4 Mt and Other 1.0 Mt (CO<sub>2</sub> eq.) in 2013. The emissions of these subcategories cover over 11% of the energy sector's emissions and almost 9% of total greenhouse gas emissions of Finland and declined 6% compared to 2012. Emissions of these two sectors (1.A 4 and 1.A 5) have fallen almost 37% since 1990, the main reason for this is the increased use of district and electric heating in residential, commercial and public buildings (Figure 3.2-15). The peak in 2010 heating energy consumption is due to exceptionally high heating degree days.

Emissions from stationary combustion accounted 69% of the emissions in the Other sectors in 2013. Most of the emissions (37%) arose from the stationary combustion from the residential category. Emissions of off-road vehicles and other machinery in agriculture, forestry and fishing accounted for 22% and stationary combustion in commercial and institutional buildings 20% of the sectors emissions.

Emissions from these sectors in 1990-2013 by subcategory are presented in Table 3.2-27.



**Figure 3.2-15** Energy consumption of heating in residential, commercial and public buildings and CO<sub>2</sub> emissions of stationary combustion in CRF 1.A.4ai, 1.A.4bi and 1.A.4ci (Energy Statistics)

**Table 3.2-27** Emissions from sectors 1.A.4 Other sectors and 1.A.5 Other in by subcategory (Mt CO<sub>2</sub>)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<b>CO<sub>2</sub></b>																
<b>4. Other sectors</b>	<b>7.27</b>	<b>5.82</b>	<b>5.55</b>	<b>5.76</b>	<b>5.71</b>	<b>5.61</b>	<b>5.51</b>	<b>5.19</b>	<b>5.07</b>	<b>4.91</b>	<b>4.43</b>	<b>4.39</b>	<b>4.67</b>	<b>4.04</b>	<b>4.29</b>	<b>4.02</b>
a. Commercial and institutional	2.26	1.39	1.35	1.39	1.38	1.35	1.32	1.26	1.25	1.21	1.03	1.06	1.15	1.04	1.12	1.05
i. stationary	2.06	1.19	1.14	1.18	1.17	1.14	1.12	1.06	1.05	1.01	0.84	0.90	0.99	0.87	0.96	0.88
ii. mobile	0.20	0.20	0.21	0.21	0.21	0.21	0.20	0.20	0.20	0.20	0.19	0.16	0.16	0.17	0.17	0.17
b. Residential	3.15	2.69	2.53	2.70	2.65	2.58	2.53	2.31	2.27	2.13	1.84	1.83	1.98	1.54	1.64	1.48
i. stationary	3.01	2.54	2.36	2.53	2.47	2.40	2.35	2.13	2.08	1.93	1.65	1.65	1.79	1.35	1.44	1.27
ii. mobile	0.14	0.15	0.17	0.17	0.17	0.17	0.18	0.19	0.19	0.20	0.19	0.18	0.19	0.20	0.20	0.21
c. Agriculture, forestry and fisheries	1.86	1.74	1.67	1.67	1.68	1.68	1.67	1.61	1.55	1.58	1.56	1.49	1.53	1.46	1.53	1.49
i. stationary	0.76	0.71	0.63	0.64	0.65	0.64	0.64	0.59	0.56	0.60	0.59	0.56	0.61	0.55	0.57	0.53
ii-iii. mobile	1.10	1.03	1.04	1.03	1.03	1.04	1.03	1.02	0.99	0.98	0.97	0.93	0.92	0.90	0.96	0.96
<b>5. Other</b>	<b>1.13</b>	<b>1.28</b>	<b>1.31</b>	<b>1.42</b>	<b>1.40</b>	<b>1.45</b>	<b>1.31</b>	<b>1.39</b>	<b>1.39</b>	<b>1.27</b>	<b>1.27</b>	<b>1.21</b>	<b>1.29</b>	<b>1.14</b>	<b>1.15</b>	<b>1.02</b>
<b>CH<sub>4</sub></b>																
<b>4. Other sectors</b>	<b>0.22</b>	<b>0.23</b>	<b>0.23</b>	<b>0.25</b>	<b>0.26</b>	<b>0.26</b>	<b>0.26</b>	<b>0.26</b>	<b>0.27</b>	<b>0.27</b>	<b>0.30</b>	<b>0.31</b>	<b>0.35</b>	<b>0.30</b>	<b>0.32</b>	<b>0.30</b>
i. stationary	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
ii-iii. mobile	0.214	0.22	0.22	0.25	0.25	0.26	0.26	0.26	0.26	0.27	0.29	0.30	0.34	0.29	0.31	0.29
<b>5. Other</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>0.004</b>	<b>0.004</b>	<b>0.004</b>	<b>0.004</b>	<b>0.004</b>	<b>0.003</b>	<b>0.004</b>	<b>0.004</b>	<b>0.004</b>	<b>0.003</b>
<b>N<sub>2</sub>O</b>																
<b>4. Other sectors</b>	<b>0.084</b>	<b>0.072</b>	<b>0.070</b>	<b>0.075</b>	<b>0.075</b>	<b>0.074</b>	<b>0.074</b>	<b>0.071</b>	<b>0.071</b>	<b>0.070</b>	<b>0.069</b>	<b>0.071</b>	<b>0.078</b>	<b>0.067</b>	<b>0.072</b>	<b>0.067</b>
i. stationary	0.018	0.011	0.010	0.011	0.011	0.011	0.010	0.010	0.010	0.010	0.008	0.009	0.010	0.009	0.009	0.009
ii-iii. mobile	0.066	0.061	0.060	0.064	0.064	0.064	0.063	0.061	0.061	0.060	0.060	0.062	0.068	0.058	0.062	0.058
<b>5. Other</b>	<b>0.009</b>	<b>0.010</b>	<b>0.010</b>	<b>0.011</b>	<b>0.011</b>	<b>0.011</b>	<b>0.010</b>	<b>0.011</b>	<b>0.011</b>	<b>0.010</b>	<b>0.010</b>	<b>0.009</b>	<b>0.010</b>	<b>0.009</b>	<b>0.009</b>	<b>0.008</b>

**Table 3.2-28** Fuel consumption in CRF categories 1.A.4 and 1.A.5 (PJ)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Liquid fuels																
Heavy fuel oil	19.3	7.5	6.6	7.7	7.7	7.5	7.6	7.2	7.0	6.6	6.0	5.5	5.8	5.1	4.6	3.6
Light fuel oil	82.7	75.5	71.4	73.4	72.0	71.0	69.3	65.0	63.1	60.0	54.3	53.3	55.7	48.2	51.6	47.9
LPG	2.0	2.4	2.6	2.6	2.7	2.8	2.8	2.9	3.3	2.8	3.5	2.9	3.8	3.7	3.9	3.2
Other liquid fuels	3.5	4.5	5.2	4.9	5.3	5.5	4.9	5.6	5.8	6.0	5.8	5.6	5.8	5.1	5.6	5.4
Solid fuels																
Hard coal	0.52	0.29	0.21	0.16	0.19	0.19	0.19	0.13	0.12	0.12	0.12	0.14	0.15	0.15	0.12	0.10
Gaseous fuels																
Natural gas and other gaseous fuels	3.0	5.3	6.4	8.0	7.9	7.9	6.4	7.5	7.8	7.4	6.4	7.0	7.6	6.8	6.6	6.5
Biomass																
Woodfuels and other biofuels	45.3	45.1	45.8	51.5	53.2	53.9	54.3	54.5	56.3	56.7	61.5	65.8	74.0	63.3	68.6	63.7
Peat																
Peat	1.4	1.1	1.3	1.5	1.6	1.7	1.8	1.6	1.6	1.8	1.9	2.1	2.6	2.1	2.3	2.3
Other																
Mixed fuels and waste	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.000	NO	NO	NO	NO	NO	NO	NO	NO

### 3.2.6.2 Methodological issues

#### *Methods*

Emissions from subcategories 1.A.4 and 1.A.5 are calculated within the ILMARI system, which has been described in Section 3.1.4, Table 3.1-6 and Figure 3.1-6. Calculation of the greenhouse gas emissions from stationary sources is based on a Tier 1 method using fuel consumption data and fuel-specific emission factors. Emissions factors are either country specific or default depending on a fuel.

#### *Activity data*

The activity data for stationary sources of category CRF 1.A 4 are taken from annual energy statistics. Only a small part of the emissions are based on actual installation bottom-up data. The fuel consumption data for CRF 1.A.4 are presented in Table 3.2-28. 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 (MJ/m<sup>3</sup>/a) and annual heating degree days.

The Raklam 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 off-road vehicles and other machinery are taken from the TYKO model of VTT Ltd. (See descriptions in Section 3.2.5.7). Activity data for fishing derive from the MEERI model of VTT (See descriptions in Section 3.2.5.6).

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.

#### *Emission factors*

The CO<sub>2</sub> emission factors are presented in Table 3.2-4.

In 2013 bioshares of gasoline and gasoil oil were 4.6% and 0.1% respectively (calculated from TJ).

The other emission factors used are partly IPCC default from 1996 guidelines and partly based on national sources (Table 3.2-29). A research study, in which new emission factors for small scale combustion will be developed, is ongoing and based on the results received, these factors will be revised after the 2016 submission.

**Table 3.2-29** 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

### 3.2.6.3 Uncertainties and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

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 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.

#### 3.2.6.4 *Category-specific QA/QC and verification*

There are numerous automatic and manual QC procedures used in the ILMARI system (see Section 3.2.4.4).

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.

#### 3.2.6.5 *Category-specific recalculations*

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

The revision of stock change data in the energy statistics affected to the residuals of fuels and statistical corrections.

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

Due to the implementation of 2006 IPCC Guidelines, off-road vehicles and other machinery in commercial, institutional and residential sectors were reallocated to 1.A 4 from 1.A 3e and emissions from lubricants were reallocated to sector 2.D 1. In addition indirect N<sub>2</sub>O emissions from NO<sub>x</sub> are reported now as a memo item and these emissions are not included in the total emissions of this sector.

#### 3.2.6.6 *Category-specific planned improvements*

A research study, in which new N<sub>2</sub>O and CH<sub>4</sub> emission factors for small-scale combustion will developed, is ongoing and based on the results received, emission factors used currently in the inventory will be revised after the 2016 submission.

### *3.3 Fugitive emissions from solid fuels and oil and natural gas and other emissions from energy production (CRF 1.B)*

#### *3.3.1 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 4.D) consistent with the *2006 IPCC Guidelines* (see Section 6.7).

There are no coal mines in Finland.

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

##### *3.3.2.1 Category description*

This 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 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 therefore 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 and it is more cost effective to get useful energy or products to sell. Some of the refinery plants have been modernised during the time series.

There are no emissions from venting, since all process gases during normal function are directed to a fuel gas system and burned in different process heaters and boilers and reported as Fuel Combustion in the Energy sector. There are however other types of fugitive or venting emissions, which are reported as NMVOC emissions in '1.B.2.d Other'. These include for example venting of oil storages, drainage systems, etc.

In 2013 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 0.12 Mt CO<sub>2</sub> eq. This is about 0.2% of Finland's total emissions. Emissions declined 16% compared to 2012 and 2% compared to 1990.

The other NMVOC emissions originate from storage of chemicals at the refineries, road traffic evaporative emissions from cars, the gasoline distribution network and refuelling of cars, ships and aircraft. The indirect CO<sub>2</sub> emissions from NMVOCs and CH<sub>4</sub> are reported aggregated in national totals (see Section 9).

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

##### *3.3.2.2 Methodological issues*

###### *Methods*

###### Oil refining

The fugitive methane emissions from the refining and storage of oil have been calculated on the basis of 2006 IPCC Guidelines 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 (Tolonen M, 2014). Calculations are based on measurements for the years 1996-2014. 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

Methane emissions from natural gas distribution are partly based on measurements (leakage in the distribution network) (1996-2013) made by Helsingin Kaasu Oy (Tolonen M., 2014) and partly on rough estimates (1991-1994) based on the volume of total distributed gas.

In 1990 natural gas was distributed only in newer parts of pipeline where no emissions are expected. The distribution of “town gas” (liquid gas, butane) started 1973 and it continued until 1993. In older parts (Helsinki area) of the distribution network natural gas distribution started partially in 1991 and in 1994 only natural gas was distributed in Helsinki area.

Town gas contains 1% methane and 20% carbon dioxide, and these emissions are included into the inventory for years 1990-1993. Methane and carbon dioxide emissions are calculated using leakage of town gas in distribution network and percentage of them in the town gas.

*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 2006 IPCC Guidelines, 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.

Plant and fuel specific emission factors are used for calculation emissions from flaring. They can be found in Table 3.2-4.

Percentage of methane and carbon dioxide in town gas are used to calculate emissions of distribution of town gas.

*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. Activity data are received from refineries and petrochemical plants, including point source data for each plant either by plant or by each flare. Flaring includes both the pilot flame and the burning of process gases released in start-ups, shutdowns and malfunctions.

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.

Sold town gas has been used as activity data. The average of leakage percentages of natural gas has been used to estimate leakage of town gas for years 1990-1993.

*3.3.2.3 Uncertainty and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents assumptions made for the analysis. A description of review and update of uncertainty analysis is included in Section 1.6.

Sources of uncertainty for estimates concerning the year 2013 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 3.2.4.3.

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  $\pm 25\%$ .

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

#### *3.3.2.4 Category-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 1.2.3. The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives. The bilateral quality meeting 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 2006 IPCC Guidelines (Chapter 1.6, Table 6.1). 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.

#### *3.3.2.5 Category-specific recalculations*

Emissions from oil refining were recalculated using default emission factor from 2006 IPCC Guidelines and emissions from distributed town gas used in Helsinki area are now included in the inventory.

#### *3.3.2.6 Category-specific planned improvements*

There are no improvements planned.

**Table 3.3-1** Fugitive emissions from oil and gas (kt CO<sub>2</sub>-eq.)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<b>CO<sub>2</sub></b>																
1.B.2c Flaring	110.8	74.6	58.5	53.0	61.5	56.0	55.0	70.5	58.3	81.0	97.2	74.8	96.5	87.8	101.9	79.3
1.B.2d Distribution of town gas	0.7	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
<b>CH<sub>4</sub></b>																
1.B.2a Oil refining	6.30	7.01	7.76	7.23	7.96	8.02	8.24	7.77	8.43	8.77	9.12	9.04	8.46	9.03	8.71	9.02
1.B.2b Natural gas	4.25	85.57	54.75	70.50	56.04	61.75	54.38	64.46	53.73	47.59	45.32	42.83	36.19	30.52	32.20	30.90
1.B.2c Flaring	0.029	0.016	0.017	0.014	0.019	0.018	0.021	0.020	0.020	0.027	0.028	0.020	0.026	0.029	0.038	0.039
1.B.2d Distribution of town gas	0.3	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
<b>N<sub>2</sub>O</b>																
1.B.2c Flaring	0.675	0.382	0.409	0.345	0.448	0.426	0.496	0.466	0.482	0.646	0.659	0.477	0.612	0.694	0.916	0.927
<b>Total kt CO<sub>2</sub> eq.</b>	<b>123.03</b>	<b>167.58</b>	<b>121.42</b>	<b>131.05</b>	<b>125.96</b>	<b>126.24</b>	<b>118.18</b>	<b>143.18</b>	<b>120.96</b>	<b>138.02</b>	<b>152.31</b>	<b>127.17</b>	<b>141.80</b>	<b>128.11</b>	<b>143.79</b>	<b>120.19</b>

## 3.4 CO<sub>2</sub> transport and storage (CRF 1.C)

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

#### 3.4.1.1 Category description

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> 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.

#### 3.4.1.2 Methodological issues

In the lime kilns of the pulp production process lime mud (basically CaCO<sub>3</sub>) is burned back to lime (CaCO<sub>3</sub> → CaO + CO<sub>2</sub>) and after that lime is reused in causticising. The limekiln has been chosen for the CO<sub>2</sub> source of PCC production because an excess amount of CO<sub>2</sub> 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 CO<sub>2</sub> comes from fuels used in the kilns.

The amount of CO<sub>2</sub> 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 CO<sub>2</sub> emissions or the amount of CO<sub>2</sub> captured. Therefore they estimate the CO<sub>2</sub> 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 CO<sub>2</sub> is subtracted from liquid fuels in subcategory 1.A 2d. 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.

A small amount of carbonate (either PCC or other carbonates) based CO<sub>2</sub> 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 2g). These emissions are taken into account in the corresponding emission factors.

**Table 3.4-1** PCC production and transferred CO<sub>2</sub> in the years 1993-2013

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<b>PCC production, 1000 t</b>	NO	123	413	403	401	430	473	425	482	532	485	421	449	408	333	306
<b>CO<sub>2</sub> transferred and subtracted from 1.A 2d (Liquid fuels), kt</b>	NO	54	182	177	176	189	208	187	212	234	213	185	198	180	147	135

### 3.4.1.3 Category-specific QA/QC and verification

Statistics Finland clarified the characteristics of CO<sub>2</sub> storage in PCC in 2008 through literature and discussions with experts. According to the Finnish experts<sup>12</sup>, PCC in paper and recycled sludge disposed in landfills or used in landscaping constitute a long-term storage for CO<sub>2</sub>. 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, CO<sub>2</sub> will be released, when PCC containing paper or sludge is burned.

The characteristics of the captured CO<sub>2</sub> were clarified from the calculation of the emissions of the plants capturing CO<sub>2</sub> for PCC production. About 85% of fuels used in the plants capturing the CO<sub>2</sub> from limekilns of pulp production process have been fossil (natural gas, different type of oils) origin, though since 2013 all CO<sub>2</sub> emissions are fossil origin. Finland deducts all captured CO<sub>2</sub> 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 CO<sub>2</sub> 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 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.

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 2000-2013). 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.

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>.

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 system (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 2005-2013. The difference is assumed to account for possible losses during transfer and production.

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<sup>12</sup> Prof. Eero Hanski, University of Oulu, prof. Olli Dahl, Helsinki University of Technology and Docent Kauko Kujala, University of Oulu (see Appendix\_3d).

#### *3.4.1.4 Category-specific recalculations*

No category-specific recalculations were done.

#### *3.4.1.5 Category-specific planned improvements*

No planned improvements.

## 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.**

$$E_{v,y} = \sum_{l=1}^9 \sum_{m=1}^{20} \sum_{p=1}^8 \sum_{r=1}^6 S_{l,m,p,r,u,v,y} \left( b_{l,m,p,r,u,v,y}^a + b_{l,m,p,r,u,v,y}^k \right)$$

$E$	is total emissions
$S$	is kilometrage
$b^a$	is the emission factor for hot driving
$b^k$	is the emission factor for cold start-ups
$l$	is type of vehicle
$m$	is Euro level 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, greenhouse gas emissions and implied emission factors for CO<sub>2</sub> 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\_App\_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	2013
<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>	<b>131.0</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	114.3
Coke	5.87	5.43	5.00	5.12	5.25	4.89	4.33	5.52	5.39	5.48	5.45	4.74	4.69	5.07	5.58	5.65	5.21	5.55	4.86	3.96	4.57	4.82	1.11	1.24
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	7.7
Coke oven gas	4.16	4.18	4.20	6.85	7.57	7.21	6.83	7.15	7.20	7.19	7.14	7.11	7.22	7.12	6.96	7.01	7.31	5.38	6.66	5.69	6.60	7.04	7.27	6.59
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	1.17
<b>Liquid fuels</b>	<b>372.7</b>	<b>364.3</b>	<b>359.5</b>	<b>344.7</b>	<b>355.4</b>	<b>344.6</b>	<b>350.2</b>	<b>350.3</b>	<b>357.6</b>	<b>359.1</b>	<b>349.4</b>	<b>354.4</b>	<b>359.5</b>	<b>360.5</b>	<b>360.0</b>	<b>353.6</b>	<b>356.2</b>	<b>359.9</b>	<b>338.2</b>	<b>325.5</b>	<b>338.7</b>	<b>324.3</b>	<b>319.9</b>	<b>308.2</b>
Heavy fuel oil	71.1	68.4	65.7	61.2	65.0	58.0	60.1	54.3	53.3	54.6	50.7	51.3	52.5	51.2	47.6	43.8	45.0	42.0	33.9	33.4	35.8	29.3	26.7	20.0
Light fuel oil	105.7	104.3	102.9	101.9	99.7	98.7	99.9	99.8	101.8	101.3	96.5	98.9	97.4	96.5	95.1	90.5	88.2	85.7	79.2	74.1	79.0	72.6	76.8	73.0
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	63.9	61.6	62.1
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	90.1	97.6	98.5	97.6	96.8
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	11.3
Refinery gases	21.0	21.8	22.5	19.8	23.5	22.6	24.4	22.7	25.3	24.1	22.0	23.1	24.6	24.6	23.5	24.2	24.7	26.2	26.0	29.3	27.3	28.9	26.9	27.1
Town gas	0.14	0.14	0.13	0.06	NO	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	0.61
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	6.5
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	4.5
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	0.04
Other oil	4.45	4.09	3.74	3.80	3.78	3.95	3.63	3.11	2.85	2.85	3.30	2.88	2.50	2.00	2.04	1.96	2.74	2.91	2.72	2.74	6.04	5.76	5.65	6.18
<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>115.0</b>	<b>107.0</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	115.0	106.9
LNG	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.1
<b>Other</b>	<b>54.4</b>	<b>57.0</b>	<b>59.6</b>	<b>65.5</b>	<b>75.1</b>	<b>80.9</b>	<b>89.1</b>	<b>89.7</b>	<b>83.6</b>	<b>74.9</b>	<b>65.8</b>	<b>91.2</b>	<b>95.8</b>	<b>105.5</b>	<b>94.6</b>	<b>73.3</b>	<b>97.5</b>	<b>106.5</b>	<b>86.3</b>	<b>78.1</b>	<b>100.4</b>	<b>89.8</b>	<b>72.0</b>	<b>65.7</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	92.3	101.5	90.5	69.4	93.9	102.7	82.1	72.7	95.1	84.9	65.0	56.9
Mixed fuels (MSW/REF/RDF/	0.2	0.2	0.2	0.2	0.5	0.5	0.2	0.3	0.4	0.4	1.7	2.6	1.6	2.1	2.5	2.5	2.4	2.7	3.4	4.5	4.2	4.1	5.8	6.9
Other fossil wastes etc.	0.89	0.78	0.67	0.80	0.89	0.98	1.41	1.35	2.55	2.75	1.67	1.64	1.91	1.90	1.66	1.37	1.11	1.11	0.87	0.78	0.99	0.78	1.20	1.98
<b>Biomass</b>	<b>179.3</b>	<b>176.7</b>	<b>174.1</b>	<b>206.6</b>	<b>214.6</b>	<b>218.4</b>	<b>218.1</b>	<b>248.4</b>	<b>254.5</b>	<b>275.6</b>	<b>274.0</b>	<b>264.5</b>	<b>286.7</b>	<b>292.9</b>	<b>308.4</b>	<b>288.7</b>	<b>322.4</b>	<b>310.9</b>	<b>320.8</b>	<b>289.9</b>	<b>343.0</b>	<b>339.5</b>	<b>354.0</b>	<b>362.4</b>
Black/sulphite liquor	87.4	87.0	86.6	104.8	111.2	111.1	108.0	129.2	129.7	139.1	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	140.7
Other woodfuels	90.5	88.2	85.9	100.2	101.4	104.8	107.8	116.7	122.0	133.8	130.9	136.0	141.9	149.6	157.3	151.9	158.9	148.0	166.1	162.3	188.4	183.5	196.7	198.1
Bio mixed fuels	0.58	0.57	0.56	0.57	0.89	0.88	0.68	0.84	0.95	0.98	1.11	1.18	1.74	2.37	2.97	3.86	3.79	4.94	5.40	6.18	6.56	6.17	7.80	8.38
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	0.99	1.13	1.75	1.53	1.75	1.89	1.73	1.69	2.22	2.41	2.39
Bio diesel	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.0	0.4	2.5	2.6	4.6	4.3	6.5
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	2.70	3.21	3.40	3.88	4.03	2.98
Bio gasoil	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.0	0.9	1.7	1.3	0.5	0.1
Bio natural gas	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.04
Hydrogen	0.62	0.79	0.95	0.88	0.93	0.95	0.82	0.93	1.03	0.87	1.10	1.09	1.25	1.22	1.29	1.13	1.36	1.19	1.14	1.00	1.10	1.13	1.01	1.05
Other non-fossil fuels	0.07	0.06	0.04	NO	0.04	0.03	0.03	0.07	0.05	0.08	0.2	0.2	0.4	0.3	0.6	0.7	0.7	0.9	1.3	2.0	1.9	1.5	1.4	2.2
<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>34.6</b>	<b>30.3</b>	<b>31.5</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	26.6
Light fuel oil	5.1	4.8	5.6	6.1	6.3	6.6	6.4	6.6	6.8	6.7	6.7	6.0	4.3	4.0	2.0	2.0	2.5	3.2	3.1	1.9	2.6	2.4	1.5	1.7
Heavy fuel oil	18.4	17.6	22.7	16.1	11.1	7.3	9.2	10.3	14.7	16.1	19.7	17.6	22.2	22.4	19.0	18.6	20.3	15.5	13.3	8.1	5.9	5.5	3.0	3.1
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	0.01

**Table 2\_App\_3b.** CO<sub>2</sub> emissions from combustion by fuel, Mt

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<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>11.1</b>	<b>19.0</b>	<b>16.7</b>	<b>12.1</b>	<b>12.8</b>	<b>16.2</b>	<b>12.4</b>	<b>10.0</b>	<b>12.8</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	15.3	13.2	8.8	10.7	13.4	9.6	7.8	10.6
Coke	0.63	0.58	0.53	0.55	0.56	0.52	0.46	0.59	0.58	0.59	0.58	0.51	0.50	0.54	0.60	0.60	0.56	0.59	0.52	0.42	0.49	0.51	0.12	0.13
Blast furnace gases	1.73	1.81	1.89	2.08	2.07	1.86	2.06	2.37	2.51	2.61	2.79	2.43	2.51	2.72	2.66	2.72	2.84	2.62	2.42	1.44	2.03	2.02	1.69	1.78
Coke oven gas	0.17	0.17	0.17	0.28	0.31	0.30	0.28	0.29	0.30	0.30	0.29	0.29	0.30	0.29	0.29	0.29	0.30	0.22	0.27	0.23	0.27	0.29	0.30	0.27
Other coal	0.002	0.003	0.005	0.014	0.033	0.037	0.018	0.010	0.005	0.011	0.008	0.018	0.014	0.013	0.013	0.013	0.009	0.011	0.012	0.025	0.024	0.007	0.044	0.106
<b>Liquid fuels</b>	<b>27.5</b>	<b>26.9</b>	<b>26.5</b>	<b>25.5</b>	<b>26.2</b>	<b>25.4</b>	<b>25.8</b>	<b>25.8</b>	<b>26.2</b>	<b>26.4</b>	<b>25.7</b>	<b>26.0</b>	<b>26.4</b>	<b>26.4</b>	<b>26.4</b>	<b>25.9</b>	<b>26.0</b>	<b>26.0</b>	<b>24.3</b>	<b>23.2</b>	<b>24.3</b>	<b>23.2</b>	<b>23.1</b>	<b>22.0</b>
Heavy fuel oil	5.60	5.39	5.18	4.82	5.12	4.57	4.74	4.28	4.20	4.30	4.00	4.05	4.14	4.04	3.75	3.45	3.54	3.31	2.68	2.63	2.82	2.31	2.11	1.58
Light fuel oil	7.8	7.7	7.6	7.4	7.3	7.4	7.4	7.4	7.5	7.5	7.2	7.3	7.2	7.2	7.0	6.7	6.5	6.3	5.9	5.5	5.8	5.4	5.7	5.4
Motor gasoline	6.24	6.23	6.26	5.89	6.02	5.96	5.76	5.91	5.84	5.80	5.59	5.67	5.77	5.79	5.89	5.88	5.83	5.83	5.21	5.02	4.92	4.66	4.49	4.53
Diesel oil	4.92	4.61	4.56	4.46	4.65	4.57	4.72	5.06	5.26	5.51	5.63	5.75	5.87	6.03	6.29	6.34	6.55	6.94	6.99	6.63	7.18	7.25	7.18	7.10
LPG	0.43	0.40	0.38	0.37	0.45	0.46	0.49	0.55	0.66	0.58	0.72	0.70	0.71	0.78	0.81	0.84	0.90	0.83	0.86	0.72	0.85	0.83	0.82	0.73
Refinery gases	1.20	1.24	1.28	1.13	1.34	1.29	1.40	1.31	1.44	1.37	1.25	1.31	1.41	1.40	1.33	1.35	1.37	1.41	1.41	1.58	1.48	1.54	1.45	1.46
Town gas	0.009	0.008	0.008	0.004	NO	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	0.08	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	0.05
Petroleum coke	0.48	0.49	0.50	0.49	0.47	0.47	0.53	0.51	0.53	0.51	0.46	0.42	0.55	0.51	0.57	0.56	0.56	0.62	0.57	0.51	0.50	0.59	0.55	0.66
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	0.33
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	0.00
Other oil	0.36	0.33	0.30	0.32	0.28	0.32	0.30	0.25	0.23	0.24	0.27	0.24	0.20	0.16	0.17	0.15	0.21	0.21	0.20	0.20	0.17	0.17	0.39	0.17
<b>Gaseous fuels</b>	<b>5.0</b>	<b>5.2</b>	<b>5.5</b>	<b>5.8</b>	<b>6.2</b>	<b>6.5</b>	<b>6.8</b>	<b>6.7</b>	<b>7.6</b>	<b>7.6</b>	<b>7.8</b>	<b>8.5</b>	<b>8.4</b>	<b>9.3</b>	<b>9.0</b>	<b>8.2</b>	<b>8.8</b>	<b>8.1</b>	<b>8.3</b>	<b>7.4</b>	<b>8.2</b>	<b>7.2</b>	<b>6.3</b>	<b>5.9</b>
Natural gas	5.0	5.2	5.5	5.8	6.2	6.5	6.8	6.7	7.6	7.6	7.8	8.5	8.4	9.3	9.0	8.2	8.8	8.1	8.3	7.4	8.2	7.2	6.3	5.9
LNG	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.003
<b>Other</b>	<b>5.7</b>	<b>6.0</b>	<b>6.2</b>	<b>6.9</b>	<b>7.9</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>10.0</b>	<b>11.0</b>	<b>9.8</b>	<b>7.6</b>	<b>10.2</b>	<b>11.1</b>	<b>9.0</b>	<b>8.1</b>	<b>10.4</b>	<b>9.3</b>	<b>7.5</b>	<b>6.7</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	9.7	10.6	9.5	7.3	9.8	10.7	8.6	7.6	10.0	8.9	6.9	6.0
Mixed fuels (MSWREF/ RDF/PDF etc.)	0.04	0.04	0.04	0.04	0.06	0.06	0.04	0.05	0.05	0.05	0.13	0.19	0.13	0.17	0.20	0.21	0.21	0.23	0.29	0.40	0.37	0.37	0.50	0.58
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	0.18	0.16	0.14	0.12	0.12	0.10	0.08	0.10	0.08	0.12	0.12
<b>Biomass</b>	<b>19.3</b>	<b>19.0</b>	<b>18.7</b>	<b>22.2</b>	<b>23.1</b>	<b>23.5</b>	<b>23.5</b>	<b>26.7</b>	<b>27.4</b>	<b>29.7</b>	<b>29.4</b>	<b>28.5</b>	<b>30.8</b>	<b>31.5</b>	<b>33.1</b>	<b>31.0</b>	<b>34.6</b>	<b>33.4</b>	<b>34.3</b>	<b>30.8</b>	<b>36.4</b>	<b>36.0</b>	<b>37.6</b>	<b>38.4</b>
Black/sulphite liquor	9.5	9.4	9.4	11.4	12.1	12.1	11.7	14.0	14.1	15.1	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	15.3
Other woodfuels	9.8	9.5	9.2	10.8	10.9	11.3	11.6	12.6	13.2	14.4	14.1	14.7	15.3	16.1	17.0	16.4	17.1	16.0	17.9	17.5	20.3	19.8	21.2	21.3
Biogas	0.005	0.005	0.005	0.006	0.005	0.036	0.038	0.040	0.044	0.043	0.048	0.042	0.05	0.06	0.06	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Bio diesel	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.0	0.0	0.2	0.2	0.3	0.3	0.5
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	0.21
Bio gasoil	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.000	0.062	0.119	0.094	0.036	0.006
Bio natural gas	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	0.000	0.000	0.001	0.002	
Bio mixed fuels	0.061	0.060	0.059	0.060	0.095	0.096	0.072	0.090	0.101	0.104	0.116	0.122	0.179	0.241	0.299	0.388	0.382	0.497	0.548	0.626	0.664	0.625	0.794	0.861
Hydrogen	NO	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	NO	0.004	0.003	0.003	0.008	0.006	0.008	0.021	0.024	0.04	0.04	0.06	0.08	0.08	0.09	0.12	0.17	0.16	0.14	0.12	0.16
<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>3.1</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>	<b>2.3</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	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	0.1	0.1	0.2	0.2	0.2	0.1	0.2	0.2	0.1	0.1
Heavy fuel oil	1.5	1.4	1.8	1.3	0.9	0.6	0.7	0.8	1.2	1.3	1.5	1.4	1.8	1.8	1.5	1.5	1.6	1.2	1.0	0.6	0.5	0.4	0.2	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	0.001

**Table 3\_App\_3b.** Implied CO<sub>2</sub> emission factors

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<b>Solid fuels</b>	<b>100.1</b>	<b>101.0</b>	<b>102.0</b>	<b>100.6</b>	<b>99.1</b>	<b>99.6</b>	<b>98.9</b>	<b>100.7</b>	<b>103.9</b>	<b>104.2</b>	<b>105.3</b>	<b>102.2</b>	<b>101.5</b>	<b>100.0</b>	<b>100.7</b>	<b>106.6</b>	<b>100.6</b>	<b>101.7</b>	<b>103.4</b>	<b>97.7</b>	<b>98.2</b>	<b>100.0</b>	<b>99.8</b>	<b>98.1</b>
Hard coal	93.6	93.6	93.6	93.6	93.6	93.7	93.7	93.7	93.7	93.7	93.7	93.7	93.7	93.7	93.7	93.1	92.8	92.9	93.1	92.8	92.4	92.4	93.2	92.4
Coke	106.7	106.8	106.8	106.8	106.8	106.8	106.8	106.8	106.8	106.8	106.8	106.7	106.7	106.7	106.7	106.7	106.7	106.6	106.7	106.7	106.7	106.8	106.7	106.2
Blast furnace gases	250.6	250.6	250.6	250.7	250.2	247.0	247.0	249.9	250.8	248.0	248.2	248.2	247.9	247.0	246.3	247.9	247.2	248.5	242.1	242.8	237.3	238.0	238.2	231.8
Coke oven gas	41.1	41.1	41.1	41.1	41.1	41.1	41.1	41.1	41.1	41.1	41.1	41.1	41.1	41.1	41.1	41.1	41.1	41.1	41.1	41.1	41.1	41.1	41.1	
Other coal	106.9	94.5	89.7	90.7	97.4	97.0	89.7	89.7	90.8	96.2	97.1	94.6	96.1	95.4	97.5	98.0	92.2	94.4	89.9	90.9	91.4	92.8	90.1	90.0
<b>Liquid fuels</b>	<b>73.9</b>	<b>73.8</b>	<b>73.7</b>	<b>73.9</b>	<b>73.6</b>	<b>73.6</b>	<b>73.6</b>	<b>73.6</b>	<b>73.4</b>	<b>73.5</b>	<b>73.4</b>	<b>73.4</b>	<b>73.4</b>	<b>73.3</b>	<b>73.3</b>	<b>73.1</b>	<b>73.1</b>	<b>72.2</b>	<b>71.8</b>	<b>71.4</b>	<b>71.7</b>	<b>71.5</b>	<b>72.3</b>	<b>71.4</b>
Heavy fuel oil	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	79.1
Light fuel oil	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	73.9	73.9	73.9	73.9	73.9	73.9	73.8	73.9
Motor gasoline	72.9	72.9	72.9	72.9	72.9	72.9	72.9	72.9	72.9	72.9	72.9	72.9	72.9	72.9	72.9	72.9	72.9	72.9	72.9	72.9	72.9	72.9	72.9	72.9
Diesel oil	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.6	73.3
LPG	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	65.0	64.9
Refinery gases	57.2	57.1	57.0	57.3	57.2	57.2	57.3	57.5	57.1	56.9	56.8	56.9	57.3	56.8	56.6	55.8	55.4	53.6	54.2	53.9	53.9	53.2	53.9	54.1
Town gas	59.4	59.4	59.4	59.4	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Recycled waste oil	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8
Petroleum coke	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	97.5	102.0	103.4	100.7	93.9	92.6	95.7	95.6	95.1	100.8
Jet fuel	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2
Aviation gasoline	71.3	71.3	71.3	71.3	71.3	71.3	71.3	71.3	71.3	71.3	71.3	71.3	71.3	71.3	71.3	71.3	71.3	71.3	71.3	71.3	71.3	71.3	71.3	71.3
Other oil	81.4	80.7	79.9	83.6	75.0	80.9	81.3	81.7	80.7	83.3	83.2	82.9	81.6	77.6	81.7	75.1	75.3	73.2	72.9	73.9	28.9	29.5	68.6	27.5
<b>Gaseous fuels</b>	<b>55.0</b>	<b>55.0</b>	<b>55.0</b>	<b>55.0</b>	<b>55.0</b>	<b>55.0</b>	<b>55.0</b>	<b>55.0</b>	<b>55.0</b>	<b>55.0</b>	<b>55.0</b>	<b>55.0</b>	<b>55.0</b>	<b>55.0</b>	<b>55.0</b>	<b>55.0</b>	<b>55.0</b>	<b>55.0</b>	<b>55.0</b>	<b>55.0</b>	<b>55.0</b>	<b>55.0</b>	<b>55.2</b>	
Natural gas	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.0	55.2
LNG	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	55.8
<b>Other</b>	<b>104.7</b>	<b>104.8</b>	<b>104.8</b>	<b>104.8</b>	<b>104.6</b>	<b>104.6</b>	<b>104.9</b>	<b>104.7</b>	<b>104.4</b>	<b>104.3</b>	<b>103.9</b>	<b>103.6</b>	<b>104.1</b>	<b>104.0</b>	<b>103.8</b>	<b>103.8</b>	<b>104.2</b>	<b>104.3</b>	<b>104.0</b>	<b>103.6</b>	<b>103.9</b>	<b>104.0</b>	<b>104.8</b>	<b>102.5</b>
Peat	104.5	104.5	104.5	104.5	104.5	104.5	104.6	104.5	104.7	104.7	104.6	104.6	104.6	104.6	104.6	104.6	104.7	104.7	104.6	104.6	104.6	104.6	106.6	106.2
Mixed fuels (MSWREF/ RDF/PDF etc.)	172.9	167.9	163.0	184.7	116.2	113.1	154.1	146.0	148.2	144.7	81.4	73.5	85.9	81.2	78.3	81.4	84.8	87.1	87.2	87.6	87.5	89.2	86.3	84.8
Other fossil wastes etc.	98.9	105.2	113.6	108.2	106.4	111.1	110.6	105.4	91.5	89.3	99.5	98.5	95.0	97.5	96.9	101.2	107.4	109.6	109.7	108.3	100.7	108.1	100.4	58.6
<b>Biomass</b>	<b>107.8</b>	<b>107.6</b>	<b>107.4</b>	<b>107.5</b>	<b>107.6</b>	<b>107.5</b>	<b>107.6</b>	<b>107.6</b>	<b>107.6</b>	<b>107.6</b>	<b>107.5</b>	<b>107.6</b>	<b>107.5</b>	<b>107.5</b>	<b>107.5</b>	<b>107.3</b>	<b>107.2</b>	<b>107.3</b>	<b>106.8</b>	<b>106.2</b>	<b>106.2</b>	<b>106.1</b>	<b>106.2</b>	<b>105.9</b>
Black/sulphite liquor	108.5	108.5	108.5	108.5	108.5	108.5	108.5	108.5	108.5	108.5	108.5	108.5	108.5	108.5	108.5	108.5	108.5	108.5	108.5	108.5	108.5	108.5	108.5	108.5
Other woodfuels	107.9	107.7	107.5	107.6	107.7	107.7	107.8	107.8	107.9	107.7	107.7	107.9	107.9	107.9	107.9	107.9	107.5	107.8	107.6	107.6	107.6	107.7	107.6	107.5
Biogas	56.1	56.1	56.1	56.1	56.1	56.1	56.1	56.1	56.1	56.1	56.1	56.1	56.1	56.1	56.1	56.1	56.1	56.1	56.1	56.1	56.1	56.1	56.1	56.1
Bio diesel	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	81.1	73.7	71.1	71.5	72.3	72.5	72.2
Bio gasoline	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	66.0	68.0	69.4	NO	66.0	66.0	71.1	69.6	62.4	70.1	69.5	69.6
Bio gasoil	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	70.8	70.8	71.3	71.3	71.3
Bio natural gas	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	40.0	54.9	54.9	54.9	55.1	55.1	55.7	55.9	56.1	56.1	56.1	56.1
Bio mixed fuels	105.1	104.9	104.8	105.3	106.8	108.9	106.5	106.8	106.5	105.7	104.7	103.8	103.0	101.6	100.8	100.4	100.8	100.7	101.4	101.3	101.2	101.2	101.8	102.7
Hydrogen	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Other non-fossil fuels	108.5	108.5	108.5	NO	108.5	108.5	108.5	108.5	108.5	96.4	104.3	105.7	106.3	106.2	107.3	107.5	107.3	96.1	88.7	86.1	86.4	87.3	81.7	71.3
<b>Bunker fuels</b>	<b>76.0</b>	<b>76.0</b>	<b>76.4</b>	<b>76.0</b>	<b>75.5</b>	<b>74.9</b>	<b>75.1</b>	<b>75.2</b>	<b>75.6</b>	<b>75.7</b>	<b>75.9</b>	<b>75.8</b>	<b>76.2</b>	<b>76.2</b>	<b>75.9</b>	<b>75.9</b>	<b>75.9</b>	<b>75.3</b>	<b>75.0</b>	<b>74.6</b>	<b>74.3</b>	<b>74.1</b>	<b>73.8</b>	<b>73.7</b>
Jet fuel	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2	73.2
Light fuel oil	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	74.1	73.9
Heavy fuel oil	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.8	78.4
Other oils	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3	73.3

**Table 4\_App 3b.** CH<sub>4</sub> emissions from combustion by fuel, kt

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<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>184</b>	<b>138</b>	<b>117</b>	<b>154</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	135
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	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	9.6
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	6.6
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	1.21
<b>Liquid fuels</b>	<b>5 898</b>	<b>5 546</b>	<b>5 335</b>	<b>5 028</b>	<b>4 776</b>	<b>4 571</b>	<b>4 461</b>	<b>4 332</b>	<b>4 207</b>	<b>4 039</b>	<b>3 781</b>	<b>3 708</b>	<b>3 520</b>	<b>3 286</b>	<b>3 085</b>	<b>2 908</b>	<b>2 759</b>	<b>2 618</b>	<b>2 283</b>	<b>2 106</b>	<b>2 090</b>	<b>1 947</b>	<b>1 920</b>	<b>1 830</b>
Heavy fuel oil	256	243	229	186	172	135	146	137	142	142	126	133	138	136	129	122	122	117	101	97	103	91	84	64
Light fuel oil	802	791	781	773	755	744	754	742	753	746	701	725	712	705	691	652	638	611	552	532	569	504	538	499
Motor gasoline	4 209	3 928	3 758	3 508	3 290	3 135	3 028	2 908	2 779	2 635	2 451	2 364	2 193	1 987	1 826	1 705	1 589	1 506	1 275	1 172	1 122	1 074	1 037	1 026
Diesel oil	546	501	487	486	477	477	450	464	445	435	418	403	390	369	352	339	318	293	263	217	205	186	172	156
LPG	28.9	27.7	26.6	24.4	26.4	26.4	26.4	26.5	28.9	23.0	28.2	28.2	29.1	31.0	31.9	33.1	35.4	33.6	34.7	28.5	32.1	32.2	31.9	28.9
Refinery gases	21.8	22.3	22.8	20.2	22.9	22.4	23.4	22.0	24.4	23.9	21.5	22.4	24.2	24.2	22.7	24.7	24.7	26.2	25.6	29.3	27.9	29.0	26.9	27.0
Town gas	0.43	0.41	0.39	0.19	NO	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	0.63
Petroleum coke	4.90	5.00	5.09	5.01	4.82	4.86	5.47	5.27	5.44	5.25	4.69	4.33	5.59	5.25	5.85	5.50	5.44	6.17	6.03	5.48	5.24	6.14	5.80	6.53
Jet fuel	13.89	14.24	13.41	13.42	14.20	13.11	15.44	16.86	18.29	19.22	19.15	17.94	18.37	19.50	17.11	19.38	17.33	16.60	17.17	16.80	16.54	15.11	14.50	12.88
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	0.02
Other oil	14.10	12.76	11.42	11.41	11.90	12.48	10.96	9.73	9.31	9.18	9.70	9.59	8.60	6.57	6.50	6.28	7.34	8.11	7.46	6.35	8.76	8.53	8.73	9.94
<b>Gaseous fuels</b>	<b>111</b>	<b>133</b>	<b>156</b>	<b>153</b>	<b>169</b>	<b>193</b>	<b>208</b>	<b>239</b>	<b>285</b>	<b>265</b>	<b>260</b>	<b>303</b>	<b>414</b>	<b>467</b>	<b>405</b>	<b>341</b>	<b>364</b>	<b>288</b>	<b>294</b>	<b>233</b>	<b>233</b>	<b>188</b>	<b>151</b>	<b>138</b>
Natural gas	111	133	156	153	169	193	208	239	285	265	260	303	414	467	405	341	364	288	294	233	233	188	151	132
LNG	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	6.5
<b>Other</b>	<b>237</b>	<b>229</b>	<b>222</b>	<b>250</b>	<b>278</b>	<b>312</b>	<b>344</b>	<b>355</b>	<b>339</b>	<b>303</b>	<b>296</b>	<b>376</b>	<b>403</b>	<b>443</b>	<b>411</b>	<b>347</b>	<b>446</b>	<b>486</b>	<b>429</b>	<b>422</b>	<b>514</b>	<b>460</b>	<b>416</b>	<b>390</b>
Peat	232	226	220	247	274	309	339	350	333	296	289	368	395	434	401	333	435	473	416	403	499	446	394	358
Mixed fuels (MSW/)	0.2	0.2	0.2	0.2	1.2	1.3	0.5	0.6	0.7	0.7	2.5	3.3	2.6	4.0	5.3	10.3	9.0	11.4	11.9	17.2	13.1	12.4	19.3	28.4
Other fossil wastes	5.1	3.2	1.4	2.4	2.7	1.9	4.5	4.5	6.3	6.1	5.3	5.1	5.5	5.1	4.4	3.2	2.1	2.2	1.8	1.5	1.8	1.7	2.1	3.6
<b>Biomass</b>	<b>8 092</b>	<b>8 135</b>	<b>8 178</b>	<b>8 321</b>	<b>8 363</b>	<b>8 651</b>	<b>9 024</b>	<b>9 113</b>	<b>9 200</b>	<b>9 115</b>	<b>8 868</b>	<b>9 870</b>	<b>10 210</b>	<b>10 365</b>	<b>10 462</b>	<b>10 437</b>	<b>10 782</b>	<b>10 833</b>	<b>11 870</b>	<b>12 426</b>	<b>13 958</b>	<b>12 193</b>	<b>13 176</b>	<b>12 189</b>
Black/sulphite liquo	87	87	87	105	111	111	108	129	130	139	140	125	141	138	145	129	156	154	142	110	136	135	136	141
Other woodfuels	8 000	8 045	8 090	8 203	8 243	8 479	8 846	8 908	8 998	8 899	8 647	9 674	9 995	10 140	10 231	10 220	10 543	10 584	11 583	12 149	13 531	11 664	12 637	11 674
Biogas	0.37	0.295	0.22	12	6	59	68	74	70	74	76	67	68	77	74	75	72	79	79	75	191	288	294	273
Bio diesel	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.02	1.22	5.95	5.52	8.71	7.67	10.43
Bio gasoline	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.77	3.59	3.33	NO	0.50	0.95	48.31	55.06	57.11	65.84	68.17	49.82
Bio gasoil	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.00	6.99	13.43	9.33	3.63	0.60
Bio natural gas	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.010	0.01	0.02	0.08	0.13	0.30	0.82	1.42
Bio mixed fuels	3.8	2.5	1.2	1.3	2.3	2.3	1.6	1.9	2.3	2.3	4.9	3.4	4.1	5.9	7.5	10.8	9.5	13.1	14.9	19.5	20.1	18.6	25.9	34.2
Hydrogen	NO	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 fue	0.30	0.23	0.16	NO	0.15	0.11	0.12	0.28	0.21	0.31	0.45	0.56	1.34	0.65	1.14	1.49	1.46	1.76	2.82	4.32	3.95	3.58	3.05	3.92
<b>Bunker fuels</b>	<b>162</b>	<b>153</b>	<b>184</b>	<b>146</b>	<b>117</b>	<b>96</b>	<b>117</b>	<b>126</b>	<b>155</b>	<b>175</b>	<b>198</b>	<b>178</b>	<b>182</b>	<b>183</b>	<b>154</b>	<b>155</b>	<b>169</b>	<b>148</b>	<b>137</b>	<b>94</b>	<b>86</b>	<b>89</b>	<b>68</b>	<b>158</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	127
Light fuel oil	22	21	24	27	28	29	29	30	30	33	31	28	20	18	9	10	12	16	15	10	13	13	8	9
Heavy fuel oil	113	109	139	99	68	45	57	64	92	104	123	110	135	138	109	114	125	97	84	52	38	35	20	21
Other oils	0.29	0.28	0.35	0.27	0.21	0.17	0.19	0.21	0.27	0.29	0.33	0.30	0.32	0.32	0.24	0.25	0.28	0.23	0.21	0.13	0.11	0.10	0.06	0.07

**Table 5\_App\_3b.** N<sub>2</sub>O emissions from combustion by fuel, kt

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<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>	<b>253</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	229
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	1.8
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	13.7
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	7.3
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	1.28
<b>Liquid fuels</b>	<b>969</b>	<b>950</b>	<b>933</b>	<b>905</b>	<b>905</b>	<b>881</b>	<b>884</b>	<b>866</b>	<b>865</b>	<b>853</b>	<b>808</b>	<b>799</b>	<b>776</b>	<b>746</b>	<b>707</b>	<b>673</b>	<b>650</b>	<b>629</b>	<b>572</b>	<b>544</b>	<b>566</b>	<b>533</b>	<b>527</b>	<b>501</b>
Heavy fuel oil	154	148	142	131	135	119	121	111	114	117	103	106	107	103	98	91	93	87	72	69	75	59	56	40
Light fuel oil	210	207	204	203	198	197	201	200	204	201	189	192	187	183	178	167	162	155	140	132	140	125	133	124
Motor gasoline	300	304	304	300	302	309	311	310	305	303	296	287	267	247	225	205	183	168	136	120	106	92	78	71
Diesel oil	220	205	198	191	181	171	160	155	143	134	124	119	116	112	107	105	106	110	116	114	130	139	150	156
LPG	10.0	9.3	8.6	8.7	10.0	10.0	10.8	12.1	14.0	13.2	15.6	15.3	15.6	17.2	17.8	18.3	19.5	18.5	18.8	15.0	17.7	17.5	17.0	15.8
Refinery gases	40.2	41.5	42.8	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	52.9
Town gas	0.14	0.14	0.13	0.06	NO	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	1.32	1.24	1.23	1.22	1.04	1.17	2.06	2.22	2.27	2.20	1.65	1.86	1.76	2.44	2.15	1.79	1.24
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	13.0
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	19.4	19.5	19.2	19.3	18.5	19.1	17.4	16.7	14.8
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	0.07
Other oil	7.8	7.1	6.5	6.6	6.8	7.5	6.9	6.1	5.6	5.5	6.2	6.7	5.3	4.2	4.2	4.1	5.1	5.4	5.0	4.6	11.3	10.9	10.9	11.2
<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>167</b>	<b>171</b>	<b>151</b>	<b>164</b>	<b>146</b>	<b>131</b>	<b>122</b>
Natural gas	103	108	113	118	127	130	139	136	154	156	163	173	170	187	182	166	177	167	171	151	164	146	131	122
LNG	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.17
<b>Other</b>	<b>171</b>	<b>185</b>	<b>198</b>	<b>224</b>	<b>256</b>	<b>294</b>	<b>343</b>	<b>350</b>	<b>330</b>	<b>282</b>	<b>263</b>	<b>375</b>	<b>417</b>	<b>454</b>	<b>405</b>	<b>322</b>	<b>410</b>	<b>445</b>	<b>360</b>	<b>321</b>	<b>432</b>	<b>399</b>	<b>298</b>	<b>270</b>
Peat	169	183	197	222	253	291	338	346	323	277	258	367	409	443	392	310	400	433	345	303	414	382	279	243
Mixed fuels (MSW/REF/RDF)	0.22	0.23	0.23	0.21	1.24	1.30	0.92	0.91	0.85	0.66	1.01	3.63	3.24	6.5	8.0	8.7	8.0	9.4	12.7	16.7	16.2	15.0	17.1	21.8
Other fossil wastes etc.	1.96	1.66	1.35	1.64	2.13	2.17	3.14	3.22	5.46	4.81	4.04	4.46	5.28	5.01	4.64	3.30	2.21	2.31	1.74	1.52	1.74	1.53	2.31	5.38
<b>Biomass</b>	<b>284</b>	<b>276</b>	<b>268</b>	<b>330</b>	<b>348</b>	<b>359</b>	<b>384</b>	<b>449</b>	<b>477</b>	<b>522</b>	<b>528</b>	<b>520</b>	<b>550</b>	<b>560</b>	<b>605</b>	<b>581</b>	<b>626</b>	<b>592</b>	<b>668</b>	<b>622</b>	<b>751</b>	<b>763</b>	<b>796</b>	<b>802</b>
Black/sulphite liquor	88	87	87	105	111	111	108	129	130	139	140	125	141	138	145	129	156	154	142	110	136	135	136	141
Other woodfuels	193	186	179	223	233	244	272	315	343	378	382	387	400	408	444	429	449	411	490	469	570	583	614	608
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	1.07	1.21	1.83	1.62	1.87	2.00	1.88	1.75	2.37	2.60	2.72
Bio diesel	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.01	0.54	3.12	3.49	6.50	6.67	10.45
Bio gasoline	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.12	0.58	0.55	NO	0.08	0.16	5.17	5.66	5.44	5.69	5.13	3.49
Bio gasoil	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.00	1.59	3.04	2.26	0.87	0.14
Bio natural gas	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.01	0.05	0.11
Bio mixed fuels	0.93	1.07	1.21	1.30	2.28	2.28	2.31	2.44	2.52	2.36	3.15	3.90	5.20	9.55	11.40	16.30	14.75	21.00	22.22	23.34	24.30	21.48	25.52	28.07
Hydrogen	0.63	0.83	1.02	0.95	1.05	1.07	0.95	1.06	1.25	0.98	1.22	1.34	1.46	1.43	1.50	1.33	1.66	1.33	1.25	1.10	1.20	1.21	1.08	1.12
Other non-fossil fuels	0.52	0.40	0.28	NO	0.27	0.20	0.21	0.49	0.34	0.50	0.90	1.01	1.31	1.39	2.18	2.64	2.91	3.13	4.88	6.23	5.96	5.31	4.46	6.75
<b>Bunker fuels</b>	<b>89</b>	<b>85</b>	<b>92</b>	<b>77</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>97</b>	<b>98</b>	<b>92</b>	<b>93</b>	<b>103</b>	<b>104</b>	<b>106</b>	<b>85</b>	<b>85</b>	<b>96</b>	<b>87</b>	<b>65</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	56
Light fuel oil	10	10	11	12	13	13	13	13	14	14	13	12	8.5	7.8	3.9	3.9	5.0	6.3	6.1	3.8	5.0	4.7	2.9	3.2
Heavy fuel oil	38	36	47	33	23	15	19	21	30	34	41	36	44	45	35	37	39	30	25	15	11	10	5	6

## 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	2013
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	305 921

The Finnish Forest Industries collected the total produced amount of PCC for years 1993-2007. Statistics Finland have collected PCC data for years 2008-2013 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	2013
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*	1**
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	99

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.

\*\* One plant used wood fuels in 2013

**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	2013
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	134 516

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 Market 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*

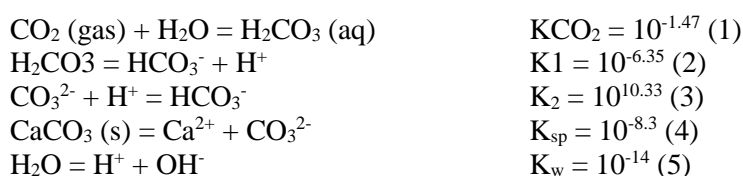
Concerning the potential emission of CO<sub>2</sub> from calcium carbonate-water interaction in fibre sludge-bearing earth structures, we state the following:

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.

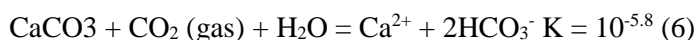
PCC-bearing fibre sludge is nowadays mainly utilized in many earth construction applications, e.g., as a hydraulic barrier in landfill cover structures, in impermeable reactive walls and in sub-base filter in roads and sport areas. Under these circumstances, it will be occasionally exposed to acid rain 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\_App\_3d. 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\_App\_3d. Contents of carbon species (mol) and Ca<sup>2+</sup> (mg/l), pH, and PCO<sub>2</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.  
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Prof. Olli Dahl

Docent Kauko Kujala

Prof. Eero Hanski

Contact information:

Prof. Olli Dahl Helsinki University of Technology  
Docent Kauko Kujala University of Oulu  
Prof. Eero Hanski University of Oulu

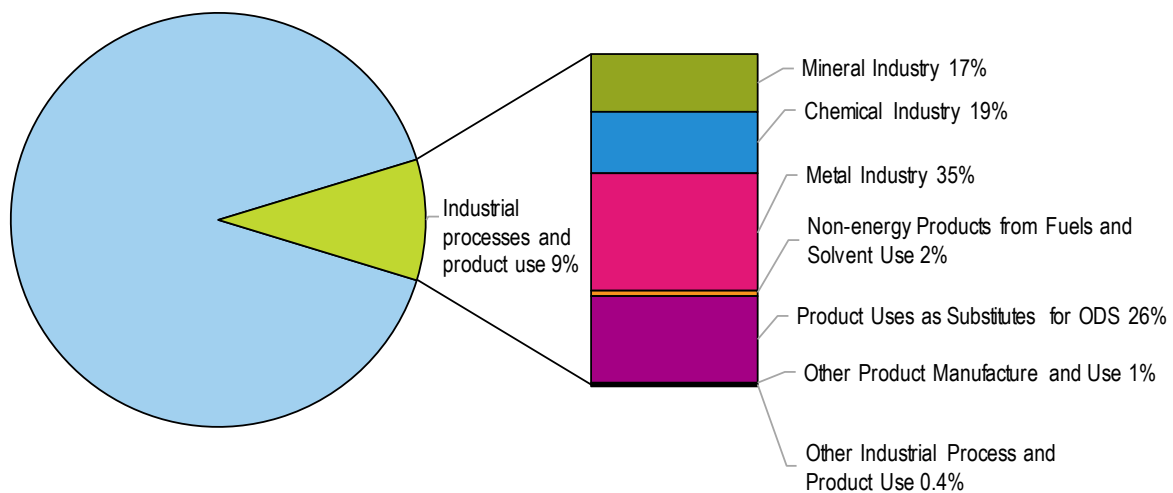
e-mail: [olli.dahl@tkk.fi](mailto:olli.dahl@tkk.fi)  
e-mail: [kauko.kujala@oulu.fi](mailto:kauko.kujala@oulu.fi)  
e-mail: [eero.hanski@oulu.fi](mailto:eero.hanski@oulu.fi)

## 4 INDUSTRIAL PROCESSES AND PRODUCT USE (CRF 2)

### 4.1 Overview of the sector

#### 4.1.1 Description and quantitative overview

Greenhouse gas emissions from Industrial Processes and Product Use contributed 9% to the total anthropogenic greenhouse gas emissions in Finland in 2013 (Figure 4.1-1), totalling 6.0 million tonnes of carbon dioxide equivalent (Mt CO<sub>2</sub> eq.).



**Figure 4.1-1** Emissions from Industrial Processes and Product Use compared with total emissions in 2013

Finnish greenhouse gas emissions from Industrial Processes and Product use are divided into following emission categories:

- Mineral Products (CRF 2.A) includes CO<sub>2</sub> emissions from cement, lime and glass production, and other process uses of carbonates.
- 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 limestone and dolomite use in chemical industry.
- 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, zinc, copper and nickel production and limestone and dolomite use.
- Non-energy Products from Fuel and Solvent Use (CRF 2.D) includes CO<sub>2</sub> emissions from lubricant and paraffin wax use and use of urea based catalyst.
- All emissions from Electronics industry (2.E) are confidential and are therefore included in Other (2.H.3)
- Product Uses as Substitutes for ODS (CRF 2.F) covers emissions of F-gases from refrigeration and air conditioning, foam blowing and aerosols. Emissions from some smaller sources, such as semiconductor manufacturing and fixed fire protection systems are reported in Other (2.H) due to confidentiality issues.
- Other Product Manufacture and Use (2.G) includes SF<sub>6</sub> emission from electrical equipment and N<sub>2</sub>O emissions from Product uses
- Other (2.H) includes emissions of grouped confidential data of halocarbons and SF<sub>6</sub> (semiconductor manufacturing, fixed fire protection systems, magnesium die casting, shoes (until 2007) and research)

Former CRF category limestone and dolomite use are due to new CRF classification reported in several CRF categories: 2.A.4a Other Process Uses of Carbonates; Ceramics, 2.A.4d Other Process Uses of Carbonates; Other, 2.B.10 Other; Limestone and Dolomite use and 2.C.1a Steel.

NMVOC emission from Industrial Processes and Product use are reported under CFR 2.B Chemical industry (2.B.10 Chemicals production), CRF 2.C Metal industry (2.C.7 Other), CRF 2.D Non-energy Products from Fuels and Solvent use (2.D.3 Other, Solvent use and Road paving with asphalt), 2.H Other (2.H.1 Pulp and paper and 2.H.2 Food and beverages industry). Indirect CO<sub>2</sub> emissions from NMVOC emissions are reported aggregated in national totals. Indirect N<sub>2</sub>O emissions from NH<sub>3</sub> emissions are estimated to be insignificant, see Chapter 9.

General assessment of completeness can be found in Section 1.7 and more detailed assessment is included in Annex 5.

The emissions from Industrial Processes and Product Use sector are increased 11 percent since 1990 (Figure 4.1-2). The main reason for growth is increased use of F-gases in refrigeration and air-conditioning. The emissions from nitric acid production decreased rapidly due to implementation of N<sub>2</sub>O abatement technology in 2009. Emissions in 2013 were at the same level than in 2012.

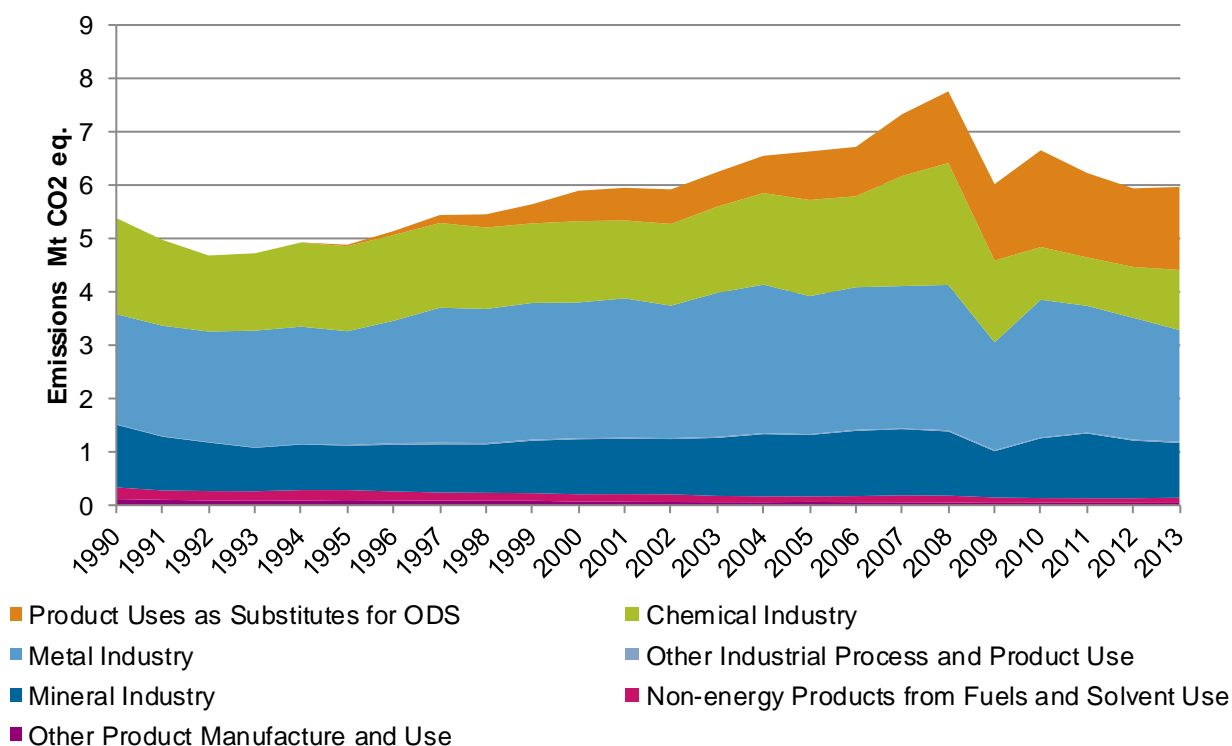
The most important greenhouse gas emission sources of Industrial Processes and Product Use in the Finnish inventory in 2013 were CO<sub>2</sub> emissions from iron and steel, hydrogen and cement production with 3.3%, 1.3% and 0.8% shares of the total national greenhouse gas emissions, respectively. F-gas emissions comprised together 2.5% 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 a year 25% due to economic turndown. In 2013 CO<sub>2</sub> emissions were 4% less than in 2012 and 13% higher than in 1990.

N<sub>2</sub>O emissions have fluctuated during the period 1990 to 2013; 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 87 since 1990. In 2013 emissions were 32% higher than in 2012.

Emissions of F-gases are increased significantly since 1990, they are now about thirtyfold compared with the 1990 as well as the 1995 emissions, which is the base year for these emissions under the Kyoto Protocol. There are no fugitive emissions from manufacturing, because F-gases are not produced in Finland. There has not been neither any manufacturing of other fluorinated gases, such as HCFCs or CFCs, 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.

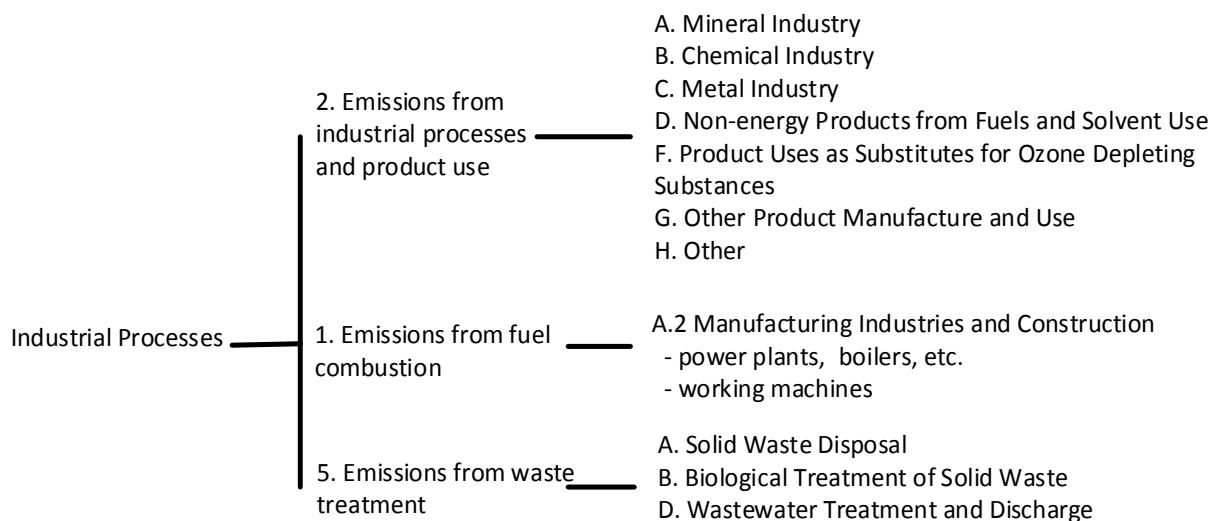
CH<sub>4</sub> emissions from coke production have increased by 70% since 1990 but their contribution to the total industrial emissions were in 2013 only 0.002%.



**Figure 4.1-2** Total greenhouse gas emission from Industrial Processes and Product Use in Finland (Mt CO<sub>2</sub> eq.)

Total industrial emissions are divided between three sectors:

- industrial process emissions are reported in sector 2: Industrial Processes and Product Use
- emissions from fuel combustion in industry are reported in sector 1: Energy
- waste and wastewater generated emissions in industry are reported in sector 5 (Figure 4.1-3). Emissions from combusted waste are reported in the energy sector.



**Figure 4.1-3** Reporting categories of emissions from industrial sources in the national greenhouse gas inventory

## 4.1.2 Key categories

The key categories in Industrial Processes and Product Use in 2013 are summarised in Table 4.1-1.

**Table 4.1-1** Key categories in Industrial Processes and Product Use (CRF 2) in 2013 (Approach 1)

Category	Gas	Criteria
2.A.1. Cement Production	CO <sub>2</sub>	L, T
2.A.2. Lime Production	CO <sub>2</sub>	L, T
2.A.4. Other Process Uses of Carbonates	CO <sub>2</sub>	T
2.B.2. Nitric Acid Production	N <sub>2</sub> O	T
2.B.10 Other	CO <sub>2</sub>	L, T
2.C.1. Iron and Steel Production	CO <sub>2</sub>	L, T
2.D. Non-energy Products from Fuels and Solvent Use	CO <sub>2</sub>	T
2.F.1. Refrigeration and Air Conditioning	Aggregate F-gases	L, T

**Table 4.1-2** Trend in greenhouse gas emissions from Industrial Processes and Product Use (Mt CO<sub>2</sub> eq.)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<b>CO<sub>2</sub></b>																
A Mineral industry	1.18	0.83	1.03	1.04	1.04	1.09	1.17	1.15	1.22	1.24	1.20	0.87	1.12	1.22	1.08	1.03
B Chemical industry	0.27	0.26	0.28	0.28	0.31	0.31	0.33	0.29	0.37	0.70	0.82	0.83	0.87	0.82	0.83	0.91
C Metal industry	1.98	2.08	2.39	2.44	2.32	2.48	2.57	2.40	2.47	2.49	2.55	1.97	2.44	2.38	2.29	2.09
D Non-energy products from fuel and solvent use	0.22	0.19	0.14	0.14	0.14	0.12	0.11	0.10	0.11	0.13	0.13	0.10	0.08	0.08	0.08	0.10
<b>CH<sub>4</sub></b>																
C Metal industry	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
D Non-energy products from fuel and solvent use	0.0003	0.0002	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
<b>N<sub>2</sub>O</b>																
B Chemical industry	1.59	1.41	1.31	1.24	1.28	1.35	1.44	1.56	1.38	1.42	1.52	0.76	0.16	0.13	0.16	0.21
D Non-energy products from fuel and solvent use	0.0017	0.0014	0.0010	0.0011	0.0011	0.0008	0.0008	0.0007	0.0008	0.0009	0.0008	0.0006	0.0005	0.0005	0.0005	0.0006
G Other product manufacture and use	0.064	0.065	0.055	0.052	0.047	0.044	0.043	0.048	0.043	0.040	0.038	0.029	0.032	0.031	0.030	0.027
<b>HFCs</b>	0.000	0.027	0.56	0.59	0.63	0.64	0.69	0.90	0.91	1.15	1.34	1.43	1.82	1.59	1.48	1.56
<b>PFC</b>	0.0002	0.0004	0.0132	0.0227	0.0165	0.0183	0.0144	0.0160	0.0192	0.0102	0.0139	0.0115	0.0009	0.0021	0.0055	0.0064
<b>SF<sub>6</sub></b>	0.052	0.037	0.026	0.026	0.025	0.026	0.024	0.022	0.028	0.019	0.027	0.027	0.022	0.024	0.022	0.031
<b>NF<sub>3</sub></b>	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
<b>Total</b>	<b>5.35</b>	<b>4.89</b>	<b>5.80</b>	<b>5.84</b>	<b>5.82</b>	<b>6.08</b>	<b>6.39</b>	<b>6.50</b>	<b>6.56</b>	<b>7.21</b>	<b>7.64</b>	<b>6.02</b>	<b>6.56</b>	<b>6.27</b>	<b>5.98</b>	<b>5.96</b>

## 4.2 Mineral Industry (CRF 2.A)

### 4.2.1 Introduction

This category consists of non-fuel carbon dioxide emissions from cement, lime and glass production and other process uses of carbonates (Table 4.2-1 and Table 4.2-2). This category has changed due to implementation of new 2006 IPCC Guidelines, as the use of limestone and dolomite other than for clinker and lime production are reported by branch of businesses. In Finland under the Mineral Industry there are reported emissions from ceramics and mineral wool production, from the wastewater treatment, from the neutralisation and from the energy industry for sulphur dioxide control and use of soda ash. Limestone and dolomite used in the chemical or metal industries are reported under corresponding categories.

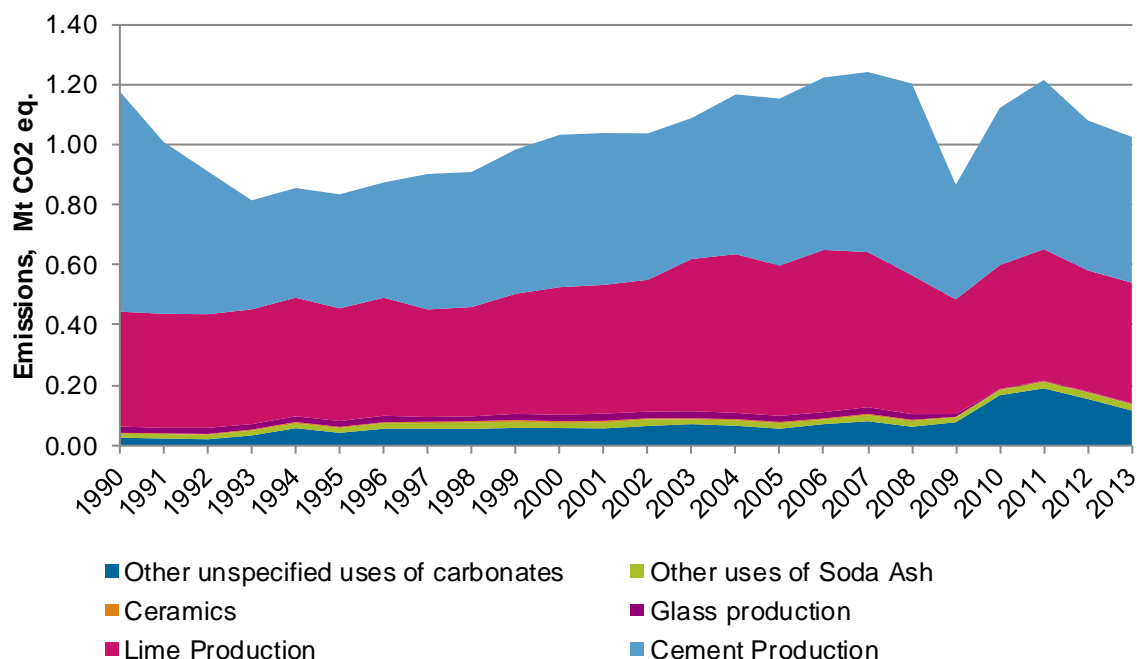
Lime production includes lime production in the iron and steel industry. All soda ash which is used in Finland are included in the inventory. All other uses of soda ash than use in glass production (2.A.3) are reported in CRF category 2.A.4b.

Production capacity of clinker in Finland in the end of time series is about 1,300,000 t (1,600,000 t cement), but in 2013 966,000 t clinker were produced (Finnsementti Oy, 2014). The production capacity has been increasing during time series when old cement kilns have been modernised or replaced.

**Table 4.2-1** Reported emissions, calculation methods and type of emission factors for the subcategory Mineral Industry 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	Glass production	CO <sub>2</sub>	Tier 3	CS
2.A.4	Other process uses of carbonates			
	- Ceramics	CO <sub>2</sub>	Tier 2	CS
	- Other uses of Soda Ash	CO <sub>2</sub>	Tier 2	CS
	- Other	CO <sub>2</sub>	Tier 2	CS

The emissions of the category Mineral Industry were 22% of the emissions of the Industrial Processes and Product Use sector in 1990 and 17% in 2013 as well as 1.6% of Finland's total greenhouse gas emissions. The amount of emissions were 1.2 Mt in 1990 and 1.0 Mt in 2013 (Figure 4.2-1). The emissions in 2013 were 13% less than in 1990 and 5% less than in 2012. The main reasons for emission reduction have been a closing down of a cement plant and glass plants in the beginning of time series.



**Figure 4.2-1** Greenhouse gas emission from Mineral Products (Mt CO<sub>2</sub> eq.)

Cement production is the biggest source of greenhouse gas emissions in the Mineral Industry category, being 0.49 Mt in 2013. Emissions were 14% in 1990 and over 8% in 2013 of the emissions in the Industrial Processes and Product Use sector and 0.8% of Finland's total emissions in 2013. 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. The emissions in 2013 were 34% less than in 1990 and 3% less than in 2012.

Lime production is the second largest source in the Mineral Industry category, the emissions were 0.40 Mt in 2013. 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. Emissions from lime production were in 2013 5% more than in 1990 and at the same level than in 2012.

Other process uses of carbonates is the third largest source in the Mineral Industry category, emissions were 0.14 Mt. Emissions of the most important sources were limestone and dolomite used in wastewater treatment and neutralisation, 59%, in sulphur dioxide control almost 17% and soda ash use over 15% of emissions of this subcategory in 2013. Since 1990 emissions have become threefold, the biggest reason were the increased use of carbonates in wastewater treatment. Emissions of other process uses of carbonates were 22% less than in 2012.

Glass production is a minor source in the category of Mineral Industry, emissions were 0.002 Mt in 2013. 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, due to economic downturn in 2009 two plants in Finnish glass industry were closed down. Emissions from glass production have decreased 90% since 1990. In 2013 emissions from glass production were less than 0.04% of the emissions of Industrial processes and Product use sector and less than 0.2% of the category of Mineral Industry.

**Table 4.2-2** CO<sub>2</sub> emissions from Mineral Products (Mt)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
2.A 1 Cement production	0.73	0.38	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	0.49
2.A 2 Lime production	0.38	0.38	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	0.40
2.A 3 Glass production	0.021	0.019	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	0.002
2.A 4 Other process uses of carbonates	0.04	0.06	0.08	0.08	0.09	0.09	0.09	0.08	0.09	0.10	0.08	0.09	0.19	0.21	0.18	0.14
- Ceramics	0.003	0.004	0.006	0.006	0.004	0.004	0.005	0.004	0.004	0.004	0.003	0.002	0.003	0.002	0.002	0.002
- Other uses of soda ash	0.013	0.016	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	0.021
- Other unspecified uses of carbonates	0.025	0.041	0.057	0.055	0.063	0.070	0.064	0.054	0.070	0.079	0.061	0.076	0.166	0.189	0.153	0.115
<b>Total of Mineral industry</b>	<b>1.18</b>	<b>0.83</b>	<b>1.03</b>	<b>1.04</b>	<b>1.04</b>	<b>1.09</b>	<b>1.17</b>	<b>1.15</b>	<b>1.22</b>	<b>1.24</b>	<b>1.20</b>	<b>0.87</b>	<b>1.12</b>	<b>1.22</b>	<b>1.08</b>	<b>1.03</b>

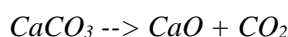
## 4.2.2 Cement production

### 4.2.2.1 Category description

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 in rotary kiln ovens, 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 other product uses of carbonates are also due to calcination of carbonates at high temperatures (Slioor, 2004).

CRF category 2.A 1 covers CO<sub>2</sub> emissions from clinker production. Clinker is mixed with gypsum and other materials that together make up the cement.

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.

### 4.2.2.2 Methodological issues

Emissions were calculated using Tier 2 methodology from the 2006 IPCC Guidelines (equation 2.2). 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.

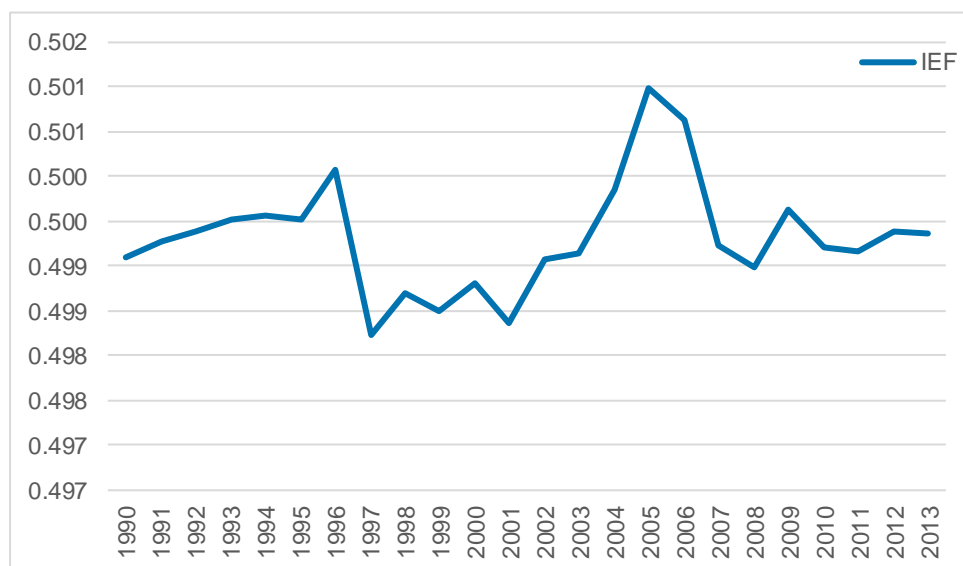
Based on recommendation by the producer (Palonen 2008), the correction factor  $c$  has been set to 0.92 throughout the time series.

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  $\text{CO}_2$  to  $\text{CaO}$  and  $\text{MgO}$ . 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  $\text{CaO}$  and  $\text{MgO}$  weight fractions by plants and produced amount of clinker.



**Figure 4.2-2** Time series of implied emission factor

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 2007-2013 from EU ETS data (Table 4.2-3).

#### 4.2.2.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

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.

#### 4.2.2.4 Category-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 1.2.3. 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 is held annually between the inventory unit and the sectoral expert. In the quality meeting January 2015 it was discussed for example how the verification of different categories could be performed, how to increase consistency of the numbers in the CRF reporter and the NIR and plan of improvements of the inventory. 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.

#### 4.2.2.5 *Category-specific recalculations*

No category-specific recalculations were done.

#### 4.2.2.6 *Category-specific planned improvements*

There are no category-specific planned improvements.

### 4.2.3 *Lime production*

#### 4.2.3.1 *Category description*

There are six lime-producing plants in Finland. (Quick) Lime is produced by heating crushed and assorted limestone to a high temperature (about 1,000 °C) in a rotary or a shaft kiln. Lime (CaO) is granular or powdery, different products are made crushing, screening and grinding. The production process causes CO<sub>2</sub> emissions. Hydrated lime, Ca(OH)<sub>2</sub>, is produced via (quick)lime by adding water to it.

#### 4.2.3.2 *Methodological issues*

Emissions are calculated using a country-specific method, which corresponds to the Tier 2 level. 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.

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.

In calculation of these emissions the amount of lime produced annually is used as activity data. Production of hydrated lime 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.

#### 4.2.3.3 *Uncertainty and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

For 2013 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%.

#### 4.2.3.4 *Category-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 1.2.3. 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 is held annually between the inventory unit and the sectoral expert. In the quality meeting January 2015 it was discussed for example how the verification of different categories could be performed, how to increase consistency of the numbers in the CRF reporter and the NIR and plan of improvements of the inventory.

In the calculation of emissions from lime production general inventory quality control procedures have been done as mentioned in 2006 IPCC Guidelines, table 6.1. 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, 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 2005-2013 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%.

#### 4.2.3.5 *Category-specific recalculations*

There were no recalculations done in this source.

#### 4.2.3.6 *Category-specific planned improvements*

There are no category-specific planned improvements.

### 4.2.4 *Glass production*

#### 4.2.4.1 *Category description*

Glass industry in Finland produces a wide range of different glass types with different chemical compositions for example container, flat, domestic and special glass and glass wool. Emissions are calculated using the use of carbonates as activity data. Limestone, dolomite and soda ash are typically used in glass industry. Barium

and potassium carbonate are used as raw materials in the production of special glasses and lithium carbonate is used to strengthen glass products. Emissions from the use of barium, lithium and potassium carbonate in glass production are also included in the inventory.

In production, homogenous glass mixtures combining primary and secondary raw materials are melted down at temperatures about 1,550 °C. The process-related CO<sub>2</sub> emissions are released from the raw material carbonates during the melting process in the furnace.

#### 4.2.4.2 Methodological issues

Emissions are calculated using Tier 3 method, as various types of carbonates consumed for glass production have been collected plant-levelly. 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. The correction factor of 0.99 has been used. Emission factor for soda ash use is 0.411 t CO<sub>2</sub> / t Na<sub>2</sub>CO<sub>3</sub>. For barium carbonate emission factor is 0.223 t CO<sub>2</sub> / t BaCO<sub>3</sub>, lithium carbonate 0.595 t CO<sub>2</sub> / t Li<sub>2</sub>CO<sub>3</sub> and potassium carbonate 0.318 t CO<sub>2</sub> / t K<sub>2</sub>CO<sub>3</sub>.

The consumption of limestone and dolomite has been used as activity data when calculating emissions from limestone and dolomite use. Activity data for 2013 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.

Activity data of used sodium carbonate 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.

Activity data for consumption of barium, lithium and potassium carbonate are collected from company for years 1995-2004 and 2007-2013. Activity data for the remaining years are estimated using partly production data and partly other years' activity data (Forsell, 2012).

#### 4.2.4.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

The combined uncertainty in glass production was estimated to be ±6%. Uncertainty in carbonate use was estimated to be ±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 2013.) 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.

#### 4.2.4.4 Category-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 1.2.3. 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 is held annually between the inventory unit and the sectoral expert. In the quality meeting in January 2015 it was discussed for example how the verification of different categories could be performed, how to increase consistency of the numbers in the CRF reporter and the NIR and plan of improvements of the inventory.

In the calculation of emissions from glass production general inventory quality control procedures have been performed as mentioned in 2006 IPCC Guidelines, table 6.1 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 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. 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.

#### *4.2.4.5 Category-specific recalculations*

No category-specific recalculations were done.

#### *4.2.4.6 Category-specific planned improvements*

No category-specific improvements have been planned.

### *4.2.5 Other process uses of carbonates*

#### *4.2.5.1 Category description*

Other process uses of carbonates comprises limestone and dolomite uses in ceramics and mineral wool production, in the wastewater treatment, in the neutralisation and in the energy industry for sulphur dioxide control and use of soda ash. There are no non metallurgical magnesia production in Finland.

#### *4.2.5.2 Methodological issues*

##### *Ceramics*

Emissions from limestone and dolomite use in production of light expanded clay aggregate (leca), tiles and porcelain are included in the sub category ceramics.

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.

The emission factors are based in default emissions factors, but they 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.

##### *Other uses of soda ash*

All uses of soda ash in Finland are assumed to release CO<sub>2</sub> emissions. However, the soda ash that is used in glass production is subtracted and corresponding emissions are reported under the category 2.A.3. 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.

CO<sub>2</sub> emissions from soda ash (Na<sub>2</sub>CO<sub>3</sub>) use are released when it is heated in high temperatures. Emissions are calculated by multiplying emission factors with the amount of used soda ash.

The emission factor is based on the IPCC's default factor. Emission factor has been modified by multiplying default emissions factor with correction factor 0.99 as not all soda ash is reacted in the process.

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.

### *Other*

In the category Other Finland reports emissions from limestone and dolomite use in mineral wool production, in the wastewater treatment, in the neutralisation and in the energy industry for sulphur dioxide.

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.

The emission factors are based in default emissions factors, but they 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.

#### *4.2.5.3 Uncertainty and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

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.

Uncertainty in emissions 2013 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.

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 2000-2013). 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.

#### *4.2.5.4 Category-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 1.2.3. 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 is held annually between the inventory unit and the sectoral expert. In the quality meeting in January 2015 it was discussed for example how the verification of different categories could be performed, how to increase consistency of the numbers in the CRF reporter and the NIR and plan of improvements of the inventory.

In the calculation of emissions from limestone, dolomite and soda ash use several general inventory quality control procedures have been performed as mentioned in 2006 IPCC Guidelines, table 6.1. 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, category-specific quality control procedures have been carried out during calculation. In use of limestone and dolomite 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. In the use of soda ash 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.

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 most plants 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.

#### 4.2.5.5 Category-specific recalculations

There are no category specific recalculations done.

#### 4.2.5.6 Category-specific planned improvements

No category-specific improvements are planned.

**Table 4.2-3** Activity data and emission factors for Mineral Products

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<b>2.A 1</b>																
Clinker production, 1 000 t	1 470	760	1 017	1 015	977	940	1 064	1 110	1 147	1 201	1 279	764	1 049	1 129	1 000	973
EF t/t	0.499	0.500	0.499	0.498	0.499	0.499	0.500	0.501	0.501	0.499	0.499	0.500	0.499	0.499	0.499	0.499
CKD correction factor	1.009	1.008	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	1.008
<b>2.A 2</b>																
Lime production, 1 000 t	488	479	540	543	559	640	667	631	683	651	590	486	524	558	513	511
EF t/t	0.784	0.784	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	0.785
<b>2.A 3</b>																
Carbonate consumption, 1 000 t	48	45	50	56	52	55	49	47	49	52	44	22	4	5	4	5
EF t/t	0.434	0.432	0.429	0.429	0.428	0.428	0.429	0.428	0.428	0.428	0.431	0.426	0.390	0.391	0.382	0.398
<b>2.A 4</b>																
<b>2.A 4a Ceramics</b>																
Carbonate consumption, 1 000 t	7	9	14	14	8	10	11	10	9	11	8	5	6	6	6	4
EF t/t	0.426	0.419	0.415	0.416	0.417	0.415	0.415	0.419	0.420	0.418	0.422	0.424	0.422	0.423	0.424	0.422
<b>2.A 4b Other uses of Soda Ash</b>																
Soda ash consumption, 1 000 t	31	39	42	48	53	37	43	44	36	49	48	39	41	52	51	51
EF t/t	0.411	0.411	0.411	0.411	0.411	0.411	0.411	0.411	0.411	0.411	0.411	0.411	0.411	0.411	0.411	0.411
<b>2.A 4d Other</b>																
Other carbonate consumption, 1 000 t	54	92	131	127	151	166	152	123	161	177	139	173	378	427	345	253
EF t/t	0.461	0.444	0.432	0.434	0.420	0.420	0.421	0.443	0.433	0.446	0.439	0.439	0.439	0.442	0.445	0.454

## 4.3 Chemical Industry (CRF 2.B)

### 4.3.1 Introduction

In the Finnish inventory this category includes emissions of nitrous oxide from nitric acid production and carbon dioxide emissions from hydrogen, phosphoric acid, ammonia and certain chemicals production (use of limestone in chemical industry is included this category). CO<sub>2</sub> emissions from titanium dioxide production are included in the Mineral industry category, since emissions are from wastewater treatment not production of titanium dioxide. Ammonia was produced only 1990-1992.

**Table 4.3-1** Reported emissions, calculation methods and type of emission factors for the subcategory Chemical Industry in the Finnish inventory

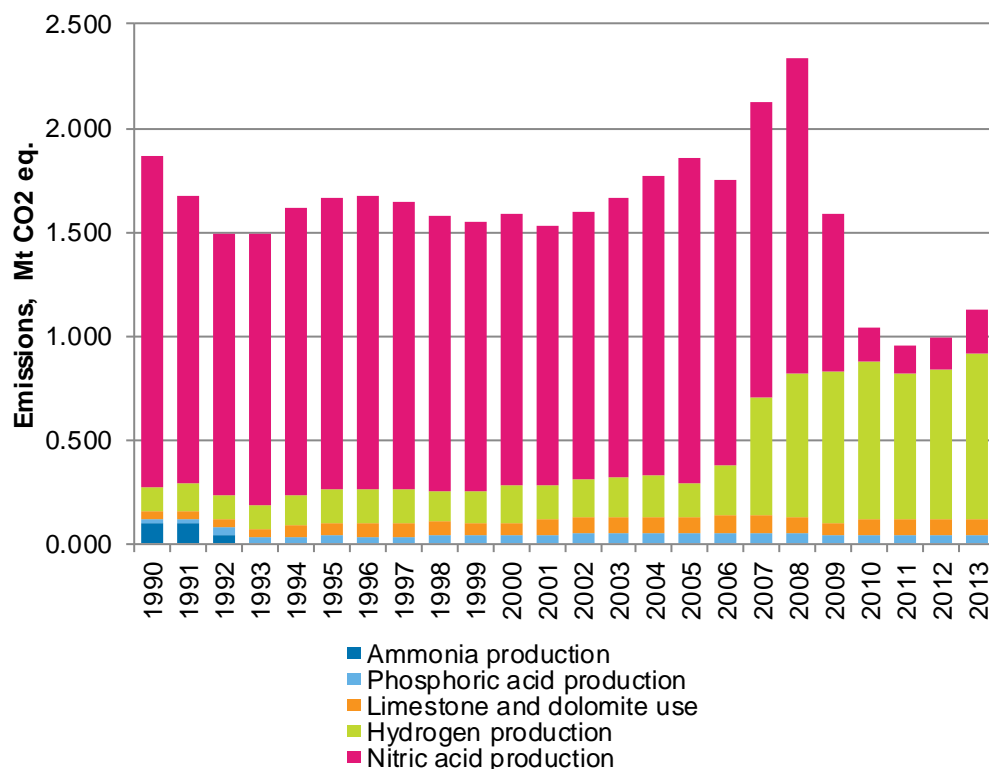
CRF	Source	Emissions reported	Methods	Emission factors
2.B.1	Ammonia Production	CO <sub>2</sub>	Tier 1	D
2.B.2	Nitric acid Production*	N <sub>2</sub> O	Tier 2 and 3	PS
2.B.6	Titanium Dioxide Production**	IE	NA	NA
2.B.10	Other			
	- Phosphoric acid Production	CO <sub>2</sub>	CS	PS
	- Hydrogen Production	CO <sub>2</sub>	Tier 2	CS
	- Limestone and dolomite use	CO <sub>2</sub>	Tier 2	CS

\* Emissions from nitric acid production includes also emissions from fertiliser production.

\*\* Emissions from titanium dioxide production are included in Mineral Industry; subcategory other.

Nitric acid and hydrogen production are key sources in 2013. All emissions of this category are presented in Table 4.3-2 by gas and subcategory. Ammonia, adipic acid, caprolactam, glyoxal, glyoxylic acid, carbides, soda ash, carbon black, dichloroethylene, ethylene oxide, acrylonitrile and methanol are not produced in Finland. Ethylene is produced in Finland, but methane emissions from the 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 2013 were 1.1 Mt CO<sub>2</sub> eq. and represented almost 19% of this sector's emissions and 1.8% of Finland's total emissions. Emissions from chemical industry decreased almost 53% between 2008 and 2013, 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 40% from year 2007 to 2013 and they are now over four-fold compared to the time before the launching of a new hydrogen plant in autumn 2006 (Figure 4.3-1). Total emissions from chemical industry in 2013 were 40% less than in 1990 and 13% higher than in 2012.



**Figure 4.3-1** Greenhouse gas emission from Chemical Industry (Mt CO<sub>2</sub> eq.)

Emissions of N<sub>2</sub>O from nitric acid production were approximately 0.7 kt (0.2 Mt CO<sub>2</sub> eq.) in 2013, which was 0.3% of Finland's total greenhouse gas emissions and 4% of emissions of the sector Industrial Processes and Product Use. In 1990 emissions from nitric acid production represented over 30% of emissions of Industrial Processes and Product Use. Emissions by gas and subcategory of Chemical industry are presented in Table 4.3-2.

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 nitric 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 85 per cent less than the time prior to instalment. Emissions include also an amount of N<sub>2</sub>O emitted from two fertiliser production plants. In 2013 emissions from nitric acid production were 87% less than in 1990 and 32% higher than in 2012.

Emissions of CO<sub>2</sub> from hydrogen production were approximately 0.8 Mt in 2013, 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. In 2013 emissions from hydrogen production were 85% higher than emissions in 1990 and 10% higher than in 2012.

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 Mt in 2013. In 2013 emissions from phosphoric acid production and neutralisation of wastewater were 69% higher than in 1990 and 2% less than in 2012.

There are a few chemical production companies in Finland which use limestone or dolomite in their production processes. These emissions were 0.08 Mt in 2013 and emissions have over doubled since 1990 and were at the same level than in 2012.

All ammonia currently used in Finland is imported. In 1990-1992 small amounts (12 - 30 kt 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. The CO<sub>2</sub> emissions from these processes have been estimated and included in the inventory.

**Table 4.3-2** Emissions by gas and subcategory (Mt CO<sub>2</sub> eq.)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<b>CO<sub>2</sub></b>																
2.B 1 Ammonia production	0.093	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.B 10 Other chemical industry																
- Phosphoric acid production	0.025	0.037	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	0.042
- Hydrogen production	0.12	0.16	0.18	0.17	0.19	0.19	0.20	0.16	0.24	0.57	0.69	0.73	0.76	0.70	0.71	0.79
- Limestone and dolomite use	0.035	0.060	0.061	0.072	0.080	0.069	0.080	0.080	0.085	0.087	0.078	0.059	0.079	0.080	0.076	0.075
<b>N<sub>2</sub>O</b>																
2.B 2 Nitric acid production	1.59	1.41	1.31	1.24	1.28	1.35	1.44	1.56	1.38	1.42	1.52	0.76	0.16	0.13	0.16	0.21
<b>Total of subcategory, Mt CO<sub>2</sub> eq.</b>	<b>1.86</b>	<b>1.67</b>	<b>1.59</b>	<b>1.53</b>	<b>1.60</b>	<b>1.67</b>	<b>1.77</b>	<b>1.85</b>	<b>1.75</b>	<b>2.12</b>	<b>2.33</b>	<b>1.59</b>	<b>1.04</b>	<b>0.95</b>	<b>0.99</b>	<b>1.12</b>

## 4.3.2 Ammonia production

### 4.3.2.1 Category description

Ammonia has been produced only in 1990-1992 small amounts (12 - 30 kt per year), mainly peat and heavy oil as feedstock for the needed hydrogen.

### 4.3.2.2 Methodological issues

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 2006 IPCC Guidelines.

#### Emission factors

Emissions have been calculated with the highest default emission factor from the 2006 IPCC Guidelines (Table 3.1, Factor derived from European average values for specific energy consumption (mix of modern and older plants, not natural gas)) since the plant was very old and it used solid or liquid raw material instead of natural gas to produce hydrogen for ammonia. The used emission factor was 3.273 tonnes CO<sub>2</sub>/tonne ammonia produced).

#### 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.

### 4.3.2.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

The uncertainty of activity data in ammonia production was estimated 5% and emission factor 50% (Forsell 2014).

### 4.3.2.4 Category-specific recalculations

The time series were recalculated using the default emission factor from the 2006 IPCC Guidelines.

### 4.3.3 Nitric acid production

#### 4.3.3.1 Category description

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. Since 2013 nitric acid production has been included in the EU ETS.

#### 4.3.3.2 Methodological issues

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 (Table 4.3-3), and Statistics Finland carried out the calculations using an agreed methodology that corresponds to the 2006 IPCC Guidelines equation 3.6. 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 3.6 simplifies to

$$N_2O \text{ emissions} = \text{specific emission factor} \times \text{production level}$$

In 2005-2013 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  $N_2O$  emissions of nitric acid plants was started in 2009. A new  $N_2O$  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 89% in this subcategory in 2008-2013, which also reflects to the emission factors used in the inventory. For more detailed information about the JI project see the project reports (YARA, 2009-2013).

For years 1990-2008 Tier 2 method was used to calculate emission but after the joint implementation project plant level emission factors were obtained from direct measurements of emissions and Tier 3 method has been used to calculate emissions from nitric acid and fertiliser production.

#### *Emission factors*

Before 2009, only one of the three plants was equipped with a continuous  $N_2O$  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  $N_2O$  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 1990-2013.

**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	2009-2013	Calculated based on VAHTI data	
C	9.3	1990-2008	Information from plant C	- 1992 2004 -
	0.6-4.3	2009-2013	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	2009-2013	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 2008 was 8.1 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 2009. The target of the joint implementation project, which was tighten during the project, for the end of 2012 was that nitrous oxide emissions measured 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 1.1 kg N<sub>2</sub>O/t nitric acid in 2013 (emissions from fertiliser plants are included).

The 2006 IPCC Guidelines provide default emission factor for process similar to those used in Finland; medium pressure plants is 7 kg N<sub>2</sub>O/t nitric acid +/- 20%. 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.

### Activity data

As described before the annual nitric acid and fertiliser production figures have been obtained from the production plants or from the VAHTI system (see description in Annex 6). 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.

#### 4.3.3.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

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 1.6) 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.

#### 4.3.3.4 *Category-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 1.2.3. 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 is held annually between the inventory unit and the sectoral expert. In the quality meeting in January 2015 it was discussed for example how the verification of different categories could be performed, how to increase consistency of the numbers in the CRF reporter and the NIR and plan of improvements of the inventory.

In the calculation of emissions from nitric acid production several general inventory quality control procedures have been performed as mentioned in 2006 IPCC Guidelines, table 6.1. 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, category-specific quality control procedures have been carried out during calculation. Plant based emission factors have been compared with IPCC defaults to verify that the plant-specific factors are reasonable. There were noticed that plant based emission factors for 2009 are higher than the default factors from the 2006 IPCC Guidelines, reason for that was that the joint implementation project started during summer 2009 and emissions decreased rapidly after installation of catalysts. For other years plant-based factors are well lower than the default factor. 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 data 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. According to Joint implementation project reports the monitoring of measurement has been done according to QAL3 requirements and a third party reviews the measurements annually. During the project emission calculations and quality assurance mechanisms are verified by a third party every half year. Emission data from 2013 have been compared with EU ETS data and only 0.03% difference between figures have been noticed.

#### 4.3.3.5 *Category-specific recalculations*

The new GWP factor was used to calculate N<sub>2</sub>O emissions as CO<sub>2</sub> equivalent from nitric acid and fertiliser production, emissions were decreased 4% for the whole time series.

#### 4.3.3.6 *Category-specific planned improvements*

There are no category-specific improvements planned.

### 4.3.4 *Titanium dioxide production*

#### 4.3.4.1 *Category description*

Titanium dioxide has been produced using sulphate route process in Finland since the 1950's. Ilmenite and sulphuric acid are the main raw materials used. According to the 2006 IPCC Guidelines the sulphate route process does not give rise to process greenhouse gas emissions that are of significance.

#### 4.3.4.2 *Methodological issues*

According to ETS data, there are CO<sub>2</sub> emissions from titanium dioxide production as limestone or other carbonates are used for wastewater treatment and neutralisation of sludges. These emissions are however included in Mineral industry, subcategory Other where all other limestone and dolomite (and other carbonate) uses for wastewater treatment are reported.

## 4.3.5 Other

### 4.3.5.1 Category description

In category Other Finland reports emissions from phosphoric acid and hydrogen production and limestone and dolomite use in chemical industry.

### 4.3.5.2 Methodological issues

#### *Phosphoric acid production*

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 been defined from a collected daily sample of apatite.

Calcite has also used in phosphoric acid plant as neutraliser in waste water handling. The amount of released  $\text{CO}_2$  is also been 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.

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.

The activity data are the used amount of apatite and calcite. The amounts of them are received from the company and are also confidential.

#### *Hydrogen production*

Hydrogen is produced in Finland in continuous steam reforming processes, where hydrocarbons dissociate on the metal surface. Also gasification in pressure with a controlled amount of oxygen and steam is used to production of hydrogen.

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  $\text{N}_2$ ,  $\text{H}_2\text{O}$ ,  $\text{CO}$ ,  $\text{CO}_2$  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  $\text{CO}_2$  emissions of combustion in Energy Sector.

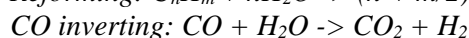
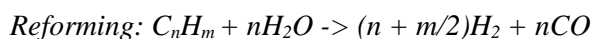
In gasification carbon from hydrocarbon reacts with steam to produce carbon monoxide and hydrogen. Hydrogen is used for hydrogen peroxide production and  $\text{CO}$  for other processes. Part of carbon from  $\text{CO}$  is bound in products and part is emitted to atmosphere. Therefore total emissions of these processes have been calculated using mass balance.

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 2006 IPCC Guidelines, for which reason the stoichiometric ratio of chemical reactions is used.

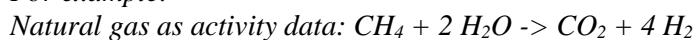
One company has a system to capture a part of formed carbon dioxide for recovery and use. The transferred  $\text{CO}_2$  is bottled and according to present knowledge is used in applications from which it is released to the

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.

No default emission factor for hydrogen production is available in 2006 IPCC Guidelines. 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 by feedstock.

**Table 4.3-4** Average of emission factors by feedstock, kt CO<sub>2</sub>/ kt feedstock

Feedstock	Emission factor
Natural gas	2.74
Naphtha	3.19
Propane	3.00
Membrane gas	2.67

The consumption of hydrocarbons is used as activity data in calculating emissions from hydrogen production. The feedstocks used are natural gas, heavy fuel oil, 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.

### *Limestone and dolomite use in chemical industry*

Emissions from limestone and dolomite use in production of chemicals are included in this sub category.

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.

The emission factors are based in default emissions factors, but they are modified by multiplying default emission factor with correction factors (0.97-0.99, 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.

**Table 4.3-5** Production amount of different chemicals (kt)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Ammonia	28.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitric acid	549	476	451	430	447	477	503	582	599	615	629	477	566	542	611	635
Ethylene	188	225	256	260	228	298	327	327	313	295	354	362	374	369	318	400
Used hydrocarbons	51	67	75	74	80	89	91	79	109	232	275	294	302	283	287	323
Limestone and dolomite	83	140	142	167	188	162	186	187	197	202	183	137	184	187	178	175

#### 4.3.5.3 *Uncertainty and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

The uncertainty in emissions in phosphoric acid production in 2013 was  $\pm 7\%$ .

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.

Combined uncertainty in limestone and dolomite use in chemical industry 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 2000-2013). 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.

#### 4.3.5.4 *Category-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 1.2.3. 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 is held annually between the inventory unit and the sectoral expert. In the quality meeting in January 2015 it was discussed for example how the verification of different categories could be performed, how to increase consistency of the numbers in the CRF reporter and the NIR and plan of improvements of the inventory.

##### *Phosphoric acid production*

In the calculation of emissions from phosphoric acid production several general inventory quality control procedures have been planned to perform as mentioned in 2006 IPCC Guidelines, table 6.1. 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.

##### *Hydrogen production*

In the calculation of emissions from hydrogen production several general inventory quality control procedures have been performed as mentioned in 2006 IPCC Guidelines, table 6.1. 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 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 three plants (out of 7) have been verified with ETS data and emissions have been found to be almost equal. Two of these plants are biggest emitters in this category, amount of their emissions represents almost 90% of category's emissions.

In the calculation of emissions from limestone and dolomite use several general inventory quality control procedures have been performed as mentioned in 2006 IPCC Guidelines, table 6.1. 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, category-specific quality control procedures have been carried out during calculation. In use of limestone and dolomite 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. In the use of soda ash 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.

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 most plants 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.

#### *4.3.5.5 Category-specific recalculations*

In limestone and dolomite use in chemical industry calculated emissions for year 2012 was corrected due to new activity data, emissions increased 0.7 kt. In hydrogen production data of a plant were included in to the inventory for the whole time series, emissions increased 0.4-0.7 kt/a.

#### *4.3.5.6 Category-specific planned improvements*

There are no category-specific improvements planned.

## 4.4 Metal Industry (CRF 2.C)

### 4.4.1 Introduction

This 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). Also emissions from limestone or dolomite used in steel production is included in this category. Emissions from lime production in steel plants are included in CRF category 2.A.2. Lime Production.

Additionally total time series of CO<sub>2</sub> emissions from zinc, copper and nickel production are reported together due to confidentiality reasons in CRF category 2.C.7 Other. Emissions are reported for the first time in the Finnish inventory, as the these companies participate now the EU ETS third phase.

There is no primary aluminium production in Finland.

Indirect CO<sub>2</sub> emissions from NMVOC emissions in metal industry are reported in Section 9.1.2.

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
	Limestone and dolomite use	CO <sub>2</sub>	Tier 2	CS
	Pig iron	IE (Steel)		
	Sinter	IE (Steel)		
	Other: Coke	CH <sub>4</sub>	Tier 1	D
2.C.2	Ferroalloys Production	IE (Iron and Steel Production)		
2.C.4	Magnesium production	IE (2.H 3)	CS	NA
2.C.6	Zinc Production	IE (Other)		
2.C.7	Other	CO <sub>2</sub>	Tier 2	CS

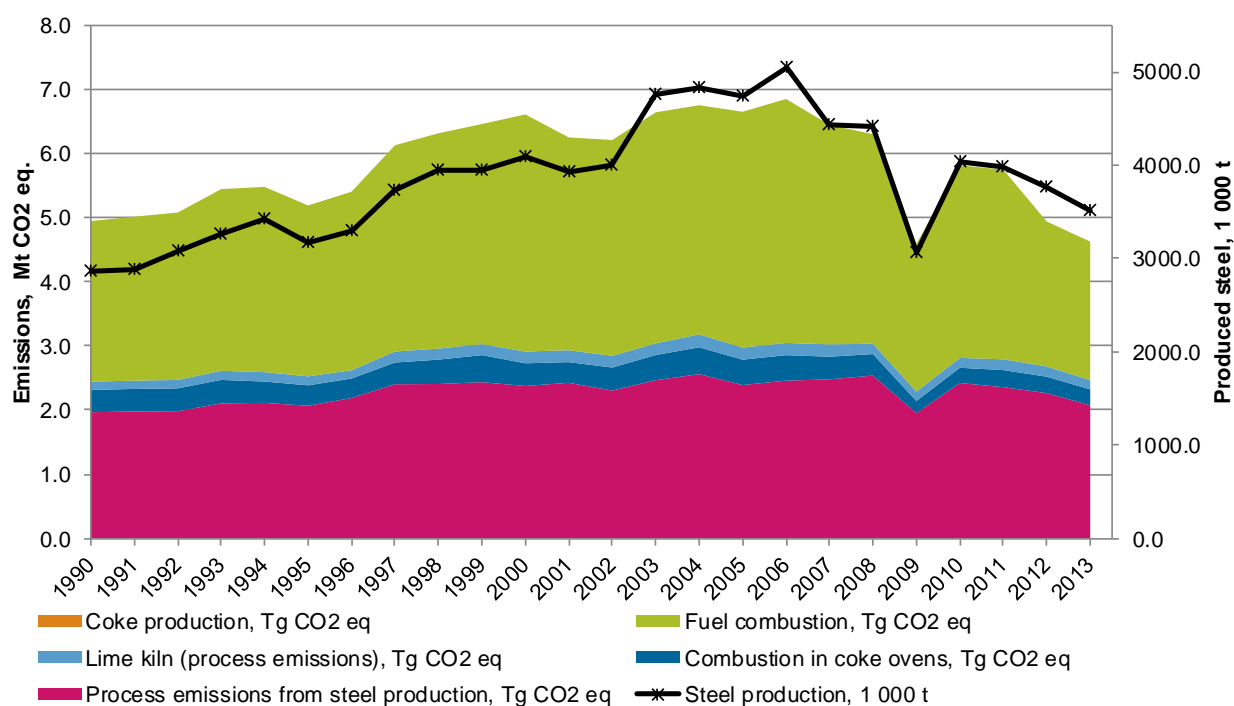
SF<sub>6</sub> emissions from magnesium die-casting are included in the inventory. However, since there is currently only one producer in Finland, these data are confidential. Emissions and consumption data were therefore grouped with other confidential SF<sub>6</sub> data, and reported under CRF category 2.H Other.

Process emissions of metal production were 2.1 Mt CO<sub>2</sub> eq. in 2013 and this was over 35% of sector's and about 3.3% of Finland's total greenhouse gas emissions. Iron and steel production contributes 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 4.2-2.

CO<sub>2</sub> emissions from zinc, copper and nickel production have more than doubled since 1990 due to increased productions.

Methane emissions from coke production almost doubled in 1993 due to opening of a second coke oven in a steel factory (Table 4.4-4).



**Figure 4.4-1** Total emissions of steel production and amount of produced steel

## 4.4.2 Iron and steel and metallurgical coke production

### 4.4.2.1 Category description

The plants included in this sector 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 electric 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.

### 4.4.2.2 Methodological issues

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 3.1) using plant/process level data. The methodology is slightly plant-specific, because all plants differ from each other.

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 (Mt CO<sub>2</sub> eq.)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<b>CO<sub>2</sub></b>																
2.C 1 Production of steel	1.97	2.07	2.38	2.43	2.30	2.47	2.56	2.39	2.46	2.48	2.54	1.95	2.42	2.36	2.26	2.07
2.C.7 Other metal industry	0.009	0.008	0.013	0.013	0.013	0.013	0.014	0.013	0.014	0.015	0.015	0.016	0.017	0.020	0.021	0.022
<b>CH<sub>4</sub></b>																
2.C 1 Coke production	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
<b>Total of subcategory, Mt CO<sub>2</sub> eq.</b>	<b>1.98</b>	<b>2.08</b>	<b>2.39</b>	<b>2.44</b>	<b>2.32</b>	<b>2.48</b>	<b>2.57</b>	<b>2.40</b>	<b>2.47</b>	<b>2.49</b>	<b>2.55</b>	<b>1.97</b>	<b>2.44</b>	<b>2.38</b>	<b>2.29</b>	<b>2.09</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 6). 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, however in 2012 one plant was closed down. 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. 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

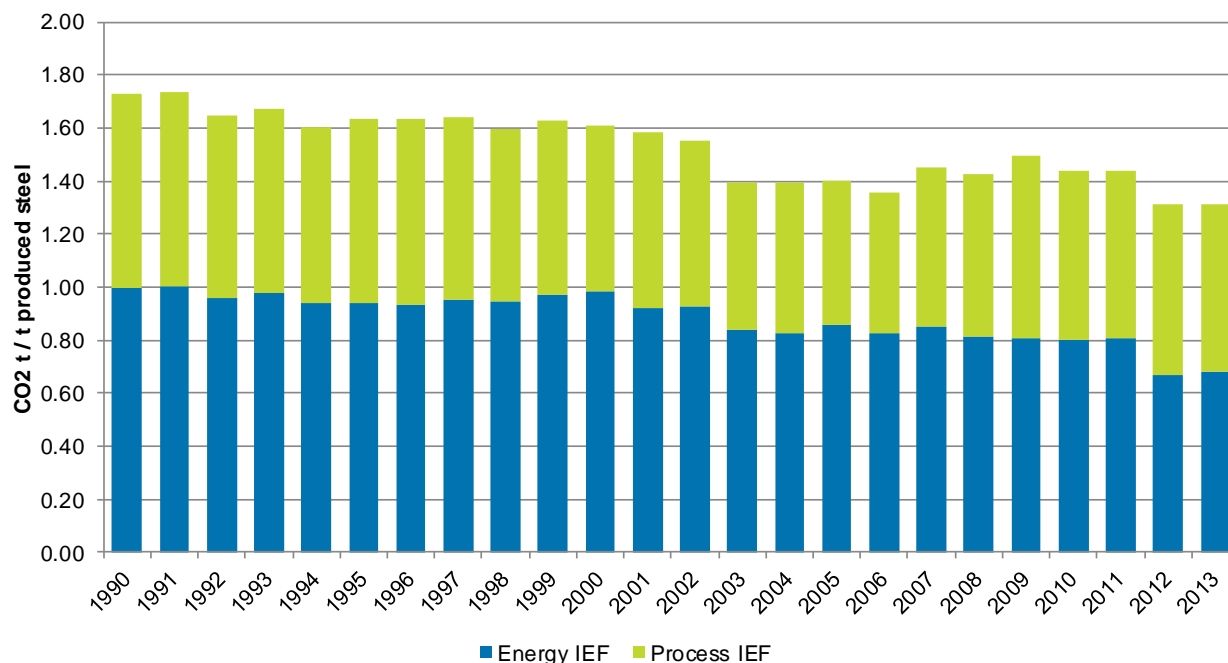
<b>CRF category</b>	<b>Emission source</b>
CRF 1.A.1c	Emissions from fuels used in coking plants (coke oven gas and BF gases)
CRF 1.A.2a	Emissions from fuels used in iron and steel plants' processes and power plants: (LPG, residual fuel oil, gasoil, coke oven gas and BF gas, excluding BF gas used for 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 and limestone used in iron and steel production)

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.

The calculation method for CH<sub>4</sub> emissions from coke production is consistent with the IPCC Guidelines.

### Emission factors

The CO<sub>2</sub> emission factors used in the calculation are presented in Table 3.2-4. 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 and Product Use in steel industry

The emission factor for limestone use is based in default emissions factor, but it is modified by multiplying default emission factor with correction factor (0.97), because not all limestone is calcinated completely in the various processes.

The emission factor 0.1 g/t used in the calculation of CH<sub>4</sub> emissions from coke production is the 2006 IPCC Guidelines default value.

### 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.

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.

Activity data for limestone use in iron and steel industry has been received directly from the producers due to confidentiality reasons the data is not reported.

**Table 4.4-4** Production of steel and coke, kt

	Production of coke	Production of crude steel
1990	487	2 861
1995	920	3 176
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
2013	878	3 517

#### 4.4.2.3 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 system, 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 4.4.2.2. 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 2. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

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 2013, 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 1.6.

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).

#### 4.4.2.4 Category-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 1.2.3. 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 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 an iron and steel plant in January 2013. 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.

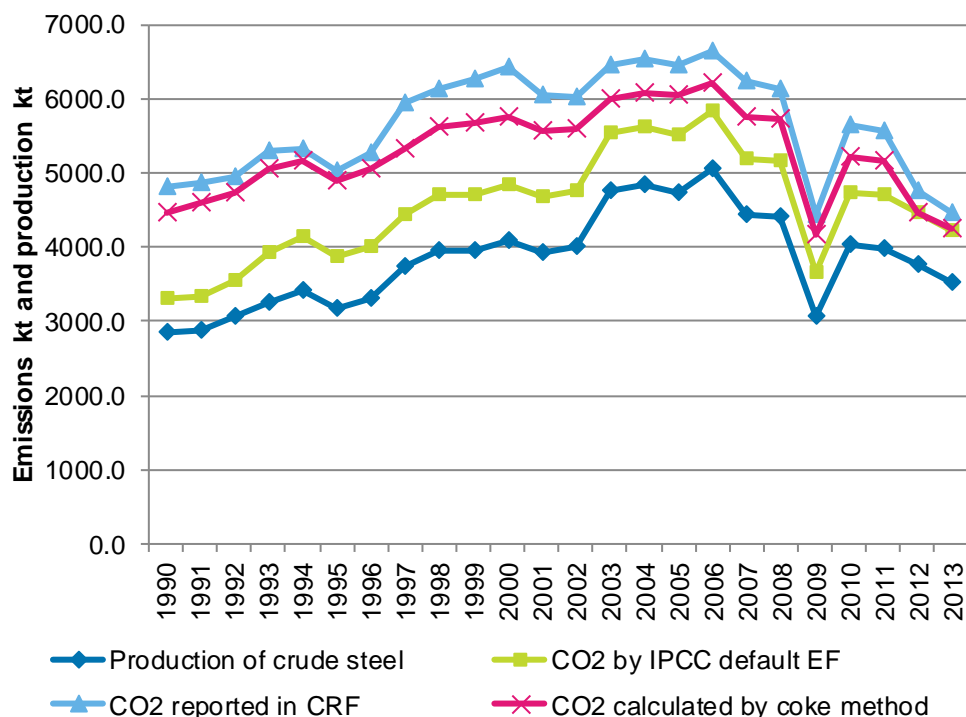
The main annual quality checks are:

- 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).

In the metallurgical coke production the calculated emissions have been compared with previous emissions of the subcategory and 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.



**Figure 4.4-3** Comparison of CO<sub>2</sub> emissions from Iron and steel, includes both energy based emissions and process emissions

#### 4.4.2.5 Category-specific recalculations

Due to change of default emission factor emissions of coke production decreased for the whole time series.

#### 4.4.2.6 Category-specific planned improvements

There are no planned category-specific improvements.

### 4.4.3 Magnesium production

#### 4.4.3.1 Category description

SF<sub>6</sub> emissions from magnesium die-casting (2.C.4) occur in Finland and emission estimation method is presented in this Section. However, due to confidentiality issues, emissions are reported aggregated in category Other (2.H.3).

Point sources, which make a considerable contribution to SF<sub>6</sub> emissions elsewhere, but are absent from Finland, include the primary aluminium and magnesium industry.

#### 4.4.3.2 Methodological issues

SF<sub>6</sub> emission from magnesium die casting are estimated with the "direct" method. Due to the small amount of SF<sub>6</sub> used in this application detailed emission estimation methods have not been seen reasonable. The emissions equal the SF<sub>6</sub> sold annually to the aforementioned application. The activity data for the calculation of emissions is obtained from annual surveys of importers of special gases.

#### 4.4.3.3 Uncertainty and time series' consistency

The time series of SF<sub>6</sub> emissions from 2.C.4 has been calculated with the same methodology for the whole time series and is therefore considered consistent.

#### 4.4.3.4 Category-specific QA/QC and verification

The general QC procedures are performed according to the QA/QC and verification plan and the resulting findings, corrections and planned improvements are recorded in the yearly QA/QC form. 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. The emission trends are graphed and explained. 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.

#### 4.4.3.5 Category-specific recalculations

Changes in the category result from the introduction of the new GWP values

#### 4.4.3.6 Category-specific planned improvements

No planned improvements in this category.

### 4.4.4 Zinc production

#### 4.4.4.1 Category description

Special high grade zinc is produced in Finland by an electrolytic process in a smelter. Electrolytic process includes four main stages: 1) Roasting of zinc concentrate in temperature of more than 900 °C (ZnO as product), 2) Leaching stage, where the zinc oxide is separated from the other calcines 3) Impurities elimination 4) Electrolysis. According to 2006 IPCC Guidelines this process does not result in non-energy CO<sub>2</sub> emissions.

#### 4.4.4.2 Methodological issues

In Finland the zinc concentrate contains a small amount of carbon, which will be released in roasting and elimination processes as CO<sub>2</sub> emission.

Due the confidentiality reasons (only one plant in Finland) emissions from zinc production are reported together with emissions of copper and nickel production in CRF 2.C.7.

#### *Emission factors*

There are no default emission factors for electro-thermic process in 2006 IPCC Guidelines, because no non-energy CO<sub>2</sub> is believed to release. However, in Finland emissions have been calculated using the carbon content of concentrate. Emission factor is an average of measured (2005 – 2013) carbon contents (confidential).

#### *Activity data*

Amount of zinc concentrate were used as activity data to calculate emissions of zinc production. Activity data were received directly from the production plant.

#### 4.4.4.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

The uncertainty in activity data in zinc concentrate was estimated at  $\pm 2\%$  and for emission factor  $\pm 5\%$ .

#### 4.4.4.4 Category-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 1.2.3. The QC procedures are performed according to the QA/QC plan in Metal

Industry sector in order to attain these quality objectives. The bilateral quality meeting is held annually between the inventory unit and the sectoral expert. In the quality meeting in January 2015 it was discussed for example how the verification of different categories could be performed, how to increase consistency of the numbers in the CRF reporter and the NIR and plan of improvements of the inventory.

In the calculation of emissions from zinc production several general inventory quality control procedures have been performed as mentioned in the 2006 IPCC Guidelines, Table 1.6. The amount of emissions were compared with the company's emission calculation which was received. Emissions were almost equal, though the company calculated emissions using the emission factor from measurement of year 2013. The yearly emission factors (carbon content) do not fluctuate substantially.

A few category-specific quality control procedures have been carried out during calculation. Activity data have been checked using VAHTI system. All activity data are site-specific and reported due to monitoring of environmental permit of a company.

#### *4.4.4.5 Category-specific recalculations*

The category has been included to the inventory for the first time.

#### *4.4.4.6 Category-specific planned improvements*

There are no category-specific improvements planned.

### *4.4.5 Other*

#### *4.4.5.1 Category description*

In Other category Finland reports emissions from copper and nickel smelting process.

#### *4.4.5.2 Methodological issues*

Copper and nickel are produced in the flash smelting process. The flash smelting process is based on utilization of the feed material's internal energy for smelting. Finely ground sulfidic copper concentrate is mixed with oxygen-enriched air to form a rapidly reacting suspension in the reaction shaft of the flash smelting furnace. Sulphide compounds of the feed ignite, oxidise and release heat, acting as a fuel for the process and no external energy is needed for smelting.

After the flash smelting the copper stone are led to the converter to oxidise iron and sulphur. The blister copper produced in converting furnace contains some sulphur, the final sulphur is removed in a anode furnace by air oxidation.

After the flash smelting the nickel stones are upgraded using leaching and extraction in a different plant.

In Finland the copper and nickel concentrates contain a small amount of carbon, which is released in smelting processes as CO<sub>2</sub> emission. The plant also uses secondary raw materials in the metal production process, even a small amount of electronic scrap is also refined in the smelter. Carbon in that scrap is released also as CO<sub>2</sub> emission.

Due the confidentiality reasons emissions from copper and nickel concentrate production are reported together with emissions of zinc production in CRF 2.C.7.

### *Emission factors*

There are no default emission factors for copper or nickel smelting processes in 2006 IPCC Guidelines. In Finland emissions have been calculated using the carbon and moisture content of concentrates and electronic scarp. Emission factors are an average of measured (2009 – 2013) numbers (confidential).

### *Activity data*

Amount of copper and nickel concentrate and used electronic scraps were used as activity data to calculate emissions of copper and nickel production. Activity data were received directly from the production plant.

#### *4.4.5.3 Uncertainty and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

The uncertainty in activity data in copper and nickel concentrate and electronic scrap were estimated at  $\pm 2\%$  and for emission factor  $\pm 5\%$ .

#### *4.4.5.4 Category-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 1.2.3. The QC procedures are performed according to the QA/QC plan in Metal Industry sector in order to attain these quality objectives. The bilateral quality meeting is held annually between the inventory unit and the sectoral expert. In the quality meeting in January 2015 it was discussed for example how the verification of different categories could be performed, how to increase consistency of the numbers in the CRF reporter and the NIR and plan of improvements of the inventory.

In the calculation of emissions from copper and nickel smelting processes several general inventory quality control procedures have been performed as mentioned in the 2006 IPCC Guidelines, Table 1.6.

A few category-specific quality control procedures have been carried out during calculation. Activity data have been checked using VAHTI system. All activity data are site-specific and reported due to monitoring of environmental permit of a company.

#### *4.4.5.5 Category-specific recalculations*

The category has been included to the inventory for the first time.

#### *4.4.5.6 Category-specific planned improvements*

There are no category-specific improvements planned.

## 4.5 Non-energy products from fuels and solvent use (CRF 2.D)

### 4.5.1 Introduction

Under non-energy products from fuels and solvent use Finland reports greenhouse gas emissions from use of lubricant, paraffin waxes and urea-based catalysts.

In this category there are reported NMVOC emissions of paint application, degreasing and dry cleaning, chemical products manufacture and processing and other. Also NMVOC emissions from road paving with asphalt are reported under this category. The calculation of these emissions are reported in Section 9.1.2.

**Table 4.5-1** Reported emissions, calculation methods and type of emission factors for the subcategory Non-energy products form fuels and solvent use in the Finnish inventory

CRF	Source	Emissions reported	Methods	Emission factors
2.D.1	Lubricant use	CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O	Tier 1	CS
2.D.2	Paraffin waxes use	CO <sub>2</sub>	Tier 1	D
2.D.3	Other			
	- Other; Use of urea-based catalysts	CO <sub>2</sub>	Tier 1	D

Emissions from non-energy products from fuels and solvent use were 0.1 Mt in 2013, these emissions were less than 2% of the emissions of Industrial processes and product use and 0.1% of the total emissions. Emissions have decreased 55% since 1990 due to reduced use of lubricants.

**Table 4.5-2** Emissions from non-energy products from fuels and solvent use, kt CO<sub>2</sub> eq.

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
2.D.1 Lubricant use	209	180	130	135	131	104	95	87	95	109	101	77	58	58	60	73
2.D.2 Paraffin waxes use	10.2	7.5	7.8	9.0	12.3	14.1	16.0	16.4	19.0	21.0	23.7	21.6	23.7	21.0	19.8	18.9
2.D.3 Use of urea-based catalysts	NO	NO	NO	NO	NO	NO	NO	NO	0.39	1.15	1.90	2.41	3.16	3.85	4.21	4.80
<b>Total of subcategory, kt CO<sub>2</sub> eq.</b>	<b>219.7</b>	<b>187.3</b>	<b>137.9</b>	<b>144.1</b>	<b>143.5</b>	<b>118.1</b>	<b>111.0</b>	<b>103.2</b>	<b>114.5</b>	<b>131.4</b>	<b>126.8</b>	<b>101.4</b>	<b>85.1</b>	<b>82.8</b>	<b>83.9</b>	<b>97.0</b>

### 4.5.2 Lubricant use

#### 4.5.2.1 Methodological issues

The use of lubricants in engines is primarily for their lubricating properties and associated emissions are considered as non-combustion emissions. In the Finnish inventory lubricants contain waste oil as well as 2-stroke and 4-stroke oil. Information on the used total amount of lubricants is received from energy statistics. Emission factor used for calculation is based on carbon content of lubricants (20 t C/TJ). The ILMARI system includes point source (bottom-up) data on waste oil combustion in different branches of industry, and these emissions are reported in corresponding subcategories of 1.A.2. 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 this category.

#### 4.5.2.2 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

#### 4.5.2.3 Category-specific QA/QC and verification

The QA/QC procedures used are described in section 3.2.4.4.

#### 4.5.2.4 Category-specific recalculations

The category has reallocated from sector 1.A.5 to sector 2.D.1 according to the 2006 IPCC Guidelines.

#### 4.5.2.5 Category-specific planned improvements

There are no category-specific improvements planned.

### 4.5.3 Paraffin waxes use

#### 4.5.3.1 Category description

Paraffin waxes use is a new category in the Finnish inventory. Paraffin waxes are used in a number of different applications. They are used in candles, corrugated boxes, paper coating, wax polishes and many others. Emissions from the use of waxes derive primarily when the waxes or derivatives of paraffin are combusted during use and when they are incinerated with or without heat recovery or in wastewater treatment. In the cases of incineration and wastewater treatment the emissions are reported in Energy or Waste Sectors.

#### 4.5.3.2 Methodological issues

Emissions from paraffin waxes use are calculated using Tier 1 method of 2006 IPCC Guidelines, Equation 5.4.

$$CO_2 \text{ emissions} = PW * CC_{Wax} * ODU_{Wax} * 44/12$$

Where:	$CO_2$ Emissions	= $CO_2$ emissions from waxes tonne $CO_2$
	PW	= total wax consumption, TJ
	$CC_{Wax}$	= carbon content of paraffin wax (default), tonne C/TJ (=kg C/GJ)
	$ODU_{Wax}$	= ODU factor for paraffin wax, fraction
	44/12	= mass ratio of $CO_2/C$

To calculate emissions with aggregated default data it has been assumed that 20 percent of paraffin waxes are used in a manner leading to emissions, mainly through the burning of candles.

In Finland also imported (and exported) paraffin containing candles are included in the inventory calculations. Emissions are calculated using same default values as for paraffin waxes except the percentage mentioned earlier.

#### Emission factors

Emissions from paraffin waxes and paraffin candles are calculated using default emission factors from 2006 IPCC Guidelines.

To calculate emissions from candles one third of imported candles are estimated (Grönfors, 2014) to be made from stearin and therefore no emissions are calculated for them.

#### Activity data

All data of import and export of paraffin waxes and candles are collected from the Customs data for the whole time series.

#### 4.5.3.3 *Uncertainty and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

The uncertainty in activity data in paraffin waxes use were estimated at  $\pm 5\%$  and for emission factor  $\pm 10\%$ .

#### 4.5.3.4 *Category-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 1.2.3. The QC procedures are performed according to the QA/QC plan in Non-energy products from fuels and solvent use sector in order to attain these quality objectives. The bilateral quality meeting is held annually between the inventory unit and the sectoral expert. In the quality meeting in January 2015 it was discussed for example how the verification of different categories could be performed, how to increase consistency of the numbers in the CRF reporter and the NIR and plan of improvements of the inventory.

In the calculation of emissions from paraffin waxes use several general inventory quality control procedures have been performed as mentioned in the 2006 IPCC Guidelines, Table 1.6. The calculation method has been checked to follow default calculation from the 2006 IPCC Guidelines and it doesn't include any transcription and transfer errors. Time series of imported paraffin waxes and candles are checked to be consistent.

#### 4.5.3.5 *Category-specific recalculations*

The category has been included to the inventory for the first time.

#### 4.5.3.6 *Category-specific planned improvements*

There are no category-specific improvements planned.

### 4.5.4 *Other*

#### 4.5.4.1 *Category description*

Under Other category Finland reports CO<sub>2</sub> emissions from use of urea based catalysts. These emissions are for the first time included to the Finnish inventory. Emissions are reported in the Industrial processes and product use sector, (CRF category 2.D.3d) as the emissions are non-combustive and the activity data are tons of urea and all emissions reported in the Energy sector have been calculated using TJs as activity data.

#### 4.5.4.2 *Methodological issues*

For estimating CO<sub>2</sub> emissions from use of urea-based additives (AdBlue) in catalytic converters are used Equation 3.2.2 from 2006 IPCC Guidelines.

$$\text{Emissions} = \text{Activity} * 12/60 * \text{Purity} * 44/12$$

where: Emissions = CO<sub>2</sub> emissions from urea-based additive in catalytic converters (kt CO<sub>2</sub>)  
 Activity = amount of urea-based additive consumed for use in catalytic converters (kt)  
 Purity = the mass fraction (=percentage divided by 100) of urea in the urea based additive

Emissions have been calculated since 2006 when the use of urea-based additive was more common.

The default purity, 32.5%, has been used to calculate emissions.

Activity data to calculate emissions have been received from LIPASTO system (see Section 3.2.5.2).

#### *4.5.4.3 Uncertainty and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

#### *4.5.4.4 Category-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 1.2.3. The QC procedures are performed according to the QA/QC plan in Non-energy products from fuels and solvent use sector in order to attain these quality objectives. The bilateral quality meeting is held annually between the inventory unit and the sectoral expert. In the quality meeting in January 2015 it was discussed for example how the verification of different categories could be performed, how to increase consistency of the numbers in the CRF reporter and the NIR and plan of improvements of the inventory.

In the calculation of emissions from lubricant use several general inventory quality control procedures have been performed as mentioned in the 2006 IPCC Guidelines, Table 1.6. The calculation method has been checked to follow default calculation from the 2006 IPCC Guidelines and it doesn't include any transcription and transfer errors. Time series are checked to be consistent.

#### *4.5.4.5 Category-specific recalculations*

The category has been included to the inventory for the first time.

#### *4.5.4.6 Category-specific planned improvements*

There are no category-specific improvements planned.

## 4.6 Electronics industry (CRF 2.E)

### 4.6.1 Introduction

HFC, PFC and SF<sub>6</sub> emissions from integrated circuit or semiconductor (2.E.1) occur in Finland and emission estimation method is presented in this Section. However, due to confidentiality issues, emissions are reported aggregated in category Other (2.H.3).

Emissions from TFT flat panel displays (2.E.2), photovoltaics (2.E.3) and heat transfer fluids (2.E.4) are not occurring in Finland.

**Table 4.6-1** Reported emissions, calculation methods and type of emission factors for the subcategory Electronics industry in the Finnish inventory

CRF	Source	Emissions reported	Methods	Emission factors
2.E.1	Integrated circuit or semiconductor	IE (2.H.3)	Tier 2a	D

### 4.6.2 Integrated circuit or semiconductor

#### 4.6.2.1 Category description

Emissions from semiconductor manufacturing cannot be reported separately due to confidentiality. Emissions are reported aggregated with other confidential F-gas emission sources in category CRF 2.H.3 Grouped confidential data of halocarbons and SF<sub>6</sub>.

Total emissions from 2.E.1 were 28% higher in 2013 compared to 2012. Emissions have increased significantly compared to 1990 and 1995. In 2013 the emissions were 38-fold compared to 1990 and 17-fold compared to 1995. There is some fluctuation in the emission level in the mid 2000's due to changes in the semiconductor market. In the recent years the emissions have been growing following the increasing trend of amount of SF<sub>6</sub> used in semiconductor manufacturing.

Small amount of NF<sub>3</sub> use in semiconductor manufacturing has been reported by one company in 2003. The emissions of NF<sub>3</sub> in 2003 are negligible and reported as not occurring in Finland. The potential use of NF<sub>3</sub> has been investigated in Finland and no other use in addition to the reported use in 2003 has been found.

#### 4.6.2.2 Methodological issues

##### Methods

The emissions from semiconductor manufacturing are reported with the IPCC Tier 2a method (Equations 6.3-6.6 in the 2006 IPCC Guidelines, See Annex 4a). The activity data to support the calculation of emissions with the IPCC guidelines methods is available from 2002 onwards. The emissions estimates 1990-2001 are calculated with a simplified method as described in Chapter 3.10 in Oinonen (2003):

$$E_n = E_{2003}(1 + 0.15)^{-(2003-n)}$$

The method assumes an annual growth of emissions of 15% for the period 1990-2001. The use of 15% reflects the general growth of production within the industry at that time (Oinonen & Soimakallio, 2001). This estimation method of missing data is consistent with the surrogate method presented in 2006 IPCC Guidelines (Volume 1, equation 5.2). The year 2003 is used as a reference year in the model since the activity data is available from all the semiconductor manufacturers from that year.

The emission factors to calculate emissions from semiconductor manufacturing are from Table 6.3 of the 2006 IPCC Guidelines (p. 6.17) and presented in Table 4.6-2. Based on communication with the Finnish semiconductor manufacturers the destruction efficiency under the Tier 2a method is assumed to be 0 percent. Only one out of three Finnish semiconductor manufacturing plants has emission control technology in use. However the plant is unable to deliver the parameters of the emission control technologies required by the Tier 2a method of the 2006 IPCC Guidelines.

**Table 4.6-2** 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)	0.1	0.4	0.6	0.6	0.9	0.8	0.8
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	0.2	0.07	0.1	0.1	0.09	NA
kg C <sub>2</sub> F <sub>6</sub> created per kg of gas i	NA	NA	NA	NA	0.1	NA	NA

### Activity data

The activity data for the calculation of emissions from semiconductor manufacturing is obtained from annual surveys to companies, research institutes and importers of special gases. All the companies expect for one semiconductor manufacturing company responded to the survey of 2014. The activity data of the missing company was imputed based on their previous response.

#### 4.6.2.3 Uncertainty and time series' consistency

Monte Carlo simulation was used to quantify uncertainty of the level of HFC, PFC and SF<sub>6</sub> emissions from electronics industry. Uncertainty in HFC emissions in 2013 was estimated at -35% to 37%, in PFC emissions at -41% to 44% and in SF<sub>6</sub> emissions at -74% to 78%. Correlation analysis of the simulation results suggests that most of the uncertainty is due to the fraction of each gas destroyed or transformed.

Emissions from this Category are estimated with the Tier 2a method given in 2006 IPCC Guidelines for years 2002-2013. Emissions from previous years are estimated with the surrogate method presented in 2006 IPCC Guidelines (Volume 1, equation 5.2) and therefore the time series can be considered as consistent.

#### 4.6.2.4 Category-specific QA/QC and verification

QA/QC procedures described in Section 1.2.3 are implemented in the category 2.E.1. The QC procedures are performed according to the QA/QC and verification plan and the resulting findings, corrections and planned improvements are recorded in the yearly QA/QC form. Bilateral quality meetings are held annually between the inventory unit and the sectoral expert. The documentation and archiving of the 2.E.1 category is detailed in Section 1.3.2.

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 2013 inventory QC checks minor errors in the movement of inventory data among processing steps were detected and corrected.

The category specific QC procedures for category 2.E.1 include emission and activity data comparisons as well as uncertainty estimates. The results are compared with those obtained using a simpler model, i.e. actual emissions are compared with potential emissions. The emission trends are graphed and explained. 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.

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 4.6.2.3 above.

#### *4.6.2.5 Category-specific recalculations*

Due to implementation of the 2006 IPCC Guidelines the time-series of HFC, PFC and SF<sub>6</sub> emissions from semiconductor manufacturing were recalculated since the default emission factors had been partly revised. Essentially the previously used Tier 1 method of the GPG 2000 is the same method as the Tier 2a method of the 2006 IPCC Guidelines. The only exception is the information of the emission control technologies in the Tier 2a method of the 2006 IPCC Guidelines. Destruction efficiency of 0 % was assumed as explained in Section 4.6.2.2 above. The emission estimates for 1990-2001 were also recalculated due to revision of some of the parameters used in the calculation model described in Section 4.6.2.2 above and in Oinonen (2003). Previously 2001 was used as the reference year in the calculation. The reference year was changed to 2003 since the activity data for 2003 is considered more reliable.

Other changes in the category result from the introduction of the new GWP values. As a result of the methodological changes and the GWP values in the semiconductor manufacturing the recalculated emission estimates between 1990 and 2002 are in average 2% lower than the previous ones. The difference is larger from 2003 onwards being in average 28%.

#### *4.6.2.6 Category-specific planned improvements*

There are no planned improvements in this category.

## 4.7 Product uses as substitutes for ozone depleting substances (CRF 2.F)

### 4.7.1 Introduction

In 2013, greenhouse gas emissions under the category CRF 2.F Emissions of Product uses as substitutes for ozone depleting substances amounted to 1.6 Mt CO<sub>2</sub> eq., which is 2.5% of the total greenhouse gas emissions in Finland. Emissions increased 6% compared to the year 2012. Compared to 1995, which is the base year for F-gas emissions under the Kyoto Protocol in Finland, the emissions were nearly 60-fold (Table 4.7-2). Emissions from different subcategories reported under this sector are listed in Table 4.7-1. Around 95% of the emissions originate from refrigeration and air conditioning equipment (Figure 4.7-1). Emissions from category 2.F.3 Fire protection cannot be reported separately due to confidentiality. HFC emissions from fire protection are reported aggregated with other confidential F-gas data in category CRF 2.H.3 Grouped confidential data of halocarbons and SF<sub>6</sub>. Emissions from Solvents (2.F.5) and other applications (2.F.6) are not occurring in Finland.

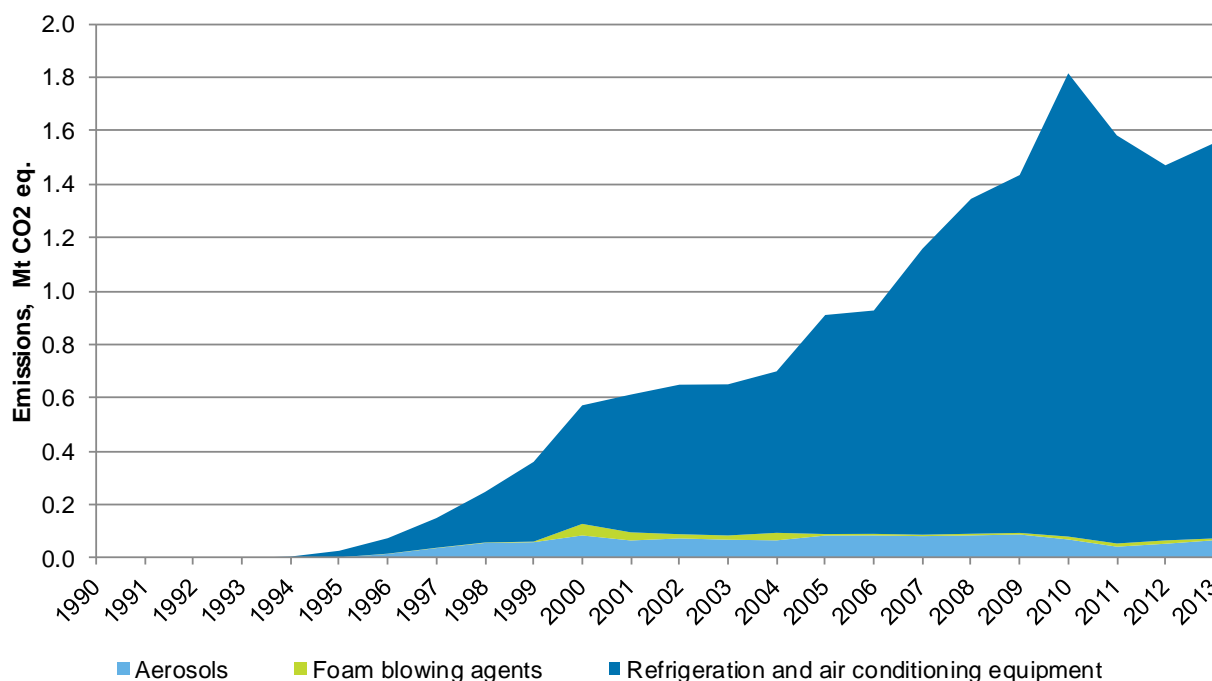
**Table 4.7-1** Reported emissions under the category Product uses as substitutes for ozone depleting substances in the Finnish inventory

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

Note that the subcategory Aerosols includes one-component polyurethane foam cans (OCF), an aerosol-like product. This practice originates from the 1996 GL. In the GPG 2000 and the 2006 IPCC Guidelines, 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 the recalculation would not improve the emission estimates.

The total emissions of F-gases from 2.F have increased significantly since 1990. In 1990 HFC containing refrigerants were already used in small quantities in stationary air conditioning. From mid-1990's emissions have increased strongly. 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.

The peak level of HFC emissions occurred in 2010. Since then the emissions have decreased mainly due to the decreased emissions from commercial refrigeration. The peak level of PFC emissions in Finland occurred in the late 1990's and early 2000's. Since then the emissions have followed the global declining trend. The usage of PFC-218 (C<sub>3</sub>F<sub>8</sub>) for servicing different refrigeration devices have decreased since the beginning of the 2000's. The imported amount of PFC-218 intended to be used for servicing refrigeration devices decreased clearly in 2010. After 2010 the emissions increased at a fairly constant level due to increased amount of PFCs used for servicing refrigeration devices. However the emissions are at the considerably lower level compared to the level before 2010.



**Figure 4.7-1** Greenhouse gas emissions from Product uses as substitutes for ozone depleting substances, Mt CO<sub>2</sub> eq.

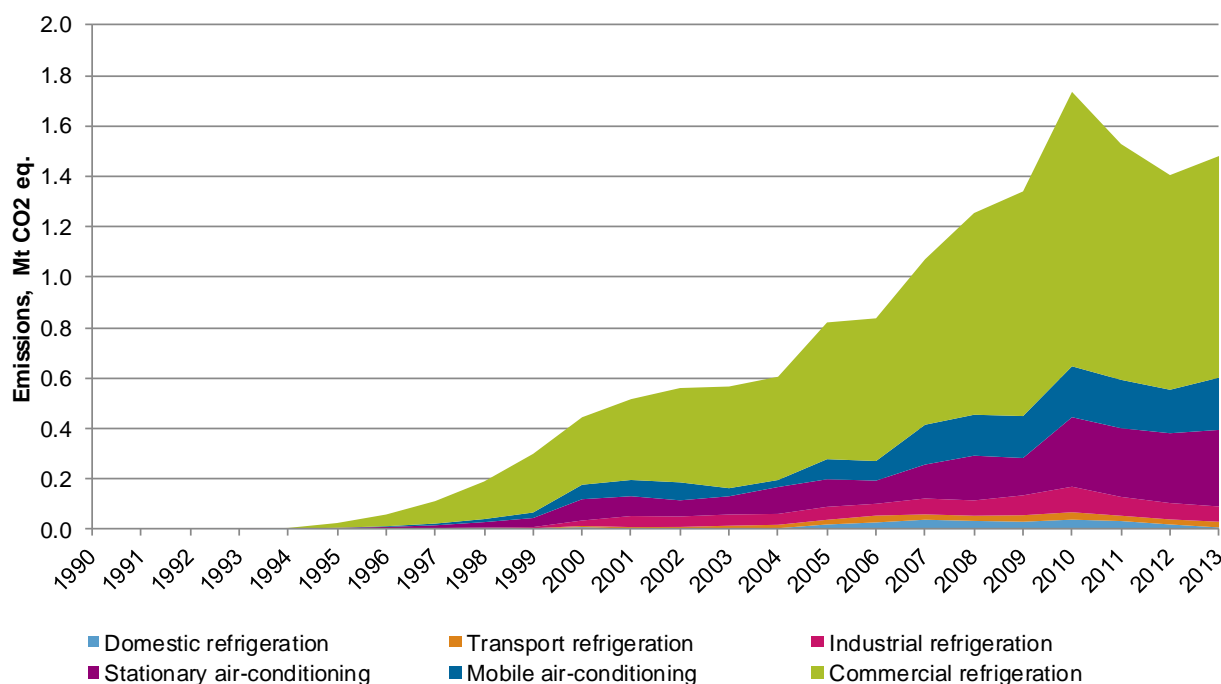
**Table 4.7-2** Emissions by gas and subcategory (Mt CO<sub>2</sub> eq.)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<b>HFC</b>																
2.F 1 Refrigeration and air conditioning equipment	0.00	0.02	0.43	0.49	0.54	0.55	0.59	0.81	0.82	1.06	1.24	1.33	1.74	1.53	1.40	1.48
2.F 2 Foam blowing agents	NO	0.001	0.043	0.030	0.016	0.016	0.028	0.006	0.006	0.005	0.006	0.006	0.012	0.015	0.016	0.012
2.F 3 Aerosols	NO	0.002	0.084	0.065	0.073	0.068	0.066	0.084	0.084	0.082	0.084	0.088	0.069	0.042	0.053	0.066
<b>PFC</b>																
2.F 1 Refrigeration and air conditioning equipment	NO	NO	0.012	0.022	0.016	0.017	0.014	0.015	0.018	0.010	0.013	0.010	0.000	0.001	0.004	0.004
<b>Total of subcategory, Mt CO<sub>2</sub> eq.</b>	<b>0.00</b>	<b>0.03</b>	<b>0.57</b>	<b>0.61</b>	<b>0.65</b>	<b>0.65</b>	<b>0.70</b>	<b>0.91</b>	<b>0.93</b>	<b>1.16</b>	<b>1.35</b>	<b>1.43</b>	<b>1.82</b>	<b>1.59</b>	<b>1.47</b>	<b>1.56</b>

## 4.7.2 Refrigeration and air conditioning

### 4.7.2.1 Category description

The category covers HFCs and PFC-218 emissions from refrigeration and air conditioning equipment based on the vapour compression cycle. Emissions are reported in six subcategories in accordance with the 2006 IPCC Guidelines. Included are commercial refrigeration, domestic refrigeration, industrial refrigeration, transport refrigeration, mobile air conditioning and stationary air conditioning. In 2013 HFC emissions totalled 1.5 Mt CO<sub>2</sub> eq. and PFC emissions 0.004 Mt CO<sub>2</sub> eq. Compared to the previous year the HFC-emissions declined 5% and the PFC emissions 3%. Majority of the HFC emissions originate from commercial refrigeration. Other significant emission sources are stationary and mobile air conditioning. PFC emissions originate from commercial and industrial refrigeration. 95% of the emissions are from commercial refrigeration (Figure 4.7-2).



**Figure 4.7-2** Greenhouse gas emission from six subcategories of the Refrigeration and air conditioning equipment (Mt CO<sub>2</sub> eq.)

#### 4.7.2.2 Methodological issues (2.F.1)

##### Methods

An overview of the methods used to quantify emissions of F-gases from category CRF 2.F.1 is presented in Table 4.7-3.

**Table 4.7-3** Summary of the methods used in category CRF 2.F.1.

Source category	Methods used	Gases reported	Notes
Commercial Refrigeration (CRF 2.F.1.a)	Top-down Tier 2	HFC-32, HFC-125, HFC-134a, HFC-143a, HFC-152a, PFC-218	-
Domestic Refrigeration (CRF 2.F.1.b)	Top-down Tier 2	HFC-125, HFC-134a	
Industrial Refrigeration (CRF 2.F.1.c)	Top-down Tier 2	HFC-23, HFC-32, HFC-125, HFC-134a, HFC-143a, HFC-152a	HFC-23 emissions from this source were reported in 2.H.3 Grouped confidential data of halocarbons and SF <sub>6</sub> due to confidentiality in 2001, 2004 and 2011. HFC-125 emissions from this source were reported aggregated in 2.F.1.a Commercial Refrigeration due to confidentiality in 1998. HFC-143a emissions from this source were reported aggregated in 2.F.1.a Commercial Refrigeration due to confidentiality in 1998. PFC-218 emissions from this source were reported aggregated in 2.F.1.a Commercial Refrigeration due to confidentiality in 2006 and 2011-2013.
Transport Refrigeration (CRF 2.F.1.d)	Top-down Tier 2	HFC-125, HFC-134a, HFC-143a, HFC-152a	-
Mobile Air-Conditioning (CRF 2.F.1.e)	Top-down Tier 2	HFC-134a	-

Source category	Methods used	Gases reported	Notes
Stationary Air-Conditioning (CRF 2.F.1.f)	Top-down Tier 2	HFC-32, HFC-125, HFC-134a, HFC-152a	HFC-227ea emissions from this source are reported in unspecified mix of HFC's in CRF 2.F.2.a due to confidentiality in 2013.

Emissions are calculated by the IPCC Tier 2b method. 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

emissions = production + imports – exports – destruction – new capacity – retiring capacity.

HFC- or PFC-containing refrigerant gases are not manufactured in Finland, thus production = 0. Some of the gas imported is stored in equipment as a new capacity. 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 new capacity and the retiring capacity are estimated with the methodology presented in page 7.54 in the 2006 IPCC Guidelines. Emissions are calculated with the same methodology for all the subcategories 2.F.1.a-f. More detailed description of calculating emissions with the IPCC Tier 2b method is presented in Appendix\_4 at the end of Chapter 4.

Emissions for 1990-1999 have been calculated according to the Tier 2 bottom-up methodology presented in the 1996 IPCC Guidelines since activity data available does not support the use of mass balance method in the 1990's. Equations 1-4 in chapter 2.17.2 of 1996 GL have been used. Emissions are calculated for all the 2.F.1.a-f subcategories.

### *Emission factors and other parameters*

The equipment lifetimes used for different equipment types in the Tier 2b method are presented in Table 4.7-4. Lifetimes are national estimates received from Finnish Refrigeration Enterprises Association (FREA).

**Table 4.7-4** Equipment lifetimes for different RAC equipment

Source category	Equipment lifetime in years
Commercial Refrigeration	12
Domestic Refrigeration	12
Industrial Refrigeration	15
Transport Refrigeration	6
Mobile Air-Conditioning	9
Stationary Air-Conditioning	15

Emission factors used in the calculation of emission for 1990-1999 are presented in Table 4.7-5. The default emission factors presented in the 1996 IPCC Guidelines have been used since national emission factors are generally not available. In the case of manufacturing of domestic refrigeration equipment, a national emission factor has been used. At that time there were three Finnish manufacturers of domestic appliances and the use of R-134a as refrigerant began in 1993. The emission factor is based on data reported by two manufacturers. The same emission factor has been assumed to be applicable also to the third manufacturer. First equipment with R-134a as refrigerant were imported and sold in Finland in 1993. It has been assumed that at the end of 1990's 40% of the domestic equipment sold annually in Finland used R-134a as refrigerant (Oinonen, 2001). The same share has been assumed for the years 1993-1999. Average charge of a 100 g of R-134a per unit sold presented in the IPCC 1996 GL has also been used in the calculations. The equipment lifetimes have been assumed to be the same as in the Tier 2b method used from 2000 onwards as presented in Table 4.7-4. No emissions from disposal occurred between 1990 and 1999.

**Table 4.7-5** Emission factors used in tier 2 bottom-up method for the years 1990-1999

Source category	Assembly losses, %	Annual leakage rate, %	Initial charge remaining, %	Recovery Efficiency, %
Commercial Refrigeration	5	17	90	80
Domestic Refrigeration	2,7	17	90	50
Industrial Refrigeration	5	17	90	80
Transport Refrigeration	5	17	90	80
Mobile Air-Conditioning	5	17	75	80
Stationary Air-Conditioning	5	17	90	80

Emission factors from the IPCC 1996 GL have been used since they are assumed to be more suitable to be used for estimating the emissions for the 1990's than the emission factors presented in the later versions of the IPCC guidelines. The verification of the RAC inventory ended up in a conclusion that the emission factors of the 2006 IPCC Guidelines would underestimate the emissions in the 1990's since the follow-up and prevention of leakages have improved significantly in the 2000's. The verification of the RAC inventory is described in more detail in Section 4.7.2.4. The emissions related refrigerant container management as presented in the 2006 IPCC Guidelines are considered negligible in Finland. According to the RAC industry no transfer of refrigerants from bulk containers to containers with smaller capacities have taken place in Finland since the late 1980's. All the refrigerants are imported in Finland in smaller containers (Hannula, 2014). Detailed description of the verification is presented in Section 4.7.2.4.

### Activity data

The activity data for the refrigeration and air conditioning sector were compiled by a survey conducted in March to April 2014. The survey to collect activity data for the inventory has been carried out annually since 2002. Until 2014 the activity data was collected and the emissions were reported as a single figure for all refrigeration and air conditioning subcategories. Due to implementation of the 2006 IPCC Guidelines the data collection was changed to cover all the six subcategories and the activity data for the inventory year 2013 were compiled at level of subcategories. In addition the activity data for the earlier years were distributed between the subcategories based on information received during the survey 2014. Details of the distribution in earlier years are presented in Section 4.7.1.5.

In the survey the following data are directly compiled at the subcategory level:

- refrigerants imported and exported in equipment
- refrigerants used in manufacturing of equipment
- refrigerants used in installation and conversion of equipment

In the case of installation and conversion, the respondents are allowed to fill in the data also without the split between the subcategories since some smaller companies may not have the data available at the level of subcategories. The following methods are used in splitting the aggregated data of installation and conversion between the applications:

- contacting the individual companies further
- assuming the same distribution between equipment as in the case of the data that has been reported in the level of equipment types

The data of bulk refrigerants imported and exported and data of destructed refrigerants are not compiled at the level of subcategories since the refrigerant distributors do not generally know the precise applications where the refrigerants will be used. The data is distributed between the applications based on the distribution of the combined amounts used in manufacturing and in installation and conversion of equipment.

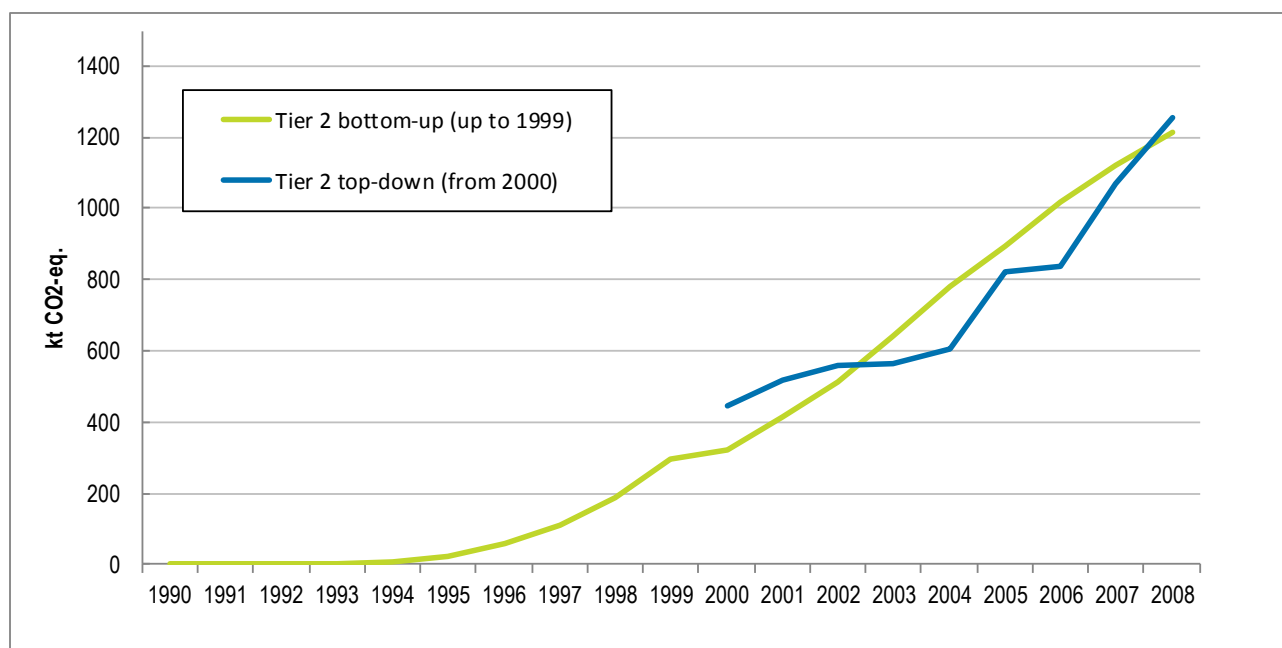
Response activity in the survey has varied from 45% to over 70%. The lowest response rate has been in 2006-7 inventories when new internet-based electronic data collection system was established. For the 2013 inventory the response activity was 69%. Since the companies have no legal obligation to report 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 2013 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.

#### 4.7.2.3 Uncertainty and time-series consistency

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 2013 inventory. Uncertainty in HFC emissions from category 2.F.1 was estimated at -8% to 8% and in PFC emissions at -19% to 20%. The uncertainty of HFC emissions between different 2.F.1 subcategories vary slightly with highest emissions in mobile air conditioning and lowest in domestic refrigeration. The simulation results suggest that most of the uncertainty in PFC emissions was due to installed amount of PFC refrigerants in commercial refrigeration sector.

Two different methods are used in the time-series of category 2.F.1. The years 1990-1999 are calculated with the Tier 2 bottom-up emission factor based method and the years from 2000 onwards with Tier 2 top-down mass balance method. Since the method is not the same in the time series, a question of time series' consistency arises. The emission estimates for 1990-1999 cannot be calculated with the mass balance method since the activity data to support the calculation is not available. Retrospective compilation of the missing data is considered too challenging and would not result in an improvement of the inventory estimates. The activity data in the 2000's can be adjusted to support the calculation of emission estimates with the bottom-up method. The issue of time series' consistency was tested by calculating the emissions from 2000 on with the bottom-up method and comparing the results of the two different methods. The results showed that although the methods do not give identical results for the overlapping years, the trend in emissions is fairly similar as illustrated in Figure 4.7-3 for the early and mid-2000's. The slight fluctuation of emissions between successive years is typical for the mass balance method.



**Figure 4.7-3** Time-series consistency of 2.F.1.

The uncertainties of the historical data are significant, especially when adjusting the activity data of the top-down method to the bottom-up method for comparison purposes. The uncertainty of the activity data in particular for the year 1999 is considered high since linear interpolation of the data from adjacent years has been used to obtain the data. The use of HFC and PFC containing refrigerants grew rapidly during the late 1990's and the slight jump in emissions between 1999 and 2000, when the methodology changes, should not be a non-consistency issue when considering the high uncertainty of the 1999 data.

The current time series of emissions should give a reliable overview of how the emissions evolved during the 1990's. The activity data in the recent years is considered less uncertain than the data of the 1990's and early 2000's. Nearly all importers, exporters and manufacturers have provided a survey response in previous years. Analysis of missing data of imports, exports and manufacturing in the time series has been carried out at the level of individual companies and the missing data has been imputed based on the companies data from the adjacent years. More uncertainty is related to the installation and service of equipment. The number of installation and servicing companies is much larger compared to importers, exporters and manufacturers. Therefore the missing data concern mainly installation and service. The procedure used in the non-response analysis and data imputation has been described in detail in Oinonen, 2004.

#### *4.7.2.4 Category-specific QA/QC and verification*

QA/QC procedures described in Section 1.2.3 are implemented in the category 2.F.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. Bilateral quality meetings are held annually between the inventory unit and the sectoral expert. The quality meeting of the 2013 inventory resulted in a more detailed analysis of the time series consistency of the category 2.F.1. The results are described in Section 4.7.2.3. The documentation and archiving of the 2.F.1 category is detailed in Section 1.3.2.

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 2013 inventory QC checks minor errors in the movement of inventory data among processing steps were detected and corrected.

The category specific QC procedures for category 2.F.1 include emission and activity data comparisons. The results are compared with those obtained using a simpler model, i.e. actual emissions are compared with potential emissions and data calculated with the scenario model used for PAM's reporting. The emission trends are graphed and explained. The activity data of the F-gas scenario model was harmonised as far as possible with the inventory data when the inventory data was changed to cover all the RAC subcategories. The purpose of this was to improve the equivalence of the inventory and scenario data and results.

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. 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.

During the time series recalculation the activity data of category 2.F.1 was verified by an external verifier from Finnish Refrigeration Enterprises Association (FREAA) with an extensive experience from the RAC industry. Detailed description of the recalculation results is presented in Section 4.7.2.5. The purpose of the verification was to investigate the activity data in the time series and trace the omissions of the data. The assumptions in the distribution of the data between the subcategories were also analysed and adjusted. In addition the applicability of the emission factors presented in Section 4.7.2.4 and used in the 1990's was confirmed. The verification resulted in a more reliable data and the previous unreal fluctuation of the data between two following years was stabilized. Some fluctuation in the activity data is also real, i.e. the varying production volume of the only passenger car manufacturing plant in Finland affects strongly the annual consumption of refrigerant R-134a in the MAC sector.

Uncertainty estimates are quantified for all of the source categories and the underlying assumptions are documented in the F-gas inventory archives explained in more detailed in Section 1.3.2. Importance analysis

is used to elucidate the factors that have significant bearing on the uncertainty of each category. The results are described in Section 4.7.1.3 above.

#### *4.7.2.5 Category specific recalculations*

Due to implementation of the 2006 IPCC Guidelines the HFC and PFC emission estimates of 2.F.1 were recalculated for the whole time-series. In addition the introduction of the new GWP values due to implementation of the revised UNFCCC reporting guidelines affect the emission estimates in the time-series. As explained in Section 4.7.1.2 the emissions were previously reported as a single figure for all the 2.F.1 subcategories. However the 2006 IPCC Guidelines require the collection of activity data and the reporting of emissions at the subcategory level if the category is a key category. Therefore the activity data for the years 1990-2012 were split between the subcategories and the time-series was recalculated at the level of subcategories 2.F.1.a-f.

In the 1990's the recalculated emission estimates were approximately at the same level as the previously reported estimates when considering the mean of the difference between the old and new estimates in different years in the 1990's, although there is some inter annual fluctuation in the difference. The recalculated emissions for the base year 1995 were 2% lower compared to the previous ones. When using the old GWP's in the calculation the emissions were 14% lower than the previous ones. The recalculated emission estimates can be considered to be more reliable than the previous ones due to the verification of the data as explained in Section 4.7.2.4 although uncertainties still remain in the data.

In the early 2000's the recalculated emissions are approximately at the same level compared to the previously reported emissions when expressed as CO<sub>2</sub> equivalents. The recalculated emissions are higher in 2000 and in 2002 but previous emission data had inter annual fluctuation due to missing activity data. From the mid 2000's the recalculated emissions are generally higher compared to the previously reported ones. Verification of the activity data improved the reliability of the data also in the 2000's. In addition the methodology for estimating the nameplate capacities of the retiring equipment was changed to better take into account the emissions from retiring equipment. The increasing emissions from retiring equipment is the main reason for increased emissions since the mid 2000's compared to the previously reported emission estimates.

#### *4.7.2.6 Category-specific planned improvements*

No planned improvements in this Category.

### *4.7.3 Foam blowing agents*

#### *4.7.3.1 Category description*

The category covers HFC emissions from foam blowing and from the use of HFC-containing foam products. In 2013 emissions totalled 0.01 Mt CO<sub>2</sub> eq. Between 2012 and 2013 the emissions decreased 25% mostly due to the significantly lower amount of HFC-152a used in XPS manufacturing. Compared to the base year 1995 the emissions are 22-fold. Emissions were not occurring in 1990 since the use of HFC blowing agents in Finland began in 1994. The peak level of emissions occurred in the early 2000's right after when HCFC's were prohibited as blowing agents and replaced by HFC-134a. At present the amounts of HFC-152a and HFC-365mfc used in manufacturing have the most significant effect on the annual level of emissions.

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 2013 about 38% 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 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 use of HFC-227ea in manufacturing has been reported since 2011. HFC-152a and HFC-227ea are reported as unspecified mix of HFC's in 2013 due to confidentiality. The confidential emissions information of HFC-227ea from category 2.F.1.f Stationary Air Conditioning is also included in the unspecified mix HFC's in 2013.

A small proportion of HFC-365mfc has been used in the production of open-celled PU flexible moulded foam in 2007-2011. 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 closed cells.

#### 4.7.3.2 Methodological issues

##### Methods

Emissions from this category are calculated by Tier 2 method described in the 2006 IPCC Guidelines (equation 7.7 in page 7.33). More detailed description of the method is presented in Appendix\_4a.

**Table 4.7-6** Summary of the methods used in category CRF 2.F.2

Source category	Methods used	Gases reported	Notes
Closed Cells (CRF 2.F.2.a)	Tier 2	HFC-134a, HFC-152a, HFC-227ea, HFC-245fa and HFC-365mfc	HFC-365mfc emissions from CFR 2.F.2.b Open Cells are included here in 2007-2011 due to confidentiality. HFC-227ea emissions from 2.F.1.f Stationary Air Conditioning are included here in 2013 due to confidentiality.
Open Cells (CRF 2.F.2.b)	Tier 2		Emissions from this source are not reported separately due to confidentiality.

The activity data for the calculation of HFC emissions by the Tier 2 method is available from 1998 on. The calculation of emissions for the years 1994-1997 is based on the method presented in the IPCC 1996 GL (p. 2.53).

##### Emission factors and other parameters

The calculation 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 (2006 Guidelines p. 7.37). The emission factors used are shown in Table 4.7-7.

**Table 4.7-7** Emission factors for foam blowing

i	Foam type	HFC-134a		HFC-152a		HFC-245fa/HFC-365mfc/HFC-227ea	
		First year loss %	Annual loss %	First year loss %	Annual loss %	First year loss %	Annual loss %
1	XPS	25	0,75	50	25		
2	PU integral skin	95	2,5			95	2,5
3	PU injected	12,5	0,5			10	0,5
4	PU appliance	7	0,5			4	0,25
5	PU discontinuous panel	12,5	0,5			12	0,5

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.

The methodology for the calculation of 1994-1997 emissions also require emission factors. Emission factors for initial and lifetime emissions selected are 7.5% and 0.5% respectively. Emission factors are from Oinonen, 2000.

### *Activity data*

The activity data for calculating emissions from foam blowing 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 87% 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. HFC-152a emissions were included in the 2012 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.

#### *4.7.3.3 Uncertainty and time-series consistency*

Monte Carlo simulation was used to quantify uncertainty of the level of HFC emissions from category 2.F.2. Uncertainty in HFC-134a emissions in 2013 was estimated at -14% to 17%. Correlation analysis of the simulation results suggests that most of the uncertainty is due to uncertainty of the emission factors for the leakage of HFC-134a banked in appliance and XPS foams and HFC-134a used for the manufacture of injected foam products. Uncertainty in combined HFC-152a and HFC-227ea (reported as unspecified mix of HFCs due to confidentiality) emissions was estimated at -22% to 21%. Most of the uncertainty is due to uncertainty of the emission factors and the amount of HFC-152a used for the manufacture of XPS foam products.

Uncertainty in HFC-245fa emissions in 2013 estimated at -27% to 29% and in HFC-365mfc at -26% to 25%. Most of the uncertainty of HFC-245fa emissions is due to uncertainty of the emission factor and amount of HFC-245fa used for the manufacture injected foams. In the case of HFC-365mfc most of the uncertainty is due to uncertainty of the amount of HFC-365mfc used for the manufacture of integral skin foams and sandwich panels.

Two different methods in the calculation of emissions are used in the time-series, the IPCC 1996 GL methodology for 1994-1997 and the Tier 2 method of the 2006 IPCC Guidelines for the emissions from 1998 on. Although the methodology is slightly different, the current emission estimates give a reliable representation of the development of emissions in the 1990's. The emission estimates between 1994 and 1999 represent the steady increase of the use of HFC-134a as blowing agent in the manufacturing of foam products. The sharp rise in emissions from 1999 to 2000 is due to prohibition of HCFC's as blowing agents from 1.1.2000. HCFC were substituted by HFC-134a.

#### 4.7.3.4 Category-specific QA/QC and verification

QA/QC procedures described in Section 1.2.3 are implemented in the category 2.F.2. The QC procedures are performed according to the QA/QC and verification plan and the resulting findings, corrections and planned improvements are recorded in the yearly QA/QC form. Bilateral quality meetings are held annually between the inventory unit and the sectoral expert. The documentation and archiving of the 2.F.2 category is detailed in Section 1.3.2.

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 2013 inventory QC checks minor errors in the movement of inventory data among processing steps were detected and corrected.

The category specific QC procedures for category 2.F.2 include emission and activity data comparisons as well as uncertainty estimates. The results are compared with those obtained using a simpler model, i.e. actual emissions are compared with potential emissions. The emission trends are graphed and explained. 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.

Uncertainty estimates are quantified for all of the source categories and the underlying assumptions documented in the F-gas inventory archives explained in more detailed in Section 1.3.2. Importance analysis is used to elucidate the factors that have significant bearing on the uncertainty of each category. The results are described in Section 4.7.2.3 above.

#### 4.7.3.5 Category specific recalculations

The foam blowing time-series was recalculated due to implementation of the 2006 IPCC Guidelines and the revised UNFCCC reporting guidelines. The revised UNFCCC reporting guidelines introduced new GWP values and some individual emission factors were changed due to implementation of the 2006 IPCC Guidelines. In 2000's the recalculated total HFC emission estimates are approximately 44% (between 16 and 55%, depending on the year in question) lower compared to the previous ones. In 2011 and 2012 the emissions are approximately at the same level.

#### 4.7.3.6 Category-specific planned improvements

No planned improvements in this category.

### 4.7.4 Fire protection

#### 4.7.4.1 Category description

Emissions from Fire protection (2.F.3) occur in Finland and emission estimation method is presented in this Section. However, emissions from fire protection cannot be reported separately due to confidentiality. Emissions are reported aggregated with other confidential F-gas emission sources in category CRF 2.H.3 Grouped confidential data of halocarbons and SF<sub>6</sub>.

Halons were phased-out in fixed fire suppression systems in the mid 1990's and substituted with an extinguishant that is a mixture of HFC-125, HFC-134a and CO<sub>2</sub>. 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 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.

#### 4.7.4.2 Methodological issues

HFC-125 and HFC-134a emissions from fixed firefighting 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.

The activity data for the calculation of emissions from fixed firefighting systems is obtained from annual surveys of companies. All the companies responded to the survey.

#### *4.7.4.3 Uncertainty and time-series consistency*

The time series of HFC emissions from 2.F.3 has been calculated with the same methodology for the whole time series and is therefore considered consistent.

#### *4.7.4.4 Category specific QA/QC and verification*

QC procedures are performed according to the QA/QC and verification plan and the resulting findings, corrections and planned improvements are recorded in the yearly QA/QC form. Bilateral quality meetings are held annually between the inventory unit and the sectoral expert.

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 2013 inventory QC checks minor errors in the movement of inventory data among processing steps were detected and corrected.

The emission trends are graphed and explained. 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.

#### *4.7.4.5 Category specific recalculations*

Changes in the category result from the introduction of the new GWP values for HFC-125 and HFC-134a. Compared to the old GWP values the values are higher for both HFC species.

#### *4.7.4.6 Category-specific planned improvements*

No planned improvements in this Category.

### *4.7.5 Aerosols (2.F.4)*

#### *4.7.5.1 Category description*

The category covers HFC-134a and HFC-152a emissions from technical and novelty aerosols, one-component polyurethane foam, tear gas and metered dose inhalers (MDIs). The emissions are reported as aggregated HFC emissions due to confidentiality. In addition metered dose inhalers cannot be reported separately due to confidentiality. For the year 2013 total emissions from aerosols and MDIs totalled 0.07 Mt CO<sub>2</sub> eq. The 2013 emissions increased 24% compared to 2012 due to the increased amount of imported HFC-134a both in bulk and in products. Emissions have increased rapidly compared to the base year 1995 when the emission totalled 0.002 kt CO<sub>2</sub> eq. One large company phased out their production during the year 2010 which caused a temporary drop of emissions in 2011. 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.

#### 4.7.5.2 Methodological issues

##### Methods

The emissions model used in the category is from the 2006 IPCC Guidelines (p. 7.28).

$$x = (1 - f)a + fb,$$

where  $f = 0.5$ ,

$a$  = quantity of HFC and PFC contained in aerosol products sold in 2012, and

$b$  = quantity of HFC and PFC contained in aerosol products sold in 2013.

Quantity of HFC and PFC contained in aerosol products sold in one year is 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\_4a.

**Table 4.7-8** Summary of the methods used in category CRF 2.F.4

Source category	Methods used and gases reported	Notes
Metered Dose Inhalers (CRF 2.F.4.a)	Tier 2	MDIs are not reported separately from other aerosols due to confidentiality.
Aerosols and one-component foam (CRF 2.F.2.b)	Tier 2 HFC-134a, HFC-152a	One-component foam cans are treated as aerosols in this inventory, cf. Section 2.3.6 of Oinonen (2003).

##### Emission factors

Emission factors were taken from the 2006 IPCC Guidelines 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).

##### Activity data

The activity data for calculating emissions from aerosols and metered dose inhalers 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). All the companies responded in the 2013 survey. Part of the activity data is confidential and cannot be presented here due to the low number of companies reporting the activities.

#### 4.7.5.3 Uncertainty and time-series consistency

Monte Carlo simulation was used to quantify uncertainty of the level of HFC emissions from category 2.F.4. Uncertainty in HFC emissions in 2013 was estimated at -43% to 47%. The simulation results suggest that most of the uncertainty was due to amounts of HFC-134a imported in bulk and exported in products.

The time series of HFC emissions from 2.F.4 has been calculated with the same methodology given in the 2006 IPCC Guidelines for the whole time series and is therefore considered consistent.

#### 4.7.5.4 Category specific QA/QC and verification

QA/QC procedures described in Section 1.2.3 are implemented in the category 2.F.4. 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 bilateral quality meeting is held annually between the inventory unit and the sectoral expert. The documentation and archiving of the 2.F.4 category is detailed in Section 1.3.2.

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 2013 inventory QC checks minor errors in the movement of inventory data among processing steps were detected and corrected.

The category specific QC procedures for category 2.F.4 include emission and activity data comparisons as well as uncertainty estimates. The results are compared with those obtained using a simpler model, i.e. actual emissions are compared with potential emissions. The emission trends are graphed and explained. 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.

Uncertainty estimates are quantified for all of the source categories and the underlying assumptions are 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 4.7.4.3 above.

#### *4.7.5.5 Category specific recalculations*

Introduction of the new GWP values due to implementation of the revised UNFCCC reporting guidelines affect the emission estimates in the time-series. Majority of the emissions from aerosols are emissions of HFC-134a and therefore the higher GWP of HFC-134a has an increasing effect on the emission estimates in the time-series. In average the new emission estimates are 8% higher compared to the previous ones.

#### *4.7.5.6 Category-specific planned improvements*

There are no planned improvements in this category.

## 4.8 Other product manufacture and use (CRF 2.G)

### 4.8.1 Introduction

Under the category Other product manufacture and use Finland reports SF<sub>6</sub> emissions from use of electrical equipment and N<sub>2</sub>O emissions from product use.

The SF<sub>6</sub> emissions from this category result from installation, use and disposal of electrical equipment. SF<sub>6</sub> emissions from electrical equipment totalled 0.01 Mt CO<sub>2</sub> eq in 2013. The emissions were approximately at the same level as in the previous year. SF<sub>6</sub> 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.

Emissions from SF<sub>6</sub> and PFCs from other product use (2.G.2) are not occurring in Finland.

N<sub>2</sub>O emissions are from all uses of N<sub>2</sub>O (includes also use as a propellant in aerosol products, primarily in food industry) in Finland and are reported under Medical applications because emissions are calculated using production or import data as activity data and there are no information where the produced or imported N<sub>2</sub>O have been used. In 2013 emissions from use of N<sub>2</sub>O were 0.03 Mt CO<sub>2</sub> eq.

**Table 4.8-1** Reported emissions, calculation methods and types of emission factors for the subcategory Other product manufacture and use in the Finnish inventory

CRF	Source	Emissions reported	Method	Emission factor
2.G.1	Electrical Equipment	SF <sub>6</sub>	Tier 2	CS
2.G.3	N <sub>2</sub> O from Product uses	N <sub>2</sub> O	CS (Tier 2)	CS

**Table 4.8-2** Emissions by gas and subcategory (kt CO<sub>2</sub> eq.)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<b>SF<sub>6</sub></b>																
2.G.1 Electrical Equipment	45.0	26.5	7.4	7.4	8.1	7.8	7.9	8.8	8.3	9.1	9.1	9.7	10.2	10.4	9.8	10.0
<b>N<sub>2</sub>O</b>																
2.G.3 N <sub>2</sub> O from Product uses	64.5	64.6	54.8	51.8	47.1	43.6	42.7	48.3	43.0	40.2	38.0	29.1	32.1	30.9	30.5	27.5
<b>Total of subcategory, kt CO<sub>2</sub> eq.</b>	<b>109.5</b>	<b>91.1</b>	<b>62.2</b>	<b>59.1</b>	<b>55.2</b>	<b>51.5</b>	<b>50.6</b>	<b>57.1</b>	<b>51.3</b>	<b>49.3</b>	<b>47.1</b>	<b>38.7</b>	<b>42.3</b>	<b>41.2</b>	<b>40.2</b>	<b>37.5</b>

### 4.8.2 Electrical equipment

#### 4.8.2.1 Category description

The SF<sub>6</sub> emissions from this category result from installation, use and disposal of electrical equipment. The SF<sub>6</sub> emissions from this category peak in 1990 as large amounts of electrical equipment was installed in 1990 and it coincides with the high level of economic activity in the country in general. Rather large amount of equipment were installed still in 1991 but the emissions decline during the next years due to 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 1996, and the amount of gas used for maintenance also increased. After the mid-1990s 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 emissions level in the 2000s and in the most recent years is fairly constant with in average a few percent increase annually. The amount of SF<sub>6</sub> banked in equipment increases slightly faster. The improved sealing of equipment and handling of the gas can therefore be observed from the trends in the 2000s.

### Methods

The inventory is based on the Tier 2 country-specific emission factor method of the 2006 IPCC Guidelines. Emissions are estimated separately for equipment manufacturing, use and disposal. Manufacturing refers to actual equipment manufacturing and on-site installation of equipment. The production of medium voltage SF<sub>6</sub> products began in one plant in Finland in 1991 and the plant was closed down in the end of 2010. The recovery in the CRF tables is treated as recovery itself and not emissions from recovery. Recovery is calculated with the simplified way of subtracting disposal emissions from the amount of SF<sub>6</sub> in products at decommissioning. The data of SF<sub>6</sub> in retiring equipment is available from 2002 onwards. Due to long lifetimes of the equipment and communication with the industry the emissions from retiring equipment are considered negligible in the 1990's. More detailed description of the method is presented in Appendix\_4a.

Previously the inventory was based on the Tier 3c mass balance method from the GPG 2000. Due to unreliability of the mass balance method the calculation method was changed parallel with the implementation of the 2006 IPCC Guidelines. This is elaborated further in Section 4.8.2.5.

### Emission factors

The country specific emission factors required for the Tier 2 method were developed by an expert group during 2014. The group was appointed by Finnish Environment Institute (SYKE), the organisation responsible for F-gas emission inventory in Finland. In addition to SYKE the group consisted of members from the industry using the SF<sub>6</sub> equipment (electricity transmission and distribution companies), Finnish SF<sub>6</sub> equipment manufacturer, a research institute (Tampere University of Technology) and National Authority for the ghg-inventory (Statistics Finland). The emission factors are presented Table 4.8-3.

**Table 4.8-3** Emission factors for electrical equipment

Year	Manufacturing (%)	Use (%)	Disposal (%)
1990	15.00	1.00	NO
1995	10.00	1.00	NO
2000	1.80	0.50	NO
2001	1.40	0.50	NO
2002	1.20	0.50	1.50
2003	1.00	0.50	1.50
2004	0.80	0.50	1.50
2005	0.76	0.50	1.50
2006	0.81	0.50	1.50
2007	0.58	0.50	1.50
2008	0.68	0.50	1.50
2009	1.80	0.50	1.50
2010	1.73	0.50	1.50
2011	1.59	0.50	1.50
2012	0.25	0.50	1.50
2013	0.25	0.50	1.50

The manufacturing EF in Table 4.8-3 consists of equipment manufacturing part and the installation part that have been added up. The aggregated EF has been used in the calculations. The actual manufacturing of equipment took place in one plant in Finland between 1991 and 2010. The plant has delivered the EF's for equipment manufacturing part. Due to confidentiality of the manufacturing part, only the aggregated EF can be shown in Table 4.8-2. The EF for 1990 is based on the GPG 2000. The expert group was unable to derive better country specific data for 1990 and the recommendation was to use the default EF which was considered suitable for Finnish conditions in the 1990's. The aggregated EF for 1991 was estimated to be at the same level as in 1990. The aggregated EF for 1995 is previously received from the industry (Pihkala 1995). The installation part of the aggregated EF for the years 2000, 2005 and 2010 are expert group's estimates. The EF's for the years 1992-1994, 1996-1999, 2001-2004 and 2006-2009 have been linearly interpolated. From 2010 onwards the EF is estimated to stay constant.

The EF's for use (leakage from the bank and servicing, maintenance or failures of the equipment) and disposal of equipment are expert group's estimates and are based e.g. on IEC standards and the companies' own follow-up of SF<sub>6</sub> balances over the years.

### *Activity data*

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. Changes in the activity data collection practises were not needed due to the change of the emission estimation methodology. 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 77%. The activity data of three 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 and 2013 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%.

#### *4.8.2.3 Uncertainty and time-series consistency*

Uncertainty in SF<sub>6</sub> emissions from category 2.G.1 was quantified using Monte Carlo simulation. Uncertainty in SF<sub>6</sub> emissions in 2013 was estimated at -33% to 38%. According to the simulation results most of the uncertainty is related to the emission factor for the leakage of SF<sub>6</sub> from the gas bank and the size of the bank itself.

The time series of SF<sub>6</sub> emissions from 2.G.1 has been calculated with the same methodology for the whole time series and is therefore considered consistent.

#### *4.8.2.4 Category specific QA/QC and verification*

QA/QC procedures described in Section 1.2.3 are implemented in the category 2.G.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 bilateral quality meeting is held annually between the inventory unit and the sectoral expert. As result of the quality meeting of the 2013 inventory the implied emission factors of 2.G.1 were compared to other countries. The documentation and archiving of the 2.G.1 category is detailed in Section 1.3.2.

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 2013 inventory QC checks minor errors in the movement of inventory data among processing steps were detected and corrected.

The category specific QC procedures for category 2.G.1 include emission and activity data comparisons as well as uncertainty estimates. The results are compared with those obtained using a simpler model, i.e. actual emissions are compared with potential emissions. The emission trends are graphed and explained. 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.

The emission estimates and activity data are compared to the emission data collected via Finnish Electrical Equipment Industry's own survey. The Electrical Equipment Industry's emission estimates are lower but it does not cover emissions from manufacturing or service work by subcontractors (Suur-Uski, 2009). Although the emission estimates are different, the difference in the calculated SF<sub>6</sub> banks is found to be in average only slightly over 2%.

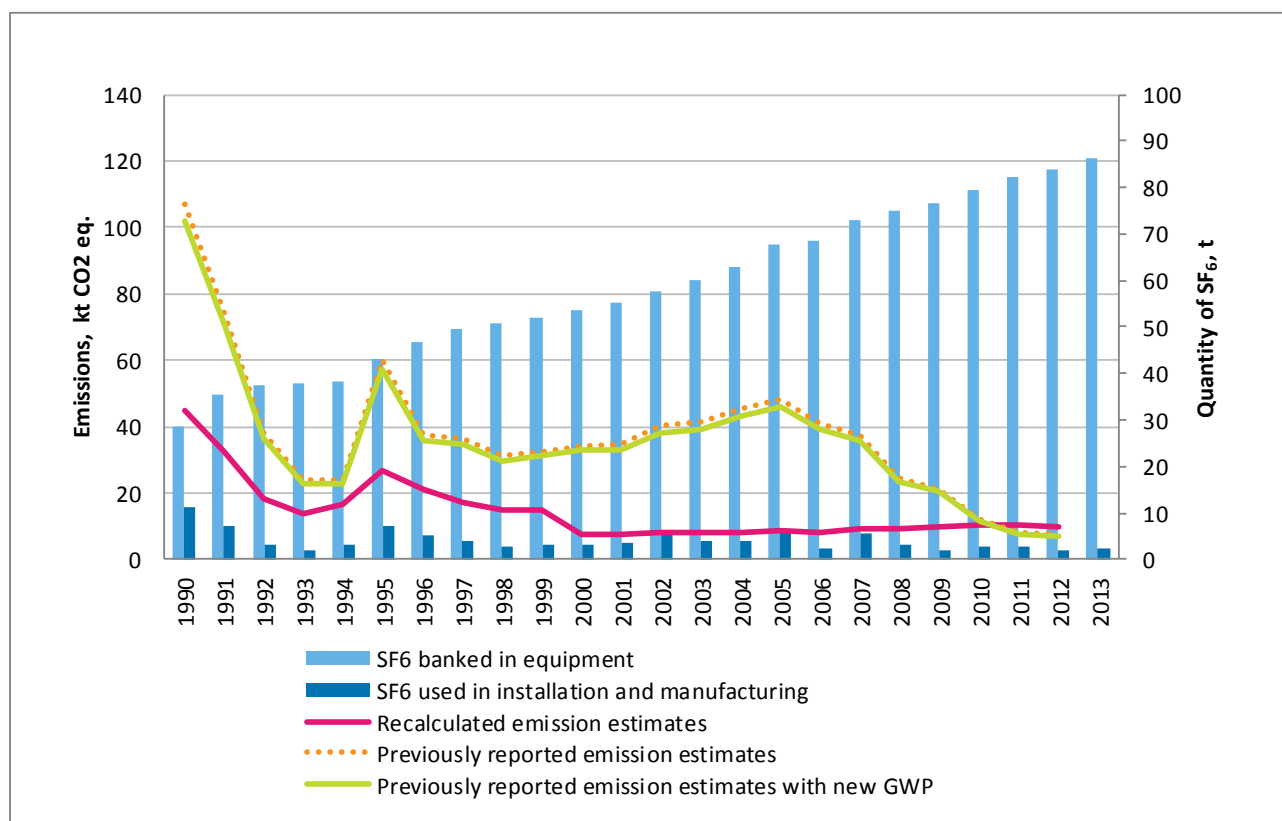
The implied emission factors for equipment manufacturing, use and disposal were compared to IEF's from other countries. The countries selected for comparison were Austria, Denmark, France, Germany and Sweden. The results showed that IEF's are consistent with other countries. Some variation in the IEF's was found in equipment manufacturing but generally other countries had a downward trend in their IEF's similar to Finland. Denmark and Sweden had a constant IEF for the whole time series. IEF's for equipment disposal were only available for Germany and Austria. Like Finland, Austria had a constant IEF for the whole time series, although it was slightly higher than the IEF of Finland. Germany had the same IEF as Finland from the end of 1990's to the mid 2000's. After the mid 2000's there was variation in Germany's IEF and it was higher compared to Finland. In the case of equipment use, Germany and France had slightly higher IEF's in the 1990's and other countries slightly lower IEF's. In the 2000's the IEF's of Finland, Sweden, Austria and Denmark were at the same level whereas France's IEF was still higher but had decreasing trend. Germany's IEF had also a decreasing trend and reached the same level as Finland at the end of the decade.

Uncertainty estimates are quantified for all of the source categories and the underlying assumptions are 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 4.8.2.3 above.

#### 4.8.2.5 Category specific recalculations

The question of the time series consistency has been addressed in this category during the reviews of the 2010-2012 submissions as two different methods were previously applied in the time-series, emission factor based Tier 2 method and country-level mass-balance. Time-series was recalculated in the 2013 submission when the emissions were calculated with the mass balance method. However this did not remove the problems related to the mass balance method.

Due to implementation of the 2006 IPCC Guidelines the emission estimation methodology of this category was changed from the mass balance methodology to the Tier 2 country specific emission factor methodology. Following this the time-series 1990-2012 was recalculated. Figure 4.8-1 illustrates both the recalculated emission estimates and the previously reported emission estimates together with estimated quantities of SF<sub>6</sub> banked in equipment and used in installation and manufacturing of equipment.



**Figure 4.8-1** Recalculated SF<sub>6</sub> emission estimates and the previously reported emission estimates in relation to the annually estimated quantities of SF<sub>6</sub> banked in equipment and used in installation and manufacturing of equipment

The recalculated emission estimates are generally lower than the previously reported emissions. Part of the difference between the recalculated and previously reported emissions is caused by the new GWP value of SF<sub>6</sub> which is lower than the old one. The recalculated emissions in Figure 4.8-1 are calculated with the new GWP and the previously reported emissions with the old GWP. Although the recalculated emissions are lower in the 1990's the trend in the emissions is the same. As the emissions were previously recalculated in the 2013 submission, the emission estimates for the years 1990-2003 calculated with the emission factor method based on IPCC default EF's were adjusted to the mass balance method by applying the overlap method. That overestimated the emissions in the 1990's. The emission estimates of the mass balance method were based on a five-year running mean of activity data to correct the unrealistic year-to-year fluctuation in the emissions. This overestimated the emissions in the early- and mid-2000s where the differences between the previously reported emissions and recalculated emissions are now the largest. The recalculated emissions reflect better the declining trend of emissions from the mid 1990's to the early 2000's due to the improved sealing of equipment and handling practices of the SF<sub>6</sub> following the rather stabilised emission levels towards the end of the decade.

#### *4.8.2.6 Category-specific planned improvements*

There are no category-specific planned improvements.

### *4.8.3 N<sub>2</sub>O from product uses*

#### *4.8.3.1 Category description*

Under N<sub>2</sub>O from product uses Finland reports the total use of N<sub>2</sub>O, it includes use in hospitals and by dentists to relieve pain and for detoxification also use as propellant in aerosol products, primarily in food industry is included.

The N<sub>2</sub>O emissions in this category are from the medical use of N<sub>2</sub>O. In 2013 these emissions totalled 27 kt CO<sub>2</sub> eq. The emission trend has been decreasing, the reduction has been 63% since 1990. The N<sub>2</sub>O emissions are calculated by Statistics Finland.

The country-specific calculation method is consistent with the method described in 2006 IPCC Guidelines. 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 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.

To estimate emissions from aerosol products has been difficult due to lack of information of purchased amount of aerosol products because they are not included in sales or import data. Therefore average of emission factors used in central Europe has been used.

#### *Activity data*

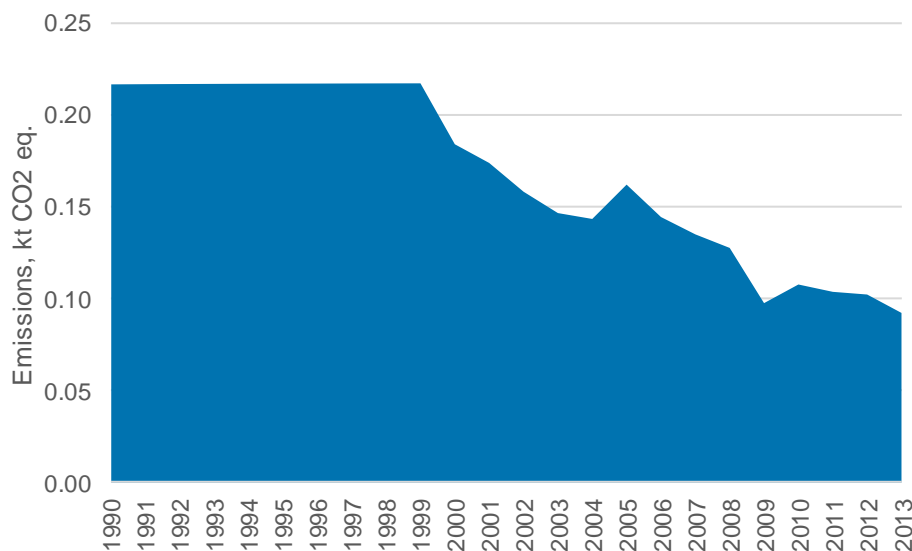
For the estimation of N<sub>2</sub>O emissions production or importation for medical use data are obtained from companies for the years 1990, 1998 and all years starting from 2000. In 2013 one company reported that they have continued to export and that has been also taken into account in the calculations.

Activity data for aerosol products is amount of inhabitant of Finland.

#### *Emission factors*

Emission factor for N<sub>2</sub>O use in medical applications is one, as all used N<sub>2</sub>O is emitted to the atmosphere.

Emission factor for N<sub>2</sub>O used in aerosol products is average of three central European countries which have reported N<sub>2</sub>O emissions from aerosol products.



**Figure 4.8-2** N<sub>2</sub>O emissions from all uses of N<sub>2</sub>O in Finland

#### 4.8.3.2 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

The uncertainty of emissions from N<sub>2</sub>O use in 2013 was estimated at  $\pm 10\%$ .

#### 4.8.3.3 Category-specific QA/QC and verification

QA/QC procedures described in Section 1.2.3 are implemented in this category. 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 bilateral quality meeting is held annually between the inventory unit and the sectoral expert. As result of the quality meeting the emissions from the use of N<sub>2</sub>O as propellant were included in to the inventory.

#### 4.8.3.4 Category-specific recalculations

N<sub>2</sub>O emissions from aerosol products have been included to the inventory since the last inventory submission.

#### 4.8.3.5 Category-specific planned improvements

There are planned no category-specific improvements.

## 4.9 Other (CRF 2.H)

### 4.9.1 Introduction

Under Category 2.H.3 Grouped confidential data of halocarbons and SF<sub>6</sub> (2.H.3) Finland reports the following sources and emissions of F-gases that have been grouped due to confidentiality:

- HFC-23 from semiconductor manufacturing
- HFC-23 from industrial refrigeration in 2001, 2004 and 2011-2012
- HFC-125 and HFC-134a from Fire protection
- CF<sub>4</sub>, C<sub>2</sub>F<sub>6</sub> c-C<sub>4</sub>F<sub>8</sub> and C<sub>3</sub>F<sub>8</sub> (until 2006) from semiconductor manufacturing
- SF<sub>6</sub> from magnesium die casting, semiconductor manufacturing, shoes (until 2007) and research

Category Pulp and paper (2.H.1) and Food and beverages industry (2.H.2) includes NMVOC emissions from forest and food industries. 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. Indirect CO<sub>2</sub> emissions from forest industry as well as from food and drink processing are considered biological (see Chapter 9).

**Table 4.9-1** Reported emissions, calculation methods and types of emission factors for the subcategory Other in the Finnish inventory

CRF	Source	Emissions reported	Method	Emission factor
2.H.3	Grouped confidential data of halocarbons and SF <sub>6</sub>	SF <sub>6</sub> , HFCs, PFCs	Tier 1, Tier 2, Other	D

Total emissions of this category were 25 kt CO<sub>2</sub> eq. in 2013. Emissions have increased threefold since 1990, and they are only 0.4% of emissions of Industrial Processes and product use.

**Table 4.9-2** Emissions by gas (kt CO<sub>2</sub> eq.)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
HFCs	0.0	0.0	0.2	2.0	0.6	2.5	3.4	0.4	1.7	1.5	6.9	1.6	3.9	3.5	6.0	1.7
PFCs	0.2	0.4	0.8	1.0	1.0	1.3	0.8	1.2	1.3	0.7	0.6	1.3	0.9	1.5	1.9	2.9
SF <sub>6</sub>	7.5	10.4	18.6	18.1	17.2	17.8	15.9	13.4	19.3	10.1	17.6	17.0	11.6	13.3	12.4	20.7
<b>Total of subcategory, kt CO<sub>2</sub> eq.</b>	<b>7.7</b>	<b>10.9</b>	<b>19.6</b>	<b>21.1</b>	<b>18.8</b>	<b>21.6</b>	<b>20.1</b>	<b>14.9</b>	<b>22.2</b>	<b>12.2</b>	<b>25.1</b>	<b>19.9</b>	<b>16.4</b>	<b>18.3</b>	<b>20.2</b>	<b>25.3</b>

### 4.9.2 Grouped confidential data of halocarbons and SF<sub>6</sub>

#### 4.9.2.1 Category description

Estimation method of HFC, PFC and SF<sub>6</sub> emissions from shoes and research is presented in this Section. SF<sub>6</sub> used in particle accelerators, as trace gas and in medical applications have been compiled under the SF<sub>6</sub> emissions from research. Due to confidentiality issues, emissions from magnesium die casting (2.C.4), semiconductor manufacturing (2.E.1) and fire protection (2.F.3) are reported aggregated in this category. Emission estimation methods for 2.C.4, 2.E.1 and 2.F.3 are described in Sections 4.4.3, 4.6.2 and 4.7.4. In 2013 the total F-gas emissions from this category amounted 0.03 Mt CO<sub>2</sub> eq. Emissions were 25% higher compared to 2012 mostly due to increased SF<sub>6</sub> emissions from semiconductor manufacturing and research. Compared to the base year 1995 the emissions have doubled.

Overall, there is a fluctuating trend in the emissions from this category. The changes in the trends of shoe sales, magnesium die-casting and semi-conductor manufacturing and the phasing out of halons in the fixed fire prevention systems affect the emissions level in the 1990's and early 2000s. 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.

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.

There are several trends that simultaneously affect emissions in this category and it is difficult to estimate how the category level emission trend will develop in the future.

#### *4.9.2.2 Methodological issues*

SF<sub>6</sub> emissions from research are reported with the "direct" method. Due to the small amount of SF<sub>6</sub> used in research detailed emission estimation methods have not been seen reasonable and the emissions equal the SF<sub>6</sub> sold annually to the aforementioned applications. 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.

The activity data for the calculation of emissions is obtained from annual surveys of importers of special gases. All the companies responded to the survey.

#### *4.9.2.3 Uncertainty and time-series consistency*

Uncertainty for the category 2.H.3 was quantified using Monte Carlo simulation. Uncertainty in HFC emissions (reported as unspecified mix of HFCs) in 2013 was estimated at -34% to 34%, in PFC (reported as unspecified mix of PFCs) emissions at -45% to 42% and in SF<sub>6</sub> emissions at -61% to 57%. Most of the uncertainty of PFC and SF<sub>6</sub> emissions was related to the emissions from electronics industry. In the case of HFC emissions, most of the uncertainty was due to uncertainty of emissions from fire protection.

Time series consistencies of SF<sub>6</sub> emissions from 2.C.4, HFC and PFC emissions from 2.E.1 and HFC emissions from 2.F.3 are presented in Sections 4.4.3.3, 4.6.2.3 and 4.7.4.3, respectively. The time series of SF<sub>6</sub> emissions from research and shoes have been calculated with the same methodology for the whole time series and are therefore considered consistent.

#### *4.9.2.4 Category-specific QA/QC and verification*

QA/QC procedures described in Section 1.2.3 are implemented in the category 2.H.3. QC procedures are performed according to the QA/QC and verification plan and the resulting findings, corrections and planned improvements are recorded in the yearly QA/QC form

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 2013 inventory QC checks minor errors in the movement of inventory data among processing steps were detected and corrected.

The category specific QC procedures for category 2.H.3 include emission and activity data comparisons. The emission trends are graphed and explained. 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.

#### *4.9.2.5 Category-specific recalculations*

The recalculation of emission estimates from electronics industry is explained in Section 4.6.2.5. Other changes in the category result from the introduction of the new GWP values.

#### *4.9.2.6 Category-specific planned improvements*

No planned improvements in this category.

## Appendix\_4a

### *The models used in calculating emissions from categories CFR 2.E, CRF 2.F and CRF 2.G*

#### HFCs, PFCs and SF<sub>6</sub> from electronics industry (CRF 2.E.1)

Emissions from category 2.E.1 are calculated by the Tier 2a method of the IPCC 2006 GL (equations 6.2-6.6, pp. 6.10-6.11). Emissions are given by

$$E_i = (1-h)FC_i(1-U_i)(1-a_i d_i)$$

where,  $E_i$  = emissions of gas  $i$ , kg  
 $FC_i$  = consumption of gas  $i$ , kg  
 $h$  = fraction of gas remaining in shipping container (heel) after use, fraction

By-product emissions of CF<sub>4</sub> are given by

$$BPE_{CF_4,i} = (1-h)B_{CF_4,i}FC_i$$

$BPE_{CF_4,i}$  = by-product emissions of CF<sub>4</sub> from the gas  $i$  used, kg  
 $B_{CF_4,i}$  = emission factor, kg CF<sub>4</sub> created/kg gas  $i$  used

By-product emissions of C<sub>2</sub>F<sub>6</sub> are given by

$$BPE_{C_2F_6,i} = (1-h)B_{C_2F_6,i}FC_i$$

$BPE_{C_2F_6,i}$  = by-product emissions of C<sub>2</sub>F<sub>6</sub> from the gas  $i$  used, kg  
 $B_{C_2F_6,i}$  = emission factor, kg C<sub>2</sub>F<sub>6</sub> created/kg gas  $i$  used

By-product emissions of CHF<sub>3</sub> are given by

$$BPE_{CHF_3,i} = (1-h)B_{CHF_3,i}FC_i$$

$BPE_{CHF_3,i}$  = by-product emissions of CHF<sub>3</sub> from the gas  $i$  used, kg  
 $B_{CHF_3,i}$  = emission factor, kg CHF<sub>3</sub> created/kg gas  $i$  used

By-product emissions of C<sub>3</sub>F<sub>8</sub> are given by

$$BPE_{C_3F_8,i} = (1-h)B_{C_3F_8,i}FC_i$$

$BPE_{C_3F_8,i}$  = by-product emissions of C<sub>3</sub>F<sub>8</sub> from the gas  $i$  used, kg  
 $B_{C_3F_8,i}$  = emission factor, kg C<sub>3</sub>F<sub>8</sub> created/kg gas  $i$  used

Emissions are calculated for each gas FC on the basis of company-specific data on gas consumption.

#### HFCs and PFC-218 from refrigeration and air conditioning (CRF 2.F 1)

Emissions from category 2.F.1 are calculated by the Tier 2b method of the 2006 IPCC Guidelines (equation 7.9, p. 7.48). Emissions are given by

$$E = \text{Annual sales} - NC + RC - \text{Destruction}$$

where  $E$  = Tier 2b emissions  
 $\text{Annual sales}$  = amount of a chemical introduced into the refrigeration sector

$NC$  = total charge of new equipment  
 $RC$  = original total charge of retiring equipment  
 $Destruction$  = quantity of the chemical destroyed.

Annual sales includes all chemical used to fill or refill equipment, whether the chemical is charged into equipment at the factory, charged into equipment after installation, or used to recharge equipment at servicing in the year of consideration. It is given by

$$Annual\ sales = I_c + I_p - E_c - E_p,$$

where  $I_c$  = imported bulk quantities  
 $I_p$  = quantities imported in products  
 $E_c$  = exported bulk quantities  
 $E_p$  = quantities exported in products.

Total charge of new equipment is the sum of the full charges of all the new equipment consumed in the country in the year of consideration. It includes both the chemical required to fill equipment in the factory and the chemical required to fill the equipment after installation. It does not include charging emissions or chemical used to recharge equipment at servicing.  $NC$  is given by

$$NC = N + M + I_p - E_p$$

where  $N$  = quantities used in installing new equipment and converting existing equipment to a new refrigerant  
 $M$  = quantities used in manufacturing equipment  
 $I_p$  = quantities imported in products  
 $E_p$  = quantities exported in products.

Original total charge of retiring equipment is estimated in the same way as total charge of new equipment, except all quantities come from the year of manufacture or import of the retiring equipment. Emissions are calculated with the same methodology for all the subcategories 2.F.1.a-f.

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 2006 IPCC Guidelines Chapter 7.1. Emissions are either not calculated separately for each process step. Therefore the background data for calculation cannot be presented in the same format as in the CRF Table 2(II).

#### HFCs from foam blowing (CRF 2.F.2)

Emissions of HFCs used as foam blowing agents for closed-cell foams are calculated using the Tier 2 model described in the 2006 IPCC Guidelines (equation 7.7, p. 7.33). 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  $t$ .

$$E_{t,i} = f_{M,i} M_{t,i} + f_{B,i} B_{t-1,i} + R_{t,i} - D_{t,i}$$

where  $E_{t,i}$  = 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

$$\begin{aligned} R_{t,i} &= 0 \\ D_{t,i} &= 0 \end{aligned}$$

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 7.8 described in the 2006 IPCC Guidelines (p. 7.34). 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 2006 IPCC Guidelines (p. 7.28)

$$x = (1 - f)a + fb, \quad (1)$$

where  $f = 0.5$ ,

$a$  = quantity of HFC and PFC contained in aerosol products sold in 2012, and  
 $b$  = quantity of HFC and PFC contained in aerosol products sold in 2013.

$f$  is dimensionless,  $a$  and  $b$  have dimensions of mass.

The equation above assumes that consumption equals sales of aerosol products to Finland. Sales is given by

$$Sales = I_c + I_p - E_p \quad (2)$$

where  $I$  denotes imports and  $E$  exports.

Equation (2) is a vector 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).

Equation (2) defines  $a$  and  $b$  of Equation (1) as sums of the elements of  $Sales$  calculated for 2012 and 2013, respectively.

#### SF<sub>6</sub> from electrical equipment (CRF 2.G.1)

SF<sub>6</sub> emissions from electrical equipment are calculated using the Tier 2 method of the 2006 IPCC Guidelines. Emissions are calculated by multiplying the national emission factors by the SF<sub>6</sub> consumption at each life cycle stage. Emissions are a sum of emissions from equipment manufacturing, equipment use and equipment disposal. Equipment manufacturing includes equipment manufacturing (from 1991 to 2011) and on-site installation of equipment. Emissions are given by

$$E_t = f_M M_t + f_U B_t + f_D D_t$$

where

$E_t$  = emissions of SF<sub>6</sub> in year  $t$

$f_M$  = emission factor for equipment manufacturing and on-site installation

$M_t$  = amount of SF<sub>6</sub> used in manufacturing and on-site installation of equipment in year  $t$

$f_U$  = emission factor for equipment use

$B_t$  = amount of SF<sub>6</sub> banked in equipment in year  $t$

$f_D$  = emission factor for equipment disposal

$D_t$  = amount of SF<sub>6</sub> in retired equipment in year  $t$

The amount of SF<sub>6</sub> banked in equipment is estimated by

$$B_t = B_{t-1} + I_t - D_t$$

where

$B_{t-1}$  = amount of SF<sub>6</sub> banked in equipment in year  $t-1$

$I_t$  = amount of SF<sub>6</sub> installed in equipment in year  $t$

## Appendix\_4b

### *Emissions of the new F-gases in Finland*

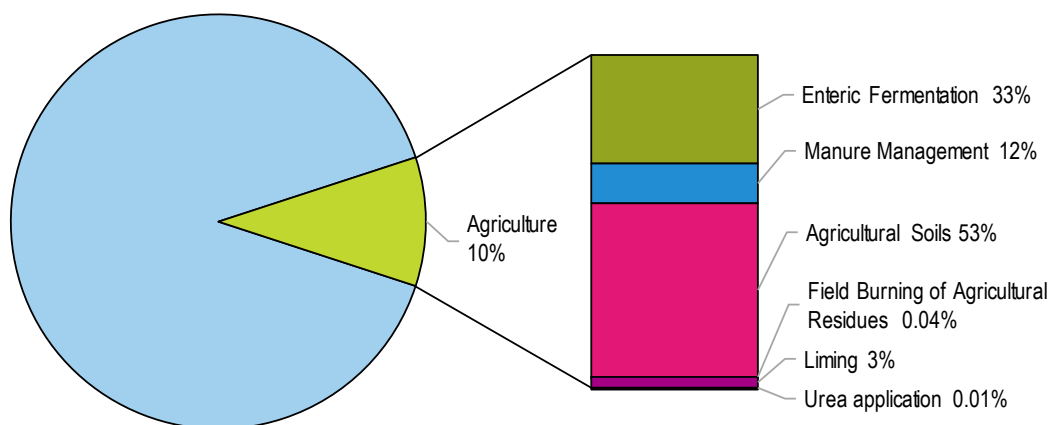
The revised UNFCCC reporting guidelines encourage Annex I Parties to report emissions of the so called new F-gases for which GWP values are available. These gases include e.g. hydrofluoroolefins (HFO's), hydrofluorethers (HFE's), perfluoropolyethers (PFPE's) and fluorinated ketones. Information on the use of these new substances has been collected in Finland since 2010 and emissions have been calculated for the years 2010-2013. Due to confidentiality the annual emission estimates cannot be presented. The total emissions from the years 2010-2013 are 0.98 kt CO<sub>2</sub> eq. Included in the emissions are HFO-1234yf (from mobile air conditioning, 2013), C<sub>6</sub>F<sub>12</sub>O (fire protection, 2010 and 2013), HFE-449sl (aerosols, 2010-2013) and HFE-569sf2 (aerosols, 2010-2013). Consequently, annual average emission from these gases are 0.25 kt CO<sub>2</sub> eq. between 2010-2013 which is 0.004% of the emissions from the industrial processes and product use sector.

## 5 AGRICULTURE (CRF 3)

### 5.1 Overview of the sector

#### 5.1.1 Description and quantitative overview

Finland's greenhouse gas emissions reported in the Agriculture sector in 2013 were 6.3 million tonnes of carbon dioxide equivalent (Mt CO<sub>2</sub> eq.) in total. Agriculture is the second largest greenhouse gas emission source sector after the energy sector with a 10% share of the total greenhouse gas emissions in 2013 (Figure 5.1-1).



**Figure 5.1-1** Agricultural emissions from the total greenhouse gas emissions in 2013

Agricultural greenhouse gas emissions in Finland consist of methane emissions from enteric fermentation of domestic livestock, methane and nitrous oxide emissions from manure management and field burning of agricultural crop residues, direct and indirect nitrous oxide emissions from agricultural managed soils and carbon dioxide emissions from liming and urea fertilization. Direct nitrous oxide emissions from managed soils include emissions from synthetic fertilisers, manure and sewage sludge applied to soils, urine and dung deposited on pasture, crop residues, drainage/management of organic soils and nitrogen mineralisation associated with loss of soil organic matter resulting from change of land use or management on mineral soils. Indirect nitrous oxide emission sources include emissions from atmospheric deposition and from nitrogen leaching and run-off to watercourses. Indirect nitrous oxide emissions are estimated also for manure management. Figure 5.1-3 and Figure 5.1-4 present sources and flows of nitrogen and magnitude of nitrous oxide emissions in the sector Agriculture from different sources according to the IPCC classification.

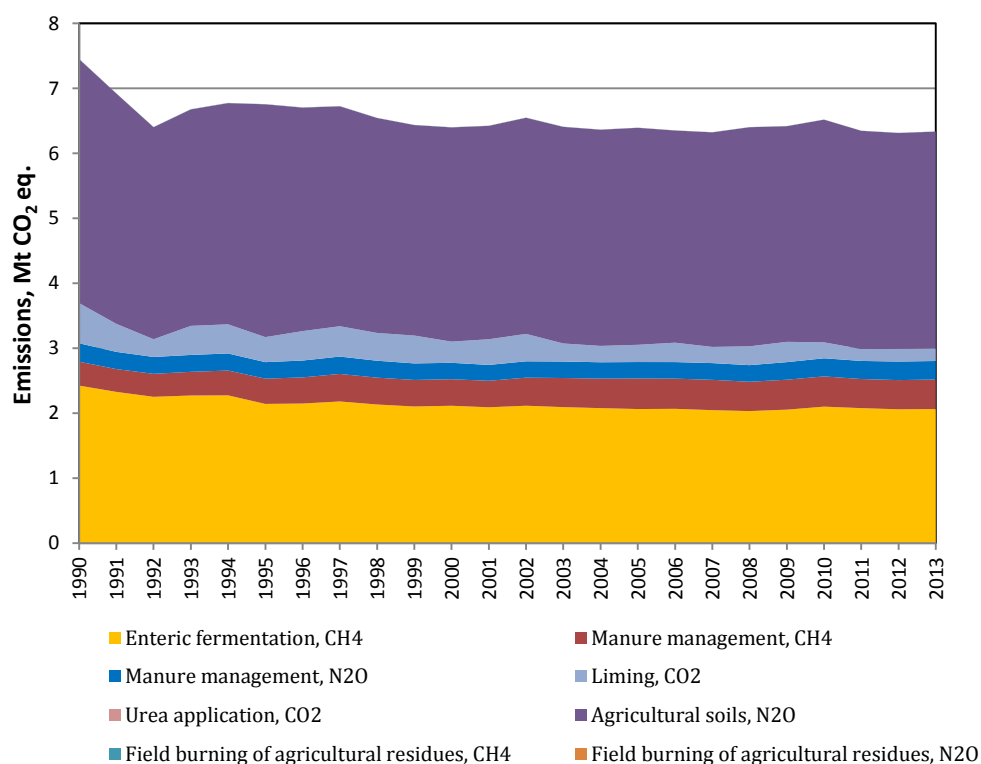
The methane emissions from enteric fermentation were 33%, methane emissions from manure management 7%, nitrous oxide emissions from manure management 4% and nitrous oxide emissions from agricultural managed soils 53% of the total agricultural emissions. Liming and urea comprise 3% of emissions, the share of field burning of agricultural crop residues is 0.04% altogether. Rice is not cultivated in Finland and savannahs do not exist in Finland. A general assessment of completeness can be found in Section 1.7 and more detailed assessment is included in Annex 5.

Emissions in the Agriculture sector have decreased by about 15% over the period 1990-2013 (Figure 5.1-2). 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 have also decreased the emissions in the

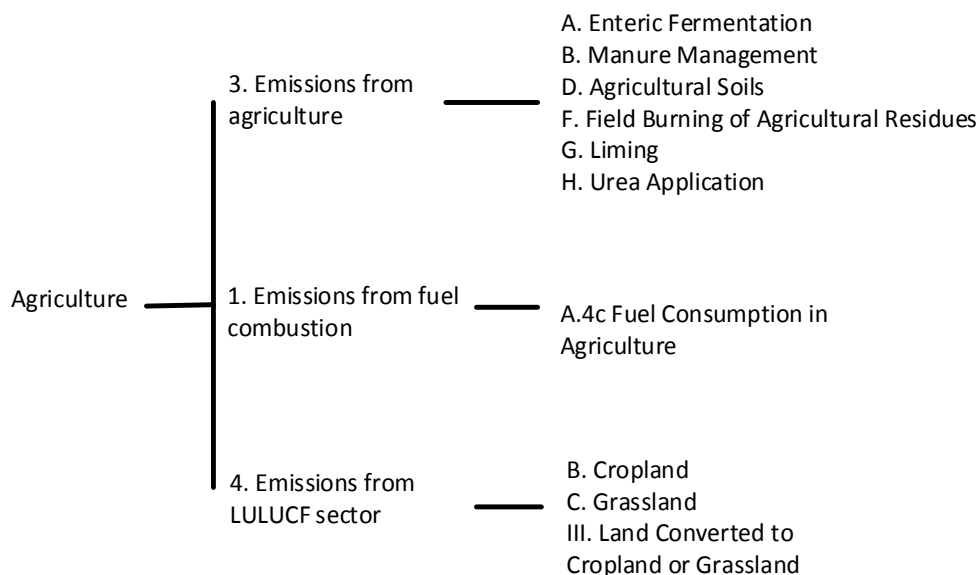
Agriculture sector. For example, the amount of mineral fertilisers used (based on sales statistics) has decreased 40% 1990-2013 and is the most important factor for the reduced emissions. Decrease in CO<sub>2</sub> emissions from liming due to reduced use of lime is also significant. However, the area of cultivated organic soils has increased during the period 1990-2013 which has increased nitrous oxide emissions. Total agricultural emissions in 2013 are almost the same as in 2012, the small increase is mainly due to emissions from cultivated organic soils.

Some inter-annual variation between the years can be noticed from the time series (Table 5.1-1). 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 managed 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.

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 5.1-3). Emissions from the energy use in agriculture were 1.2 Mt CO<sub>2</sub> eq. and agricultural emissions reported in Land-use, land-use change and forestry (LULUCF) 7.0 Mt CO<sub>2</sub> eq. in 2013. When all agricultural emission sources from different reporting sectors (agriculture, LULUCF and Energy) are taken into account, agricultural emissions totalled 14.5 Mt CO<sub>2</sub> eq. in 2013 (see Figure 5.1-2).



**Figure 5.1-2** Trend in emissions in the Agriculture sector by category (Mt CO<sub>2</sub> eq.). The CH<sub>4</sub> and N<sub>2</sub>O emissions from field burning of agricultural residues as well as CO<sub>2</sub> emissions from urea application are very small and therefore not discernible in the figure



**Figure 5.1-3** Agricultural sources of emissions and their reporting in the Common Reporting Format (CRF) categories in the national greenhouse gas inventory

**Table 5.1-1** Finland's greenhouse gas emissions from sector Agriculture by source and gas, Mt CO<sub>2</sub> eq.

Year	Enteric fermentat.	Manure management		Agric. soils	Liming	Urea application	Burning of agric. residues		Total CH <sub>4</sub> emissions	Total N <sub>2</sub> O emissions	Total emissions
	CH <sub>4</sub>	CH <sub>4</sub>	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	CH <sub>4</sub>	N <sub>2</sub> O	CH <sub>4</sub> , N <sub>2</sub> O, CO <sub>2</sub>
1990	2.43	0.37	0.28	3.76	0.62	0.0007	0.0031	0.0009	2.80	4.04	7.46
1995	2.14	0.39	0.25	3.58	0.39	0.0002	0.0025	0.0008	2.53	3.84	6.76
2000	2.11	0.41	0.25	3.30	0.33	0.0002	0.0027	0.0008	2.53	3.55	6.40
2001	2.09	0.41	0.24	3.28	0.39	0.0003	0.0024	0.0007	2.50	3.53	6.43
2002	2.12	0.43	0.25	3.33	0.42	0.0003	0.0024	0.0008	2.55	3.58	6.55
2003	2.09	0.45	0.25	3.33	0.28	0.0003	0.0023	0.0007	2.54	3.59	6.41
2004	2.08	0.45	0.25	3.33	0.25	0.0003	0.0023	0.0007	2.53	3.58	6.37
2005	2.06	0.47	0.25	3.34	0.26	0.0003	0.0022	0.0007	2.54	3.59	6.40
2006	2.07	0.47	0.25	3.27	0.30	0.0005	0.0020	0.0006	2.53	3.52	6.35
2007	2.05	0.47	0.26	3.30	0.25	0.0008	0.0022	0.0007	2.52	3.56	6.33
2008	2.03	0.45	0.26	3.37	0.29	0.0005	0.0021	0.0007	2.49	3.63	6.41
2009	2.05	0.46	0.27	3.32	0.31	0.0004	0.0021	0.0006	2.52	3.59	6.42
2010	2.10	0.47	0.28	3.43	0.25	0.0004	0.0014	0.0004	2.57	3.71	6.52
2011	2.08	0.45	0.28	3.36	0.18	0.0007	0.0017	0.0005	2.53	3.64	6.35
2012	2.06	0.45	0.29	3.32	0.19	0.0004	0.0016	0.0005	2.51	3.61	6.32
2013	2.06	0.46	0.28	3.34	0.19	0.0003	0.0021	0.0006	2.52	3.62	6.34

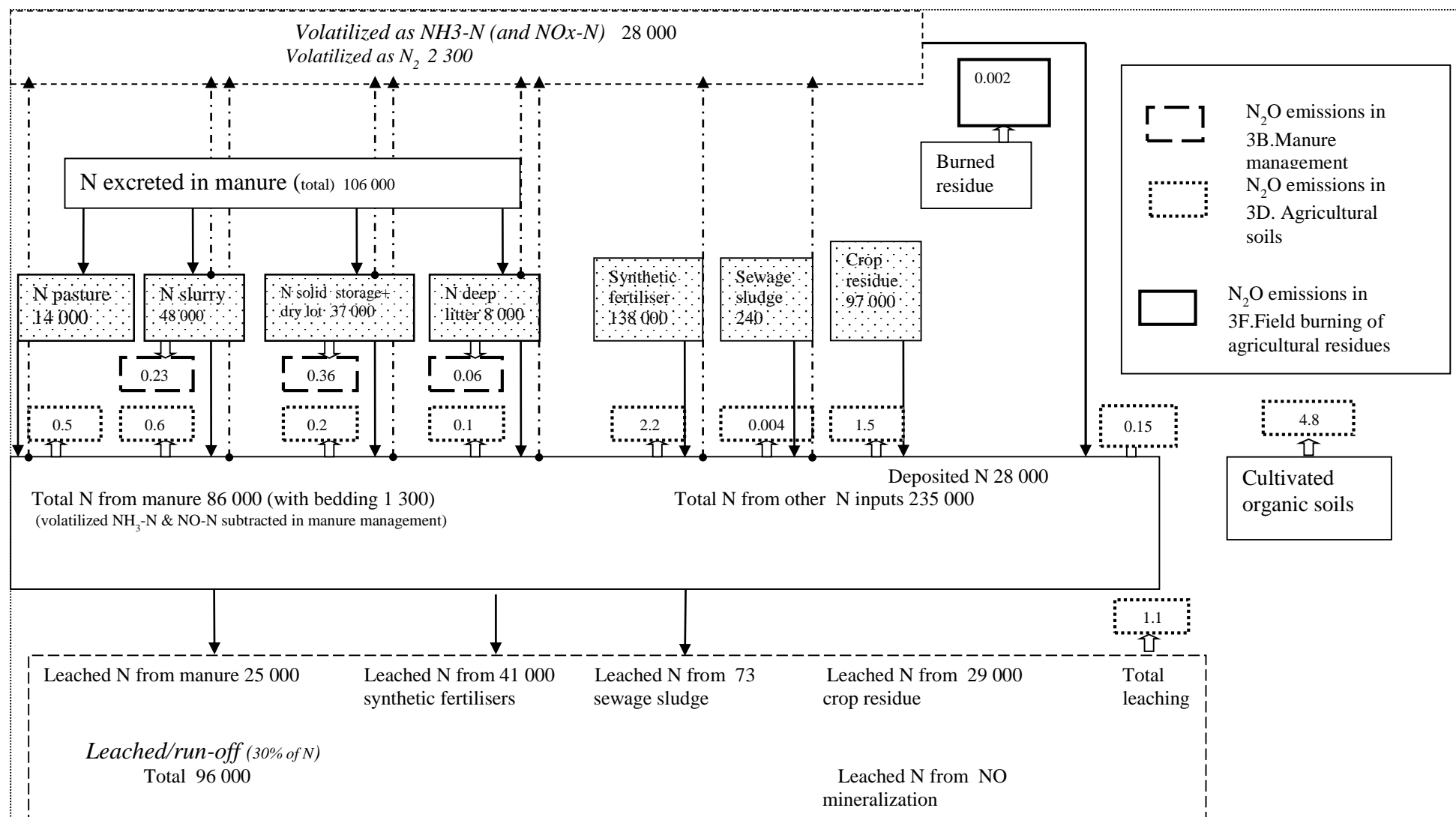
*Key categories*

The key categories in agriculture in 2013 are summarised in Table 5.1-2.

**Table 5.1-2** Key categories in Agriculture (CRF 3) in 2013 (Approach 1)

<b>IPCC category</b>	<b>Gas</b>	<b>Identification criteria</b>
3.A. Enteric Fermentation	CH <sub>4</sub>	L, T
3.B. Manure Management	CH <sub>4</sub>	L, T
3.B. Manure Management	N <sub>2</sub> O	L
3.D.1. Direct N <sub>2</sub> O Emissions from Managed Soils	N <sub>2</sub> O	L, T
3.D.2. Indirect N <sub>2</sub> O Emissions from Managed Soils	N <sub>2</sub> O	L
3.G. Liming	CO <sub>2</sub>	L, T

**Figure 5.1-4** Nitrogen flows and emissions of nitrous oxide in Agriculture sector 2013 (Bulk arrows stand for  $\text{N}_2\text{O}$  emissions, thin arrows for N flows and broken arrows mean N volatilization as ammonia ( $\text{NH}_3\text{-N}$ ) during application on soil. Nitrogen amounts are in t/year and emissions (fragmental line) in kt/year



## 5.2 Enteric Fermentation (CRF 3.A)

### 5.2.1 Category description

Methane emissions from enteric fermentation of domestic livestock comprised 33% of total emissions in the sector Agriculture in Finland, being 2.1 Mt CO<sub>2</sub> equivalents in 2013.

This category includes emissions from cattle (dairy cows, suckler cows, bulls, heifers and calves), horses (including ponies), 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 5.2-1). There are no emissions from the enteric fermentation or manure management originated from the following livestock groups: buffalo, camels and llamas, deer, mules and asses, rabbit and ostrich.

**Table 5.2-1** 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
3.A 1	Cattle			
	Dairy Cattle	CH <sub>4</sub>	Tier 2	CS
	Non-Dairy Cattle	CH <sub>4</sub>	Tier 2	CS
3.A 2	Sheep	CH <sub>4</sub>	CS	CS
3.A 3	Swine	CH <sub>4</sub>	CS	CS
3.A 4	Other livestock			
	-Goats	CH <sub>4</sub>	Tier 1	D
	-Horses	CH <sub>4</sub>	Tier 1	D
	-Poultry	NE <sup>1)</sup>	NA	NA
	- Reindeers	CH <sub>4</sub>	CS	CS
	- Fur-bearing animals	CH <sub>4</sub>	Tier 1	OTH

<sup>1)</sup> No methodology is available to estimate emissions from enteric fermentation of poultry.

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) ([www.fao.org](http://www.fao.org)) but other animals may also be significant emission sources if their number is large.

The emissions have decreased by 15% since 1990 especially due to the decreasing number of cattle (Table 5.2-2). The number of dairy cattle, for example, declined from 490,000 in 1990 to 283,000 in 2013 (Table 5.2-3).

**Table 5.2-2** Methane emissions (kt) from enteric fermentation in 1990-2013 by animal type

	Cattle					Sheep	Swine			Other livestock			Total
	DC	SC	B	H	C	Sh	Sw	Ho	Po	G	F	R	
1990	55.0	1.3	8.4	9.7	14.6	0.7	1.3	0.7	0.1	0.03	0.3	4.8	97.0
1995	47.1	2.7	6.4	8.7	13.1	1.1	1.3	0.8	0.1	0.03	0.4	4.1	85.7
2000	46.6	2.7	6.9	9.0	11.9	0.7	1.3	0.9	0.1	0.04	0.3	4.0	84.6
2001	46.2	2.6	6.8	8.9	12.1	0.7	1.2	0.9	0.1	0.04	0.3	3.7	83.7
2002	46.1	2.7	7.3	9.0	12.0	0.7	1.3	0.9	0.1	0.03	0.3	4.0	84.6
2003	45.0	2.7	7.6	9.1	11.9	0.7	1.4	1.0	0.1	0.03	0.4	3.9	83.7
2004	44.5	3.0	7.4	8.9	11.6	0.8	1.4	1.0	0.1	0.04	0.4	4.0	83.1
2005	43.8	3.4	7.2	8.7	11.6	0.7	1.4	1.0	0.1	0.03	0.4	4.1	82.6
2006	43.2	3.8	7.6	8.9	11.3	1.0	1.4	1.0	0.1	0.03	0.3	3.9	82.7
2007	42.0	4.3	7.6	8.8	11.3	1.0	1.5	1.1	0.2	0.03	0.3	3.8	81.9
2008	41.1	4.8	7.5	8.8	11.1	1.0	1.5	1.1	0.2	0.03	0.3	3.9	81.3
2009	41.6	5.2	7.6	8.7	11.2	1.0	1.4	1.1	0.2	0.03	0.3	3.8	82.2
2010	42.0	5.7	8.1	8.9	11.4	1.1	1.4	1.2	0.2	0.02	0.3	3.9	84.0
2011	41.4	5.9	7.8	8.8	11.3	1.1	1.3	1.2	0.2	0.02	0.3	3.9	83.1
2012	41.2	5.8	7.5	8.6	11.3	1.1	1.3	1.2	0.2	0.02	0.3	3.8	82.4
2013	41.4	5.8	7.6	8.7	11.2	1.1	1.3	1.2	0.2	0.02	0.3	3.8	82.5
Share of total (%) in 2013	50.1	7.0	9.2	10.5	13.5	1.3	1.6	1.4	0.2	0.0	0.4	4.6	100.0

DC=Dairy cows, SC=Suckler cows, B=Bulls, H=Heifers, C=Calves, Sh=Sheep, Sw=Swine, Ho=Horses, Po=Ponies, F=Fur animals, R=Reindeer, Poultry not estimated.

## 5.2.2 Methodological issues

### 5.2.2.1 Methods

Emissions from enteric fermentation of domestic livestock have been calculated by using the IPCC Tier 1 and Tier 2 methodologies presented in the 2006 IPCC Guidelines. The total emission is the sum of emissions from each category (2006 IPCC Guidelines, chapter 10, p. 28).

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 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 2006 IPCC Guidelines. The Tier 2 method has been used for cattle (see the Appendix\_5a.). Methane emissions from enteric fermentation have been identified as a key category, but only emissions from cattle meet the criteria given in the 2006 IPCC Guidelines for significant sub-categories. For swine classes, country specific calculation method uses feeding information of Finnish pigs the Evapig program (<http://www.evapig.com/IMG/pdf/EvaPigManualEquations-3.pdf>) and calculation formulas of Finnish expert, see Appendix 5 for details. 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. Equations used for calculating the GE for sheep and reindeer are presented in more detail in the Appendix\_5a.

Livestock characterization (animal numbers, cattle weights and daily weight gains, milk production and fat content, digestible energy, pregnancy percent) is consistent with the data used in nitrogen excretion calculations. Methane conversion rate (6.5%) is considered appropriate for Finnish conditions by the expert as well (Nousiainen, J, 2014).

#### 5.2.2.2 Activity data

Animal numbers are presented in Table 5.2-3 (and Appendix\_5b).

The numbers 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. Cattle numbers are from 1 May or 1 June, swine numbers from 1 April or May or June, poultry from 1 April or May, sheep & goats from 1 May or June. 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 5.3.2.2).

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 reindeers was taken from the Yearbook of Farm Statistics and it describes the number of counted reindeer left alive during the reindeer herding year.

#### 5.2.2.3 Emission factors and other parameters

Emission factors for methane emissions from enteric fermentation are presented in Table 5.2-4. Emission factors for cattle and swine are updated annually.

Country-specific 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\_5a. 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 ca 260 MJ/animal/day in 1990 to ca 340 MJ/animal/day in 2013 resulting in a change in the emission factor being 112 in kg CH<sub>4</sub>/animal/a in 1990 and 146 kg CH<sub>4</sub>/animal/a in 2013 (Figure 5.2-1).

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, pregnancy, digestible energy of forage and length of pasture season (for this see Section 5.3.2.1). This information has been received from the Association of Rural Advisory Centres (ProAgria; pasture season) and an expert of MTT Agrifood Research Finland (Nousiainen, J.). For bulls and suckler cows *C<sub>fi</sub> (in \_ cold)* was estimated for cold/cool season, assuming that 40% of bulls and 60% of suckler cows are kept in conditions where air temperature is close to outdoor temperature. This raised *C<sub>fi</sub>* compared to what was given in Table 10.4 in 2006 Guidelines. For bull *C<sub>fi</sub>* is 0.400 and for suckler cow 0.399. The live weights of cattle are estimated based on slaughter weights and ages from agricultural statistics. The mature weight of heifers and calves are based on the weighted average of dairy and suckler cows and bulls.

Cattle live weights and mature weights are presented in Table 2 in Appendix 5b (Source: Nousiainen, J.). The amount of milk produced per dairy cow and the fat content of milk are given in Table 5.2-5. Data on milk production (l/animal/a) and fat content 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 1990-2013, being 1,620 kg/a (Source:

Nousiainen, J.). Average daily weight gain for cattle increased in 1990-2013 proportionally to the animal weights. They are (kg) 0.04-0.06 for dairy cow, 0.02-0.03 for suckler cow, 0.6-0.7 for bull, 0.4-0.5 for heifer and 0.8-1.0 for calves (Source: Nousiainen J.). See details in Appendix\_ 5a.

The country-specific 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\_5a (Source: Nousiainen, J.). The IPCC gives no default emission factor for reindeer, thus it has been calculated by using the country-specific methodology for estimating gross energy intake of reindeer based on their forage. The same equation has been used for sheep, too.

IPCC default emission factors were used for calculating methane emissions from enteric fermentation of goats and horses (Tier 1 method). As no separate EF is available for ponies, the same EF is used as for horses.

Because no country-specific 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).

**Table 5.2-3** Animal numbers in Finland (x 1 000)

	<b>Cattle</b>		<b>Sheep</b>	<b>Swine<sup>4</sup></b>	<b>Other livestock</b>				
	<b>DC</b>	<b>NDC<sup>1</sup></b>			<b>P<sup>5</sup></b>	<b>Ho<sup>2</sup></b>	<b>G<sup>3</sup></b>	<b>F<sup>6</sup></b>	<b>R</b>
1990	490	870	103	1 381	9 663	45.4	5.9	3 283	239
1995	399	749	159	1 400	10 358	49.9	6.0	3 749	208
2000	364	692	100	1 296	12 570	57.4	8.6	3 361	203
2001	355	683	96	1 261	10 554	58.6	7.4	2 943	186
2002	348	678	96	1 315	10 734	59.1	6.6	3 410	200
2003	334	666	98	1 375	10 997	60.2	6.8	3 583	197
2004	324	645	109	1 365	10 405	61.1	7.3	3 530	201
2005	319	640	90	1 401	10 538	63.8	6.9	3 786	207
2006	309	640	117	1 436	10 239	66.1	6.7	3 448	198
2007	296	631	119	1 448	9 791	68.0	6.2	3 481	193
2008	289	626	122	1 483	10 522	69.4	5.9	2 700	195
2009	290	628	118	1 381	9 369	72.3	5.9	3 443	193
2010	289	636	126	1 367	9 587	74.3	4.9	3 474	194
2011	286	629	129	1 335	10 236	75.5	4.9	2 898	196
2012	284	629	130	1 290	10 761	75.4	4.9	3 376	192
2013	283	629	136	1 300	11 981	75.0	4.5	3 376	192

DC=Dairy cattle, Non-dairy cattle (Suckler cows, Bulls, Heifers, Calves), P=Poultry, Ho=Horses ( incl. Ponies), G=Goats, F=Fur-bearing animals, R=Reindeer

<sup>1</sup> Includes suckler cows, bulls (>1 year), heifers and calves (<1 year). The number presented describes the numbers on 1 May or 1 June (Source: Yearbook of Farm Statistics).

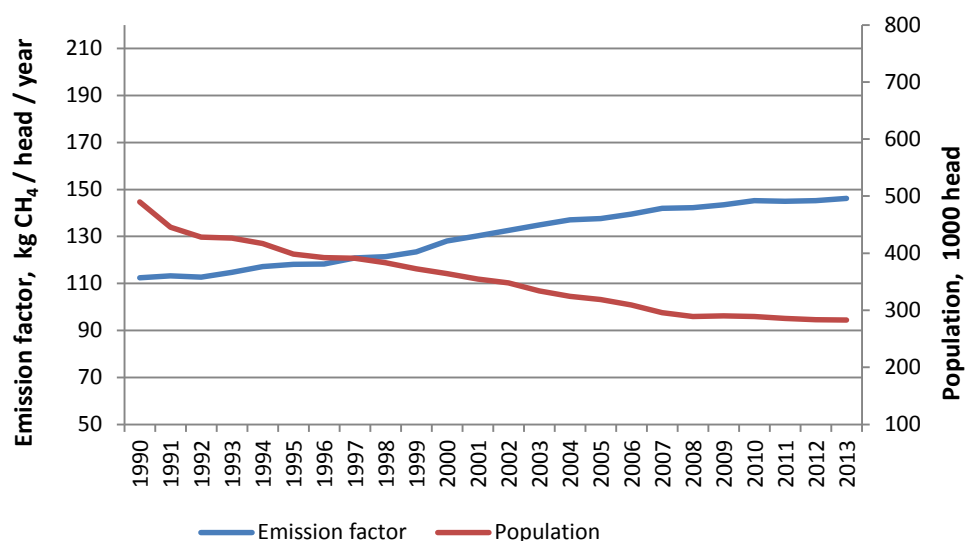
<sup>2</sup> Source: Finnish Trotting and Breeding Association (Suomen Hippos).

<sup>3</sup> The number of goats was not available for the year 1991, and the average of numbers for the years 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 5.2-1** Development of the emission factor and population of dairy cows

**Table 5.2-4** Emission factors for methane emissions from enteric fermentation in 2013

Animal type		Emission factor (kg CH <sub>4</sub> / animal/a)	EF type	Method for calculating EF
Cattle	Dairy cow	158.49146.19	Country-specific	IPCC, Tier 2
	Non-dairy cattle IEF	52.78	Country-specific	IPCC, Tier 2
	Suckler cows	100.94	Country-specific	IPCC, Tier 2
	Bulls	69.03	Country-specific	IPCC, Tier 2
	Heifers	53.49	Country-specific	IPCC, Tier 2
	Calves	37.25	Country-specific	IPCC, Tier 2
	Sheep	8.39	Country-specific	Country-specific
Swine	Sows	3.59	Country-specific	Country-specific
	Piglets	0.13	Country-specific	Country-specific
	Fattening pigs (>50 kg)	1.23	Country-specific	Country-specific
	Boars	3.47	Country-specific	Country-specific
	Weaned pigs (20-50 kg)	0.61	Country-specific	Country-specific
	Swine average IEF	1.00	Country-specific	Country-specific
Other livestock	Horses	18.00	IPCC default	IPCC, Tier 1
	Goats	5.00	IPCC default	IPCC, Tier 1
	Fur animals	0.10	Modified IPCC default*	IPCC, Tier 1
	Reindeer	19.90	Country-specific	Country-specific

\*see 'Emission factors and other parameters'

**Table 5.2-5** 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
1995	4.34	6 161
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
2013	4.28	8 216

<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).

### 5.2.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 2. A description of uncertainty analysis is included in Section 1.6.

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 2013) 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 the 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, swine, reindeer, sheep and fur animals), the default uncertainty of  $\pm 30\%$  is used for the emission factor. For the national EFs of swine, reindeer and sheep the uncertainties are estimated at  $\pm 30\%$ ,  $-90\ldots+250\%$  and  $\pm 40\%$ , respectively. For fur animals the EF is from Norway, and its uncertainty is estimated at  $-70\ldots+150\%$ .

As the same calculation methods are used for the whole time series 1990-2013, 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 animal numbers are obtained either 1.6., 1.5. or 1.4. each year (see Section 5.2.2. for details). These temporal changes in statistics cannot be observed from the animal number graphs suggesting that they do not create inconsistency.

### 5.2.4 Category-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 1.2.3. The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives. The bilateral quality meeting is held annually between the inventory unit and the sectoral expert. In the quality meeting 2015 for example the ERT Review and National Inventory Report text were discussed as well as changes to calculation due to Guidelines 2006.

#### General Quality Control (QC) procedures applied to the category Enteric fermentation (CRF 3.A):

The QA/QC plan for the agricultural sector includes the QC measures presented in the 2006 IPCC Guidelines (Vol 1, Chapter 6, Table 6.1). 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 (LUKEagri check) is used during the inventory. The check includes for example checking formulas, links between sheets and evaluating correctness of parameters used with cross-checks to previous years. Due to comments in FCCC/ARR/2014/FIN, e.g. the mature weight values for heifers and calves were added to inventory report.

#### Category-specific QC for activity data:

A checklist (LUKEagri check) 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. With respect to quality of data collection, Information Centre of the Ministry of Agriculture and Forestry (now part of Natural Resources Institute Finland) which provides data of animal numbers has a description of the data collection process. Part of this description is in English on page: <http://www.maataloustilastot.fi/en/tilasto/163/kuvaus/1016>. More detailed description is provided in Finnish on page: <http://www.maataloustilastot.fi/tilasto/36/laatuseloste/3921>.

As a result of quality control checks, an inconsistency was detected with manure deposited on pasture between N model and enteric fermentation (EF). Both models use same pasture season data but the EF calculation was lacking information of the share of animals on pasture and other details concerning pasturing. This error was corrected (see Section 5.2.5 Category-specific recalculations).

#### Category-specific QC for emission factors:

It is checked annually if new data for updating emission factors has been published. New national published experimental results concerning enteric fermentation were not available for this inventory. An expert (J. Nousiainen) calculated country-specific digestible energy per cents for each cattle group. They are close to the one reported by Sweden (69% in 2014 submission). The  $Y_m$  is a default from Guidelines 2006 and was evaluated to be suitable for Finnish cattle (J. Nousiainen).

#### Quality assurance and verification:

The calculation models are sent yearly to another institute to a person who is not directly involved in calculating greenhouse gas emissions from agriculture at national level. Instead, this person uses the models for emission calculation at the regional level in Finland and informs the national inventory expert of any errors found in the models.

For 2016 submission the IEFs of enteric fermentation will be compared with the ones from Sweden.

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.

### 5.2.5 *Category-specific recalculations*

The calculations now follows the 2006 IPCC Guidelines. In addition to this some updates were done to the parameters. Previously, digestible energy had a single value 70, now different cattle subgroups have their own values ranging from 64 to 71.5 depending on subgroup (J. Nousiainen) (see Appendix 5a). Country-specific values for cattle subgroups were calculated to improve the accuracy of DE as suggested by the 2006 IPCC Guidelines (chapter 10). ‘Percent pregnant’ was also updated, it was previously assumed to be 100% and is now 80 for dairy cattle and 90 for suckler cows (calculated by J. Nousiainen). Also, the NEa calculation was corrected so that the pasture% for cattle is the same as in N mass flow model (previously only length of pasture season from the model was used and e.g. time spend inside during pasture season was not taken into account). Parameters for calculating the pasture-% changed when AWMS data was updated (see Section 5.3.5). All these updates and corrections had approx. a 1.5% effect on enteric CH<sub>4</sub> emissions. The number of fur animals was updated for the year 2012 because the data was not available before the 2014 submission and numbers of horses and ponies updated for the year 2012 as there had been errors in statistics. These had a very small effect on the emissions.

### 5.2.6 *Category-specific planned improvements*

There are no planned improvements.

## 5.3 Manure Management (CRF 3.B)

### 5.3.1 Category description

Nitrous oxide and methane emissions from manure management were 1.0 kt and 18.2 kt in 2013, respectively, and their emissions as CO<sub>2</sub> equivalents were 0.7 Mt altogether. Nitrous oxide emissions from manure management were about 7% and methane emissions about 4% of total emissions in sector Agriculture in 2013.

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 (Table 5.3-1). There are no emissions from the enteric fermentation or manure management originated from the following livestock groups: buffalo, camels and llamas, deer, mules and asses, rabbits and ostrich.

**Table 5.3-1** Reported emissions according to the classification of the CRF tables, calculation methods and types of emission factors for the subcategory CRF 3.B Manure Management in the Finnish inventory

CRF	Source	Emissions reported	Method	Emission factor
3.B 1	Cattle	CH <sub>4</sub>	Tier 2	CS
		N <sub>2</sub> O	Tier 2	D
	Non-Dairy Cattle	CH <sub>4</sub>	Tier 2	CS
		N <sub>2</sub> O	Tier 2	D
3.B 2	Sheep	CH <sub>4</sub>	Tier 2	CS
		N <sub>2</sub> O	Tier 2	D
3.B 3	Swine	CH <sub>4</sub>	Tier 2	CS
		N <sub>2</sub> O	Tier 2	D
3.B 4	Other livestock -Poultry	CH <sub>4</sub>	Tier 2	CS
		N <sub>2</sub> O	Tier 2	D
	-Horses	CH <sub>4</sub>	Tier 2	CS
		N <sub>2</sub> O	Tier 2	D
	-Goats	CH <sub>4</sub>	Tier 2	CS
		N <sub>2</sub> O	Tier 2	D
	-Fur animals	CH <sub>4</sub>	Tier 2	CS
		N <sub>2</sub> O	Tier 2	D
	- Reindeer	CH <sub>4</sub>	Tier 2	CS
		N <sub>2</sub> O	Tier 2	D

Source	Emissions reported	Method	Emission factor
Anaerobic lagoon	NO	NA	NA
Liquid system	N <sub>2</sub> O	T2	D
Daily spread	NO	NA	NA
Solid storage and dry lot	N <sub>2</sub> O	T2	D
Pasture, range, and paddock <sup>1</sup>	N <sub>2</sub> O	IE	IE
Composting <sup>2</sup>	Emissions negligible	NA	NA
Digesters <sup>3</sup>	Emissions negligible	NA	NA
Burned for fuel or as waste <sup>4</sup>	NO	NA	NA
Other <sup>5</sup>	N <sub>2</sub> O	T2	D

<sup>1</sup> Emissions from pasture are calculated under manure management but reported in the CRF subcategory 3 D.3 Agricultural soils/ Pasture, range and paddock manure.

<sup>2</sup> Emissions negligible

<sup>3</sup> Emissions negligible

<sup>4</sup> Not estimated as burning of manure is very rare

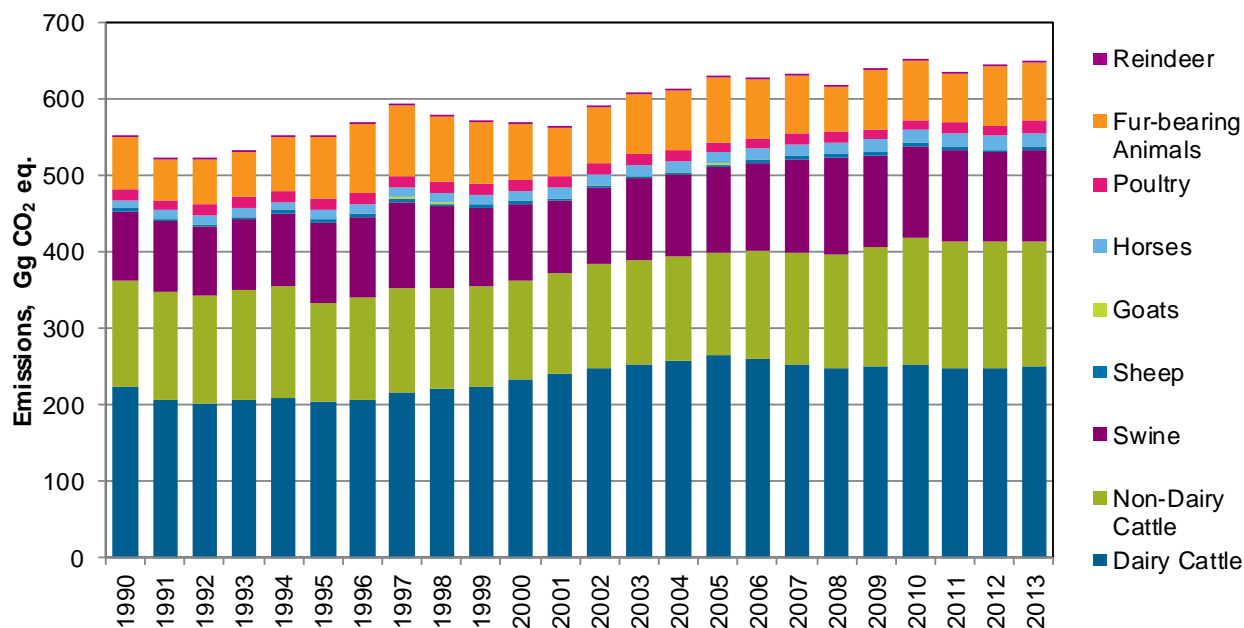
<sup>5</sup> Other AWMS (animal waste management system) is deep litter.

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 first decreased and then increased in the time series. Cattle numbers have decreased which explains the decreasing trend. There is an increase by 16% in 2013 emission compared with 1990 (Table 5.3-2 and Figure 5.3-1). New data on manure system distribution was obtained from a questionnaire sent to farms (Grönroos & Luostarinen 2013. Manuscript) and this data were used from the year 2006 onwards to update the previous figures. Emission factors for slurry and solid manure are now similar in 2006 IPCC Guidelines, so changes in their shares do not have as much impact on emissions as previously. However, slurry has now two EFs (0 or 0.5% depending on crust), and the share of cattle slurry with crust has increased over time therefore increasing the emissions from slurry (floating covers are considered identical with natural crust in Finnish inventory). Also, the number of horses is rising and they are kept in dry lots part of the time. As dry lot system has high EF compared to other systems, the emissions of horses also have a slight effect on the rising trend.

Methane emissions from manure management have increased by 24% since 1990 (Table 5.3-4). This is due to an increase in the number of animals kept in slurry systems. Slurry-based systems increase methane emissions per animal compared with solid storage or pasture. However, dairy cattle emissions have started to decrease as slurry with crust/floating cover is becoming more common and has a smaller EF than slurry with no crust.

Total emissions from manure management (kt CO<sub>2</sub> eq.) have increased about 14% 1990-2013. 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 to changes in the distribution of the manure management systems used.



**Figure 5.3-1** Emissions of manure management by animal type, kt CO<sub>2</sub> eq.

**Table 5.3-2** Direct nitrous oxide emissions (kt) from manure management by animal type (emissions from pasture not included, they are reported under CRF 3.D Agricultural soils/Pasture, range and paddock manure)

Year	Cattle					Sheep	Swine	Other livestock				Total	
	DC	SC	B	H	C			P	Ho	G	F		
1990	0.24	0.01	0.05	0.04	0.10	0.01	0.09	0.03	0.03	0.006	0.04	0	0.62
1995	0.20	0.02	0.04	0.03	0.07	0.01	0.06	0.03	0.03	0.007	0.05	0	0.55
2000	0.19	0.02	0.04	0.04	0.07	0.01	0.06	0.02	0.04	0.009	0.05	0	0.54
2001	0.19	0.02	0.04	0.04	0.07	0.01	0.06	0.02	0.04	0.008	0.04	0	0.52
2002	0.18	0.02	0.04	0.04	0.07	0.01	0.06	0.02	0.04	0.007	0.05	0	0.54
2003	0.17	0.02	0.05	0.04	0.07	0.01	0.06	0.02	0.04	0.007	0.06	0	0.54
2004	0.17	0.02	0.05	0.04	0.07	0.01	0.06	0.02	0.04	0.008	0.06	0	0.53
2005	0.16	0.02	0.04	0.04	0.07	0.01	0.06	0.02	0.04	0.008	0.07	0	0.53
2006	0.17	0.02	0.05	0.04	0.08	0.01	0.06	0.02	0.04	0.007	0.06	0	0.55
2007	0.17	0.03	0.05	0.04	0.08	0.01	0.06	0.02	0.04	0.006	0.06	0	0.56
2008	0.18	0.03	0.05	0.04	0.09	0.01	0.05	0.02	0.04	0.006	0.05	0	0.56
2009	0.19	0.03	0.05	0.05	0.09	0.01	0.05	0.02	0.04	0.005	0.06	0	0.60
2010	0.20	0.04	0.06	0.05	0.10	0.01	0.05	0.02	0.04	0.004	0.06	0	0.63
2011	0.21	0.04	0.06	0.05	0.10	0.01	0.04	0.02	0.05	0.004	0.05	0	0.63
2012	0.22	0.04	0.05	0.06	0.11	0.01	0.04	0.02	0.05	0.004	0.06	0	0.65
2013	0.22	0.04	0.05	0.06	0.10	0.01	0.04	0.02	0.05	0.004	0.06	0	0.65
Share of total (%) in 2013*	33.5	5.8	8.3	8.6	16.2	1.6	6.1	3.2	7.2	0.1	9.4	0	100

**Table 5.3-3** Indirect N<sub>2</sub>O emissions from manure management (kt)

Year	Indirect N <sub>2</sub> O emission
1990	0.33
1995	0.31
2000	0.31
2001	0.30
2002	0.31
2003	0.32
2004	0.31
2005	0.32
2006	0.31
2007	0.31
2008	0.30
2009	0.31
2010	0.31
2011	0.30
2012	0.31
2013	0.31

**Table 5.3-4** Methane emissions from manure management by animal type (kt)

Year	Cattle					Sheep	Swine	Other livestock					Total
	DC	SC	B	H	C			P	Ho	G	F	R	
1990	6.12	0.10	0.96	0.72	1.45	0.02	2.64	0.26	0.10	0.001	2.25	0.09	14.71
1995	5.83	0.21	0.87	0.73	1.42	0.03	3.45	0.28	0.10	0.001	2.57	0.08	15.55
2000	7.02	0.29	0.94	0.75	1.29	0.02	3.25	0.28	0.11	0.001	2.30	0.07	16.34
2001	7.37	0.29	0.93	0.75	1.30	0.02	3.17	0.28	0.12	0.001	2.02	0.07	16.31
2002	7.77	0.30	1.00	0.76	1.30	0.02	3.32	0.29	0.12	0.001	2.34	0.07	17.29
2003	8.00	0.31	1.03	0.76	1.28	0.02	3.57	0.29	0.13	0.001	2.45	0.07	17.92
2004	8.31	0.35	1.00	0.75	1.25	0.02	3.58	0.28	0.13	0.001	2.42	0.07	18.18
2005	8.60	0.39	0.98	0.73	1.25	0.02	3.76	0.28	0.14	0.001	2.59	0.08	18.83
2006	8.36	0.41	1.06	0.78	1.21	0.02	3.90	0.29	0.15	0.001	2.36	0.07	18.60
2007	8.03	0.42	1.08	0.80	1.20	0.03	4.24	0.28	0.15	0.001	2.38	0.07	18.68
2008	7.75	0.43	1.09	0.82	1.18	0.03	4.39	0.30	0.15	0.001	1.85	0.07	18.06
2009	7.72	0.43	1.12	0.84	1.18	0.03	4.28	0.27	0.16	0.001	2.36	0.07	18.45
2010	7.67	0.42	1.20	0.89	1.19	0.03	4.29	0.31	0.16	0.001	2.38	0.07	18.61
2011	7.43	0.40	1.17	0.91	1.17	0.03	4.27	0.32	0.16	0.001	1.98	0.07	17.91
2012	7.25	0.36	1.14	0.91	1.17	0.03	4.24	0.33	0.16	0.001	2.31	0.07	17.98
2013	7.38	0.36	1.15	0.93	1.16	0.03	4.30	0.36	0.16	0.001	2.31	0.07	18.22
Share of total (%) in 2013*	40.5	2.0	6.3	5.1	6.4	0.2	23.6	2.0	0.9	0.0	12.7	0.4	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&Ponies, P=Poultry, F=Fur animals, R=Reindeer

## 5.3.2 Methodological issues

### 5.3.2.1 Methods

#### Nitrous oxide

Direct N<sub>2</sub>O emissions and deposition from manure management are calculated by the Nitrogen mass flow model. Leaching is calculated separately. Only leaching from dry lots is estimated for manure management systems, other systems are considered ‘liquid tight’ as required by the Finnish environmental legislation (Ministry of the Environment 2010: Guidelines for environmental protection in animal husbandry (in Finnish)).

#### *Nitrogen mass flow model (manure management)*

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 in the same calculation model. For storing of manure also NO-N and N<sub>2</sub> losses are estimated. 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 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 3.B) are calculated in the model by using the IPCC methodology (2006 IPCC Guidelines, Eq. 10.25). The equation is presented in the Appendix\_5a. Dry lot (for cattle and horses) was included in the model according to the 2006 IPCC Guidelines. The amount of nitrogen excreted annually per animal has been divided between different manure management systems. Systems are slurry, solid storage (dung & urine together or dung & urine separated), deep litter and dry lot. Nitrogen excretion per year per animal and the distribution of manure management systems are country-specific data (Appendix\_5b).

For each manure management system, the amount of nitrogen is multiplied with the IPCC’ s system-specific default emission factor. For slurry, the share of slurry with cover (natural or floating) and no natural cover has been estimated. This information has already been used in previous submissions when estimating ammonia emissions and now, also different EFs of direct N<sub>2</sub>O emissions are applied. For solid storage, the share of separated dung & urine per dung & urine combined fluctuates over time. The share of urine is 55% of the separated urine & dung nitrogen (according to a generalisation made in N mass flow model based on cattle manure qualities).

The amount of N volatilised as NH<sub>3</sub>-N and NO-N from manure management systems (animal shelter, filling storage, manure storing; Frac<sub>GASMS</sub> being ca. 32-37%) is calculated in the model separately from the application to fields (NH<sub>3</sub>-N during and after spreading). Therefore, indirect N<sub>2</sub>O emissions from atmospheric deposition for manure management systems, as well as for field application, can be calculated by using the N volatilised which is then multiplied with the IPCC default EF. The emission factors for calculating N<sub>2</sub>O emissions from manure management are presented in Table 5.3-6.

Nitrogen mass flow model is also used in the calculation of emissions from agricultural soils (manure and synthetic fertiliser) (see 5.5 Agricultural soils).

#### 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 (2006 IPCC Guidelines, Eq. 10.22). 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\_5a.

### 5.3.2.2 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, with an exception of the number of sows and piglets in calculations of 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

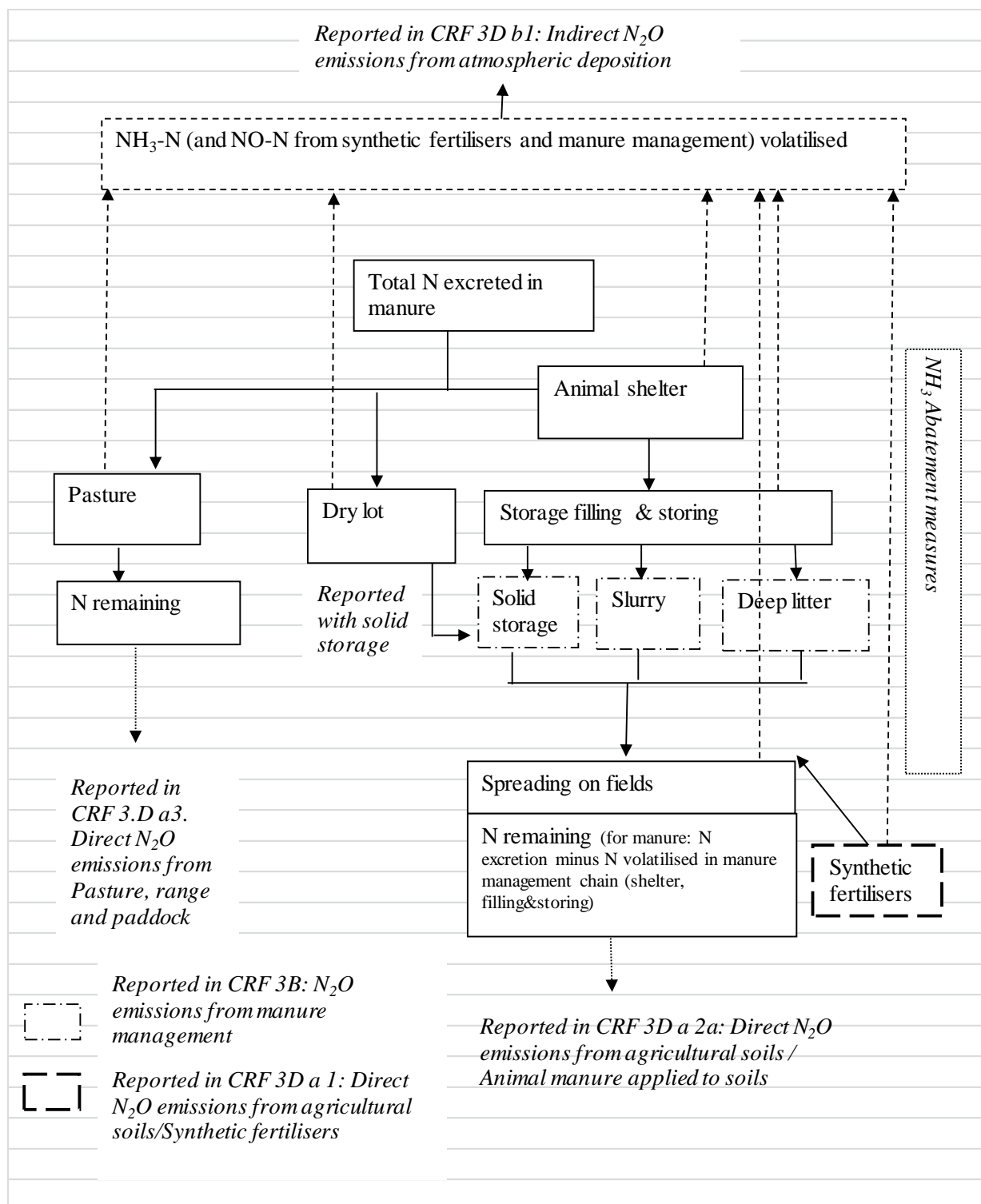
Annual nitrogen excretion per animal has been calculated by animal nutrition experts of MTT Agrifood Research Finland (Appendix\_5b). The values of animal specific nitrogen excretion rates were based on nutrient balance calculations. N excretion for different animal classes is calculated as N intake 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 to obtain the energy need from feed and then nitrogen content in feed is estimated from feed consumption data (per energy unit).

The reason for the increasing trend in N excretion rates is the increased production level of animals (e.g. amount of milk per cow) demanding higher nitrogen intake. Thus, nitrogen excretion has increased despite the fact that N utilisation has improved. 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).

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 need to update the N excretion rates is evaluated annually in cooperation with the animal nutrition experts.

**Table 5.3-5** Source of data for calculating N excretion per animal

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	



**Figure 5.3-2** Distribution of manure N in the N flow model and reporting of direct and indirect  $N_2O$  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 and manure storing). The magnitude of  $N_2O$  emissions from each source is not presented here but in Figure 5.1-4.

### *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; for the 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 on 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 3 in Appendix 5b 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 obtained 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) from 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 and estimated difference between breeding station results and common farm conditions, as well as several feeding experiments. The nitrogen content of feed is estimated from the digestible protein recommendations. Also feeding examples (Komulainen 1989, Kytäjä et al. 1999 and Siljander-Rasi et al. 2006) are utilised.

### *Horses and ponies*

For horses and ponies, the statistics of the Finnish Trotting and Breeding Association, Suomen Hippos are used. Nitrogen excretion is in most cases calculated with nitrogen balance estimation which is similar 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 feeding examples 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, feeding examples (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 of eggs, per 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.

### Manure management systems

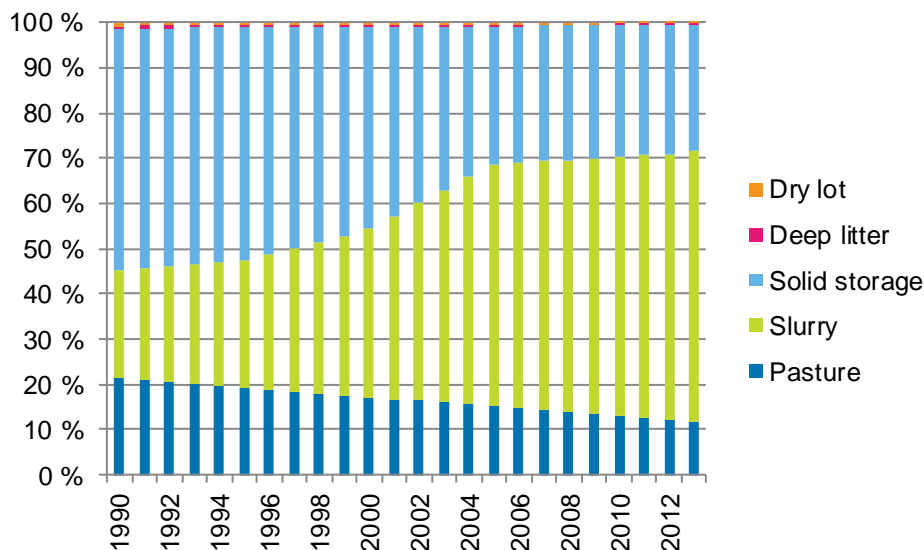
For greenhouse gas inventory, the manure management systems reported are slurry, solid storage, deep litter, dry lot and pasture, 'solid' includes urine and dung either together or separated (Table 4 in Appendix\_5b).

The distribution of manure management systems is estimated by using different data sources as no statistics available for the inventory purposes exists in Finland. Some manure management data is collected by LUKE (Natural Resources Institute Finland) but e.g. the division of the data does not match with the needs of the inventory. The distribution of manure management systems was estimated in 2009 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). The method has been described in Grönroos et al. (2009). However, as the study did not result in enough information (only 8 questionnaires were received back), the distribution of different manure management systems is quite uncertain. A new questionnaire (Grönroos J & Luostarinen S, Suomen lantojen käsittely (*Manure management in Finland*). Manuscript.) was made and sent to farmers in 2013 (to 11 120 farms, stables or fur farms, c. 23 % answered). Based on the answers, activity data of shares of manure management systems for years 1990-2005 stayed the same but from 2006 onwards the values were updated (also, dairy pasture parameters were updated for whole time series). This was done by updating the year 2012 management system data and interpolating years 2006-2011. The year 2013 value is based on estimated trend between 2012 and 2020 (e.g. share of slurry is assumed to continue to increase). Some information about the changes made to the data can be found in Grönroos 2014 (*in Finnish*). Share of manure in dry lots is still a rough estimate which will be updated when more data is available (now 1-3% of excreted manure).

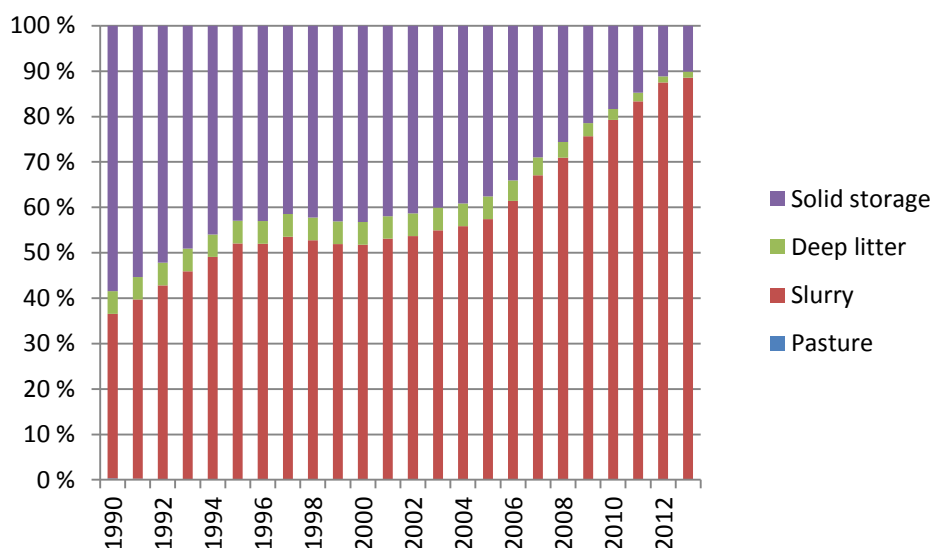
About aerobic treatment, the questionnaire 2013 included questions concerning composting. The results suggest that only approx. 5% of all "dry manure" (deep litter & solid manure) is composted, most of it is passive windrow composting (N<sub>2</sub>O default EF is 0.01). This means max. 7 kt CO<sub>2</sub>-equivalents more emissions for 'N<sub>2</sub>O manure' (and would decrease methane emissions from manure).

There were 12 farm-scale biogas plants (using mostly cattle and some swine manure) in Finland in 2013 according to the Finnish Biogas Association and 5 centralized plants which use manure along with other material in their process. It was calculated ( $MCF_{slurry} (0.17) * Bo * VS_{storage} * 0.67$ ) that the methane emissions from stored digestate would be about 70-90 tonnes of methane per year. The estimate of manure input (30-50 000 t) to the farm-scale plants is both an expert judgement (S. Luostarinen 2015) and an estimate based on methane production of plants. In centralized plants the digestate goes to the post digestion pool and after that to processing (e.g. separation) and is not stored as slurry. The methane emissions from anaerobic digestion and N<sub>2</sub>O emissions from composting are negligible. Acquiring data for the time series of

emissions would require disproportionately resources considering the size of emissions and therefore manure composting and biogas are excluded from the inventory.



**Figure 5.3-3** Fraction of manure of dairy cows in different manure management systems



**Figure 5.3-4** Fraction of manure of swine in different manure management systems

### 5.3.2.3 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, dry lot and slurry (Table 5.3-6).

EF for solid storage (dung and urine together or dung and separated urine) is the same as for slurry with natural crust (or with floating cover). EF for slurry without crust or floating cover is zero.

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). For dry lot ammonia volatilisation is at the moment the same as for pasture until better estimates are acquired.

EFs for indirect emissions from manure management are default values ( $\text{Frac}_{\text{Leach}}$  0.3, EF for leaching 0.0075 and EF for deposition 0.01).

**Table 5.3-6** 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
Slurry with cover (natural or floating)	0.005	-50% / +100% (lognormal)	IPCC 2006 Guidelines
Slurry without cover	0	-50% / +100% (lognormal)	IPCC 2006 Guidelines
Solid storage (incl. urine)	0.005	-50% / +100% (lognormal)	IPCC 2006 Guidelines
Deep litter (cattle & swine)	0.01	-50% / +100% (lognormal)	IPCC 2006 Guidelines
Poultry manure with litter	0.001	-50% / +100% (lognormal)	IPCC 2006 Guidelines
Dry lot	0.02	-50% / +100% (lognormal)	IPCC 2006 Guidelines

### Methane

The country-specific emission factors for each cattle subcategory have been calculated by using the IPCC Tier 2 methodology (2006 IPCC Guidelines, Eq. 10.23). Equations are presented in the Appendix\_5a. In calculation of emission factors, both IPCC default values and national data have been used. Emission factors are presented in Table 5.3-7.

For cattle, emission factors have been calculated by using the 2006 IPCC Guidelines default values for ash content of manure, Methane Producing Potential (Bo) and Methane Conversion Factor (MCF). The values of digestible energy (DE) and gross energy intake (GE) for cattle from enteric fermentation are used in calculating volatile solids excretion (VS<sub>i</sub>). For other animals, emission factors have been calculated using the 2006 IPCC Guidelines default values for Methane Producing Potential (Bo), Methane Conversion Factor (MCF) and volatile solids excretion (VS<sub>i</sub>). VS values for piglets and weaned pigs are from an expert (J. Nousiainen). 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 5.3-7** Country-specific emission factors in 2013 used for calculating methane emissions from manure management

Animal category	Emission factor (kg CH <sub>4</sub> /head/year)
Cattle	
Dairy cattle	26.05
Non-dairy cattle	
Suckler cows	6.28
Bulls	10.47
Heifers	5.76
Calves	3.88
Sheep	0.25
Swine	3.31
Fattening pigs	4.95
Boars	6.32
Weaned pigs	2.71
Sows	6.32
Piglets	0.55
Other livestock	
Poultry	0.03
Horses	2.14
Goats	0.18
Fur animals	0.68
Reindeer	0.36

### 5.3.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 2. A description of uncertainty analysis is included in Section 1.6.

The uncertainties in manure management are estimated by applying Tier 2 Monte Carlo simulation directly to the emission calculation models (LUKEAgri 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  $-43\% \dots +67\%$ . 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 are  $-50\% \dots +100\%$  (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 methods are used for the whole time series 1990-2013, the time series can be considered consistent. Updates were done to manure management data and interpolation/extrapolation was used to combine new and previous data and predict future development (see Section 5.3.2.2. Manure management systems).

### 5.3.4 Category-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 1.2.3. The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives. The bilateral quality meeting is held annually between the inventory unit and the sectoral expert. In the quality meeting 2015 for example the ERT Review and National Inventory Report text were discussed as well as changes to calculation due to Guidelines 2006.

#### General Quality Control (QC) procedures applied to the category Manure management (CRF 3.B):

The QA/QC plan for the agricultural sector includes the QC measures presented in the 2006 IPCC Guidelines (Vol 1, Chapter 6, Table 6.1). 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 (LUKEagri check) is used during the inventory. The check includes for example checking formulas, links between sheets and evaluating correctness of parameters used with cross-checks to previous years.

The results from the N mass flow model are compared with a more simple calculation periodically to examine possible problems with the model

#### Category-specific QC for activity data:

A checklist (LUKEagri check) 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. No errors were detected for this inventory. The LUKEagri calculation sheet has a check for N<sub>2</sub>O manure management to ensure that N model and calculation sheet use same activity data. New data was obtained concerning animal waste management systems (Grönroos & Luostarinen 2013. Manuscript.)

#### Category-specific QC for emission factors:

It is checked annually if new data for updating emission factors has been published. New national published experimental results concerning manure management were not available for this inventory.

#### Quality assurance and verification:

The calculation models are sent yearly to another institute to a person who is not directly involved in calculating greenhouse gas emissions from agriculture at national level. Instead, this person uses the models for emission calculation at the regional level in Finland and informs the national inventory expert of any errors found in the models.

In 2015 there will be a comparison of IEFs of enteric fermentation with Swedish values. In upcoming years, comparisons will be done for other agricultural sectors as well.

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.

### 5.3.5 Category-specific recalculations

Calculation now follows the 2006 IPCC Guidelines. Animal waste management system (AWMS) data was updated, especially for years 2006-2012 (for years 1990-2005 only small refinements were made). Also, some refinements were made to ammonia volatilization parameters (Grönroos 2014). Change to methane emissions

of 1990 was less than 1% but for 2012 emissions increased over 10% compared with new 2006 Guidelines calculation with old AWMS data. For nitrous oxide emissions the impact of updated AWMS data and ammonia data was about 1%.

### *5.3.6 Category-specific planned improvements*

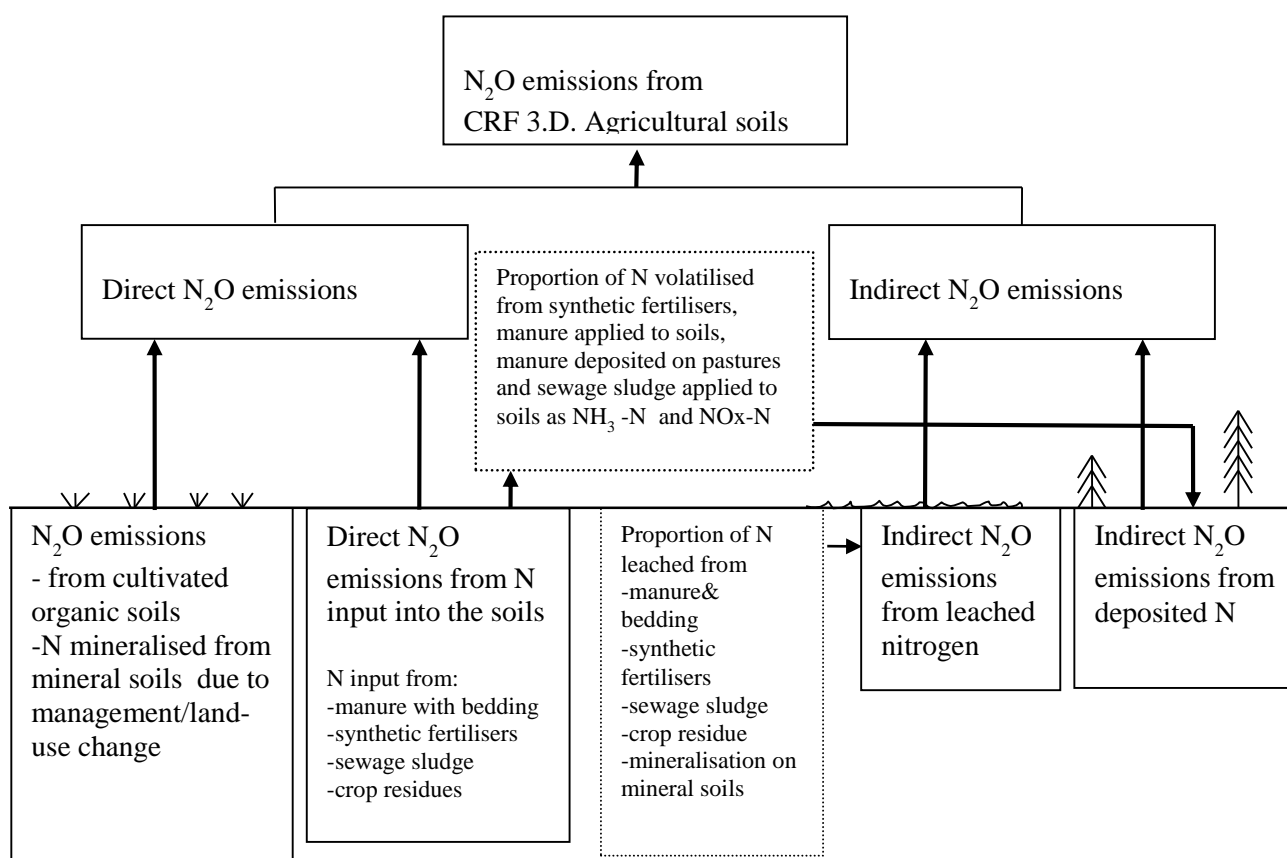
Volatile solids (other than cattle and swine) used in the inventory, and for which now default values are used, will be evaluated with an expert.

## 5.4 Agricultural Soils (CRF 3.D)

### 5.4.1 Category description

Nitrous oxide emissions from agricultural soils (CRF 3.D) are a significant emission source comprising about 52% of total agricultural emissions in 2013, being 3.3 Mt as CO<sub>2</sub> equivalents.

Direct N<sub>2</sub>O emissions (CRF 3.D a) include emissions from synthetic fertilisers, animal manure (including bedding) and sewage sludge applied to soils, urine and dung N deposited on pasture, crop residues, drainage/management of organic soils and mineralisation due to management/land-use change on mineral soils. Indirect N<sub>2</sub>O emissions (CRF 3.D b) include emissions arising from nitrogen volatilised as ammonia (NH<sub>3</sub>) and other oxides of nitrogen (NO<sub>x</sub>; synthetic fertilisers), as well as nitrogen leached from the sources mentioned above (except organic soils). Indirect emissions from manure management systems are reported in CRF 3B.



**Figure 5.4-1** Reported emissions under the subcategory Agricultural Soils CRF 3.D in the Finnish inventory

**Table 5.4-1** 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
3.D a	<u>Direct Soil Emissions</u>			
	- Synthetic Fertilisers	N <sub>2</sub> O	Tier 1	D
	- Animal Manure Applied to Soils	N <sub>2</sub> O	Tier 1	D
	- Municipal Sewage Sludge Applied to Soils	N <sub>2</sub> O	Tier 1	D
	- Pasture, Range and Paddock Manure	N <sub>2</sub> O	Tier 1	D
	- Crop Residue	N <sub>2</sub> O	Tier 1	D
	- Mineralization associated with loss of soil organic matter (mineral soils)	N <sub>2</sub> O	Tier 1	D
	- Cultivation of Histosols	N <sub>2</sub> O	Tier 2	D,CS*
3.D b	<u>Indirect Emissions</u>			
	- Atmospheric Deposition	N <sub>2</sub> O	Tier 1	D
	- Nitrogen Leaching and Run-off	N <sub>2</sub> O	Tier 1	D
*both country-specific and IPCC Wetlands Supplement emission factors used				

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 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.

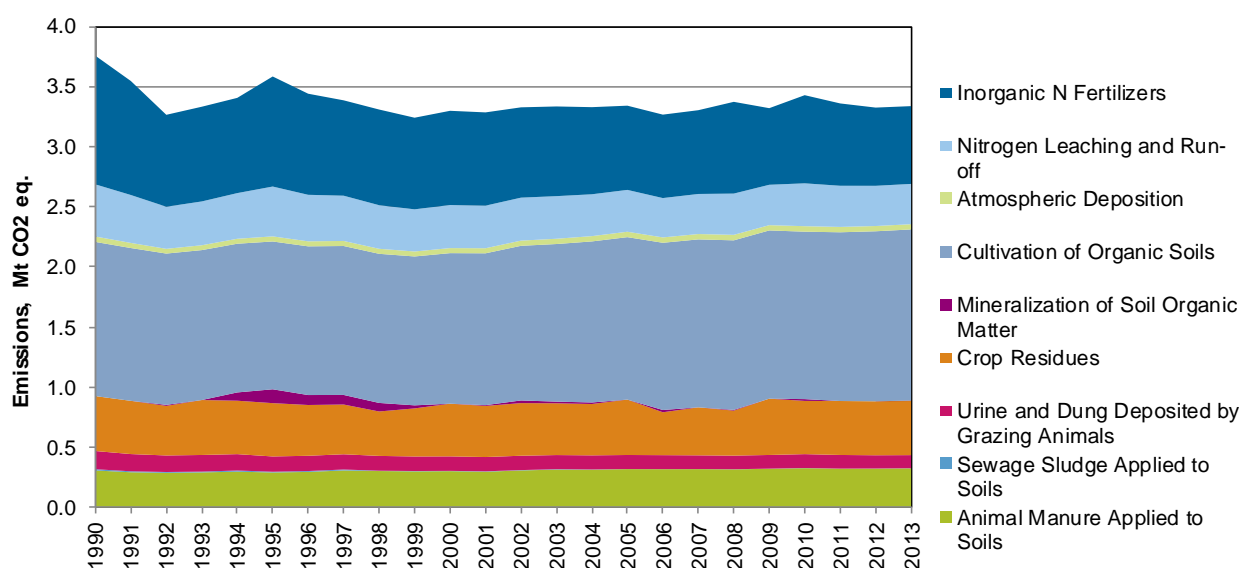
Agricultural production changed considerably due to Finland's decision to join the EU. Many farms were given up and the area of fallow more than doubled in 1990-1991 and after that in 1995-1996, the total area of agricultural land diminished when Finland joined the EU. Nitrous oxide emissions from agricultural soils have decreased by 11%, from 12.6 kt in 1990 to 11.2 kt in 2013 (Table 5.4-2, Figure 5.4-2). The main reason for the decreasing trend is the fall in the amount of synthetic fertilisers used annually. Declining emission from pasture also has some effect (less manure is excreted to pasture, more animals are kept inside). The emissions from cultivated organic soils have increased as a result of the increased area of these soils, though the area of organic grassland (now included in calculation) is decreasing.

**Table 5.4-2** Direct and indirect nitrous oxide emissions from agricultural soils by category (kt)

Year	Direct emission sources							Indirect emission sources		Total
	S	MS	MP	C	SW	O	M	A	L	
1990	3.59	1.03	0.51	1.53	0.03	4.30	0.00	0.15	1.46	12.60
1995	3.07	0.97	0.43	1.49	0.02	4.13	0.39	0.14	1.39	12.03
2000	2.63	1.01	0.40	1.47	0.01	4.20	0.00	0.14	1.20	11.07
2001	2.60	0.99	0.40	1.43	0.01	4.24	0.02	0.14	1.19	11.02
2002	2.52	1.03	0.40	1.47	0.01	4.32	0.07	0.14	1.20	11.16
2003	2.50	1.05	0.39	1.44	0.01	4.40	0.05	0.15	1.19	11.19
2004	2.43	1.05	0.39	1.43	0.01	4.50	0.04	0.15	1.17	11.17
2005	2.35	1.07	0.39	1.55	0.00	4.53	0.00	0.15	1.17	11.21
2006	2.33	1.06	0.39	1.20	0.00	4.67	0.06	0.15	1.10	10.96
2007	2.34	1.07	0.38	1.34	0.00	4.69	0.00	0.15	1.12	11.08
2008	2.56	1.06	0.38	1.26	0.00	4.73	0.02	0.15	1.15	11.32
2009	2.14	1.08	0.38	1.57	0.00	4.70	0.00	0.15	1.13	11.14
2010	2.46	1.09	0.39	1.49	0.01	4.67	0.05	0.15	1.20	11.50
2011	2.30	1.08	0.38	1.51	0.00	4.71	0.00	0.15	1.15	11.27
2012	2.18	1.08	0.37	1.51	0.00	4.75	0.00	0.15	1.12	11.16
2013	2.17	1.09	0.37	1.52	0.00	4.78	0.00	0.15	1.13	11.20
Share of total(%) in 2013 *	19	10	3	14	0	43	0	1	10	100

\* The sum of the shares differs from 100 due to rounding.

S=synthetic fertilisers, MS= manure (with bedding) applied to soils, MP=manure deposited on pastures by grazing animals, C=crop residues, M=mineralisation on mineral soils, O=cultivation of organic soils, SW=sewage sludge application, A=atmospheric deposition, L=leaching and run-off

**Figure 5.4-2** Nitrous oxide emissions from agricultural soils (atmospheric deposition, nitrogen leaching and run-off are indirect emissions, all other direct), Mt CO<sub>2</sub> eq

## 5.4.2 Methodological issues

### 5.4.2.1 Methods

Emissions have been calculated by using the 2006 IPCC Guidelines methodology. Direct emissions have been calculated using Equation 11.1 from the chapter 11. Indirect emissions have been calculated using Equation 11.9 for atmospheric deposition and 11.10 for leaching and run-off (2006 IPCC Guidelines). Detailed equations are provided in the Appendix\_5a. Activity data sources of this category are presented in Table 5.4-3 and emission factors in Table 5.4-8. Default EFs are used for direct soil emissions (except for organic soils) and for indirect emissions. For manure and synthetic fertilisers, the Nitrogen mass flow model has been used in calculation. Reporting of manure and synthetic fertiliser N is presented in Table 5.4-1. N flows and N<sub>2</sub>O emissions from sector Agriculture are presented in Figure 5.4-1.

#### Nitrous oxide from manure and synthetic fertilisers

Emissions from applied manure and synthetic fertilisers on managed agricultural soils, as well as pasture emissions, are mostly calculated in Nitrogen mass flow model, except for leaching/run off. Leaching is calculated from the amount of synthetic fertiliser nitrogen sold each year and for applied manure it is calculated from the total amount of manure nitrogen applied on soil. Bedding nitrogen is added to manure nitrogen when calculating emissions from application. Leaching from pasture is calculated from the total amount of nitrogen deposited on the ground in urine and dung.

#### *Nitrogen mass flow model (agricultural soils)*

Nitrogen mass flow model is used in calculation of direct and indirect (deposition) agricultural soils emissions (from manure applied on soil and for synthetic fertilisers) as well as for emissions from manure management (see 5.3.2.1). Leaching/run off is not calculated. Volatilised nitrogen (as NH<sub>3</sub>-N, NO-N, N<sub>2</sub> and N<sub>2</sub>O-N) from manure management systems is subtracted from the amount of total manure nitrogen entering the manure systems, before calculating direct N<sub>2</sub>O emissions from manure applied to soils (CRF 3.D a.2a). Bedding nitrogen is added in manure nitrogen entering the soil. Ammonia volatilisation during and after spreading depends on the type of field (arable/plant covered/stubble) and application method. The model takes into account various NH<sub>3</sub> abatement measures (e.g. incorporation with ploughing in less than 4 hours, injection) and their ability to reduce ammonia emissions on fields. More detailed information about the model parameters are found in Grönroos et al. (2009) page 13. Dry lot dung&urine is not applied, it is assumed to stay on the ground of the corrals similar to pasture (dry lot emissions are calculated in Manure management 5.3).

Direct and indirect emissions from dung and urine on pasture are calculated. Volatilisation results in 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 60-100% of cows (depending on year) spend nights inside (11-12 hours) during pasture season. The length of pasture season has been estimated as 125-112 days for dairy cows, 140-170 for suckler cows, 130-140 for heifers, 100-130 for calves, 140-180 for horses and ponies, 140-150 for sheep and goats, 365 for reindeer and 0 for bulls, swine (some exceptions), poultry and fur animals (Grönroos et al. 2009; Grönroos & Luostarinen 2013. (Manuscript)).

Direct emissions from synthetic fertiliser application (CRF 3.D a1) are calculated in the model. Nitrogen volatilised as NH<sub>3</sub>-N and NO-N from synthetic fertilisers (Frac<sub>GASF</sub>, ca. 1.5%, NO-N share is 0.7% of fertiliser N) is calculated considering different fertiliser types, grassland/arable land division and placement fertilisation. 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 (EEA 2007; Grönroos et al. 2009).

*Nitrous oxide from sewage sludge, crop residue, drainage/management of organic soils and mineralisation due to management/land-use change on mineral soils*

*Sewage Sludge*

Other emission sources are not included in the Nitrogen mass flow model. Sewage sludge (CRF 3.D a2b) emissions are calculated from the sludge used in agriculture. Indirect emissions of sludge from deposition are calculated assuming that the share of volatilised ammonia is the same as for applied manure (including bedding) and manure to pasture (FracGasm of sewage ca. 8-9%). Better estimate for ammonia loss for sewage sludge is not available. Also leaching emissions of sludge are calculated.

*Crop residue*

Crop residue calculation follows in principle the 2006 IPCC Guidelines with small refinements. N<sub>2</sub>O emissions are now calculated based on all cultivated plants in Finland, including the areas of crop failure caused by e.g. exceptional weather conditions. Plants are divided into 11 groups: winter wheat, spring wheat, rye, barley, oat, turnip rape, rape, pea, potato, sugar beet and silage. Emissions of vegetables are calculated similarly as for peas. Both aboveground and belowground crop residue is included. Straw used for bedding and burned on field is excluded. Calculation is described in more detail in Appendix\_6j. Crop yields change from year to year, as well as cultivated area, and cause fluctuations in crop residue emissions.

*Drainage/management of organic soils*

Nitrous oxide emissions from cultivated organic soils have been calculated with the IPCC methodology by dividing the area of cropland into grass and other crops and using EFs from IPCC Wetlands Supplement 2013 for both crop types (Chapter 2). Emissions from Grassland are calculated now as well and a country-specific EF is used (Maljanen et al. 2010b).

The EFs for boreal cropland (annual crops) and grassland (perennial crops) from the IPCC Wetlands Supplement were considered suitable for estimating the emissions of N<sub>2</sub>O from active fields in the cropland category since many of the measurements behind the EFs were done in Finland and they are based on a larger dataset than the former national EFs. However, the EF for the grassland category was taken from Maljanen et al. 2010b since the EF based on measurements on abandoned fields was found to represent the area in the grassland category better.

*Mineralisation due to management/land-use change on mineral soils*

The amount of N mineralised from loss in soil organic C in mineral soils through land use change or management practices is calculated by using Tier 3 method for the carbon losses and equation 11.8 in the 2006 IPCC Guidelines. Net soil carbon losses are calculated as described in Chapter 6.5 by using Yasso07 soil carbon model (Appendix 6e). C:N ratio of the soil organic matter (13) is a country-specific estimate (Sheehy et al. 2012). EF for direct emissions as well as for leaching (Frac<sub>Leach</sub> & EF<sub>Leach</sub>) are defaults. Mineralisation emissions due to management changes in Cropland remaining cropland are reported under Agricultural soils 3D (including leaching), other N<sub>2</sub>O emissions from mineralization are reported under 4B and 4C.

*Indirect emissions*

Nitrous oxide emissions from the atmospheric deposition are calculated from the total amount of NH<sub>3</sub>-N volatilized during spreading of manure, sewage sludge and mineral fertilizers as well as manure excreted on pastures by multiplying the total amount of N volatilised with the specific emission factor for atmospheric deposition (see Table 5.4-8). Fraction volatilized for synthetic fertilizers and applied manure are presented in Table 5.4-9.

Nitrous oxide emissions from leaching and run-off are calculated from the amount of N input from fertilisers (synthetic, applied manure (including pasture & bedding) and sewage sludge), nitrogen from the crop residues and mineralisation due to management/land-use change on mineral soils. Leaching from organic soils is not estimated. Fraction leached is presented in Table 5.4-9 and EF in Table 5.4-8. They are all defaults.

### 5.4.2.2 Activity data

Activity data are country-specific and obtained mainly from the annual agricultural statistics of the Ministry of Agriculture and Forestry (Table 5.4-3). Other data sources are the Finnish Environment Institute (the amount of nitrogen in sewage sludge) and Finnish Forest Research Institute (area of organic agricultural soils). Animal numbers are the same as those used for calculating enteric fermentation and manure management emissions (Table 5.2-3, Appendix 5b). 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 obtained 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 6) see Table 5.4-4. Crop yields of cultivated plants are from the Ministry of Agriculture and Forestry and the areas of individual plants have been taken from Land Parcel Identification System (EU 1992) (Table 5.4-6). The area of organic soils was derived as described in Section 6.3 (Table 5.4-7). 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. Estimation of the area of grassland is reported in Section 6.3.

There are no statistics for the whole time series on the distribution of fertiliser types but Table 5.4-5 shows that most mineral fertilisers are sold as NPK. 'Other NK and NPK' fertilizers consist of tens of different fertilizers that have a N content ranging from 3 to 27 per cent. Urea is mainly used in forestry and rarely used in Finnish agriculture due to short growing season and acid soils. 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).

**Table 5.4-3** 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	<a href="http://www.hippos.fi">Finnish Trotting and Breeding Association (http://www.hippos.fi)</a>
Number of fur animals	Finnish Fur Breeders Association
Distribution of manure management systems	Grönroos et al. (2009), Grönroos J & Luostarinen S, Suomen lantojen käsittely (Manure management in Finland). Manuscript. (2013)
Nitrogen excretion by animal type	MTT Agrifood Research Finland, i.e. current Natural Resources Institute 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), Land Parcel Identification System (EU 1992), (Palosuo, Heikkinen & Regina 2014: Method for estimating soil carbon stock changes in Finnish mineral croplands and grasslands. Manuscript)
Ammonia emission estimates	Nitrogen mass flow model, Grönroos et al.(2009)
Area of cultivated organic soils	Finnish Forest Research Institute, i.e. current Natural Resources Institute Finland
Net carbon stock change in mineral soils	Yasso07 soil carbon model
The amount of synthetic fertilisers sold annually	Yearbook of Farm Statistics

**Table 5.4-4** Nitrogen input to soils via synthetic fertilisers, manure, bedding and sewage sludge application (t N a<sup>-1</sup>) (the fraction lost as NH<sub>3</sub> and NO<sub>x</sub> during application has not been subtracted)

Year	Synthetic fertilisers <sup>1</sup>	Manure <sup>2</sup>	Bedding	Sewage Sludge <sup>3</sup>
1990	228 470	83 576	3 455	2 202
1995	195 460	77 340	2 424	1 316
2000	167 276	78 985	2 257	513
2001	165 621	77 699	2 085	725
2002	160 403	80 139	2 047	616
2003	159 288	81 398	2 000	754
2004	154 708	81 268	1 898	441
2005	149 562	82 310	1 842	143
2006	148 161	82 134	1 775	156
2007	148 784	82 066	1 724	147
2008	162 905	81 576	1 641	257
2009	136 009	82 672	1 530	266
2010	156 523	83 957	1 464	338
2011	146 189	82 859	1 383	148
2012	138 900	82 527	1 301	245
2013	138 136	82 918	1 272	245*

<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 2012

**Table 5.4-5** Distribution of mineral N-fertilizers used in Finland by fertilizer type. Share of each fertilizer depends on the year (Source: Yara Finland)

Fertilizer type	% of applied N
Ammonium sulphate	0.0
Ammonium nitrate	0.0
Calcium ammonium nitrate	14.1-19.6
Anhydrous ammonia	0.0
Urea	0.0
Nitrogen solutions	0-0.04
Ammonium phosphates	0.13-0.16
Other NK and NPK	80.2-85.7
Nitrate only	0.05-0.08

**Table 5.4-6** Parameters for calculating crop residue emissions (Palosuo et al. 2015)

	1990		2013		res/yield	above N	below N
	yield (kg DM/ha)	area, ha	yield (kg DM/ha)	area, ha			
Winter wheat	3 356	12 548	2 664	14 117	1.38	0.006	0.009
Spring wheat	2 935	88 152	3 395	217 009	1.38	0.006	0.009
Rye	2 585	20 801	1 835	12 416	1.50	0.005	0.011
Barley	3 118	516 317	3 363	533 809	0.89	0.007	0.014
Oats	3 200	329 437	3 038	368 320	1.17	0.007	0.008
Turnip rape	1 689	87 847	1 387	38 140	1.86	0.006	0.009
Rape	2 004	1 168	1 660	16 404	1.86	0.006	0.009
Pea	2 472	15 038	2 161	50 678	1.00	0.008	0.008
Potato	4 943	35 438	6 304	22 174	0.49	0.019	0.014
Sugar beet	7 803	35 969	9 314	12 006	0.11	0.016	0.014
Silage	7 446	770 387	5 545	724 380	0.19	0.015	0.012

DM = dry matter; yield = average crop yield; res/yield = above ground plant residues/crop yield, dry matters above N & below N=nitrogen content of above ground (below ground) residues

**Table 5.4-7** Area of cultivated organic soils in Finland (ha)

Year	Total ha	Cropland, annual ha	Cropland, perennial ha	Grassland ha
1990	295 211	74 035	135 568	85 608
1991	291 374	73 788	135 498	82 088
1992	287 454	73 425	134 889	79 140
1993	284 059	73 158	134 215	76 686
1994	280 938	72 918	133 585	74 435
1995	278 700	72 787	133 079	72 834
1996	276 946	80 896	124 265	71 785
1997	276 227	82 881	122 514	70 832
1998	275 750	84 279	121 434	70 037
1999	276 412	80 935	125 768	69 709
2000	277 907	85 116	123 378	69 413
2001	280 130	84 845	126 482	68 803
2002	284 128	87 980	127 590	68 558
2003	289 304	89 190	131 355	68 759
2004	294 001	93 875	131 427	68 699
2005	298 216	89 608	139 712	68 896
2006	302 452	103 022	130 041	69 389
2007	304 349	101 416	133 648	69 285
2008	305 597	105 618	131 087	68 892
2009	307 003	94 944	143 432	68 627
2010	308 458	86 393	153 877	68 188
2011	309 611	89 434	152 419	67 758
2012	311 457	90 712	153 181	67 564
2013	312 927	92 077	153 606	67 244

### 5.4.2.3 Emission factors and other parameters

IPCC default emission factors have been used for calculating nitrous oxide emissions from agricultural soils (Table 5.4-8) as no country-specific emission factors were available with an exception of organic grasslands. However, the emission factors for cropland organic soils on annual and perennial crops are based on IPCC Wetlands Supplement (Chapter 2). EF for organic grassland is country-specific (Maljanen et al. 2010b).

The values for  $\text{Frac}_{\text{GASF}}$  (1.5%) and  $\text{Frac}_{\text{GASM}}$  (8-9%) are country-specific 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 5.4.2.1 *Nitrogen mass flow model (agricultural soils)*).

For crop residue, plant biomasses and crop residues are estimated on the basis of group specific dry matter contents, harvest indices and shoot to root ratios. Country-specific parameters are used (Palosuo, Heikkinen & Regina: Method for estimating soil carbon stock changes in Finnish mineral croplands and grasslands. Manuscript) (see Appendix 6j). N contents are taken from the 2006 IPCC Guidelines (Table 5.4-8).

**Table 5.4-8** 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	0.01 kg $\text{N}_2\text{O}$ -N/kg N	2006 IPCC GLs, table 11.1
Animal wastes and sewage applied to soils	0.01 kg $\text{N}_2\text{O}$ -N/kg N	2006 IPCC GLs, table 11.1
N excretion on pasture range and paddock	0.02 and 0.01 kg $\text{N}_2\text{O}$ -N/kg N	2006 IPCC GLs, table 11.1
Crop residue	0.01 kg $\text{N}_2\text{O}$ -N/kg N input	2006 IPCC GLs, table 11.1
Mineralisation on mineral soils	0.01 kg $\text{N}_2\text{O}$ -N/kg N mineralised	2006 IPCC GLs, table 11.1
Cultivation of organic soils on annual crop (cropland)	13.0 kg $\text{N}_2\text{O}$ -N/ha/a	IPCC Wetlands Supplement (2013; table 2.5): Augustin <i>et al.</i> , 1998; Drösler <i>et al.</i> , 2013; Elsgaard <i>et al.</i> , 2012; Flessa <i>et al.</i> , 1998; Kasimir-Klemedtsson <i>et al.</i> , 2009; Maljanen <i>et al.</i> , 2003a,b, 2004, 2007; Petersen <i>et al.</i> , 2012; Regina <i>et al.</i> , 2004; Taft <i>et al.</i> , 2013
Cultivation of organic soils on perennials (cropland)	9.5 kg $\text{N}_2\text{O}$ -N/ha/a	IPCC Wetlands Supplement (2013; table 2.5): Grønlund <i>et al.</i> , 2006; Hyvönen <i>et al.</i> , 2009; Jaakkola, 1985; Maljanen <i>et al.</i> , 2001, 2003a, 2004, 2009, 2010a; Nykänen <i>et al.</i> , 1995; Regina <i>et al.</i> , 1996, 2004
Cultivation of organic soils (grassland)	5.7 kg $\text{N}_2\text{O}$ -N/ha/a	Maljanen et al. (2010b)
Atmospheric deposition	0.01 kg $\text{N}_2\text{O}$ -N/kg $\text{NH}_3$ -N & $\text{NO}_x$ -N deposited	2006 IPCC GLs, table 11.3
Nitrogen leaching and run-off	0.0075 kg $\text{N}_2\text{O}$ -N/kg N/a	2006 IPCC GLs, table 11.3

**Table 5.4-9** 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	Fra <sub>CLEACH</sub>	0.3	2006 IPCC GLs
Fraction of N input that volatilises as NH <sub>3</sub> and NO <sub>x</sub> from synthetic fertilisers	Fra <sub>CGASF</sub>	0.015	Based on Nitrogen mass flow model, Grönroos et al. (2009). EEA 2007.
Fraction of manure N input* that volatilises as NH <sub>3</sub> and NO <sub>x</sub>	Fra <sub>CGASM</sub>	0.08-0.09	Based on Nitrogen mass flow model, Grönroos et al. (2009)

\*pasture&manure&bedding application, same Fra<sub>CGasm</sub> is used for sewage

### 5.4.3 Uncertainty and time series' consistency

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 (LUKEAgri 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 the 2006 IPCC Guidelines (-70...+200). Uncertainties in the national emission factors for nitrous oxide from histosols are estimated at -37...+38% (cereals) and -52...+47% for perennials (lognormally distributed) based on IPCC Wetlands Supplement 2013. For grassland the uncertainty is estimated to be ±64% (Maljanen 2010b). The uncertainty in indirect nitrous oxide emission factor from atmospheric deposition is estimated at -80...+400% based on uncertainty range in the 2006 IPCC Guidelines and the uncertainty in indirect nitrous oxide emission factor for leaching is -66...+167%. 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 3.B). Uncertainty estimates of other activity data were based on expert judgement.

As the same calculation methods are used for the whole time series 1990-2013, the time series can be considered consistent (see also Sections 5.2.3 and 5.3.3 for animal numbers and manure management data).

### 5.4.4 Category-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 1.2.3. The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives. The bilateral quality meeting is held annually between the inventory unit and the sectoral expert. In the quality meeting 2015 for example the ERT Review and National Inventory Report text were discussed as well as changes to calculation due to Guidelines 2006.

#### General Quality Control (QC) procedures applied to the category Agricultural soils (CRF 3.D):

The QA/QC plan for the agricultural sector includes the QC measures presented in the the 2006 IPCC Guidelines (Vol 1, Chapter 6, Table 6.1). 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 (LUKEagri check) is used during the inventory. The check includes for example checking formulas, links between sheets and evaluating correctness of parameters used with cross-checks to previous years. No errors were detected for this inventory. The results from the N model are compared with a more simple

calculation periodically to examine possible problems with the model. Due to FCCC/ARR/2014/FIN comments, e.g. the explanation of change in agricultural production in early 1990s was added to Section 5.4.1.

#### Category-specific QC for activity data:

A checklist (LUKEagri check) 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.

#### Category-specific QC for emission factors:

It is checked annually if new data for updating emission factors has been published. For organic grassland a national EF was chosen (see Section 5.4.2.1).

#### Quality assurance and verification:

The calculation models are sent yearly to another institute to a person who is not directly involved in calculating greenhouse gas emissions from agriculture at national level. Instead, this person uses the models for emission calculation at the regional level in Finland and informs the national inventory expert of any errors found in the models.

In 2015 there will be a comparison of IEFs of enteric fermentation with Swedish values. In upcoming years, comparisons will be done for other agricultural sectors as well.

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.

### *5.4.5 Category-specific recalculations*

Calculation now follows the 2006 IPCC Guidelines and IPCC Wetlands Supplement (IPCC 2013) (organic soil EFs for annual and perennial crops). Area of organic soils (annual, perennial) diminished as the area of Dystric gleysols was excluded from the area of organic soils and this decreases emissions by about 30% compared with 2006 Guidelines calculation with old areas. Animal waste management system (AWMS) data update had impact especially on pasture emissions which would be about 30% higher with old AWMS data for year 2012. Adding N<sub>2</sub> and NO emissions to nitrogen cycle had only minor effect on the manure N application on fields (decrease of few per cent).

### *5.4.6 Category-specific planned improvements*

There are no planned improvements.

## 5.5 Field Burning of Agricultural Residues (CRF 3.F)

### 5.5.1 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. It is becoming increasingly rare, though some exceptional weather conditions can enhance burning (if harvesting is difficult). The machinery is usually able to manage the excess straw left on fields after harvesting. Cereal 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 5.5-1** 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
3.F.1	Cereals	CH <sub>4</sub> , N <sub>2</sub> O	D	D
3.F.2	Pulses	NA	NA	NA
3.F.3	Tubers and roots	NA	NA	NA
3.F.4	Sugar cane	NO	NA	NA
3.F.5	Other	NA	NA	NA

### 5.5.2 Methodological issues

#### 5.5.2.1 Methods

The emissions were calculated according to the 2006 IPCC Guidelines chapter 2 equation 2.27 with slight modification. Quantity of dry residue (straw) left on fields per hectare for each cereal was calculated first. Total dry above-ground biomass (see Crop residue calculation, BM<sub>AG</sub>) was obtained, after which harvest biomass was diminished. This resulted in straw residue per hectare, and harvest losses left on field were included as well. Residue per hectare was multiplied with area of each cereal and then with fraction burned, combustion factor and emission factors.

#### 5.5.2.2 Activity data

The annual crop yields for cereals and other crops were based on data from the Yearbook of Agricultural Statistics and the areas for cultivated cereals were also obtained from TIKE (the Information Centre of the Ministry of Agriculture and Forestry). The share of burned residue from total cereal residue on the fields for the years 1990-2013 was re-evaluated and simplified. The situation of residue burning for years 2013 (0.9%) and 2012 (0.7%) is rather accurately known as TIKE made an inquiry to the farmers. The situation in the beginning of the 1990's is, however, still highly uncertain. Most likely, burning has been more common than nowadays and expert opinion (2007) supports this. Therefore, field burning in the year 1990 was estimated to be twice as much as the average of years 2012 and 2013 and was assumed to rise linearly from year 2012 backwards.

**Table 5.5-2** Estimation of the burned fraction. Fraction of total residue burned is calculated by dividing the burned straw with total residue of all crops (as dry matter)

Year	Frac of residue burned, cereals	Frac of residue burned, total residue
1990	0.0160	0.0069
1995	0.0137	0.0059
2000	0.0117	0.0060
2001	0.0113	0.0056
2002	0.0109	0.0056
2003	0.0105	0.0053
2004	0.0101	0.0052
2005	0.0097	0.0049
2006	0.0093	0.0053
2007	0.0090	0.0050
2008	0.0086	0.0051
2009	0.0082	0.0043
2010	0.0078	0.0033
2011	0.0074	0.0037
2012*	0.0070	0.0035
2013*	0.0090	0.0045

\*an estimate based on TIKE inquiry

### 5.5.2.3 Emission factors and other parameters

Emission factors (table 2.5, chapter 2, 2006 IPCC GLs) are defaults. The default EF for N<sub>2</sub>O is 0.07, for CH<sub>4</sub> 2.7, for CO<sub>2</sub> 92 and for NO<sub>x</sub> 2.5. Combustion factor 0.9 is a default (table 2.6, 2006 IPCC GLs). Dry matter contents of crops are defaults but harvest index and harvest losses national data (see Crop residue calculation for details).

## 5.5.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 2. A description of uncertainty analysis is included in Section 1.6.

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 default emission factors for methane and nitrous oxide are not presented in the 2006 IPCC Guidelines chapter 2, table 2.5 and therefore are assumed to be -90%.. +100%, 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%.

As the same calculation methods are used for the whole time series 1990-2013, the time series can be considered consistent

## 5.5.4 Category-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 1.2.3. The QC procedures are performed according to the QA/QC plan in order

to attain these quality objectives. The bilateral quality meeting is held annually between the inventory unit and the sectoral expert. In the quality meeting 2015 for example the ERT Review and National Inventory Report text were discussed as well as changes to calculation due to Guidelines 2006.

General Quality Control (QC) procedures applied to the category Field burning of agricultural residues (CRF 3.F):

The QA/QC plan for the agricultural sector includes the QC measures presented in the the 2006 IPCC Guidelines (Vol 1, Chapter 6, Table 6.1) 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 (LUKEagri check) is used during the inventory. The check includes for example checking formulas, links between sheets and evaluating correctness of parameters used with cross-checks to previous years.

Category-specific QC for activity data:

A checklist (LUKEagri check) 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.

For Field burning of agricultural residues, better data for burned fraction were asked and received from TIKE (the Information Centre of the Ministry of Agriculture and Forestry) through an inquiry for years 2012 and 2013.

Category-specific QC for emission factors:

It is checked annually if new data for updating emission factors has been published. New national published experimental results were not available for this inventory.

Quality assurance and verification:

The calculation models are sent yearly to another institute to a person who is not directly involved in calculating greenhouse gas emissions from agriculture at national level. Instead, this person uses the models for emission calculation at the regional level in Finland and informs the national inventory expert of any errors found in the models.

In 2015 there will be a comparison of IEFs of enteric fermentation with Swedish values. In upcoming years, comparisons will be done for other agricultural sectors as well.

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.

### *5.5.5 Category-specific recalculations*

Calculation now follows the 2006 IPCC Guidelines. Time series of fraction burned was updated as more accurate data was obtained for the year 2012 and previous years were interpolated (year 1990 was assumed to be twice the share for year 2012). Year 1990 emissions increased c. 37% and year 2012 emissions 244%.

### *5.5.6 Category-specific planned improvements*

There are no planned improvements.

## 5.6 Liming (CRF 3.G)

### 5.6.1 Category description

Liming is used to reduce soil acidity and improve plant growth but adding carbonates to soils in the form of lime (e.g., calcic limestone ( $\text{CaCO}_3$ ), or dolomite ( $\text{CaMg}(\text{CO}_3)_2$ ) leads to  $\text{CO}_2$  emissions as the carbonate limes dissolve and release bicarbonate which evolves into  $\text{CO}_2$  and water. Emissions from liming of cropland and grassland are reported under Agriculture. Most of the lime use is assumed to take place on cropland, but a minor part is used on grassland. Forest lands are not limed in Finland. Emissions from liming have decreased slightly as the usage of lime has declined

### 5.6.2 Methodological issues

#### 5.6.2.1 Methods

The emissions from liming have been calculated using the IPCC method described in the 2006 Guidelines (eq. 11.12). Limestone ( $\text{CaCO}_3$ ), dolomite ( $\text{MgCa}(\text{CO}_3)_2$ ) 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  $\text{CO}_2$  by multiplying it by 44/12.

#### 5.6.2.2 Activity data

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 5.6-1). 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 5.6-1). The emissions were divided between limestone and dolomite (50:50). For the year 2013 the year 2012 figures were used.

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.

#### 5.6.2.3 Emission factors and other parameters

The IPCC default emission factors are used for calculating  $\text{CO}_2$  emissions from agricultural lime application. The emission factors are 0.12 for limestone and 0.13 for dolomite and 0.12 for briquette lime (the 2006 IPCC Guidelines).

**Table 5.6-1** The amount of lime sold annually (1,000 t/year). Statistics no longer available after year 2012

	<b>Cropland Limestone+ briquette lime</b>	<b>Dolomite</b>	<b>Grassland Limestone</b>	<b>Dolomite</b>	<b>Total</b>
1990	624	707	7	7	1 345
1995	603	238	8	8	856
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

### 5.6.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 2. A description of uncertainty analysis is included in Section 1.6.

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.

### 5.6.4 Category-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 1.2.3. The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives. The bilateral quality meeting is held annually between the inventory unit and the sectoral expert. In the quality meeting 2015 for example the ERT Review and National Inventory Report text were discussed as well as changes to calculation due to Guidelines 2006.

#### General Quality Control (QC) procedures applied to the category Liming (CRF 3.G):

The QA/QC plan for the agricultural sector includes the QC measures presented in the the 2006 IPCC Guidelines (Vol 1, Chapter 6, Table 6.1) 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 (LUKEagri check) is used during the inventory. The check includes for example checking formulas, links between sheets and evaluating correctness of parameters used with cross-checks to previous years.

#### Category-specific QC for activity data:

A checklist (LUKEagri check) 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.

Category-specific QC for emission factors:

It is checked annually if new data for updating emission factors has been published. New national published experimental results were not available for this inventory.

Quality assurance and verification:

The calculation models are sent yearly to another institute to a person who is not directly involved in calculating greenhouse gas emissions from agriculture at national level. Instead, this person uses the models for emission calculation at the regional level in Finland and informs the national inventory expert of any errors found in the models.

In 2015 there will be a comparison of IEFs of enteric fermentation with Swedish values. In upcoming years, comparisons will be done for other agricultural sectors as well.

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.

### *5.6.5 Category-specific recalculations*

Calculation follows the 2006 IPCC Guidelines. No recalculations were made.

### *5.6.6 Category-specific planned improvements*

The possibility of obtaining the yearly data of sold lime will be examined.

## 5.7 Urea application (CRF 3.H)

### 5.7.1 Category description

Urea fertilization to soils leads to a loss of CO<sub>2</sub>. Urea is converted into ammonium, hydroxyl ion, and bicarbonate in the presence of water and urease enzymes. Bicarbonate evolves into CO<sub>2</sub> and water. Finland does not have a method for estimating the consumption of urea in agriculture. Inquiry to the Information Centre of the Ministry of Agriculture and Forestry revealed that no survey has been done on the use of urea on fields. Expert judgements (e.g. from Yara; Marko Toimela 2013) reveal that hardly any urea is used in agriculture, most of it is used in forestry. Finland has a short growing season and acid soils which are not suitable for urea fertilizing. Annual CO<sub>2</sub> emissions from urea application to forests were 0.3 kilotons for 2013.

### 5.7.2 Methodological issues

#### 5.7.2.1 Methods

Urea fertilization CO<sub>2</sub> emissions are calculated following the 2006 IPCC Guidelines (eq. 11.13). Carbon is converted to CO<sub>2</sub> by multiplying it by 44/12.

#### 5.7.2.2 Activity data

The annual amount of urea fertilizer applied to forest soils was used as an activity data (data from Yara).

#### 5.7.2.3 Emission factors and other parameters

Default EF of 0.2 was applied to estimate CO<sub>2</sub> emissions, based on the 2006 IPCC Guidelines.

### 5.7.3 Uncertainty and time series' consistency

Uncertainty estimates were based on the 2006 IPCC Guidelines. The time series was checked for the consistency.

### 5.7.4 Category-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 1.2.3. The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives. The bilateral quality meeting is held annually between the inventory unit and the sectoral expert.

For example, as a general QC check the multiplication of activity data and emission factor was double checked for CO<sub>2</sub> emissions from urea fertilisation.

### 5.7.5 Category-specific recalculations

CO<sub>2</sub> emissions from urea fertilization were estimated for the first time for 2013 and no recalculations were made.

### 5.7.6 Category-specific planned improvements

No improvements are currently planned.

## Appendix\_5a

### The equations used in the calculation of greenhouse gas emissions from the Agriculture sector

#### Enteric Fermentation

For enteric fermentation calculation the, equations 10.19 and 10.20 in the 2006 IPCC Guidelines are used:

Methane emission (kt/year) = emission factor (*EF*) (kg/animal/year) x number of animals/(10<sup>6</sup> kg/kt)

Total CH<sub>4</sub> emissions =  $\sum E_i$

*Index i* = sums all livestock categories and subcategories

*E<sub>i</sub>* = emissions for the *i*<sup>th</sup> livestock categories and subcategories

#### 1) 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 10.21 in the 2006 IPCC Guidelines:

$EF = (GE * Y_m * 365 \text{ days/year}) / (55.65 \text{ MJ/kg CH}_4)$ , 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 0.065 used)

The country-specific 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. 10.16 in the 2006 IPCC Guidelines.

$GE = \{[(NE_m + NE_a + NE_l + NE_p)/REM] + [(NE_g)/REG]\} / (DE/100)$

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 been excluded: *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>*, *NE<sub>g</sub>*, *REM*, *REG* are as follows:

$NE_m = C_{fi} * (\text{Cattle weight})^{0.75}$

$NE_a = [C_{ap} * t_p/365 + C_{ao} * (1 - t_p/365)] * NE_m$

$NE_l = \text{Milk} * (1.47 + 0.40 * \text{Fat})$

$NE_p = C_p * NE_m$

$NE_g = 22.02 * (BW/(C * MW))^{0.75} * WG^{1.097}$

$REM = [1.123 - (4.092 * 10^{-3} * DE) + [1.126 * 10^{-5} * (DE)^2] - (25.4/DE)]$

$REG = [1.164 - (5.160 * 10^{-3} * DE) + (1.308 * 10^{-5} * (DE)^2) - (37.4/DE)]$

where,

$C_{fi}$  = Coefficient, the IPCC default value 0.322 is used for heifers and calves and 0.379 for dairy (for non-lactation time (11% of time)  $C_{fi}$  is 0.322, otherwise 20% higher), 0.399 for suckler cows (mean of lactating/non-lactating + effect of outdoor temperature (60% outdoors)) and 0.400 for bulls (0.370 + effect of outdoor temperature (40% outdoors))

$C_{fi}(in\_cold) = C_{fi} + 0.0048 \cdot (20 - ^\circ C)$  (eq. 10.2 the 2006 IPCC Guidelines) (for temperature, cool and cold season temperatures of Central Finland used)

$t_p$  = Length of pasture season

$C_{ap}$  = Coefficient for pasture, the IPCC default value 0.17 used

$C_{ao}$  = Coefficient for stall, the IPCC default value 0.00 used

$Milk$  = 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 (weighted with 0.9 for suckler cows and 0.8 for dairy cows)

$BW$  = the average live body weight (BW) of the animals in the population, kg

$C$  = Coefficient related to growth, bulls 1.2, heifers 0.8 and calves an average of these, 1, was used

$MW$  = the mature live body weight of an adult in moderate body condition, kg

$WG$  = Average weight gain (kg/day), 0.04-0.06 for dairy cows, 0.02-0.03 for suckler cows, 0.6-0.7 for bulls, 0.4-0.5 for heifers and 0.8-1.0 for calves were used (weight gain increases in time series). Average daily weight gain figures are from the same data as nitrogen excretion calculations. The functions in use are based on age and mature weight and with them the growth and weight on each day can be calculated and average value is taken for weight gain. (J. Nousiainen)

$DE$  = Digestible energy expressed as a percentage of gross energy, the proportion of feed energy (%) not excreted with feces, 70 was used for dairy and bulls, 64 for suckler cows, 69 for heifers and 71.5 for calves (country-specific values)

DE calculation of cattle (J. Nousiainen): Typical feeding per cattle subgroup is based on expert judgement and data from ProAgria. Properties of fodder are from feed tables: <https://portal.mtt.fi/portal/page/portal/Rehutaulukot/Rehutaulukot/marehtijat>. Digestible energy is calculated from gross energy by using digestibility coefficients (from feed tables):

Digestible energy =  $0.0226 \cdot \text{crude protein} \cdot 10 \cdot (\text{crude protein digestibility coefficient}) + 0.0407 \cdot \text{crude fat} \cdot 10 \cdot (\text{crude fat digestibility coefficient}) + 0.0192 \cdot \text{crude fibre} \cdot 10 \cdot (\text{crude fibre digestibility coefficient}) + 0.0177 \cdot \text{nitrogen free extracts} \cdot (\text{nitrogen free extracts digestibility coefficient})$

Refinement was made for dairy cattle because DE is smaller due to higher level of feeding. OMD (organic matter digestibility) was solved from formula (Journal of Dairy Sci. 96 :1–18, Development of equations for predicting methane emissions from ruminants. M. Ramin and P. Huhtanen, page 3):

OMDm (maintenance level of feeding, g/kg) =  $OMD + 1.83 \cdot (DMIBW - 10)$ , where OMD and DMIBW (Dry matter intake per kilogram of body weight) are expressed in grams per kilogram.

It was assumed that DE decreases in the same proportion.

National data for average milk production, animal weight and fat content of milk and the IPCC default value for methane conversion rate ( $Y_m = 0.065$ ) have been used.

## 2) Equations for calculating methane emissions from enteric fermentation of sheep and reindeer

$EF = (GE \cdot Y_m \cdot 365 \text{ days/year}) / (55.65 \text{ MJ/kg } CH_4)$  (IPCC 2006)

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 0.065 used)

The equation for calculating the GE for sheep and reindeer (McDonald et al. 1988, p.349):

$GE \left( \frac{MJ}{kg} \right) = 0.026 \cdot CP + 0.0407 \cdot EE + 0.0192 \cdot CF + 0.0177 \cdot NFE$  where CP, EE, CF and NFE are expressed as g/kg, CP is crude protein, EE is ether extract, CF is crude fibre and NFE is nitrogen free extracts

*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:

$((\text{GE (MJ/kg) for lichen} * \text{kg dm lichen} + \text{GE (MJ/kg) for hay} * \text{kg dm hay}) / 365 \text{ days})$

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 McDonald et al. (1988) has been used to calculate the GE for each forage separately.

CP, EE, CF and NFE are in g/kg. 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).

### *3) 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 weaned pigs based on their feed uptake. The Evapig program is used for calculating the methane energy (Evapig 2008, page 13) but the calculation method is laborious, therefore a ratio was developed which links the methane energy (by Evapig) to feed unit consumption. The formulas are (J. Nousiainen):

$\text{Methane E/ Feed units} = (\text{Age factor} + 0.02997 * \text{crude fiber (\%)} + \text{interaction} * \text{crude fiber (\%)})$

Age factors: growing pigs 0.004479, adult pigs 0.01075

Interaction: growing pigs -0.01748, adult pigs 0.000

Therefore, when feed unit consumption is known, methane energy can be obtained by multiplying consumption with the ratio.

About Evapig: The feed evaluation system of swine has been revised by MTT (now LUKE) feed value team in 2014 due to the need to update calculation principles for feed energy and protein. The new system was developed in France and is called INRA\_AFZ. In INRA\_AFZ the feed energies are based on net energy and they are calculated based on feed chemical properties by using feed specific or common equations. Growing and adult pigs have they own energy figures. In practice, the calculations are performed with EvaPig®-program which contains data of over hundred feed substances. The program calculates several energy contents (e.g. metabolizable energy) for feed ration and has formulas also for methane energy calculation.

#### 4) Equations for calculating methane emissions from enteric fermentation of horses, goats and fur animals

The EFs of horse and goat are defaults (IPCC Guidelines 2006) and the EF for fur animals is obtained from the inventory of Norway.

### Manure Management

#### 5) Equations for calculating nitrous oxide emissions from manure management

Direct nitrous oxide emissions from manure management have been calculated as follows:

$$N_2O\_Emissions\_manure\ management = \sum_{(S)} \{ [\sum_{(T)} (N_{(T)} * N_{ex(T)} * MS_{(T,S)})] * EF_{(S)} \} * 44/28$$

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)

$MS_{(T,S)}$  = 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 (now called Natural Resources Institute Finland). The distribution of manure management systems is country-specific data, based on Nitrogen mass flow model.

Indirect nitrous oxide emissions from manure management include atmospheric deposition and leaching/run-off. Deposition is calculated in N mass flow model: NH<sub>3</sub>-N and NO-N emissions from animal shelter, filling storage and storing phases are calculated and different abatement measures are taken into account. Dry lot volatilization (4.4% of nitrogen) is added to the volatilized amount. Total volatilized N is multiplied with default EF (0.01 kg N<sub>2</sub>O-N/kg N volatilized). Leaching/run-off is calculated from dry lot manure nitrogen. It is multiplied with Fraction leached (0.3) and EF (0.0075 kg N<sub>2</sub>O-N / kg N leached ) which are defaults. N<sub>2</sub>O-N is multiplied with 44/28 to obtain N<sub>2</sub>O emissions.

#### 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 10.23 in the 2006 IPCC Guidelines:

$$EF_i = (VS_i * 365 \text{ days/year}) * [Bo_i * 0.67 \text{ kg/m}^3 * \sum_{(jk)} MCF_{jk} * MS_{ijk}]$$

$VS_i$  = 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<sup>3</sup> CH<sub>4</sub>/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 (the 2006 IPCC Guidelines, Eq. 10.24). For swine, country-specific values are used for piglets (0.04) and weaned pigs (0.17) and for other swine groups they are defaults. For other animals (sheep, goats, horses, poultry, reindeer, fur animals) IPCC default values for VS have been used.

$$VS_{cattle} = [GE * (1 - DE/100) + (UE * GE)] * (1 - ASH/18.45)$$

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)

18.45 = conversion factor for dietary GE per kg of dry matter (MJ/kg)

UE\*GE = urinary energy expressed as fraction of GE, 0.04

Data about the distribution of different manure management systems have been received from the Nitrogen mass flow model. For the MCF, the 2006 IPCC Guidelines default values are used.

**Table 1\_App\_5** Methane conversion factors used for manure management

MCF	%
Slurry without natural crust	17
Slurry with crust	10
Solid storage (including urine)	2
Deep litter (cattle, swine)	17
'Deep litter' (poultry)	1.5
Deep litter (sheep, goats, horses)	1
Dry lot	1
Pasture	1
Fur animals	8
Reindeer	2

## Agricultural soils

### 7) Equations for calculating nitrous oxide emissions from agricultural soils

Nitrous oxide emissions from agricultural soils include emissions from synthetic fertilisers and organic N applied to soils, crop residues, manure deposited on pasture, N mineralisation associated with loss of soil organic matter resulting from management of mineral soils and drainage/management of organic soils.

*Direct nitrous oxide emissions from agricultural soils* (IPCC Guidelines 2006, Eq.11.1)

$$N_2O-N_{Direct} = (F_{SN} + F_{ON} + F_{CR} + F_{SOM}) * EF_1 + N_2O-N_{OS} + N_2O-N_{PRP}$$

$$N_2O_{Direct} = N_2O-N_{Direct} * 44/28$$

$F_{SN}$  = annual amount of synthetic fertiliser N applied to soils (=sold annually), kg N/a

$F_{ON}$  = annual amount of animal manure and sewage sludge applied to soils kg N/a

$F_{CR}$  = annual amount of N in crop residues (above-ground and below-ground) returned to soils, kg N/a  
(Calculation of  $F_{CR}$  is described in more detail in Appendix 6j)

$F_{SOM}$  = annual amount of N in mineral soils that is mineralised, in association with loss of soil C from soil organic matter as a result of changes to land use or management, kg N/a

$EF_1$  = emission factor for  $N_2O$  emissions from N inputs,  $EF$  is 0.01 kg  $N_2O-N$ / kg N input

$$F_{ON} = F_{AM} + F_{SEW} \text{ (Eq. 11.3)}$$

$F_{AM}$  = annual amount of animal manure N applied to soils, kg N/a

$F_{SEW}$  = annual amount of total sewage N used in agriculture, kg N/a (from the Finnish Environment Institute)

and  $F_{AM} = N_{MMSAvb}$  (Eq. 10.34)

$$N_{MMSAvb} = \sum_s \left\{ \sum_T \left[ \left[ (N_T * Nex_{(T)} * MS_{(T,S)}) * \left( 1 - \frac{Frac_{LossMS}}{100} \right) + [N_T * MS_{(T,S)} * N_{BeddingMS}] \right] \right] \right\}$$

$N_{MMSAvb}$  = amount of managed manure nitrogen available for application to managed soils, kg N/a

$N_T$  = number of head of livestock species/category  $T$  in the country

$Nex_{(T)}$  = annual average N excretion per animal of species/category  $T$  in the country, kg N/animal/a(MTT)

$MS_{(T,S)}$  = fraction of total annual nitrogen excretion for each livestock species/category  $T$  that is managed in manure management system  $S$  in the country

$Frac_{LossMS}$  = amount of managed manure nitrogen for livestock category  $T$  that is lost in the manure management system  $S$ , % (for manure,  $N_2O$ ,  $NH_3$ ,  $NO$  and  $N_2$  emissions during storage have been subtracted before manure N is applied to soils)

$N_{BeddingMS}$  = amount of nitrogen from bedding (solid storage and deep bedding), kg N/animal/a (estimate)

$S$  = manure management system

$T$  = species/category of livestock

$$F_{SOM} = \left[ \left( \Delta C_{Mineral, CLrem} * \frac{1}{R} \right) * 1000 \right] \text{ (Eq. 11.8 modified)}$$

$F_{SOM}$  = the net annual amount of N mineralised in mineral soils as a result of loss of soil carbon through change in land use or management, kg N

$\Delta C_{Mineral, CLrem}$  = average annual loss of soil carbon for Cropland remaining cropland, tonnes C (from former Finnish Forest Research Institute, now Natural Resources Institute Finland)

$R = 13$

$$N_2O - N_{OS} = F_{OS,perennial} * EF1 + F_{OS,annual} * EF2 + F_{GL} * EF3 \text{ (Eq. 11.1 modified)}$$

$N_2O - N_{OS}$  = nitrous oxide N from managed/drained organic soils

$F_{OS}$  = annual area of managed/drained organic soils, ha

$EF1$  = EF for Cropland remaining and converted, perennials, 9.5 kg  $N_2O - N$ /ha/year (IPCC Wetlands Supplement 2013)

$EF2$  = EF for Cropland remaining and converted, annual crops 13.0 kg  $N_2O - N$ /ha/year (IPCC Wetlands Supplement 2013)

$EF3$  = EF for Grassland, 5.7 kg  $N_2O - N$ /ha/year (Maljanen et al. 2010b)

The areas of cultivated organic soils have been received from Finnish Forest Research Institute (now Luke, National Resources Institute Finland).

$$N_2O - N_{PRP} = F_{PRP,CPP} * EF_{PRP,CPP} + F_{PRP,SO} * EF_{PRP,SO} \text{ (Eq. 11.1)}$$

$F_{PRP}$  = annual amount of urine and dung N deposited by grazing animals on pasture, range and paddock, kg N yr<sup>-1</sup>, CPP refer to cattle, poultry and pigs, and SO to sheep and other animals

$EF_{PRP,CPP} = 0.02$  kg  $N_2O - N$  (kg/N)

$EF_{PRP,SO} = 0.01$  kg  $N_2O - N$  (kg/N)

### *Indirect nitrous oxide emissions from agricultural soils*

*Atmospheric deposition* (IPCC Guidelines 2006, Eq.11.9 modified)

$$N_2O_{AD} - N = \left[ (F_{SN} * Frac_{Gasf}) + (F_{MN} * Frac_{Gasm1} + F_{SW} * Frac_{Gasm2} + F_{PRP} * Frac_{Gasm3}) \right] * EF$$

$F_{SN}$  = annual amount of synthetic fertiliser N applied to soils (=sold annually), kg N/a

$Frac_{Gasf} = c.$  0.015 kg N volatilized/kg of N applied (from Nitrogen mass flow model, country-specific)

$F_{MN}$  = annual amount of animal manure applied to soils, kg N/a

$Frac_{Gasm1} = c.$  0.08-0.1 kg N volatilized/kg of N applied (not including dry lot & pasture)

$F_{SW}$  = annual amount of sewage applied to soils, kg N/a

$Frac_{Gasm2} = c.$  0.08-0.09 kg N volatilized/kg of N applied or deposited (not including dry lot, including pasture)

$F_{PRP}$  = annual amount of urine& dung N deposited by grazing animals on pasture, kg N/a

$Frac_{Gasm3} = c.$  0.044 kg N volatilized/kg of N deposited

$Frac_{Gasm}$  and  $Frac_{Gasf}$  are calculated from the data acquired from the N mass flow model.

$EF = 0.01$  kg  $N_2O - N$ /kg N volatilized (default)

*Nitrogen leaching and run-off (IPCC Guidelines 2006, Eq.11.10)*

$$N_2O - N = (F_{SN} + F_{ON} + F_{PRP} + F_{CR} + F_{SOM}) * \text{Frac}_{LEACH} * EF$$

$N_2O - N$  = annual amount of  $N_2O - N$  produced from leaching and runoff of N additions to managed soils, kg  $N_2O - N/a$

$F_{SN}$  = annual amount of synthetic fertiliser N applied to soils, kg N/a

$F_{ON}$  = annual amount of managed animal manure and sewage sludge applied to soils, kg N/a

$F_{PRP}$  = annual amount of urine and dung N deposited by grazing animals, kg N/a

$F_{CR}$  = amount of N in crop residues (above- and below-ground returned to soils annually, kg N/a

$F_{SOM}$  = annual amount of N mineralised in mineral soils associated with loss of soil C from soil organic matter as a result of soil management (Cropland remaining cropland), kg N/a

$\text{Frac}_{LEACH}$  = fraction of all N added to/mineralised in managed soils that is lost through leaching and runoff, 0.3 kg N/kg of N additions (default)

$EF$  = emission factor for  $N_2O$  emissions from N leaching and runoff, 0.0075 kg  $N_2O - N/kg$  N leached and runoff (default)

### **Field burning of agricultural residues**

*8) Equations for calculating field burning of agricultural residues (cereal straw) (IPCC Guidelines 2006 eq.2.27 modified)*

$$L_{fire} = M_{DM} * \text{Frac}_B * C_f * G_{ef} * 10^{-3}$$

where,

$L_{fire}$  = amount of greenhouse gas emissions from fire, tonnes of each GHG

$M_{DM}$  = quantity of cereal crop residue left on field, kg DM

$\text{Frac}_B$  = fraction burned on field

$C_f$  = combustion factor

$G_{ef}$  = emission factor, g kg<sup>-1</sup> dry matter burnt (defaults used, 2.7 for methane, 0.07 for  $N_2O$ , 92 for CO and 2.5 for  $NO_x$ )

### **Liming**

*9) Equations for calculating Liming emissions (IPCC Guidelines 2006 eq. 11.12)*

$$CO_2 \text{ emission} = (M_{limestone} * EF_{limestone}) + (M_{dolomite} * EF_{dolomite})$$

$CO_2$  emission = annual C emissions from lime application, tonnes C/a

$M$  = annual amount of calcic limestone ( $CaCO_3$ ) or dolomite ( $CaMg(CO_3)_2$ ), tonnes/a

$EF$  = emission factor, tonne of C/tonne of limestone or dolomite, defaults used 0.12 for limestone and 0.13 for dolomite

### **Urea application**

*10) Equations for calculating Urea emissions (IPCC Guidelines 2006 eq. 11.13)*

$$CO_2 \text{ emission} = M * EF * \frac{44}{12}$$

$CO_2$  emission = annual C emissions from urea application, tonnes C/a

$M$  = annual amount of urea fertilisation, tonnes urea/a

$EF$  = emission factor, tonnes of C/(tonnes of urea), default 0.20

## Appendix\_5b

### Activity data for the Agricultural sector

Table 1\_App\_5b. Animal numbers in Finland (x 1000)

Year	Cattle				Swine					
	Dairy cows	Suckler cows	Heifers >1 yr	Bulls >1 yr	Calves <1 yr	Sows (w. piglets)	Piglets	Fattening pigs	Boars	Veaned pigs
1990	489.90	14.20	218.80	148.90	487.90	178.76	445.72	437.71	5.93	313.27
1991	445.60	21.20	213.50	144.10	485.50	173.96	433.75	425.96	5.77	304.86
1992	428.20	27.90	211.10	143.30	462.70	167.96	418.78	411.26	5.57	294.34
1993	426.40	33.10	216.70	139.20	436.90	164.69	410.65	403.27	5.47	288.62
1994	416.70	32.60	214.80	143.50	425.40	168.01	418.91	411.38	5.58	294.43
1995	398.50	29.20	188.90	109.30	422.00	161.10	475.70	450.80	6.50	306.10
1996	392.20	31.10	201.10	114.70	406.50	179.80	455.50	444.70	6.60	308.80
1997	390.90	32.40	196.80	120.50	401.80	185.20	437.60	470.40	7.10	366.70
1998	383.05	30.58	190.35	114.75	398.35	186.50	428.70	420.60	7.80	357.40
1999	372.40	29.60	187.50	118.10	379.20	180.20	437.30	431.10	5.80	296.90
2000	364.12	27.83	185.00	114.89	364.76	184.30	411.70	404.90	6.00	289.20
2001	354.83	27.18	181.73	111.34	362.34	163.60	408.90	391.20	5.40	291.60
2002	347.78	28.13	179.98	115.28	354.21	172.20	436.70	404.80	5.30	296.00
2003	333.87	28.15	178.54	115.46	344.15	178.10	450.70	444.00	5.00	297.10
2004	324.38	30.83	173.09	110.45	330.39	175.00	452.40	441.20	4.70	291.30
2005	318.76	34.61	168.78	107.81	328.97	176.70	451.00	459.70	4.40	309.30
2006	309.42	38.91	170.83	112.47	317.66	170.89	477.50	457.42	4.04	326.61
2007	296.07	43.28	166.47	109.78	311.10	174.60	427.75	496.69	4.07	344.93
2008	289.28	48.22	164.74	108.52	304.58	168.63	451.69	504.34	3.88	354.23
2009	290.04	51.82	162.55	109.51	304.35	152.86	396.24	491.88	3.18	337.05
2010	289.34	55.37	163.77	114.22	303.11	150.54	409.33	487.78	3.12	316.17
2011	285.53	57.26	161.92	110.78	298.56	142.69	391.82	470.51	3.26	326.83
2012	283.62	57.95	159.66	108.59	302.95	133.14	375.04	477.14	2.67	302.31
2013	283.12	57.33	161.80	109.63	299.97	124.95	359.54	489.71	2.25	323.93

N.B. Fattening pigs = 50+ kg and veaned pigs = 20-50 kg

Year	Poultry						Sheep	Goats	Horses	Ponies	Minks & fitches	Foxes & racoons	Reindeer
	Laying hens	Broilers	Chickens	Cockerels	Broiler hens	Turkeys Other poultry							
1990	4844.80	2993.00	1632.50	49.70	61.83	59.90 20.77	103.30	5.90	39.40	6.00	1804.89	1477.65	239.07
1991	4138.00	3249.68	1303.50	44.80	97.20	63.92 31.80	106.70	5.35	41.73	6.39	1505.20	1091.60	259.61
1992	3968.90	3506.36	1597.50	39.90	132.57	67.94 42.93	108.40	4.80	42.72	6.40	1576.25	1272.31	231.64
1993	4024.90	3763.04	1522.30	35.00	167.94	71.96 54.06	120.40	4.80	42.65	6.33	1658.74	1220.81	215.36
1994	4089.80	4019.72	1421.60	30.10	203.31	75.98 65.19	121.10	5.70	42.13	6.16	1639.39	1644.72	214.27
1995	4178.80	4276.40	1482.30	25.20	239.80	80.00 75.20	158.60	6.00	43.71	6.23	1944.66	1803.90	208.14
1996	4183.50	4052.40	1245.60	24.60	278.60	95.80 54.30	149.50	6.50	45.62	6.41	1801.32	2343.89	212.85
1997	4151.50	4911.10	1287.80	32.00	299.20	111.60 33.40	150.10	8.00	47.87	6.75	1828.21	2493.41	202.62
1998	3801.80	5507.20	1184.70	29.50	347.10	144.80 34.50	128.29	8.11	49.24	6.90	1646.03	2321.78	196.14
1999	3361.30	5998.20	1025.30	17.20	382.40	210.00 39.20	106.60	7.90	49.60	6.60	1732.71	1972.34	195.44
2000	3110.00	7917.90	914.40	17.60	363.50	214.50 31.60	99.60	8.60	50.70	6.70	1497.86	1862.64	203.42
2001	3201.70	5412.10	1043.00	12.40	393.90	455.40 35.10	96.00	7.45	51.90	6.70	1398.71	1544.16	185.73
2002	3212.50	5766.30	772.30	9.40	401.60	530.50 41.40	95.88	6.61	52.10	7.00	1407.66	2002.59	199.71
2003	3016.20	6050.30	930.90	10.10	346.00	603.40 40.20	98.41	6.76	52.90	7.29	1378.50	2204.85	196.73
2004	3069.20	5573.20	911.60	10.40	287.40	535.30 18.10	108.89	7.27	53.76	7.30	1355.01	2174.68	201.06
2005	3127.60	5472.30	953.60	12.30	456.99	495.40 19.95	89.74	6.94	56.11	7.66	1465.75	2319.98	207.16
2006	3103.33	5366.14	844.01	13.40	404.54	492.64 14.95	116.65	6.67	58.05	8.00	1422.42	2025.37	197.80
2007	3134.43	5074.09	763.87	12.90	350.94	430.51 24.33	119.25	6.18	59.50	8.50	1768.26	1712.56	193.34
2008	3190.25	5674.55	865.46	18.51	338.86	414.77 19.26	122.22	5.92	60.55	8.80	1259.40	1440.34	195.42
2009	2926.09	4918.45	858.92	15.50	328.58	306.11 15.80	117.67	5.92	63.00	9.30	1327.40	2115.82	192.92
2010	3393.77	4616.21	837.85	14.24	432.64	279.67 12.43	125.67	4.89	64.60	9.70	1576.29	1897.96	193.65
2011	3304.31	5421.35	745.35	21.73	420.61	308.14 14.19	129.09	4.90	65.30	10.20	1114.52	1783.69	196.37
2012	3172.60	6038.34	743.44	27.09	470.63	294.64 13.84	130.01	4.89	65.00	10.40	1401.91	1973.89	191.92
2013	3432.19	6861.15	857.56	22.45	520.14	274.34 12.73	135.55	4.51	64.60	10.40	1401.91	1973.89	191.60

**Table 2\_App\_5b.** Cattle live weights and mature weights, kg (Source: Natural Resources Institute Finland LUKE)

Year	Dairy cow		Suckler cow		Bull (>1 year)		Heifer		Calf (<1 year)	
	Live weight	Mature weight	Live weight	Mature weight	Live weight	Mature weight	Live weight	Mature weight	Live weight	Mature weight
1990	520	540	585	596	442	815	351	542	187	679
1991	520	542	591	602	454	819	354	545	189	682
1992	515	538	596	608	451	816	353	543	188	680
1993	531	556	601	613	454	842	363	561	194	701
1994	535	561	607	619	463	851	368	567	196	709
1995	533	559	612	624	460	848	366	564	195	706
1996	535	561	618	630	466	853	368	567	197	710
1997	545	571	623	636	463	867	373	577	200	722
1998	547	575	629	641	460	872	375	580	200	726
1999	552	580	634	647	464	880	378	585	202	732
2000	569	596	640	652	474	903	387	601	207	752
2001	577	605	645	658	487	916	394	609	211	763
2002	585	613	651	663	508	927	403	617	215	772
2003	594	623	652	664	525	941	410	627	219	784
2004	605	634	675	684	538	959	417	639	224	799
2005	607	636	668	680	537	962	418	640	224	801
2006	613	642	674	687	547	972	424	647	227	810
2007	624	654	674	687	560	988	431	658	231	823
2008	628	658	684	698	563	997	436	664	234	830
2009	634	663	687	1 005	567	1 005	440	670	236	838
2010	645	675	710	723	581	1 027	449	684	241	856
2011	649	678	716	729	577	1 033	450	688	242	861
2012	649	679	692	703	567	1 026	447	684	239	855
2013	647	676	691	703	567	1 023	444	681	238	852

**Table 3\_App\_5b.** 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. Natural Resources Institute Finland LUKE)

Year	Dairy cows	Suckler cows	Bulls	Heifers	Calves	Fattening pigs	Weaned pigs	Boars	Sows (including piglets) <sup>1</sup>	Piglets
						(50- kg)	(20-50 kg)			
1990	91.3	62.5	47.1	39.5	27.2	18.3	8.8	19.6	27.8	IE
1995	96.6	64.2	50	42.3	29.1	17.4	8.5	19.1	26.5	IE
2000	107.7	66	54.1	45.5	32	17.5	8.6	17.8	26.8	IE
2001	110.5	66.3	56	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	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	17.6	9	20.5	29.1	IE
2008	124.7	68.7	66.9	52.8	38.3	17.6	9	20.3	29.5	IE
2009	126.9	68.9	67.1	53.6	39.1	17.5	9	20.3	29.5	IE
2010	129.2	70.3	68.7	54.9	40.1	17.6	9	20.5	29.9	IE
2011	129.6	70.7	68.1	55.1	40.2	17.5	9	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
2013	129.0	69.3	66.4	54.1	39.5	17.4	9.1	20.4	30.7	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 & fiches	Foxes & racoons
1990	0.6	0.4	0.4	1.1	0.6	59.4	43.4	8.5	1.2	2.1
1995	0.6	0.4	0.4	1.3	0.6	60.5	44.4	8.7	1.3	2.2
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	44	9.6	1.3	2.7
2005	0.6	0.4	0.4	1.5	0.7	61	43.6	9.9	1.3	2.8
2006	0.6	0.4	0.4	1.5	0.6	60.9	43.5	10	1.3	2.8
2007	0.6	0.4	0.4	1.5	0.6	61	43.3	10	1.3	2.9
2008	0.6	0.5	0.4	1.5	0.6	60.9	43.2	10	1.3	3
2009	0.6	0.5	0.4	1.6	0.6	61.2	43.4	10	1.3	3
2010	0.6	0.5	0.4	1.6	0.6	61.1	43.5	10	1.3	3
2011	0.6	0.5	0.4	1.6	0.6	61.3	43.5	10	1.3	3
2012	0.6	0.5	0.4	1.6	0.6	61.3	43.5	10	1.3	3
2013	0.6	0.5	0.4	1.7	0.6	61.6	43.7	10.0	1.3	3.0

**Table 4\_App\_5b** Fraction of manure managed in each manure management system (Sources: Grönroos et al. (2009) and Grönroos & Luostarinen (2013, based on a questionnaire to farms))

	1990	1995	2000	2005	2010	2011	2012	2013		1990	1995	2000	2005	2010	2011	2012	2013
<b>Dairy cows</b>									<b>Horses</b>								
Pasture	0.22	0.19	0.17	0.15	0.13	0.12	0.12	0.12	Pasture	0.36	0.36	0.36	0.36	0.39	0.38	0.36	0.36
Slurry	0.24	0.28	0.37	0.53	0.57	0.58	0.59	0.60	Slurry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solid storage	0.53	0.52	0.45	0.30	0.29	0.29	0.29	0.28	Solid storage	0.42	0.25	0.25	0.42	0.37	0.37	0.37	0.37
Deep litter	0.008	0.004	0.004	0.004	0.003	0.003	0.003	0.002	Deep litter	0.00	0.17	0.17	0.00	0.04	0.05	0.06	0.06
Dry lot	0.008	0.004	0.004	0.004	0.003	0.003	0.003	0.002	Dry lot	0.21	0.21	0.21	0.21	0.20	0.21	0.21	0.21
<b>Suckler cows</b>									<b>Reindeer</b>								
Pasture	0.35	0.36	0.36	0.36	0.41	0.41	0.42	0.42	Pasture	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Slurry	0.03	0.03	0.16	0.19	0.07	0.05	0.03	0.03	Slurry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solid storage	0.27	0.27	0.17	0.15	0.24	0.26	0.28	0.28	Solid storage	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Deep litter	0.13	0.12	0.12	0.12	0.10	0.09	0.09	0.09	Deep litter	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dry lot	0.22	0.21	0.18	0.17	0.18	0.18	0.18	0.18	<b>Laying hens</b>								
<b>Bulls (&lt;1 year)</b>									Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pasture	0.00	0.00	0.00	0.00	0.02	0.03	0.04	0.04	Slurry	0.00	0.02	0.02	0.02	0.07	0.08	0.09	0.09
Slurry	0.30	0.40	0.40	0.40	0.50	0.52	0.53	0.54	Solid storage	0.95	0.93	0.93	0.93	0.76	0.72	0.69	0.69
Solid storage	0.64	0.54	0.54	0.54	0.39	0.35	0.32	0.32	Deep litter	0.05	0.05	0.05	0.05	0.17	0.20	0.22	0.22
Deep litter	0.06	0.06	0.06	0.06	0.09	0.10	0.11	0.10	<b>Chickens</b>								
Dry lot	0.00	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	0.00
<b>Heifers</b>									Slurry	0.00	0.02	0.02	0.00	0.00	0.00	0.00	0.00
Pasture	0.36	0.35	0.35	0.35	0.28	0.26	0.24	0.24	Solid storage	0.95	0.93	0.93	0.95	0.70	0.65	0.60	0.60
Slurry	0.19	0.24	0.24	0.24	0.34	0.36	0.38	0.39	Deep litter	0.05	0.05	0.05	0.05	0.30	0.35	0.40	0.40
Solid storage	0.43	0.40	0.40	0.40	0.33	0.32	0.30	0.30									
Deep litter	0.01	0.01	0.01	0.01	0.03	0.03	0.04	0.03									
Dry lot	0.01	0.01	0.01	0.01	0.03	0.03	0.04	0.03									

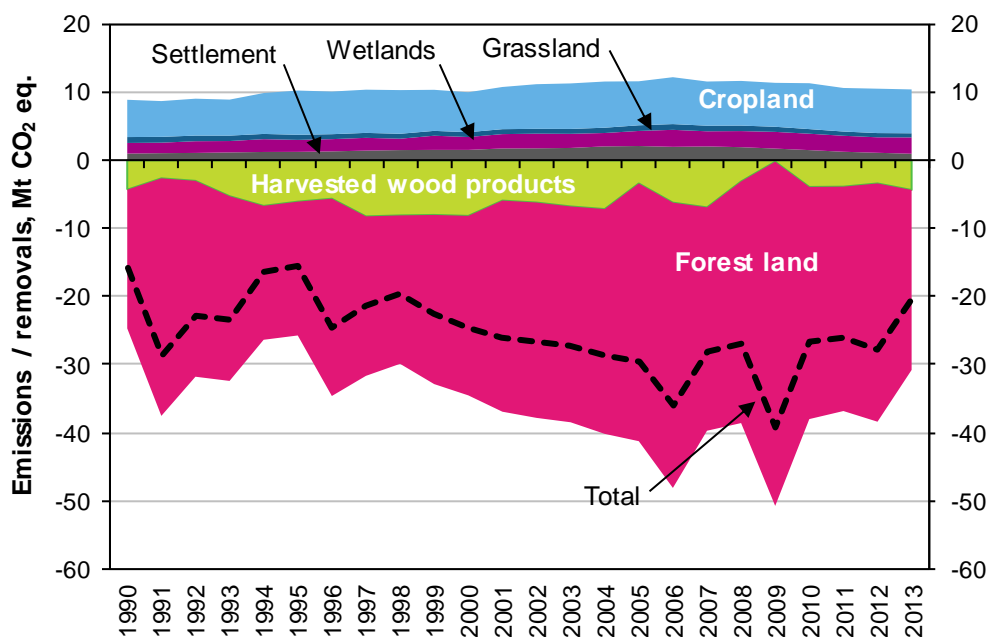
	1990	1995	2000	2005	2010	2011	2012	2013
<b>Calves (&lt;1 year)</b>								
Pasture	0.08	0.07	0.07	0.07	0.09	0.10	0.10	0.10
Slurry	0.28	0.35	0.35	0.35	0.34	0.34	0.33	0.34
Solid storage	0.55	0.55	0.55	0.55	0.45	0.43	0.41	0.40
Deep litter	0.05	0.01	0.01	0.01	0.06	0.07	0.08	0.08
Dry lot	0.05	0.01	0.01	0.01	0.06	0.07	0.08	0.08
<b>Swine</b>								
Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slurry	0.36	0.52	0.52	0.57	0.79	0.83	0.88	0.89
Solid storage	0.58	0.43	0.43	0.38	0.18	0.15	0.11	0.10
Deep litter	0.05	0.05	0.05	0.05	0.02	0.02	0.01	0.01
<b>Sheep</b>								
Pasture	0.36	0.32	0.32	0.32	0.35	0.35	0.35	0.35
Slurry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solid storage	0.06	0.07	0.07	0.07	0.25	0.29	0.33	0.33
Deep litter	0.57	0.61	0.61	0.61	0.40	0.36	0.33	0.33
<b>Goats</b>								
Pasture	0.36	0.32	0.32	0.32	0.35	0.35	0.35	0.35
Slurry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solid storage	0.06	0.07	0.07	0.07	0.25	0.29	0.33	0.33
Deep litter	0.57	0.61	0.61	0.61	0.40	0.36	0.33	0.33

	1990	1995	2000	2005	2010	2011	2012	2013
<b>Cockerels</b>								
Pasture	0.00	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	0.00
Solid storage	0.95	0.94	0.94	0.95	0.63	0.56	0.50	0.50
Deep litter	0.05	0.05	0.05	0.05	0.37	0.44	0.50	0.50
<b>Broiler hens</b>								
Pasture	0.00	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	0.00
Solid storage	0.00	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	1.00
<b>Broilers</b>								
Pasture	0.00	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	0.00
Solid storage	0.00	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	1.00

## 6 LAND USE, LAND-USE CHANGE AND FORESTRY (CRF 4)

### 6.1 Overview of the sector

The Land Use, Land-Use Change and Forestry (LULUCF) sector in 2013 as a whole acted as a CO<sub>2</sub> sink for -20.4 million tonnes of CO<sub>2</sub> equivalent (Mt CO<sub>2</sub> eq.) because the total emissions resulting from the sector were smaller than the total removals (Figure 6.1-1, Table 6.1-2). The sink in 2013 was 32% of the total national emissions, not including the LULUCF sector.



**Figure 6.1-1** Net emissions and removals in the LULUCF sector by land-use category and harvested wood products, Mt CO<sub>2</sub> eq.

Emissions and removals from the LULUCF sector were calculated and reported according to the 2006 IPCC Guidelines. Land area is divided into six land-use categories 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 2006).

The carbon stock changes and greenhouse gas emissions reported from LULUCF sector are listed in Table 6.1-1. Other land is considered as unmanaged land and the emissions and removals are not reported, or in the case of land-use change to Other land, the carbon stock changes and other emissions were judged to be zero. Emissions and removals from harvested wood products (HWP) are included in the LULUCF estimates.

A general assessment of completeness can be found in Section 1.7 and a more detailed assessment is included in Annex 5.

**Table 6.1-1** 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	Emissions reported	Methods	Emission factors
4.A	Forest land ( <i>remaining, converted</i> )				
	- living biomass	carbon/ CO <sub>2</sub>		Tier 3	CS
	- DOM, SOM (mineral and organic soils)	carbon/ CO <sub>2</sub>		Tier 3, Tier 2	CS
4.B	Cropland ( <i>remaining, converted</i> )				
	- living biomass	carbon/ CO <sub>2</sub>		Tier 3	CS, D
	- DOM, SOM (mineral and organic soils)	carbon/ CO <sub>2</sub>		Tier 3, Tier 2	CS, D
4.C	Grassland ( <i>remaining, converted</i> )				
	- living biomass	carbon/ CO <sub>2</sub>		Tier3	CS, D
	- DOM, SOM (mineral and organic soils)	carbon/ CO <sub>2</sub>		Tier 3, Tier 2	CS, D
4.D	Wetlands ( <i>remaining, converted</i> )				
	- peat extraction areas: living biomass	carbon/ CO <sub>2</sub>		Tier 3	CS
	- peat extraction areas: DOM, SOM	carbon/ CO <sub>2</sub>		Tier 2	CS
	- flooded land: living biomass	carbon/ CO <sub>2</sub>		Tier 3	CS
	- flooded land: DOM, SOM	carbon/ CO <sub>2</sub>		Tier 1	CS, D
	- other wetlands: SOM	carbon/ CO <sub>2</sub>		Tier 2	CS
4.E	Settlements ( <i>converted</i> )				
	- living biomass	carbon/ CO <sub>2</sub>		Tier 3	CS
	- DOM, SOM	carbon/ CO <sub>2</sub>		Tier 2	CS
4.F	Other land ( <i>converted</i> )				
	- living biomass	carbon/ CO <sub>2</sub>		Tier 1	D
	- DOM, SOM	carbon/ CO <sub>2</sub>		Tier 1	D
4.G	Harvested Wood Products	carbon/ CO <sub>2</sub>		Tier 2	D
4(I)	Direct N <sub>2</sub> O emissions from fertilisation				
	- Forest land		N <sub>2</sub> O	Tier 1	D
4(II)	Non-CO <sub>2</sub> emissions from drainage and rewetting and other management of organic and mineral soils <sup>1</sup>				
	- Wetlands: Peat extraction areas		CH <sub>4</sub> , N <sub>2</sub> O	Tier 2	CS
	- Wetlands: Flooded land		CH <sub>4</sub>	Tier 1	D
	- Other Wetlands		CH <sub>4</sub> , N <sub>2</sub> O	Tier 2	CS
	- Forest land: Drained organic forest soils		CH <sub>4</sub> , N <sub>2</sub> O	Tier 2, Tier 1	CS, D
4(III)	Direct non-CO <sub>2</sub> emissions from N mineralisation/immobilisation				
	-Settlements, Cropland, Grassland		N <sub>2</sub> O	Tier 1	CS, D
4(IV)	N <sub>2</sub> O emissions from N leaching and runoff				
	- Land converted to Cropland and Grassland		N <sub>2</sub> O	Tier 1	D
4(V)	Biomass burning				
	- Forest land		CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O, NO <sub>x</sub> , CO	Tier 2	CS, D

<sup>1</sup> N<sub>2</sub>O emissions from agricultural soils are reported under the Agriculture sector.

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. Harvested Wood Products have totalled a net sink even though the paper sub-category has in some years acted as a source. The level, trend and the inter-annual variability in the sink for the whole LULUCF sector are determined by the Forest Land sink (Figure 6.1-1).

In 2013, the estimated net sink in living biomass on Forest Land was 26.9 Mt 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 8.4 Mt CO<sub>2</sub>. In organic forest soils those carbon pools amounted to emissions of 6.8 Mt. The non-CO<sub>2</sub> emissions from drainage of Forest Land were 2.0 Mt CO<sub>2</sub> eq. Minor emission sources in the Forest Land category included N fertilisation on forest land (0.013 Mt CO<sub>2</sub> eq.) and biomass burning (0.006 Mt CO<sub>2</sub> eq.).

The high fluctuation in net biomass removals in the Forest Land category during the period 1990-2013 was mainly caused by the changes in the international market of forest industry products, which affected the amount of domestic commercial roundwood fellings. In 2013, the roundwood removals were at its highest level ever at 65 million m<sup>3</sup> (Finnish Statistical Yearbook of Forestry 2014). The other significant factor affecting the 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 2014).

In the cropland category mineral soils were a sink of -0.2 Mt CO<sub>2</sub> and organic soils were a source of 5.9 Mt CO<sub>2</sub> in 2013. Woody living biomass on cropland was only a minor source of CO<sub>2</sub>. Organic soils in the grassland category were a source of 0.9 Mt CO<sub>2</sub> in 2013 (Table 6.1-2, Figure 6.1-2).

In 2013, emissions in the Wetlands category were a source of 2.4 Mt CO<sub>2</sub> eq., of which emissions from peat extraction were 92%. The rest of the emissions come from flooded land and other wetlands.

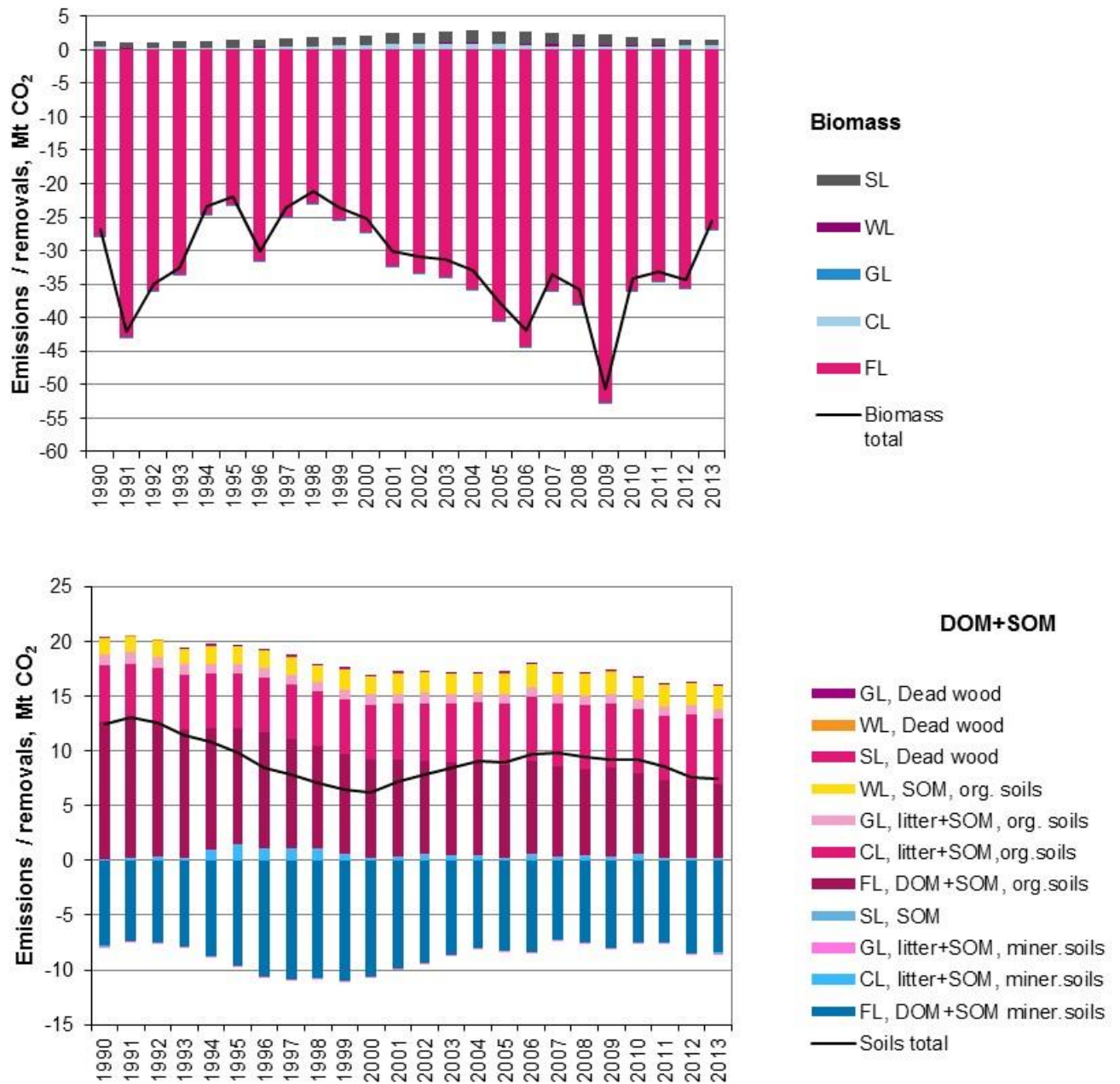
Emissions from Settlements were in 2013 a source of 1.0 Mt CO<sub>2</sub> eq. The CO<sub>2</sub> emissions consist of biomass and deadwood loss due to conversion and emissions from litter and soil organic matter after conversion. The N<sub>2</sub>O emissions are due to N mineralisation in the soil organic matter after conversion.

In 2013, harvested wood products constituted a carbon sink of 4.4 Mt CO<sub>2</sub> eq. 35% of the sink originated from domestically consumed HWP and 65% from the exported HWP. HWP have been a net sink for the whole reported time series. The most important component of the HWP sink is sawn wood. Paper and paperboard have acted both as a sink and as a source because they are sensitive to the changes in production due to short lifetime compared to other HWP.

Chapter 6 and emission and removal estimates for LULUCF are prepared by the Finnish Forest Research Institute (Metla) and MTT Agrifood Research Finland, which from 1 January 2015 continued their work in the new research institute Natural Resources Institute Finland (Luke)<sup>13</sup>.

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<sup>13</sup> Natural Resources Institute Finland <http://www.luke.fi/en/>



**Figure 6.1-2** Emissions (positive sign) and removals (negative sign) from biomass (upper) and from soils (soil and dead organic matter) (lower) in different land-use classes, Mt CO<sub>2</sub>. (FL = Forest Land, CL=Cropland, GL=Grassland, SL= Settlements, WL=Wetland)

**Table 6.1-2** Greenhouse gas emissions and removals from the LULUCF sector (Mt CO<sub>2</sub> eq.) (positive figures indicate emissions, negative removals)

Mt CO <sub>2</sub> eq.	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<b>4.A Forest land</b>	<b>-20.4</b>	<b>-19.7</b>	<b>-26.4</b>	<b>-31.0</b>	<b>-31.6</b>	<b>-31.7</b>	<b>-33.0</b>	<b>-37.9</b>	<b>-41.9</b>	<b>-32.8</b>	<b>-35.5</b>	<b>-50.6</b>	<b>-34.1</b>	<b>-33.0</b>	<b>-35.0</b>	<b>-26.4</b>
Biomass, mineral soils	-16.8	-10.7	-12.1	-16.5	-17.0	-17.4	-19.0	-23.1	-26.5	-19.4	-22.2	-34.6	-20.5	-19.3	-20.2	-12.9
Biomass, organic soils	-11.1	-12.5	-15.1	-15.9	-16.2	-16.5	-16.8	-17.3	-18.0	-16.6	-15.8	-18.2	-15.5	-15.3	-15.5	-14.0
DOM1+SOM, mineral soils	-7.8	-9.6	-10.6	-9.9	-9.3	-8.6	-8.0	-8.2	-8.3	-7.2	-7.5	-8.0	-7.5	-7.5	-8.5	-8.4
DOM1+SOM, organic soils	12.6	10.6	8.9	8.8	8.6	8.5	8.4	8.5	8.5	8.2	7.9	8.1	7.4	7.2	7.2	6.8
4(I) N fertilisation	0.021	0.005	0.007	0.008	0.009	0.009	0.009	0.008	0.014	0.013	0.027	0.019	0.017	0.016	0.012	0.013
4(V) Biomass burning	0.009	0.008	0.004	0.005	0.009	0.008	0.004	0.007	0.018	0.007	0.011	0.007	0.006	0.014	0.002	0.006
4(II) CH <sub>4</sub> and N <sub>2</sub> O emissions from drained forest land	2.63	2.55	2.44	2.41	2.38	2.35	2.32	2.28	2.25	2.22	2.15	2.09	2.02	1.96	1.96	1.96
<b>4.B Cropland</b>	<b>5.5</b>	<b>6.5</b>	<b>5.9</b>	<b>6.2</b>	<b>6.6</b>	<b>6.7</b>	<b>6.8</b>	<b>6.5</b>	<b>6.9</b>	<b>6.5</b>	<b>6.6</b>	<b>6.5</b>	<b>6.7</b>	<b>6.4</b>	<b>6.5</b>	<b>6.4</b>
Biomass	0.51	0.25	0.71	0.82	0.90	0.97	0.93	0.80	0.72	0.56	0.46	0.53	0.58	0.55	0.62	0.63
Dead wood	0.000	0.001	0.004	0.005	0.006	0.006	0.006	0.005	0.005	0.003	0.002	0.002	0.003	0.002	0.003	0.003
DOM2+SOM, mineral soils	-0.055	1.312	0.082	0.228	0.389	0.329	0.327	0.072	0.408	0.133	0.250	0.104	0.359	-0.002	-0.013	-0.154
DOM2+SOM, organic soils	5.02	4.92	5.07	5.13	5.25	5.37	5.51	5.57	5.74	5.78	5.84	5.81	5.79	5.85	5.90	5.95
4(III) N mineralisation	0.008	0.008	0.008	0.010	0.010	0.011	0.012	0.011	0.013	0.010	0.011	0.009	0.012	0.011	0.011	0.011
<b>4.C Grassland</b>	<b>0.9</b>	<b>0.8</b>	<b>0.7</b>	<b>0.7</b>	<b>0.7</b>	<b>0.7</b>	<b>0.8</b>	<b>0.8</b>	<b>0.8</b>	<b>0.8</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>
Biomass	-0.191	-0.160	-0.163	-0.141	-0.153	-0.152	-0.093	-0.048	-0.043	-0.060	-0.075	-0.133	-0.192	-0.240	-0.238	-0.242
Dead wood	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000
DOM2+SOM, mineral soils	-0.045	-0.026	-0.021	-0.019	-0.015	-0.013	-0.011	-0.008	-0.005	-0.004	-0.003	-0.003	-0.006	-0.010	-0.013	-0.014
DOM2+SOM, organic soils	1.10	0.93	0.89	0.88	0.88	0.88	0.88	0.88	0.89	0.89	0.88	0.88	0.88	0.87	0.87	0.86
4(III) N mineralisation	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001
<b>4.D Wetlands</b>	<b>1.6</b>	<b>1.8</b>	<b>1.9</b>	<b>2.1</b>	<b>2.2</b>	<b>2.1</b>	<b>2.0</b>	<b>2.2</b>	<b>2.5</b>	<b>2.2</b>	<b>2.4</b>	<b>2.5</b>	<b>2.4</b>	<b>2.3</b>	<b>2.3</b>	<b>2.4</b>
Biomass	0.001	0.106	0.076	0.075	0.072	0.112	0.094	0.140	0.162	0.238	0.223	0.208	0.168	0.164	0.096	0.086
Dead wood	0.000	0.002	0.001	0.001	0.001	0.001	0.001	0.002	0.003	0.004	0.003	0.003	0.002	0.002	0.001	0.001
SOM	1.44	1.52	1.67	1.88	1.93	1.81	1.72	1.92	2.18	1.82	1.98	2.08	2.07	2.01	2.01	2.14
4(II) CH <sub>4</sub> and N <sub>2</sub> O emissions	0.12	0.13	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.16	0.16	0.16	0.17	0.17	0.17	0.17
<b>4.E Settlement</b>	<b>1.0</b>	<b>1.2</b>	<b>1.5</b>	<b>1.7</b>	<b>1.8</b>	<b>1.8</b>	<b>2.0</b>	<b>2.1</b>	<b>2.0</b>	<b>2.0</b>	<b>1.9</b>	<b>1.7</b>	<b>1.5</b>	<b>1.3</b>	<b>1.1</b>	<b>1.0</b>
Biomass	0.80	1.05	1.33	1.54	1.55	1.60	1.82	1.87	1.74	1.80	1.69	1.48	1.26	1.03	0.88	0.74
Dead wood	0.013	0.017	0.023	0.025	0.025	0.026	0.032	0.034	0.033	0.033	0.032	0.025	0.020	0.015	0.012	0.009
SOM	0.16	0.16	0.16	0.17	0.17	0.17	0.18	0.18	0.19	0.19	0.20	0.20	0.20	0.20	0.20	0.20
4(III) N mineralisation	0.014	0.013	0.014	0.014	0.015	0.015	0.015	0.016	0.016	0.016	0.017	0.017	0.017	0.017	0.017	0.017
<b>4.G Harvested wood products</b>	<b>-4.3</b>	<b>-6.1</b>	<b>-8.2</b>	<b>-5.9</b>	<b>-6.2</b>	<b>-6.8</b>	<b>-7.2</b>	<b>-3.4</b>	<b>-6.2</b>	<b>-6.9</b>	<b>-3.1</b>	<b>-0.2</b>	<b>-3.9</b>	<b>-3.9</b>	<b>-3.4</b>	<b>-4.4</b>
4(IV) Indirect N <sub>2</sub> O emissions	0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.003	0.002	0.003	0.003	0.003	0.003
<b>4 Total CO<sub>2</sub> eq.</b>	<b>-15.8</b>	<b>-15.5</b>	<b>-24.5</b>	<b>-26.2</b>	<b>-26.6</b>	<b>-27.2</b>	<b>-28.6</b>	<b>-29.6</b>	<b>-35.9</b>	<b>-28.1</b>	<b>-26.9</b>	<b>-39.4</b>	<b>-26.7</b>	<b>-26.2</b>	<b>-27.9</b>	<b>-20.4</b>

1 Dead organic matter in dead wood and litter

2 Dead organic matter in litter

## 6.1.1 Key Categories

The key categories in the LULUCF sector in 2013 are summarised in Table 6.1-3.

**Table 6.1-3** Key categories in the LULUCF sector (CRF 4) in 2013 (Approach 1)

IPCC category	Gas	Identification criteria
4.A.1. Forest Land remaining Forest Land	CO <sub>2</sub>	L, T
4.A.2. Land converted to Forest Land	CO <sub>2</sub>	L, T
4.B.1. Cropland remaining Cropland	CO <sub>2</sub>	L, T
4.B.2. Land converted to Cropland	CO <sub>2</sub>	L, T
4.D.1.1. Peat Extraction remaining Peat Extraction	CO <sub>2</sub>	L, T
4.D.1.3. Other Wetlands remaining Other Wetlands	CO <sub>2</sub>	T
4.D.2. Land converted to Wetlands	CO <sub>2</sub>	T
4.E.2. Land converted to Settlements	CO <sub>2</sub>	L, T
4.G Harvested Wood Products	CO <sub>2</sub>	L, T
4.(II). Drainage and Rewetting and Other Management of Soils	CH <sub>4</sub>	L, T
4.(II). Drainage and Rewetting and Other Management of Soils	N <sub>2</sub> O	L, T

## 6.2 Land-use definitions and the classification systems used and their correspondence to the LULUCF

For the GHG inventory, Finland's land area and inland water bodies are classified according to the 2006 IPCC Guidelines. The data source for activity data of land use, that is the areas of land-use categories and sub-categories, is National Forest Inventory (NFI). The land and site-class classification scheme of NFI is employed to re-classify lands into the IPCC land-use categories (Tomppo et al. 2011, Table 6.2-1). The recommendation given by a working group on a follow-up system for land use and land-use changes in Finland was mainly followed (MMM 2005).

### *National application of IPCC land-use categories in the Finnish inventory*

**Forest Land.** The forest definition Finland has employed for the FAO's Forest Resource Assessments (FRA) is applied in the GHG inventory to define Forest Land (FRA 2010). The FAO definition for forest in FRA 2010 was: "Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds *in situ*. It does not include land that is predominantly under agricultural or urban land use." This definition was used for FRA 2010 except the requirement of the minimum area of 0.5 ha. Minimum area of forest land is not exact, but a guide of 0.25 ha for a forest stand in Southern Finland and 0.5 ha in Northern Finland is given. In Figure 6.2-1 are given the boundaries for Southern and Northern Finland. Young natural and planted stands established for forestry purposes that have yet to reach a crown density of 10% or a tree height of 5 m are included in forest, 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. For linear formations, a minimum width of 20 m is applied but as a part of continuous forest area in which forestry can be practised, the 20 m minimum width is not required. Parks and yards are excluded, regardless of whether they would meet the forest definition (FRA 2010). 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 Forest Land is considered managed land.

**Cropland.** The area of cropland comprises the area defined as arable crops, rotational grass, set-aside, permanent horticultural crops, greenhouses and kitchen gardens. All croplands are considered managed land.

**Grassland.** Grassland includes the area of extensive grass, 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 as Wetlands that have undergone a change in land management are considered managed lands.

**Settlements.** Settlements comprise built-up land, power supply lines and roads, which include roads and railroads with 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 bare soil and rock, vegetated lands on mineral soils, which do not fulfil the threshold values of Forest Land, or are not included in the other land-use categories. Typical sites are rocky lands and treeless mountain areas. Other Land is managed if it has converted from other land-use, otherwise it is considered unmanaged land.

**Table 6.2-1** Connection between the IPCC land-use categories and national land classification

National land class	
<p><i>Forest land</i> is land used or available for growing trees. The mean annual increment under favourable growing conditions and with recommended rotation length is at least 1 m<sup>3</sup>/ha including bark or 0.85 m<sup>3</sup>/ha excluding bark. Forest land includes afforested (planted or seeded) stands.</p> <p><i>Poorly productive forest land</i> is land used or available for tree growing. The mean annual increment is 0.10–0.99 m<sup>3</sup>/ha/year including bark.</p> <p><i>Unproductive land</i> is forestry land where potential growth is less than 0.10 m<sup>3</sup>/ha/year. Single, poorly growing trees and shrubs may occur on unproductive land.</p> <p><i>Other forestry land</i> includes forestry roads, seed production stands, permanent depots and built-up land related to forestry. It includes also gravel pits, and game feeding areas etc. within forests.</p> <p><i>Arable land</i> includes fields, pastures, and waste land inside these land use classes, small roads and buildings (other than houses) used for agriculture. It also includes <i>abandoned arable lands, without or with tree cover but which not yet can be considered as forest land</i>.</p> <p><i>Built-up land</i> is land used for buildings, houses, and factories and land in the immediate vicinity of these. This class includes peat production areas, where peat harvesting has been started and the site has not reforested. Also mechanised gravel production sites are included in this class. It includes also some wooded areas like parks, grave yards and corresponding areas.</p> <p><i>Roads</i> include roads and railroads, including ditches and side areas related to these. It includes also airports. Roads inside build-up areas (cities etc.) are classified in built-up land.</p> <p><i>Power supply lines</i> include electricity lines, water tube lines and gas tube lines, The width of the line must be at least 5 meters. If the line is inside other land uses classes than forestry land (1-4) it is included in the surrounding land use class no matter the width.</p> <p><i>Inland water</i>. Water basins (rivers etc.) less than 5 meters in width are included in the surrounding land use class.</p> <p><i>Seawater areas</i>.</p>	
IPCC	National
Forest Land	<p>All national forest land</p> <p>Poorly productive forest land which is Forest Land according to the FAO/FRA definition</p> <p>Other forestry land e.g. forest roads, excludes built-up land, gravel and sand production sites</p>
Cropland	Arable land excluding natural pastures, small roads and buildings, ditches more than 3 m wide, lands for bioenergy plant production
Grassland	Arable land not included in Croplands e.g. natural pastures, ditches more than 3 m wide, lands for bioenergy plant production, abandoned arable lands
Wetlands	<p>Poorly productive forest land which is not Forest Land according to the FAO/FRA definition and is on organic soils</p> <p>Unproductive land on organic soils</p> <p>Peat production areas of built-up land</p> <p>Inland waters</p>
Settlements	<p>Built-up land excluding peat production areas</p> <p>Roads</p> <p>Power supply lines</p> <p>Part of other forestry land including built-up land for forestry purposes, gravel and sand production sites</p> <p>Part of arable land including small roads and buildings used for agriculture</p>
Other Land	<p>Poorly productive forest land which is not Forest Land according to the FAO/FRA definition and is on mineral soils</p> <p>Unproductive land on mineral soils</p>



**Figure 6.2-1** The partitioning of the country to Southern Finland (pale grey) and Northern Finland (dark grey)

The areas of IPCC land-use categories are given in Table 6.2-2 where the total land area refers to Finland's official land area in 1.1.2014. The total area is the official area of Finland including inland waters.

**Table 6.2-2** 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	Forest land	Cropland	Grassland	Wetlands			Settlements	Other land	Total		
				Other Wetlands	Peat extraction	Inland waters			Wetlands total	Land	Land and inland waters
1990	22 110	2 471	268	2 924	82	3 452	6 459	1 222	1 314	30 391	33 843
1995	22 127	2 451	243	2 912	90	3 453	6 454	1 255	1 313	30 391	33 843
2000	22 107	2 439	235	2 897	98	3 453	6 448	1 301	1 313	30 390	33 843
2001	22 094	2 442	234	2 894	99	3 454	6 447	1 313	1 313	30 390	33 843
2002	22 080	2 448	233	2 893	99	3 454	6 446	1 324	1 313	30 390	33 843
2003	22 063	2 455	233	2 891	99	3 454	6 445	1 336	1 313	30 389	33 843
2004	22 044	2 460	234	2 890	99	3 454	6 443	1 349	1 313	30 389	33 843
2005	22 025	2 464	235	2 888	100	3 454	6 443	1 363	1 313	30 389	33 843
2006	22 008	2 468	236	2 887	101	3 454	6 442	1 377	1 313	30 389	33 843
2007	21 991	2 468	238	2 885	104	3 454	6 443	1 391	1 313	30 389	33 843
2008	21 976	2 468	238	2 884	106	3 455	6 445	1 404	1 312	30 389	33 843
2009	21 962	2 470	239	2 883	108	3 455	6 446	1 415	1 312	30 389	33 843
2010	21 950	2 471	240	2 882	109	3 455	6 447	1 424	1 312	30 388	33 843
2011	21 940	2 472	240	2 882	111	3 455	6 448	1 432	1 312	30 388	33 843
2012	21 930	2 474	241	2 881	111	3 456	6 448	1 438	1 311	30 388	33 843
2013	21 921	2 476	242	2 881	112	3 456	6 448	1 444	1 311	30 388	33 843
	1.0	4.2	8.2	5.2	29.8			5.6	12.8		%

Land-use conversion matrix between all land-use categories were calculated based on the NFI sample plots (Table 6.2-3). Land-use changes were assessed in field and completed with auxiliary information on land-use

changes. Remote sensing (RS) data and digital maps were used to check any undetected and post-measurements land-use changes on sample plots. The RS and other spatial data included satellite images, digital maps, thematic maps and shape files of EU Land Parcel Identification System (LPIS) for monitoring of the agricultural land parcels (EU 1992). In the first stage of image interpretation RS data were supported by NFI parameters, for example, with stand age to encompass all sample plots with potential land-use changes. Aerial images were utilized at the final stage of the interpretation to ensure each individual land-use change. The findings were used to complement the land-use change observations. The land-use changes which occurred after NFI measurements were updated to the NFI 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 6.10.2).

**Table 6.2-3** The land-use change matrix for IPCC land-use categories from 31.12.1993 to 31.12.2013 (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	21 799 (1%)	35 (15.6%)	53 (13.4%)	18 (24.8%)	16 (26.2%)	1 (141.6%)	0	21 921
Cropland	97 (17%)	2 354 (4.4%)	8 (51.8%)	15 (55.4%)	2 (0%)	0	0	2 476
Grassland	14 (36.6%)	45 (22.8%)	175 (10.4%)	6 (80%)	2 (141.4%)	0	0	242
Wetlands	30 (39%)	1 (141.4%)	1 (98.4%)	2 959 (5.2%)	1 (200%)	0	0	2 992
Settlements	183 (10.8%)	23 (35.2%)	13 (38.6%)	3 (107.2%)	1 220 (5.6%)	2 (103.6%)	0	1 444
Other land	0	0	0	0	0	1 311 (12.8%)	0	1 311
Inland waters	0	0	1 (115.8%)	2 (115.6%)	0	0	3 452 (0%)	3 456
Total (initial)	22 124	2 459	252	3 003	1 240	1 314	3 453	33 843
NET change	-202	18	-10	-10	203	-2	3	0

#### *Recalculation of areas for the land-use categories*

The land-use areas were recalculated due to new NFI data, updated land-related data on sample plots and error corrections in calculations. The new data and updating affected the areas of land-use changes at the end of time-series, since 2006. The effect of the changes is shown in Table 6.2-4. In the year 2012, a decrease in the area of Forest Land and increase in the area of other land is mainly due to the new data, especially in the northernmost Finland. In the previous submission Grassland areas were based on both statistical areas and NFI, now only NFI, which explains the increase in Cropland area and decrease in Grassland area.

**Table 6.2-4** The difference due to recalculation in the areas of the land-use categories between the 2014 and 2015 submissions (1 000 ha)

	Areas in Submission 2014		Areas in Submission 2015		Difference in areas 2015–2014	
	Year 1990	Year 2012	Year 1990	Year 2012	Year 1990	Year 2012
Forest land	22 187	22 024	22 110	21 930	-77	-94
Cropland	2 454	2 439	2 471	2 474	17	35
Grassland	283	267	268	241	-15	-26
Wetlands	3 005	2 990	3 006	2 992	1	2
Settlements	1 224	1 431	1 222	1 438	-2	7
Other land	1 239	1 237	1 314	1 311	75	74
Inland waters	3 450	3 454	3 452	3 456	2	2

### *6.3 Information on the approaches used for representing land areas and on the land-use data used for the inventory preparation*

The data source in which the areas of land-use categories are based on is the National Forest Inventory (NFI). 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. Area time series since 1990 are computed from the most recent inventories the 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 to report land-use categories in sub-categories Lands Remaining and Lands Converted, and also for the estimation of carbon stock changes in mineral soil. More information on NFI is provided in Appendix\_6a.

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 regardless of land ownership and all land-use types, ii) NFI data cover the whole time span needed for GHG 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 trees on different land use, v) NFI is a continuous system which provides data also for recent years.

The area estimation method bases on the methodology used in NFI. Each sample plot, or strictly speaking the centre point of a sample plot, represents particular area depending on the sample density region in which the sample plot belongs (see Appendix\_62, Figure 1\_App\_6a). Finland's official total land area is used to compute the representativeness of the sample plots. Official areas of municipalities are published annually by the National Land Survey of Finland (NLS) based on the NLS Topographic database. The method, how official areas were employed for area estimation is described by Tomppo et al. (2011) and briefly in Appendix\_6a. Since some changes occur between years in the surface area of municipalities caused by improvements in the mapping precision and changes in water and land areas, a fixed total area is used in the GHG inventory. In this submission, the reference date for official area data has been changed from 1.1.2009 to 1.1.2014 (Land Survey of Finland 2014a). If significant changes occur, the new official land area will be used. The Luke's steering group for the greenhouse gas inventory for the LULUCF sector and the advisory board for the greenhouse gas inventory set by the Statistics Finland will decide up on the change.

Areas for each land-use category were calculated by multiplying the number of the sample plot centres belonging to a particular land-use category with the area representativeness of a sampling density region. Areas were calculated separately for Southern and Northern Finland by sampling density regions (Figure 1\_App\_6a), as well as separately for land areas and inland waters. The sum of all different land-use categories, remaining and converted, is the total area of Finland.

The primary task was to create the six IPCC land-use categories according to Finnish circumstances. This is described in Section 6.2. Secondly, the employed NFI sample plot and stand level data were classified into the six IPCC land-use categories. The area estimates for land-use categories were computed separately for Southern and Northern Finland but final results are reported at the country level (Figure 6.2-1). A 20-year period is used for converted lands, except for peat extraction where 5-years conversion period is used. 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 reported annual areas of land-use changes in 1990-2013 are based on a five-year moving average method. As the time series were produced from NFI data, the five-year moving averages were computed 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\_6b.

Information on land-use changes before 1990 was needed, for example, for the estimation of carbon stock changes in mineral soil. Therefore, the areas of land-use changes were estimated also for 1971-1989 by employing NFI7-NFI9 data. Assessed land-use changes for the past 10-year period made that possible. For

pre-1990 time series, the average annual land-use changes areas were estimated for NFI mean years, and interpolated between mid-years.

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 where soil type was not assessed in field (croplands and part of the grasslands). Polygons that were smaller than 6.25 ha were merged with adjacent larger polygons in the database. The soil database was published in 2009 and produced by Agrifood Research Finland (MTT), the Finnish Forest Research Institute (Metla) and the Geological Survey of Finland (GTK).

## 6.4 Forest Land (CRF 4.A)

### 6.4.1 Category description

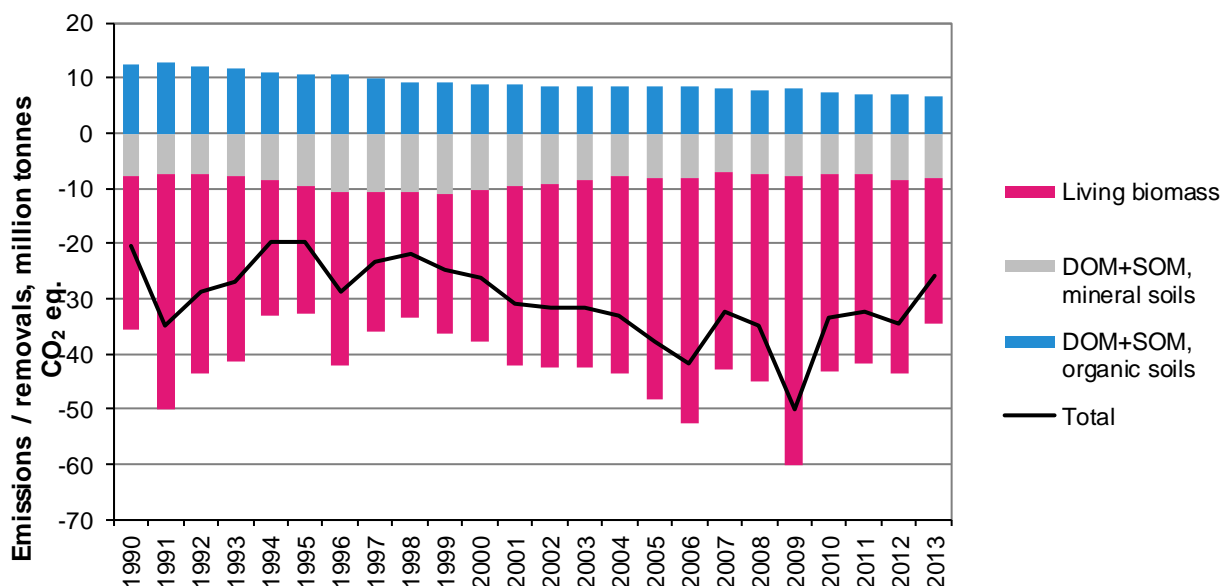
Forest Land was a net sink in 2013 as it has been since 1990. The net removals due to the changes in carbon stocks were 28.4 Mt CO<sub>2</sub>. The CRF 4.A category includes emissions and removals resulting from carbon stock changes in living biomass, litter and dead wood (DOM), and soil organic matter (SOM). Category is subdivided into CRF 4.A.1 Forest Land Remaining Forest land, and 4.A.2 Land Converted to Forest Land.

Forest Land is defined as a land with a tree crown cover of more than 10%. The trees should be able to reach a minimum height of 5 m. According to the national forest land definition, a minimum area for forest is not exactly set, but a guide of 0.25 ha for a forest stand in Southern Finland and 0.5 ha in Northern Finland is given. The definition does not comply strictly with the FAO definition, but to include all national forest lands in the GHG inventory, the minimum area of 0.5 ha is not fully applied for the Convention reporting. (See Section 6.2)

Living biomass was a net sink of 26.9 Mt CO<sub>2</sub> in 2013. Living biomass and mineral soils have been a net sink during the whole time series, whereas the organic soils have been a net source. In 2013, the sink of mineral soils was 8.4 Mt CO<sub>2</sub> and the emissions of organic soils 6.8 Mt CO<sub>2</sub>. Compared to previous year, the sink of Forest Land has decreased by 23%. This was a consequence of the very high harvest level in 2013. The main proportion of the sink was from Forest Land Remaining Forest Land while Land Converted to Forest Land acted a minor role (1.6%).

The most important components of the forest sink are the increment of growing stock and the harvest removals. The growth has increased since 1990 from 78 million m<sup>3</sup> to 104 million m<sup>3</sup> measured in the 11<sup>th</sup> National Forest Inventory (NFI). Between years there is less fluctuation in the growth contrary to the harvest rates. In 2013, the total drain was 79 million m<sup>3</sup> being at its highest level ever (Finnish Statistical Yearbook of Forestry 2014) (Figure 6.4-1).

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 removals in the period 1990-2013: 1) due to drainage, non-forested sites have been transferred to Forest land; and 2) the growing stock has increased. The first factor has slightly increased the total emissions caused by peat decomposition. The second factor has increased the removals in drained peatlands by increasing the biomass growth and 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.



**Figure 6.4-1** Emissions (positive sign) and removals (negative sign) in Forest Land

Forest Land Remaining Forest land and Lands Converted to Forest Land are key categories.

#### *Definitions of carbon pools*

**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. Tree biomass includes stem wood, stem bark, living and dead branches, needles/foilage, stump, and roots down to a minimum diameter of 1cm (Repola 2008, Repola 2009). The biomass of other vegetation includes the biomass of ground vegetation, which consists of moss, lichen, shrub and dwarf shrub vegetation. This biomass is not included in carbon stock changes in 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 waste wood 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. Soil carbon model Yasso07 estimates soil carbon stocks and their changes to a depth of one metre (Appendix\_6e). 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.

## 6.4.2 Methodological issues

### 6.4.2.1 Forest Land Remaining Forest Land (CRF 4.A 1)

#### Activity data

Land use area calculations are described in detail in Section 6.3. The activity data for Forest Land Remaining Forest Land is the difference between total Forest Land area and the area of Land converted to Forest Land. Organic soils were divided into undrained and drained soils and the drained soils further into five site types based on the fertility of the soil (Table 6.4-1). NFI7-NFI11 data were used to estimate the proportional distribution of site types. Areas of site types were interpolated between different NFIs (Section 6.3). Definition for Forest Land is given in Section 6.2.

**Table 6.4-1** Areas of organic soils (peatlands) of Forest Land Remaining Forest Land by site type (1 000 ha)

Year	Undrained	Vaccinium				Caldina type (Jatkg)
		Herb-rich type (Rhtg)	myrtillus type (Mtkg)	Vaccinium vitis- idaea type (Ptkg)	Drwarf shrub type(Vatkg)	
1990	1 752	694	1 143	1 494	856	8
1995	1 691	666	1 173	1 567	826	23
2000	1 639	645	1 193	1 628	800	37
2001	1 632	642	1 194	1 636	796	39
2002	1 619	646	1 185	1 636	810	39
2003	1 606	651	1 176	1 636	824	40
2004	1 593	655	1 167	1 636	837	40
2005	1 580	660	1 158	1 635	851	41
2006	1 567	664	1 149	1 635	865	42
2007	1 555	669	1 140	1 635	879	42
2008	1 567	655	1 138	1 641	875	43
2009	1 579	641	1 137	1 646	870	45
2010	1 592	628	1 135	1 652	866	46
2011	1 605	614	1 134	1 658	862	47
2012	1 606	615	1 135	1 659	863	47
2013	1 606	615	1 135	1 659	863	47

#### Carbon stock change in living biomass

Carbon stock changes in living tree biomass are reported as an aggregated estimate for above-ground and below-ground biomass. Biomass of other plants was assumed not to change; hence the change is not estimated for the category Forest Land Remaining Forest Land.

The employed method is a Tier 3 Biomass Gain-Loss method (2006 IPCC Guidelines, Vol. 4, Equation 2.7). National Forest Inventory (NFI) provides tree-level increments and increment of growing stock data to employ tree species specific biomass functions for direct estimation of biomass growth (Repola 2008, Repola 2009, Repola et al. 2007). From the same data biomass conversion and expansion factors for biomass increment, cutting removals and natural losses can be estimated, and then, for example, apply to convert statistical data of drain to estimate biomass losses.

The annual gain (growth) in living tree biomass was estimated first to the total forest land and then to lands converted to forest land. Reminder of these two estimates was the biomass growth estimate for Forest Land Remaining Forest Land. The method is described in Appendix\_6c. Employed biomass models are given in Appendix\_6d.

The biomass loss in living trees in Forest Land Remaining Forest Land was estimated as the difference between the total biomass loss and the biomass losses due to forest land being converted to other land uses. The total biomass estimate is based on the statistics on the total drain of growing stock. The official drain and harvest statistics are annually published in the Yearbook of Forestry. The biomass losses removed from forest tie in with the land-use changes were based on the NFI data. Method is described in Appendix\_6c.

To convert biomass to carbon, the default conversion factor 0.5 was used.

### *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 Forest Land, the Yasso07 model (Tuomi et al. 2011b) was applied. For a more detailed description of the Yasso07 model, see Appendix\_6e. 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) would be 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 types of litter and different SOM types. The Yasso07 simulations were made separately for the mineral soils of Southern and Northern Finland.

Before soil carbon stock change simulations, preliminary preparations had to be done involving three steps:

- i) Estimating the litter input data from standing tree stock, 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 Southern and Northern 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\_6d). The method to estimate carbon stocks of living tree biomass is described in Appendix\_6c. 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 other 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 2014). The volumes of the harvesting residues and unrecovered natural losses were converted to biomass using the expansion factors computed from NFI data; their derivation is explained in Appendix\_6c, subsection Losses 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 6.4-2) 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 6.4-3).

**Table 6.4-2** 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 6.4-3** 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	-	Southern Finland	Mineral soils
Total, North Finland	66.6	-	Northern 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 Southern and Northern Finland. The 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 Southern and Northern Finland for the period 1971-2013.

The model initialisation was done using NFI6 data from 1971-1974 in Southern Finland and from 1975-1976 in Northern 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 Forest Land (see Appendix\_6f).

## 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 6.4-4) by the corresponding area estimates based on the NFI data (Table 6.4-1).

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 6.4-2). The annual below-ground litter production from ground vegetation was estimated according to Laiho et al. (2003) (Table 6.4-3). 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 6.4-4** 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 annual estimated carbon stock changes in soils are presented for Forest Land Remaining Forest Land, separately for Southern and Northern Finland and by fertility type in Appendix\_6f.

#### 6.4.2.2 Land Converted to Forest Land (CRF 4.A.2)

##### Activity data

Land use area calculations are described in detail in Sections 6.2 and 6.3 and in Appendix\_6b. Land Converted to Forest Land are cumulative sum of the converted areas over a 20-year period. There were land-use conversions from all other LU categories to Forest Land. Former Wetlands could have previously been either peat extraction areas or wetlands drained for forestry purposes. Former Settlements are a diverse group of lands. Areas belonging to this group include, for example, large forested gravel pits, former power supply lines, forested roads and abandoned dwelling places (Section 6.3).

### *Carbon stock change in living biomass*

Emissions and removals are reported from carbon stock changes in living tree biomass including above-ground and below-ground biomass. The carbon stock change in living biomass of trees was estimated according to the Tier 3 method in the 2006 IPCC Guidelines (Vol. 4, Eq. 2.15). 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. Annual mean increments were multiplied by the area of the land-use change. Trees measured in NFI sample plots were used to estimate biomass and biomass growth. The used method is described in Appendix\_6c.

### *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 Land Converted to Forest Land (see Appendix\_6e). 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).

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 would be 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 6.4-5).

The mean temperature, precipitation and amplitudes ( $0.5 \times (\text{minimum monthly mean} - \text{maximum monthly mean})$ ) were estimated for Southern and Northern Finland for 1971 – 2013 (see a more detailed description of weather data derivation under the section on mineral soils above).

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 6.4-5). 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 wheat and barley values (AWEN) were 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 (AWEN) with the regression models of Ryan et al (1990). The Yasso07 soil model was driven using mean weather data from the years 1971-2013. For unvegetated settlements the starting value of soil carbon was assumed to be equal to zero.

**Table 6.4-5** The carbon stocks of mineral agricultural soils and settlements (tons of carbon per ha) before land-use change for Southern Finland (SF) and Northern 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	5.69	0.67	0.56	5.72	44.56	57.21
Cropland NF	6.64	0.82	0.74	6.74	36.97	51.91
Grassland SF	7.06	0.99	0.75	7.52	44.94	61.26
Grassland NF	8.23	1.15	0.87	8.76	37.3	56.31
Settlements	-	-	-	-	-	0

For Land 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 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.

Annual estimates for carbon stock changes in soils are presented for Land Converted to Forest Land and separately for Southern and Northern Finland in Appendix\_6f.

### 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 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 from ground vegetation 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 6.4-6** The emissions of the original land use on organic soils converted to forests (tonnes C per ha)

Original land use	Assumed previous emissions of CO <sub>2</sub> (tonnes 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 6.4-4.	(Minkinen et al. 2007)

For organic lands converted to forests, previous emissions were obtained mainly from MTT Agrifood (Table 6.4-6). 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 Southern and Northern Finland in Appendix\_6f.

### 6.4.3 Uncertainty and time series' consistency

#### 6.4.3.1 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 (2009-13) using the standard approach of the Finnish NFI. As explained in above, 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 6.4-7.

**Table 6.4-7** 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 <sub>V</sub> million m <sup>3</sup> /a	U(I <sub>V</sub> ), %	BCEF	U(BCEF), %	Biomass inc., I <sub>B</sub> Mt/a	U(I <sub>B</sub> ), %
south	mineral	pine	22.25	2.3	0.572	0.3	12.73	2.3
		spruce	22.73	2.8	0.681	0.7	15.48	2.9
		deciduous	14.26	3	0.805	0.6	11.48	3.1
	organic	pine	6.44	3.1	0.587	0.4	3.78	3.1
		spruce	4.30	5.5	0.711	1.3	3.06	5.7
		deciduous	3.90	4.8	0.813	1.2	3.17	4.9
north	mineral	pine	13.27	6.2	0.613	0.4	8.13	6.2
		spruce	3.81	7.5	0.8	1.4	3.05	7.6
		deciduous	3.65	8.3	0.961	1.7	3.51	8.5
	organic	pine	5.60	3.8	0.62	0.4	3.47	3.8
		spruce	1.98	8.5	0.812	1.7	1.61	8.7
		deciduous	2.84	6.2	0.807	1.3	2.29	6.3
Total, using Equation 3.2 in 2006 IPCC Guidelines, Vol. 1 (2006 IPCC GLs)							71.761	1.3

The uncertainty in the expansion factors for fellings due to NFI sampling was also assessed by region, soil species and propagated into the sampling uncertainty in the total biomass of fellings as reported in

Table 6.4-8

**Table 6.4-8** Sampling uncertainties, twice the relative standard errors, for the biomass loss due to fellings in 2013

Region	Soil	Tree species	Volume mill.m <sup>3</sup>	BCEF	Biomass Mt	U(biomass), %
south	mineral	pine	17.643	0.62	10.974	1.2
		spruce	19.640	0.73	14.318	1.4
		deciduous	12.667	0.85	10.704	10.1
	organic	pine	2.560	0.63	1.610	1.9
		spruce	2.480	0.78	1.927	4.7
		deciduous	2.929	0.88	2.566	7.1
	mineral	pine	7.591	0.63	4.805	2.7
		spruce	1.491	0.81	1.209	4.8
		deciduous	2.052	0.91	1.861	11.7
north	organic	pine	1.149	0.64	0.740	3.4
		spruce	0.380	0.85	0.323	6.4
		deciduous	1.764	0.86	1.512	4.0
	Total, using Equation 3.2 in 2006 IPCC Guidelines, Vol. 1 (2006 IPCC GLs)				52.549	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 5.4% total sampling uncertainty for fellings. The sampling uncertainty, 14.7%, in the total biomass of unrecovered natural losses, 4.38 Mt/a, was estimated in the same way as demonstrated for fellings in Table 6.4-9. Propagation of sampling uncertainty for the net change in living biomass is reported in Table 6.4-9.

**Table 6.4-9** Sampling uncertainties, twice the relative standard errors, for the net change in living biomass in 2013

Source	Biomass change, Mt	Uncertainty, %
Increment	71.761	1.3
Fellings	-52.549	5.4
Natural losses	-4.38	14.7
Net change (GPG 2000, eq. 6.3)	14.832	20.6

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\_6g). The resulting estimates of model uncertainty are reported in Table 6.4-10.

**Table 6.4-10** Model uncertainties based on permanent sample plots, twice the relative standard errors, for net change in living biomass in 2013

Tree species	Biomass change, Mt	Uncertainty, %
pine	9.939	2.99
spruce	5.286	6.95
deciduous	1.962	32.63
Total	17.187	4.6

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 6.4-9 and Table 6.4-10 is 21.1%.

#### 6.4.3.2 Uncertainty for Carbon stock changes in dead wood, litter and soil organic matter

Uncertainty estimation for mineral soils is described in Appendix 6h, yielding 46.8% uncertainty for the 2013 in Southern Finland, 26.2% uncertainty in Northern 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 6.4-4), was added to the total variance estimate, yielding a 150% uncertainty for carbon stock change in organic soils in the year 2013.

#### 6.4.3.3 Combined uncertainty for carbon stock changes in Forest Land Remaining Forest Land

The uncertainty estimates reported for tree biomass change and for soil carbon change are combined in Table 6.4-11.

**Table 6.4-11** Uncertainties, twice the relative standard errors, for carbon stock changes in Forest Land Remaining Forest Land in 2013

Component	Change, kt C	Uncertainty, %
Tree biomass	7 030	21.1
Mineral soils	2 248	24.1
Organic soils	-1 797	150
Total	7 481	41.7

#### 6.4.3.4 Uncertainty of carbon stock changes in Land Converted to Forest Land

The propagation of uncertainty for 2013 carbon stock changes on lands converted to forest land is reported in Table 6.4-12. 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.

**Table 6.4-12** Uncertainties, twice the relative standard errors, for carbon stock changes in land converted to forest land in 2013

Component	Area, 1000 ha	Emission factor, t C/ha	Changes in carbon stock, kt C	Uncertainty, %		
				Area	EF	Combined
Tree biomass	122.410	1.61	197.325	9.4	20	22.1
Mineral soils	80.111	-0.18	-14.353	16	60	62.1
Organic soils	42.299	-1.52	-64.199	20	90	92.2

#### 6.4.3.5 *Time series' consistency*

The main data source for estimation of carbon stock changes in forest land was NFI. The assessment methods, definitions and classification of variables have maintained unchanged 1990 onward which ensure the data consistency. The methodology in GHG inventory change time to time and therefore the whole time series are re-calculated.

The entire time series for Forest Land area in 1990-2013 was calculated from NFI10 and NFI11 data. Therefore, possible inconsistencies due to a different sample design or different classification between inventories were avoided. The effect of recalculations in the activity data is described in Section 6.2.

#### 6.4.4 *Category-specific QA/QC and verification*

The quality objectives and the QA/QC and verification plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.2.3. The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives. The bilateral quality meeting is held annually between the inventory unit and the sectoral expert. In the 2015 quality meeting was discussed about the QA/QC issues, especially the agreement between emission and removal numbers in the NIR and those in the CRF Tables. More time will be reserved for checking numbers in the NIR against the numbers in CRF Tables.

Until the end of 2014, the Finnish Forest Research Institute (Metla) had a management team to guide and supervise the reporting of emissions and removals for the LULUCF sector, which was under Metla's responsibility. The members had 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 were discussed and approved by the management team before they were introduced to the advisory board (see Section 1.2.1). Representatives from Statistics Finland and Agrifood Research Finland were invited to the meetings. The management team met 2-4 times per year. From 2015 onward, a new management team will be set up in Luke.

NFI data are employed for area and biomass estimation and to compute biomass conversion and expansion factors, which ensure the fit between different estimates. Data have gone through NFI's quality checks and control according to the QA/QC procedures developed for the Finnish NFI. The methods applied in the GHG inventory are based on the NFI's methods, which are published in reviewed scientific articles and books. The biomass models are also published in scientific articles.

Increment of the growing stock was first calculated for a national forest land and compared to estimates presented by NFI to ensure that all trees and sample plots are included in the biomass estimation, just after that the biomasses were computed.

Soil carbon model Yasso07 has been tested against empirical data by Rantakari et al. (2012) and Ortiz et al. (2013). The soil carbon stock change estimates are compared and verified against results of these papers.

The quality assurance system of the NFI data collection is described in publication Tomppo et. al (2011). NFI has also its internal quality handbook, where each part of NFI data collection and data processing are described as well as responsibilities; instructions for field work, data handling, correctness of data, training of field workers, measurement of increment cores in laboratory, estimation of results, etc.

#### 6.4.5 *Category-specific recalculations, including changes made in response to the review process*

Activity data, area of forest land and lands converted to forest land, were recalculated. Due to that, time series for gains and losses in living tree biomass, DOM and SOM were recalculated. NFI data for year 2013 was employed for computations and that had effects to end of time series. Recalculation of losses in living biomass was also due to a fact that statistics on total drain had been corrected for years 2008-2012. An error was detected in the estimation of biomass growth for Land Converted to Forest Land. Correction increased biomass gains for the end of the time series.

**Table 6.4-13** Implication of recalculations made in Forest Land category to the emission level in 1990 and 2012 (kt CO<sub>2</sub> eq.)

	Submission 2014 1990	Submission 2015	Difference	Submission 2014 2012	Submission 2015	Difference
<b>FL remaining FL</b>						
Biomass	-27 508	-27 857	<b>-348</b>	-37 934	-35 645	<b>2 289</b>
Mineral soil	-7 691	-7 753	<b>-62</b>	-7 872	-8 506	<b>-634</b>
Organic soil	12 088	12 569	<b>480</b>	7 485	7 174	<b>-311</b>
Total	-23 111	-23 041	<b>70</b>	-38 321	-36 976	<b>1 345</b>
<b>Lands converted to FL</b>						
Biomass	-430	-688	<b>-258</b>	-406	-789	<b>-383</b>
Mineral soil	112	60	<b>-52</b>	29	-14	<b>-43</b>
Organic soil	449	456	<b>8</b>	261	259	<b>-2</b>
Total	131	-172	<b>-303</b>	-116	-544	<b>-428</b>

### 6.4.6 Category-specific planned improvements

The work to improve tree biomass removal estimates has started at the Finnish Forest Research Institute in 2011. The aim is to have better estimates for the allocation of cutting removals to mineral and organic Forest Land, as well for land converted to and from Forest Land. A development project to improve the estimates of harvested wood products started in the end of 2014. Volume of cutting removals (losses in tree biomass) are linked to HWP specially under the KP reporting, and these two issues will be handled together. The results of the project will be ready to be implemented in the GHG inventory earliest in the 2017 submission.

## 6.5 Cropland (CRF 4.B)

### 6.5.1 Category description

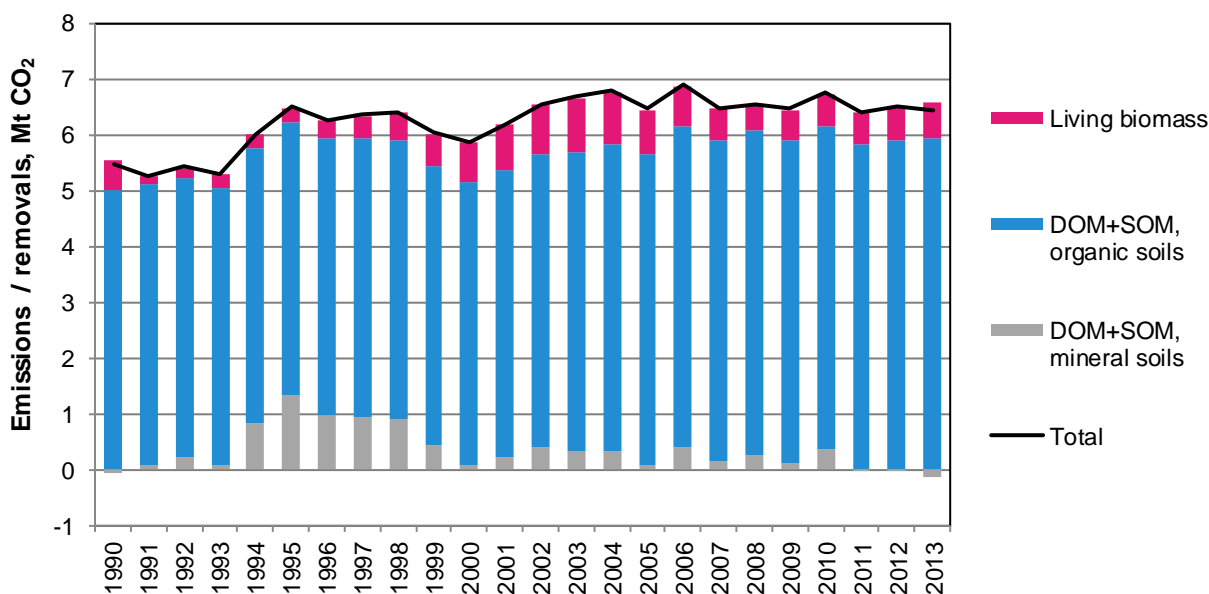
The total net emissions from croplands were 5.5 Mt CO<sub>2</sub> eq. in 1990 and 6.4 Mt CO<sub>2</sub> eq. in 2013. The CO<sub>2</sub> emissions from cultivated organic soils were 5.9 Mt and the sink of mineral soils 0.2 Mt. The carbon stock change in living biomass was 0.003 Mt in 2013.

The cropland category includes carbon stock changes in soils and living biomass reported as CO<sub>2</sub> emissions as well as N<sub>2</sub>O emissions from mineral soil conversion to cropland and leaching of the mineralized N. Nitrous oxide emissions from fertilization of croplands and mineralization of soil organic matter in cropland remaining cropland are reported under the category of agriculture (3.D Agricultural soils).

The area of cropland comprises of the area used for arable crops, grass (rotational), 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 6.1.2).

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, soil management and climatic variables (IPCC, 1997). Soils may act as sources of or sinks for CO<sub>2</sub> depending on the conditions.

Croplands have been a net source of CO<sub>2</sub> since 1990. The mineral soils are occasional sinks for CO<sub>2</sub> and the magnitude of the sink or source varies according to the C input to the soils. The organic soils have been an increasing source of CO<sub>2</sub> due to their increased area. The changes in living biomass vary according to the activities in clearance of forest to new fields (Figure 6.5-1).



**Figure 6.5-1** Emissions and removals in cropland, Mt CO<sub>2</sub>

## 6.5.2 Methodological issues

### 6.5.2.1 Cropland remaining cropland

#### Activity data

The area estimates for cropland remaining as cropland were obtained from the NFI data. The distribution of the whole area to mineral and organic soils is based on the NFI and soil database. The area estimate for cultivated organic soils was derived in the manner described in Section 6.1.2. The proportions of grass and other crops grown on organic soils were obtained from the agricultural statistics. 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 6.5-1** Area of cropland remaining cropland (kha)

		1990	1995	2000	2005	2010	2013
Mineral soils	South	1 954	1 946	1 935	1 929	1 922	1 917
	North	257	254	250	250	249	248
Organic soils	South annual crops	58	58	65	64	59	62
	South perennial crops	73	73	64	67	73	70
	North annual crops	7	7	10	11	11	11
	North perennial crops	44	44	43	44	46	47

#### 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). See Appendix\_6c.

#### Carbon stock changes in soil and dead organic matter

##### Mineral soils

The changes in mineral soil carbon stock were estimated using a model based Tier 3 approach which is basically similar to the one used in mineral forest soils. The method combines the agricultural statistics, biomass functions and Yasso07 soil carbon model. Model description of Yasso07 is given in Appendix 6e. However, in the case of cropland and grassland the parameterization of the Yasso07 was the one reported in Tuomi et al. (2011b). The modelling was done at the level of regional ELY Centres (The Centres for Economic Development, Transport and the Environment) (Figure 1\_App\_6a).

Soil C input of cropland was derived estimated as described in Appendix 6j. Crop specific soil carbon inputs were weighted with cultivated area of each crop taken from the LPIS, Land Parcel Identification System (EU 1992) to obtain the average soil carbon input in each ELY centre. The chemical quality of litter was as in Table 2\_App\_6j.

Weather data applied in the modeling was monthly 10km\*10km gridded data from 1961 to 2013 obtained from the Finnish Meteorological Institute. The annual values of temperature, precipitation, and temperature amplitude between the warmest and coldest month applied by the Yasso07 model were averaged for each ELY Centre region from the gridded data. The initialization of the model was done by running the model using the average climate 1961-1990 with the average soil carbon input from 1990-1999 for 100 years before the simulation period. Modelling the yearly changes in soil carbon stock between 1990 and 2013 was done by applying the annual soil carbon input and the average climate data of 1970-2013. The soil carbon stock change simulations based on litter and manure input, weather data and the Yasso07 model resulted in emission factors for the mineral soils (see Appendix\_6j). Overall nationwide soil C stock change was calculated by multiplying soil carbon stock change per hectare aggregated for south and north Finland with the respective area (Table 6.2-3). The emissions were reported as running 5-yr averages.

## 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, the emission factors are 5.7 t C ha<sup>-1</sup> for grass and 7.9 t C ha<sup>-1</sup> for annual crops (IPCC 2014b).

## Dead organic matter

The net carbon stock change in dead organic matter was considered insignificant and reported as 'NE'.

### 6.5.2.2 Land converted to cropland

#### Activity data

Areas and proportions of mineral and organic soils in the class of land converted to cropland (Table 6.5-2) were estimated using the NFI data together with the soil database as described in Sections 6.2 and 6.3.

**Table 6.5-2** Areas of land converted to cropland by land use and soil type (1 000 ha).

Converted from	Soil type	1990	1995	2000	2005	2010	2013
Forest land	mineral	49.4	43.4	43.4	51.0	53.1	58.0
	organic	22.4	18.4	20.4	31.0	34.8	38.9
Grassland	mineral	0.7	1.1	2.5	5.1	6.0	6.7
	organic	0.1	0.3	0.3	1.0	1.3	1.8
Wetland	mineral <sup>a</sup>	NO	NO	NO	NO	NO	NO
	organic	4.1	4.6	6.0	12.5	15.2	15.1
Settlements	mineral	NO	NO	NO	NO	0.8	1.5
	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\_6e). The removal of biomass after the conversion of grassland to cropland was 4.1 t C/ha and the 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 are national values 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 (Appendix\_6i). The mean deadwood carbon stocks were estimated separately for Southern and Northern Finland but only for organic soils since they are included in the estimate of soil C in mineral soils (see Appendix\_6e).

**Table 6.5-3** Carbon stock change in living biomass and DOM (kt C) in forest land converted to cropland

	Soil	1990	1995	2000	2005	2010	2013
Living biomass	mineral	-108.2	-65.7	-136.2	-154.6	-118.7	-122.3
	organic	-34.7	-14.1	-82.5	-97.9	-58.1	-70.3
DOM	organic	-0.12	-0.21	-1.12	-1.35	-0.68	-0.81

### *Carbon stock changes in soil*

#### **Mineral soil**

Carbon stock changes in land converted to cropland on mineral soils were estimated using the Yasso07 model (Appendix\_6e). The method is the same as for cropland remaining cropland but the initial state of the soil when starting the simulation was as in forest land remaining forest land or grassland remaining grassland. The same annual input data derived from agricultural statistics was used for all classes and the method is described in detail in Appendix 6j. The simulation produces specific emission factors for each year after the conversion. Thus, the land area converted each year since 1970 was multiplied with a specific emission factory depending on the age of the conversion and the emissions for each inventory year consist of all these conversions.

#### **Organic soil**

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 (6.8 t C ha<sup>-1</sup>) (IPCC 2014b).

### *6.5.3 Uncertainty and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

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.

The time series is mainly consistent except that the crop yield data is available only since 1995. Thus, the C input data for modelling years 1990-1994 is based on average yields from the later years.

### *6.5.4 Category-specific QA/QC and verification*

The quality objectives and the QA/QC and verification plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.2.3. The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives in LULUCF. The bilateral quality meeting 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 2006 IPCC Guidelines (Vol 1, Chapter 6, Table 6.1). 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 quality assurance and verification 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). Another study confirmed that Yasso07 is also suitable for simulating C stock changes in cropland remaining cropland (Karhu et al. 2012).

### *6.5.5 Category-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 6.1.3) and all soil and biomass emissions were recalculated. The area of organic soils diminished by 100 000 ha due to the exclusion of Dystric gleysols from this class. Now the soil types reported under organic soils are only Histosols and Umbric gleysols which is in line with the IPCC definition of organic soils. The method for cropland remaining cropland was changed from Tier 1 to Tier 3. The emission factors for organic soils were changed to those from IPCC Wetlands Supplement (2014b).

### *6.5.6 Category-specific planned improvements*

The work to improve tree biomass removal estimates has started at LUKE 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.

## 6.6 Grassland (CRF 4.C)

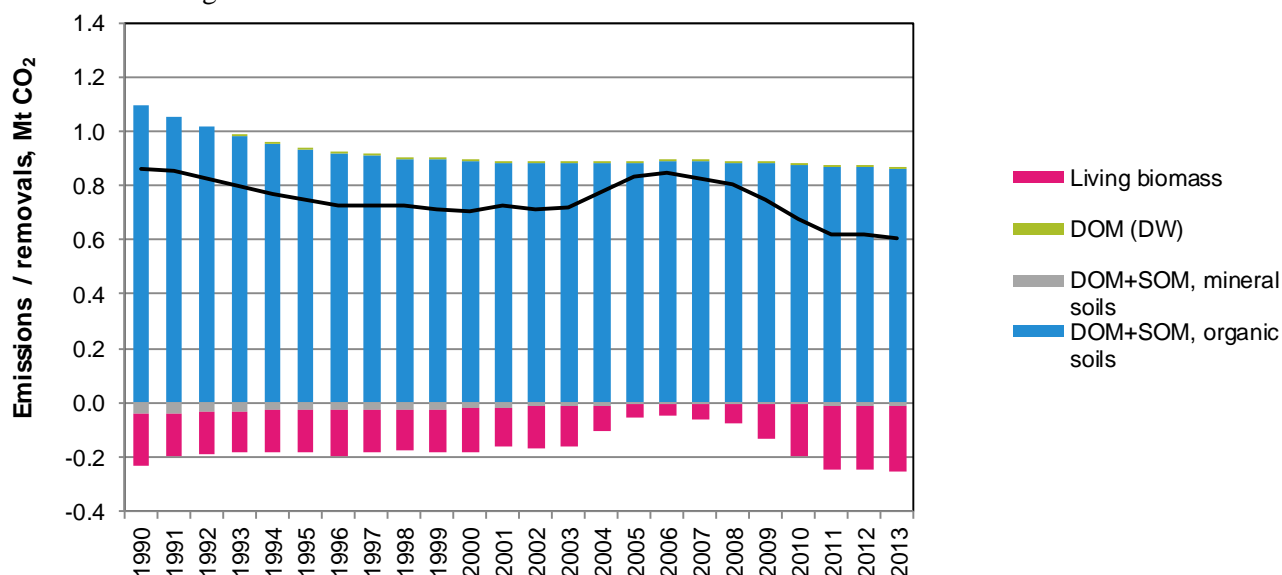
### 6.6.1 Category description

Carbon stock changes in organic and mineral grassland are reported under the grassland category. The emissions of organic soils on grasslands were 0.9 Mt CO<sub>2</sub> in 2013 and the sink for mineral soils was 0.01 Mt CO<sub>2</sub>. The sink of living biomass was 0.24 kt CO<sub>2</sub>. The net emissions from grasslands were 0.6 Mt CO<sub>2</sub> in 2013.

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 of long-term grasslands and meadows 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 6.6-1). The reason for the decrease is that some grassland have been converted to cropland. The trend in biomass varies according to clearance of new grassland from forest.



**Figure 6.6-1** Emissions and removals in grassland, Mt CO<sub>2</sub>

## 6.6.2 Methodological issues

### 6.6.2.1 Grassland remaining grassland

#### Activity data

The area estimate for grasslands was derived from the NFI data in the manner described in Section 6.3.

**Table 6.6-1** Distribution of areas of soil types and management on grassland remaining as grassland (1,000 ha)

		1990	1995	2000	2005	2010	2013
Mineral soils	South	78.3	77.4	80.6	87.4	91.6	92.0
	North	24.5	25.8	27.5	30.1	32.8	34.0
Organic soils	South	30.7	24.8	23.8	23.9	22.7	21.6
	North	36.8	31.2	29.1	28.0	27.9	27.8
Total		170.3	159.2	161.0	169.5	175.0	175.5

#### Carbon stock changes in biomass

The gain in tree biomass on abandoned fields, which represents a small sink of carbon, was estimated as described in Appendix\_6c.

#### Carbon stock changes in soils and dead organic matter

##### Mineral soils

It was assumed that no changes in C stocks occur in this category since no changes were anticipated in the carbon input or quality during the inventory period.

##### Organic soils

Organic soils are determined to be 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 (3.5 t C ha<sup>-1</sup> a<sup>-1</sup>) (Maljanen et al. 2010).

The amount of carbon released is converted to CO<sub>2</sub> by multiplying it by 44/12.

##### Dead organic matter

The net carbon stock change in dead organic matter was considered insignificant and reported as 'NE'.

### 6.6.2.2 Land converted to grassland

#### Activity data

The area estimate for grasslands was derived from the NFI data in the manner described in Sections 6.2 and 6.3. The area estimates for land converted to grassland divided by the soil type are presented in Table 6.6-2.

**Table 6.6-2** Areas of land converted to grassland by soil type (1,000 ha)

Converted from	Soil type	1990	1995	2000	2005	2010	2013
Forest land	mineral	7.86	8.49	8.12	9.71	11.85	10.21
	organic	NO	0.15	0.98	2.28	3.71	4.04
Cropland	mineral	71.71	58.75	48.48	37.29	32.84	35.54
	organic	18.12	16.64	15.50	12.99	10.61	9.31
Wetland	mineral	NO	NO	0.44	1.09	1.25	1.65
	organic	NO	NO	NO	1.67	3.25	4.43
Settlements	mineral	NO	0.04	0.36	0.67	1.00	1.65
	organic	7.86	8.49	8.12	9.71	11.85	10.21
Other land	mineral	NO	0.15	0.98	2.28	3.71	4.04

### *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\_6d). 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 grass biomass was 4.1 t C/ha (national data). 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 Southern and Northern Finland for organic soils (see Appendix\_6i). In mineral soils, DOM is included in the estimate of soil carbon.

**Table 6.6-3** Changes in biomass and DOM (kt C) in forest land converted to grassland

	1990	1995	2000	2005	2010	2013
Living biomass	-16.8	-21.3	-21.7	-62.2	-19.8	-6.3
DOM	NO	-0.04	-0.04	-0.21	-0.05	-0.05

Carbon stock changes in land converted to grassland on mineral soils were estimated using the Yasso07 model (Appendix\_6e). The initial state values for the simulation were as in forest land remaining forest land or cropland remaining cropland. The carbon input values were as described in Appendix 6j. The simulation produces specific emission factors for each year after the conversion. Thus, the land area converted each year since 1970 was multiplied with a specific emission factory depending on the age of the conversion and the emissions for each inventory year consist of all these conversions.

### 6.6.3 *Uncertainty and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

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.

### 6.6.4 *Category-specific QA/QC and verification*

The quality objectives and the QA/QC and verification plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.2.3. The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives in LULUCF. The bilateral quality meeting 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 2006 IPCC Guidelines (Vol 1, Chapter 6, Table 6.1). 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 was finished. The results of the project showed that Yasso07 can be used for simulating C stock changes in grasslands (Heikkinen et al. 2014).

### 6.6.5 *Category-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 6.2) and all emissions from soils were recalculated. The area of organic soils diminished due to the removal of Dystric gleysols from this class. Now the soil types reported under organic soils are only Histosols and Umbric gleysols which is in line with the IPCC definition of organic soils. The C stock changes of mineral soil grassland remaining grassland were not estimated any more due to the method change from Tier 1 to Tier 3 and the assumption that no management changes occur in such areas. The emission factor of organic soils was updated to that of Maljanen et al. (2010).

### 6.6.6 *Category-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.

## 6.7 Wetlands (CRF 4.D)

### 6.7.1 Category description

The total emissions from Wetlands were 2.4 Mt of CO<sub>2</sub> for 2013 (Figure 6.7-1). According to the 2006 IPCC Guidelines, Vol. 4, wetlands include peat extraction areas and 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 (2006 IPCC Guidelines). Wetlands are reported on in the sub-categories Wetlands remaining Wetlands (CRF 4.D 1) and Lands converted to Wetlands (CRF 4.D 2).

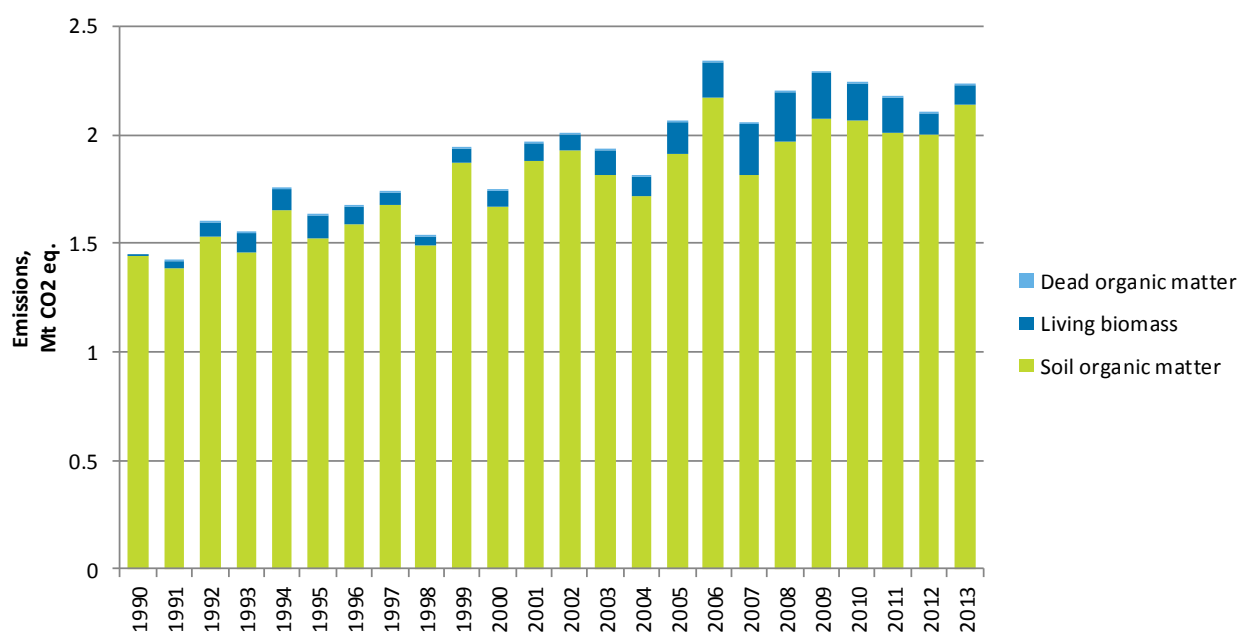
Wetlands Remaining Wetlands are divided to unmanaged and managed ones. The unmanaged Wetlands consist of natural lakes and rivers, and peatlands that do not fulfil the definition of forest land, that is Other Wetlands. These peatlands are for the most part undrained and thus can be considered unmanaged (CRF 4.D.1.3). In managed wetlands the water table is artificially changed (e.g., drained or raised) or they are created through human activity.

The subgroups belonging to the managed Wetlands Remaining Wetlands (4.D.1.2) include land remaining in peat extraction, remaining reservoirs and human made impoundments (Flooded Land Remaining Flooded Land), as well as peat extraction areas converted to other wetlands and to flooded land and other Wetlands that are converted to flooded land. Peat extraction under this category includes land remaining in peat extraction and other wetlands converted to peat extraction. Also emissions from horticultural peat are reported here and the activity data are based on reported production values.

All areas converted to Wetlands are considered managed. Land Converted to Wetlands is divided into three subcategories according to the type of conversion: to Peat extraction, Flooded land, or Other Wetland, and for further division within each subcategory the original land use is considered.

The category Land converted to Peat extraction (CRF 4.D.2.1) is further divided into three subcategories according to the original land use: Forest land, Cropland, or Grassland. The category Land converted to Flooded Land (CRF 4.D.2.2.) is further divided into five subcategories according to the original land use: Forest land, Cropland, Grassland, Settlements and Other land. Land converted to Other Wetlands (CRF 4.D.2.3) is further divided into three subcategories according to the original land use: Forest land, Grassland and Settlements. Other Wetlands under this category include lands that have regressed so that they no longer fulfil the definition of Forest Land or the lands have been rewetted. Peat extraction under this category includes land converted to peat extraction from all other land uses.

N<sub>2</sub>O and CH<sub>4</sub> emissions from wetlands are reported in category CRF 4(II). The emissions from peat extraction fields include 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 land converted to inland waters consist of diffusive emissions during ice-free period.



**Figure 6.7-1** Emissions from wetlands, Mt CO<sub>2</sub> eq.

## 6.7.2 Methodological issues

### 6.7.2.1 Wetlands remaining Wetlands

#### Activity data

The activity data are calculated from NFI. Conversion period is 20 years, except 5 years for peat extraction. Peat extraction 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 vegetation zone data. The vegetation zone data (different boreal zones) were obtained from the Finnish Environment Institute (2010).

Peat extraction remaining peat extraction areas include also converted areas from other wetlands. Managed Other Wetlands Remaining Other Wetlands are those areas, which were converted to other Wetlands over 20 years ago. Managed inland waters under Flooded Land Remaining Flooded Land are areas, which converted from other land use over 20 years ago. Land-use conversions from other wetlands and peat extraction to inland waters are also reported under Flooded Land Remaining Flooded Land.

#### Carbon stock changes in living biomass

Losses in living biomass are reported under Peat Extraction Remaining Peat Extraction (CRF 4.D.1.1) and Flooded Land Remaining Flooded Land (CRF 4.D.1.2). The loss in living tree biomass is due to the conversion of management practices within the Wetlands category. Losses are reported for the years when the change has occurred. The same method was use as for the land-use change Forest Land converted to other land use. Methodology is described in Appendix\_6c.

For Other Wetlands Remaining Other Wetlands (CRF 4.D.1.3) carbon stock change in living biomass is assumed to be zero and notation key 'NO' is reported.

### Peat Extraction Remaining Peat Extraction

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-free period) CO<sub>2</sub> emissions 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 6.7-1).

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 emission estimates of CO<sub>2</sub> fluxes for stockpiles during a summer day were 83 g m<sup>-2</sup>, whereas for a winter day they were 139 g m<sup>-2</sup>. 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 6.7-1** Emission factors used in calculating of CO<sub>2</sub> 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		
		South Boreal	Middle Boreal	North Boreal
<b>Stockpiles</b>	2%	293 955	293 955	293 955
<b>Ditches</b>	7%	90	90	90
<b>Production</b>	91%	9 860	9 460	8 400
<b>Total emissions</b>	<b>100%</b>	<b>14 615</b>	<b>14 250</b>	<b>13 282</b>

## Off-site emissions from horticultural peat

Off-site CO<sub>2</sub> emissions from peat removed for horticultural use were estimated for this submission for the first time. All CO<sub>2</sub> emissions from horticultural use are reported combined with the on-site CO<sub>2</sub> emissions under Peat Extraction Remaining Peat Extraction (4.D.1.1)

Activity data for peat removed for horticultural use are peat production volumes compiled from peat producers (Finnish Statistical Yearbook of Forestry 2014). They consist of all horticultural peat produced in Finland including exported peat (2006 IPCC Guidelines). The CO<sub>2</sub> emissions from peat extraction are a key category in Finland and following the IPCC guidelines for reporting key categories, a country specific emission factor was developed. In Finland the peat removed for horticultural use is predominantly light and less decomposed, therefore the weighted average density of the horticultural peat (90 g L<sup>-1</sup>) is less than the value (166 g L<sup>-1</sup>) upon which IPCC default emission factor and carbon fraction are based. The country specific carbon fraction is 0.045 t C m<sup>-3</sup> air dry peat. Emissions are calculated as  $\text{Volume}_{\text{dry peat}} \times \text{C fraction}_{\text{peat}}$  and immediate emission in the harvesting year is assumed.

## Flooded land Remaining Flooded Land

Emissions were estimated for lands converted to Inland waters from Wetlands. Method applied for CO<sub>2</sub> is the Level 1 method presented in 2006 IPCC Guidelines, Vol. 4, Appendix 2. Level 1 method includes only the diffusive emissions during the ice-free period. Diffusive emissions during the 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 kg CO<sub>2</sub> ha<sup>-1</sup> day<sup>-1</sup> (2006 IPCC Guidelines, Table 2A.2, p. Ap2.6). Length of ice-free period was assumed to be 180 days.

## Other Wetlands Remaining Other Wetlands

Emissions for peat extraction areas converted to other wetlands were calculated with emission factor for Dwarf shrub type (Vatkg) (Table 6.4-4). Other managed wetlands include lands that have been converted over 20 years ago. Emissions for land converted from peat extraction over 20 years ago were computed with emission factor for Dwarf shrub type (Vatkg) (Table 6.4-4). For land converted from forest land over 20 years ago emission factor for *Cladina* type (Jätkg) (Table 6.4-4) was applied.

### 6.7.2.2 Land converted to Wetlands

#### Activity data

The activity data are calculated from NFI similarly as for Wetlands Remaining Wetlands (See 6.7.2.1).

#### Carbon stock changes in living biomass

**Land converted for Peat Extraction.** 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 of peat and is thicker than 150 cm. For further information on the method, see Appendix\_6c. The loss in carbon stock due to the removal of annual non-woody crops from conversion of Cropland to peat extraction in the conversion year was 4 t C/ha, which is a national value of mean crop biomasses based on yields. The corresponding EF for lands converted from Grassland to peat extraction was 4.1 t C/ha.

**Land converted to Flooded land.** It was assumed that due to the conversion from Forest Land to inland water, all tree biomass is removed. For further information on the method, see Appendix\_6c. Due to the conversions from Cropland to Flooded Land 4 t C ha<sup>-1</sup> in biomass was assumed to be lost. In conversion from Grassland to Flooded Land no loss in biomass is reported, but all biomass was assumed to be left on the site.

**Land converted to Other Wetlands.** This category consists of organic forest land that have regressed to wetlands, and grassland and settlements converted to Other Wetlands (CRF 4.D.2.3). When forest land

regresses to wetlands, the biomass is not removed. The biomass is assumed in steady state, so that gains equal removals.

*Carbon stock changes in dead wood, litter and soil organic matter*

**Land converted to Flooded Land.** The emissions were estimated with the same method as for flooded land remaining flooded land (2006 IPCC Guidelines, Vol. 4, Appendix 2).

**Land converted for Peat Extraction.** 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\_6i. The emissions from lands converted to peat extraction sites were calculated in the same way as emissions for peat extraction remaining peat extraction (See 2006 IPCC Guidelines, Vol. 4, Section 6.7.2.1). In this conversion category, 'IE' is reported for CSC in litter. When Forest Land is converted to peat extraction, after the clear cut timber, slash and stumps are removed. Timber is used for wood products, slash and stumps are piled, chipped and used for energy. Losses in carbon stock due to the removal of these tree components are reported under losses in living biomass. The surface (incl. litter) of the peat is also removed. The surface matter can be combusted with peat in power plant, and in this case the emissions are reported under the energy sector, or used to construct a stable ground for stock piles. In that case, the decomposition of litter is included in the emissions from stock piles. EFs for peat extraction include emissions from production fields, stock piles and ditches. Emissions due to decomposition of fine dead roots (litter in peat) are included in the EFs from peat production fields.

**Land converted to Other Wetlands.** This category consists of organic forest land, grassland and settlements that have regressed to wetlands (CRF 4.D.2.3). Emissions from these soils were estimated by applying the emission factors shown in Table 6.7-2.

**Table 6.7-2** Estimated carbon stock changes of soil organic matter and dead organic matter in organic 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

### 6.7.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents the assumptions made for the analysis.

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%. If the uncertainty for summertime CO<sub>2</sub> emissions is estimated using 2SD ( $\pm 12-16\%$ ), the contribution of winter CO<sub>2</sub> with lower emission rates can be expertly deemed to increase the level of uncertainty to  $\pm 25\%$  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 6.2-2). Applicable data are 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. For deadwood losses during these conversions it was assumed that total uncertainty is 103%.

The area estimations are based on NFI data and the total areas of the peat extraction fields are consistent for the entire time series (1990-2013) 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> emissions from flooded land and from land converted to flooded land were estimated with 2006 IPCC Guidelines default emission factor values and the uncertainty of those were estimated to be one order of magnitude, i.e. 100%.

### *6.7.4 Category-specific QA/QC and verification*

The quality objectives and the QA/QC plan and verification for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.2.3.

Until the end of 2014, the Finnish Forest Research Institute (Metla) had a management team to guide and supervise the reporting of emissions and removals for the LULUCF sector, which was under Metla's responsibility. The members had 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 were discussed and approved by the management team before they were introduced to the advisory board (see Section 1.2.1). Representatives from Statistics Finland and Agrifood Research Finland were invited to the meetings. The management team met 2-4 times per year. From 2015 onward, a new management team will be set up in Luke.

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 country-specific emissions factor used to estimate off-site emissions from horticultural peat were compared to those of Sweden. The type and quality of peat in Finland differs from the peat to which the IPCC default EF is based on. The Swedish values were in line with Finnish values.

The quality control procedures specified in the 2006 IPCC Guidelines 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 6.7-3). Areas are greater according to the NFI than statistics. NFI covers all peat extraction fields regardless of the size or production activity, only focusing on land-use at the time of assessment in the field. In 2013, the statistical peat extraction area is closer to 80,000 ha since part of data from Western-Finland is not 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 6.7-3** Area of industrial peat extraction in Finland (1000 ha) compared to the statistics

Year	Area of peat extraction	Area from statistics	Difference
1990	82.395	64.7	17.695
1995	89.583	73.8	15.783
2000	98.083	83.3	14.783
2001	99.345	83.5	15.845
2002	99.403	82.2	17.203
2003	99.264	82.1	17.164
2004	99.181	88.3	10.881
2005	100.34	87.2	13.14
2006	101.233	86.8	14.433
2007	103.548	85.3	18.248
2008	106.113	87.3	18.813
2009	108.211	85.1	23.111
2010	109.387	87.2	22.187
2011	110.791	83.7	27.091
2012	111.104	82.1	29.004
2013	111.577	77.9	33.677

### 6.7.5 Category-specific recalculations

New area estimates were calculated due to updating of NFI data (see Section 6.2). This resulted in recalculation for the whole time series. Off-site CO<sub>2</sub>-emissions from horticultural peat were reported for the first time.

**Table 6.7-4** Recalculations made in Wetlands category and their implications to the emission level in 1990 and 2012 (kt CO<sub>2</sub>)

Year	2014 submission	2015 submission	difference
1990	1 310.8	1 440.0	129.2
2012	1 753.2	2 103.5	350.3

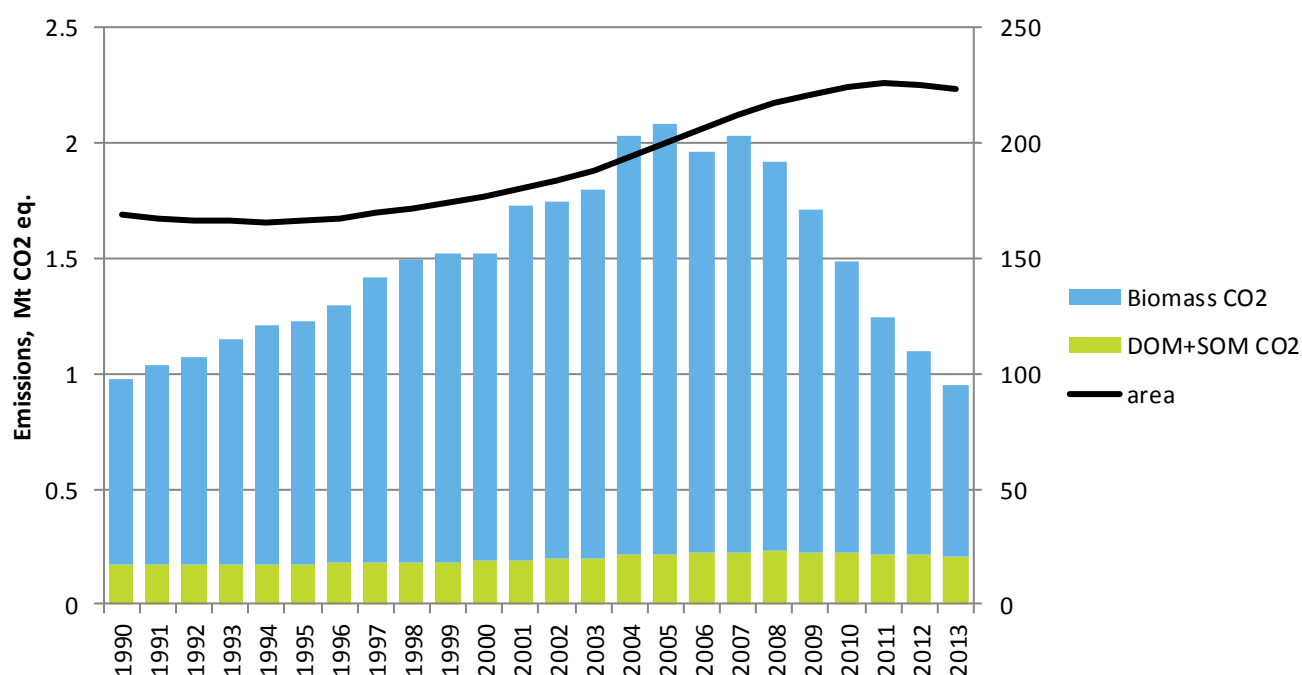
### 6.7.6 Category-specific planned improvements

The development project on harvested wood products will provide NFI based estimates for tree biomass losses, by land use categories and land-use change types. If the developed method will give more accurate estimates for all land-use change types, the method will be implemented in GHG inventory in 2018.

## 6.8 Settlements (CRF 4.E)

### 6.8.1 Category description

The areas of Settlements comprise nationally defined built-up land, roads, railroads, gravel collection sites and power lines (see Section 6.2). Finland reports CO<sub>2</sub> emissions from losses in living biomass due to conversion under Forest land, Cropland, Grassland and Wetlands converted to Settlements. Biomass and deadwood loss due to conversion and emissions from litter and soil organic matter after conversion are reported under Forest land converted to Settlements. Emissions from Forest Land converted to Settlements were 0.96 Mt CO<sub>2</sub> eq. in 2013 (Figure 6.8-1). After 2005 there is a declining trend in the emissions due to declining yearly areas converted to Settlements. The 20-year conversion area is however only slightly turning downwards after peak year 2011. Emissions from dead wood and soil are small compared to emissions from biomass loss.



**Figure 6.8-1** Emissions (Mt CO<sub>2</sub>) of Forest Land Converted to Settlements

### 6.8.2 Methodological issues

#### 6.8.2.1 Settlements Remaining Settlements

The areas of Settlements Remaining Settlements were calculated from NFI data (See 6.7.2.1). According to Tier 1 method it was assumed there are no changes in biomass, DOM and SOM carbon pools (2006 IPCC Guidelines, Vol. 4, Ch. 8, p. 8.7, p. 8.13, 8.15), and a notation key is 'NO' is reported.

#### 6.8.2.2 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 NFI data. 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 land is converted to developed use, such as for infrastructure or urban areas, the trees and other biomass are usually removed. The resulting emissions are reported based on the assumption that all of the biomass is removed. If biomass left to grow in the settlement area, the gain in biomass is not reported. This is due to fact that currently we do not have enough data for this and the methodology is under development. For further information on the method, see Appendix\_6c.

### *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\_6i). 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 converted to GL emissions factors. 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 in litter- and soil organic matter pools.

## *6.8.3 Uncertainty and time series' consistency*

Uncertainty due to sampling in the area of Settlements was estimated by the standard method of Finnish NFI (Table 6.2-2). Applicable data are 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 (1990-2013) 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 Land 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%.

The uncertainty of emissions from soil organic matter and deadwood were assumed to be 106%.

### 6.8.4 Category-specific QA/QC and verification

The quality objectives and the QA/QC and verification plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.2.3

Until the end of 2014, the Finnish Forest Research Institute (Metla) had a management team to guide and supervise the reporting of emissions and removals for the LULUCF sector, which was under Metla's responsibility. The members had 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 were discussed and approved by the management team before they were introduced to the advisory board (see Section 1.2.1). Representatives from Statistics Finland and Agrifood Research Finland were invited to the meetings. The management team met 2-4 times per year. From 2015 onward, a new management team will be set up in Luke.

QA/QC related issues are discussed together with the inventory unit at Statistics Finland 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.

### 6.8.5 Category-specific recalculations

New area estimates were calculated due to new data, updating of NFI data and error corrections (see Section 6.2). This resulted in recalculations for the whole time series (Table 6.8-1)

**Table 6.8-1** The difference in the emissions from Forest Land Converted to Settlements due to recalculation between 2014 and 2015 submissions (kt CO<sub>2</sub>)

Year	2014 submission	2015 submission	difference
1990	929.35	989.30	59.94
2012	906.40	1 110.63	204.23

### 6.8.6 Category-specific planned improvements

A method to estimate tree biomass gains for lands remaining in same land use is under development. In NFI, the trees outside forest have been measured once. Since there are no data of the increment of trees outside forest, the method applied to Forest Land, is not appropriate. A method based on growth rates is under development. The results are expected to be ready for the 2017 GHG inventory. The development project on harvested wood products will provide NFI based estimates for tree biomass losses, by land use categories and land-use change types. If the developed method will give more accurate estimates for all land-use change types, the method will implemented in GHG inventory in 2018.

## 6.9 Other land (CRF 4.F)

### 6.9.1 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\_6a). In principle Other lands are considered unmanaged land, but Lands converted to Other Land are managed. The method for estimating the areas of other lands is provided in Section 6.1.2. No carbon stock changes or non-CO<sub>2</sub> emissions are reported in this category.

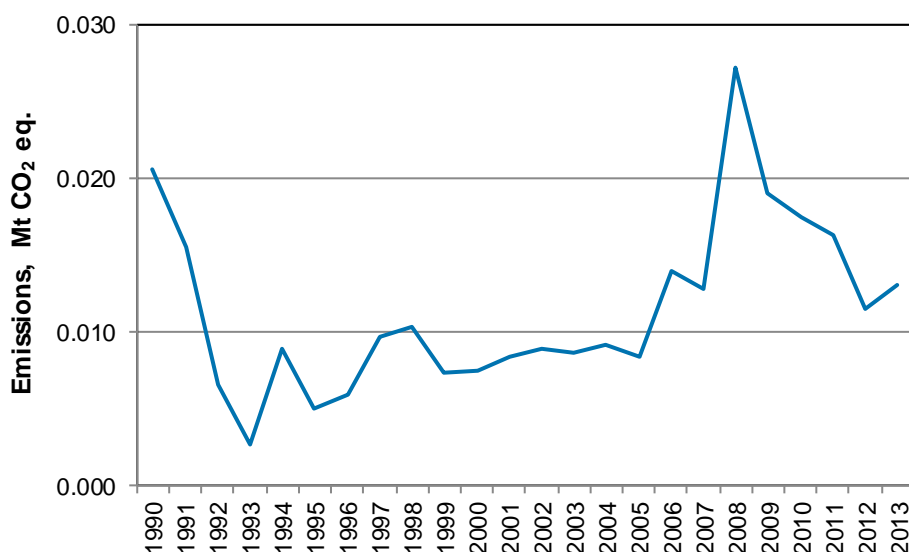
## 6.10 Non-CO<sub>2</sub> emissions

### 6.10.1 Direct N<sub>2</sub>O emissions from fertilisation (CRF 4 (I))

#### 6.10.1.1 Category description

This category covers direct nitrous oxide emissions from forest fertilisation (CRF 5 (I)) (Figure 6.10-1). 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 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 until 2013 when the emissions increased a little. In 2013 the emissions from forest N<sub>2</sub>O fertilisation were 0.013 Mt CO<sub>2</sub> eq.



**Figure 6.10-1** N<sub>2</sub>O emissions from forest fertilisation (Mt CO<sub>2</sub> eq.)

#### 6.10.1.2 Methodological issues

The IPCC default method (Tier 1) is used to estimate N<sub>2</sub>O emissions from forest fertilisation (2006 IPCC Guidelines). 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% is used (2006 IPCC Guidelines, Vol. 4, Table 11.1).

#### 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 6.10-1). Yara Suomi Oy, previously Kemira GrowHow Oy, produces the information. The company delivers almost 100% of fertilisers applied to forests.

**Table 6.10-1** 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
1995	1 066
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
2013	2 790

### 6.10.1.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents the assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

Uncertainty estimate for the activity data is  $\pm 10\%$  and for the emission factor -70 to +200% (Default value 0.01 with uncertainty range of 0.003-0.03). The same estimates 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.

### 6.10.1.4 Category-specific QA/QC and verification

The quality objectives and the QA/QC and verification plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.2.3. The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives. The bilateral quality meeting is held annually between the inventory unit and the sectoral expert.

Until the end of 2014, the Finnish Forest Research Institute (Metla) had a management team to guide and supervise the reporting of emissions and removals for the LULUCF sector, which was under Metla's responsibility. The members had 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 were discussed and approved by the management team before they were introduced to the advisory board (see Section 1.2.1). Representatives from Statistics Finland and Agrifood Research Finland were invited to the meetings. The management team met 2-4 times per year. From 2015 onward, a new management team will be set up in Luke.

The general quality control procedures specified in the 2006 IPCC Guidelines 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 2014). 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.

#### *6.10.1.5 Category-specific recalculations*

The emission factor was updated according to 2006 IPCC Guidelines. This resulted in recalculation for the whole time series (Table 6.10-2).

**Table 6.10-2** The difference in the emissions from direct N<sub>2</sub>O emissions from fertilisation due to recalculation between 2014 and 2015 submissions (kt CO<sub>2</sub> eq.)

	<b>Emissions, kt CO<sub>2</sub> eq.</b>	
	<b>1990</b>	<b>2012</b>
Submission 2014	26.8	15.0
Submission 2015	20.6	11.5
Difference 2015-2014	-6.2	-3.5

#### *6.10.1.6 Category-specific planned improvements*

No planned improvements.

### *6.10.2 Non-CO<sub>2</sub> emissions from drainage and rewetting and other management of organic and mineral soils (CRF 4 (II))*

#### *6.10.2.1 Category description*

Finland reports non-CO<sub>2</sub> emissions in the CRF Table 4 (II) that is, N<sub>2</sub>O and CH<sub>4</sub> emissions from drained organic forest soils (both Forest Land Remaining Forest Land and Land Converted to Forest Land), N<sub>2</sub>O and CH<sub>4</sub> emissions from peat extraction areas, and CH<sub>4</sub> emissions from land converted to inland waters and to other wetlands. CO<sub>2</sub> emissions from peat extraction areas and land converted to inland waters are reported in category 4.D Wetlands (Section 6.7).

In 2013, the N<sub>2</sub>O emissions from drained organic forest soils were 1.1 Mt CO<sub>2</sub> equivalents, while CH<sub>4</sub> emissions were 0.8 Mt CO<sub>2</sub> equivalents in total, see Table 6.10-3. This estimate includes emissions from both Forest Land Remaining Forest Land and those converted to Forest Land.

**Table 6.10-3** Methane and nitrous oxide emissions from Forest Land, kt CO<sub>2</sub> eq.

	FL, CO <sub>2</sub> eq.			
	N <sub>2</sub> O	CH <sub>4</sub>	CH <sub>4</sub>	CH <sub>4</sub> tot
	emissions	emissions	emissions,ditch	
1990	1 163	909	576	1 486
1995	1 164	812	587	1 398
2000	1 179	693	594	1 287
2001	1 177	663	595	1 258
2002	1 174	633	596	1 229
2003	1 177	603	597	1 200
2004	1 174	573	599	1 171
2005	1 161	542	600	1 142
2006	1 157	512	601	1 113
2007	1 149	482	602	1 084
2008	1 140	426	600	1 025
2009	1 133	369	597	966
2010	1 130	312	595	907
2011	1 123	256	593	849
2012	1 123	255	592	848
2013	1 121	255	592	847

#### 6.10.2.2 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 Table 6.10-5. The fertility classification was based on the one presented in Table 6.4-1, but slightly modified to match emissions factors classes provided by Ojanen et al. 2010.

Emissions of CH<sub>4</sub> from drained organic forest lands are reported for the first time in the 2015 submission. The CH<sub>4</sub> emissions consist of emissions from drained land (97.5% of the area, country specific EFs) and from ditches (2.5%, default fraction and EF 217 kg CH<sub>4</sub> ha<sup>-1</sup> for boreal/ temperate zone given the IPCC Wetlands Supplement). Country-specific emission factors for CH<sub>4</sub> from drained organic land by drainage class are net emission of 11.6 kg CH<sub>4</sub> ha<sup>-1</sup> for poorly or recently drained land and net uptake of -2.8 kg CH<sub>4</sub> ha<sup>-1</sup> for well drained land (based on Ojanen et al. 2010) (Table 6.10-5). Emissions were estimated with Tier 2 and with Tier1 (ditches) methods by multiplying land areas of drained organic forest soils with emissions factors. The uncertainty in the emission factors for CH<sub>4</sub> was estimated as standard errors of mean: 11.6±4.8 kg CH<sub>4</sub> ha<sup>-1</sup>, and -2.8 ± 0.4 kg CH<sub>4</sub> ha<sup>-1</sup> (Ojanen et al. 2010).

The non CO<sub>2</sub> emissions from peat extraction fields include the CH<sub>4</sub> and N<sub>2</sub>O emissions from the area of active and temporarily set-aside peat extraction fields and abandoned, non-vegetated peat extraction areas, emissions from stockpiles and emissions from ditches (Table 6.10-4), following principles of IPCC Wetlands Supplement. Also CH<sub>4</sub> emissions from peat extraction fields that converted to other wetlands are reported under this category, the emission factors are those based on CH<sub>4</sub> from poorly drained organic soils. (Ojanen et al. 2010). N<sub>2</sub>O emissions do not occur in rewetted organic soils (IPCC 2014b).

**Table 6.10-4** Emission factors used in calculating of non-CO<sub>2</sub> 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	CH <sub>4</sub> emissions			N <sub>2</sub> O emissions		
		South Boreal	Middle Boreal	North Boreal	South Boreal	Middle Boreal	North Boreal
Stockpiles	2%	6 275	6 275	6 275	910	910	910
Ditches	7%	3 724	3 724	3 724	1	1	1
Production	91%	105	105	105	961	961	961
<b>Total emissions</b>	<b>100%</b>	<b>468</b>	<b>468</b>	<b>468</b>	<b>895</b>	<b>895</b>	<b>895</b>

**Table 6.10-5** Emissions factors and their uncertainty for N<sub>2</sub>O and CH<sub>4</sub> emissions from drained Forest Land, by fertility class and by drainage condition, based on Ojanen et al. (2010)

Site type	EF g N <sub>2</sub> O m-2 a-1	SE g N <sub>2</sub> O m-2 a-1	Ditch condition	EF g CH <sub>4</sub> m-2 a-1	SE g CH <sub>4</sub> m-2 a-1
Rhtkg	1.85	0.065	Poor	1.16	0.48
MtkgI	1.16	0.035	Good	-0.028	0.04
MtkgII	1.67	0.072			
PtkgII	0.28	0.01			
PtkgII	0.71	0.016			
Vatkg	0.29	0.007			
Jätkg	0.29	0.007			

*Non-CO<sub>2</sub> emissions from flooded land include ice-free season diffusive CH<sub>4</sub> emissions.*

CH<sub>4</sub> emissions were estimated with Tier 1 method of the 2006 IPCC Guidelines, Vol. 4, 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 kg CH<sub>4</sub> ha<sup>-1</sup> day<sup>-1</sup> (2006 IPCC Guidelines, Vol. 4, Table 3A.2, p. Ap3.5). Length of ice-free period was assumed to be 180 days. Following the 2006 IPCC guidelines, once an area is flooded the CH<sub>4</sub> emissions will be sustained from thereon, in contrast to CO<sub>2</sub> emissions which are limited to the first 10 years.

### 6.10.2.3 Uncertainty and time series' consistency

The uncertainties for emission factors were reported in Table 6.10-5, while uncertainties of land areas were estimated as described in Section 6.2. The total uncertainty was propagated according to IPCC (2006). It was assumed that the uncertainties between site types were independent from each other. The total uncertainty of the N<sub>2</sub>O and CH<sub>4</sub> emissions from drained forest land was ±30%. The uncertainty of emissions due to drainage and re-wetting were assumed to be 82% for CH<sub>4</sub> and 80% for N<sub>2</sub>O emissions. These error estimates combine uncertainties of land area estimate and that of emissions factor.

The aggregated uncertainty of non-CO<sub>2</sub> emissions from land converted to wetlands and also from lands remaining wetlands were assumed to be up to 170%. This high uncertainty results from small land areas and also from the fact that there is limited amount of data behind measurements.

The fluxes of CH<sub>4</sub> and N<sub>2</sub>O from peat extractions sites 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 from peat extraction is estimated using 2SD (±12-16%), the contribution of winter 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. It was assumed that combined uncertainty for land area estimate and emissions were 55% for non-CO<sub>2</sub> emissions from peat extraction lands.

The CH<sub>4</sub> emissions from flooded land and from land converted to flooded land were estimated with 2006 IPCC Guidelines default emission factor values and the uncertainty of those were estimated to be one order of magnitude, i.e. 100%.

#### 6.10.2.4 Category-specific QA/QC and verification

The quality objectives and the QA/QC and verification plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.2.3. The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives. The bilateral quality meeting is held annually between the inventory unit and the sectoral expert.

Until the end of 2014, the Finnish Forest Research Institute (Metla) had a management team to guide and supervise the reporting of emissions and removals for the LULUCF sector, which was under Metla's responsibility. The members had 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 were discussed and approved by the management team before they were introduced to the advisory board (see Section 1.2.1). Representatives from Statistics Finland and Agrifood Research Finland were invited to the meetings. The management team met 2-4 times per year. From 2015 onward, a new management team will be set up in Luke.

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.

#### 6.10.2.5 Category-specific recalculations

Emissions of CH<sub>4</sub> from drained organic forest land are reported for the first time. New area estimates were calculated due to updating of NFI data (see Section 6.2). This resulted in recalculation for the whole time series Table 6.10-6.

**Table 6.10-6** The difference in the emissions from non-CO<sub>2</sub> emissions from drainage and rewetting and other management of organic and mineral soils due to recalculation between 2014 and 2015 submissions (kt CO<sub>2</sub> eq.)

	Submission 2014	Submission 2015	Difference	Submission 2014	Submission 2015	Difference
	1990			2012		
<b>Forest Land</b>						
CH <sub>4</sub>	NE	59.425	<b>59.4</b>	NE	33.909	<b>33.9</b>
N <sub>2</sub> O	3.682	3.843	<b>0.2</b>	3.86	3.731	<b>-0.1</b>
<b>Wetlands</b>						
CH <sub>4</sub>	1.978	1.840	<b>-0.1</b>	2.696	2.749	<b>0.1</b>
N <sub>2</sub> O	0.238	0.238	<b>0.0</b>	0.322	0.325	<b>0.0</b>

#### 6.10.2.6 Category-specific planned improvements

There are no planned improvements.

### 6.10.3 Direct N<sub>2</sub>O emissions from N mineralisation/immobilisation (CRF 4 (III))

#### 6.10.3.1 Category description

This category consists of direct N<sub>2</sub>O emissions from N mineralisation/immobilisation associated with loss or gain of soil organic matter resulting from change of land use or management of mineral soils. Emissions of N<sub>2</sub>O following the conversion of forest land into cropland, grassland or settlements, cropland into grassland and grassland into cropland are reported under this category. In 2013, the emissions from forest land and grassland converted into cropland were 0.0419 kt and those converted from forest land or cropland to grassland 0.005 kt. The emissions from forest land converted to settlements were 0.056 kt. 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 2013.

#### 6.10.3.2 Methodological issues

##### Methods

The N<sub>2</sub>O emissions from forest land and grassland converted into cropland and forest land converted to settlements were calculated according to Equations 11.2 and 11.8 in the 2006 IPCC Guidelines, Vol. 4:

$$N_2O_{SOM-N} = EF_1 * F_{SOM}$$

where

$N_2O_{SOM-N}$  = additional emissions arising from the land use change, kg N<sub>2</sub>O-N a<sup>-1</sup>

$EF_1$  = IPCC default EF, 0.01 kg N<sub>2</sub>O-N/kg N

$N_{net-min}$  = N released annually by net soil organic matter mineralization, kg N a<sup>-1</sup>

$$F_{SOM} = \Delta C * 1 / C:N \text{ ratio}$$

where

$\Delta C$  = carbon loss from soil as a result of conversion, kg C a<sup>-1</sup> (see Sections 6.5, 6.6 and 6.8)

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% is used (2006 IPCC Guidelines). 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 6.3. The reduction of the C stock due to conversion was determined as described in Appendix\_6c.

#### 6.10.3.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents the assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

The time series is consistent.

#### 6.10.3.4 Category-specific QA/QC and verification

The quality control procedures specified in the 2006 IPCC Guidelines (Vol 1, Chapter 6, Table 6.1) were followed.

Until the end of 2014, the Finnish Forest Research Institute (Metla) had a management team to guide and supervise the reporting of emissions and removals for the LULUCF sector, which was under Metla's responsibility. The members had 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 were discussed and approved by the management team before they were introduced to the advisory board (see Section 1.2.1). Representatives from Statistics Finland and Agrifood Research Finland were invited to the meetings. The management team met 2-4 times per year. From 2015 onward, a new management team will be set up in Luke.

#### 6.10.3.5 Category-specific recalculations

The whole time series was recalculated as the result of updated time series for the area data (see Section 6.2) and the update of the EF from IPCC (2006). The emissions from forest land converted to settlements are reported for the first time in this submission.

#### 6.10.3.6 Category-specific planned improvements

No improvements are planned at the moment.

### 6.10.4 N<sub>2</sub>O emissions from N leaching and runoff (CRF 4 (IV))

#### 6.10.4.1 Category description

N<sub>2</sub>O emissions from N leaching related to land-use conversions were calculated for all classes of mineral soils converted to cropland or grassland if they experienced C stock loss. The total amount of emissions reported in this category was 0.009 kt.

#### 6.10.4.2 Methodological issues

##### *Methods*

The N<sub>2</sub>O emissions were calculated according to equation 11.10 of IPCC (2006):

$$N_2O_{L-N} = F_{SOM} * Frac_{LEACH} * EF_5$$

where

$N_2O_{L-N}$  = emissions from leaching and runoff of mineralized N related to land use change, kg N<sub>2</sub>O-N a<sup>-1</sup>

$Frac_{LEACH}$  = fraction of N lost through leaching (0.3)

$EF_5$  = IPCC default EF, 0.0075 kg N<sub>2</sub>O-N/kg N

##### *Emission factors and other parameters*

The IPCC default fraction of leached N (0.3) and emission factor of 0.0075% is used (2006 IPCC Guidelines).

##### *Activity data*

The area estimate was obtained as described in Section 6.1.2. The reduction of the C stock due to conversion was determined as described in Sections 6.5 and 6.6.

#### 6.10.4.3 *Uncertainty and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents the assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

The time series is consistent.

#### 6.10.4.4 *Category-specific QA/QC and verification*

The quality control procedures specified in the 2006 IPCC Guidelines (Vol 1, Chapter 6, Table 6.1) were followed.

#### 6.10.4.5 *Category-specific recalculations*

The category was reported for the first time.

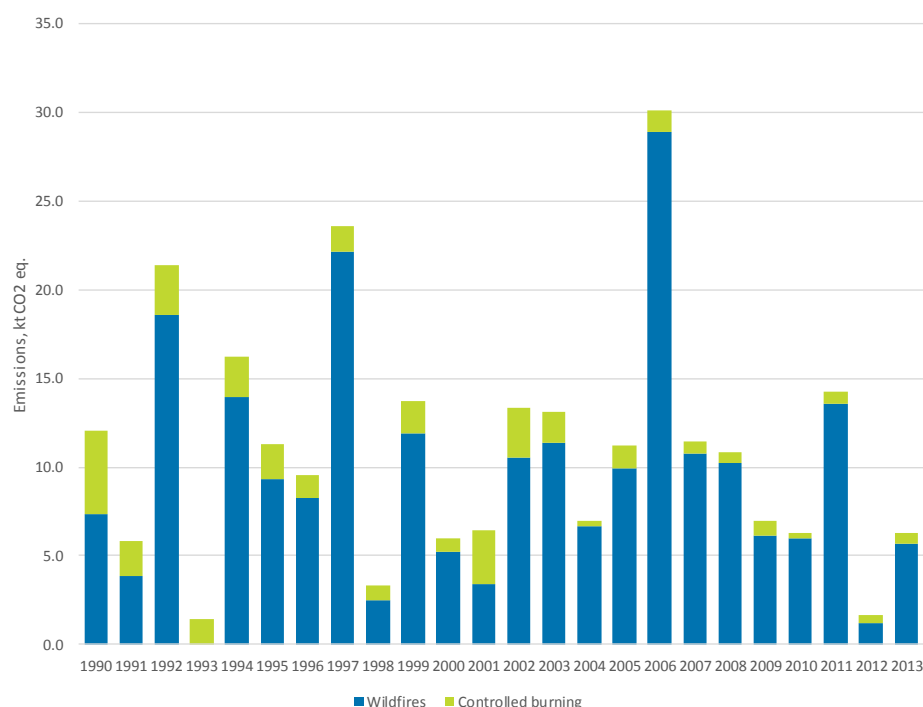
#### 6.10.4.6 *Category-specific planned improvements*

No improvements are planned at the moment.

### 6.10.5 *Biomass burning (CRF 4 (V))*

#### 6.10.5.1 *Category description*

This 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 from wildfires and controlled burnings (Table 6.10-2). 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. When classifying land area by IPCC land-use category, forest fires can occur on Forest Land, Wetlands and Other Land. These emissions are not reported from croplands or grasslands since it is stated in the fire statistics that no woody biomass has been burned in wildfires in 1995-2012 on cropland or grassland. Because orchards are a rare form of land use, it can be assumed that no woody biomass was burned in 1990-1994 or 2013 either. All wildfires are reported under category 4.A 1: Forest Land Remaining 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 to the mean biomasses applied in the KP-LULUCF reporting.



**Figure 6.10-2** Emissions from biomass burning (kt CO<sub>2</sub> eq.)

#### 6.10.5.2 Methodological issues

The default IPCC method was applied using national activity data and IPCC default emission factors. Equation 2.14 was used to estimate the annual losses of carbon and non-CO<sub>2</sub> emissions from carbon released (IPCC 2003).

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.

#### 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 6.2). 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 total biomass per hectare of burned area has been approximately 60 tonnes. The combustion efficiency is based on expert judgement<sup>14</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 burned. For clear-cut forests emissions were estimated as those from prescribed burnings.

<sup>14</sup> Ilkka Vanha-Majamaa (Finnish Forest Research Institute) and Timo Heikkilä (Ministry of the Interior), 2007

### 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 Southern and Northern 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>Southern Finland</u>	<u>Northern 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>15</sup> that 25% ( $\pm 5\%$ ) of the tree biomass, 20% ( $\pm 10\%$ ) of the field layer biomass and 12.5% ( $\pm 7.5\%$ ) of the bottom layer biomass would burn. The IPCC default carbon fraction (50%), emission ratios and N/C ratio were used.

### *Activity data*

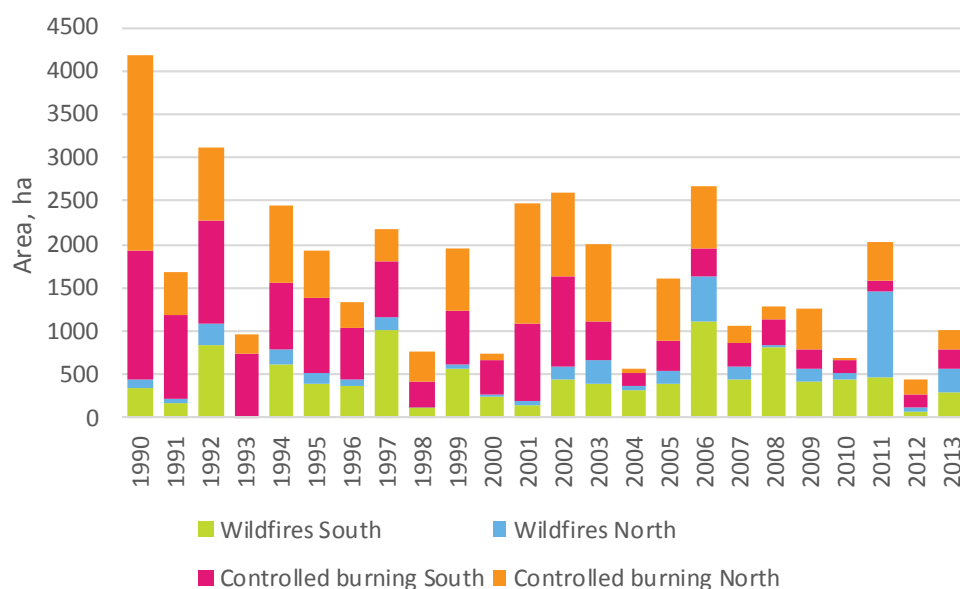
The activity data of the burned area are presented in Figure 6.10-3. The information source for the area of wildfires is the Ministry of the Interior that provided the database of individual landfires to be used in the estimation. In that database area has been divided into clear-cut areas and into stocked forests.

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.

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.

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<sup>15</sup> Ilkka Vanha-Majamaa (Finnish Forest Research Institute) and Timo Heikkilä (Ministry of the Interior), 2007



**Figure 6.10-3** Burned area, ha

#### 6.10.5.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents the assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

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 are consistent.

#### 6.10.5.4 Category-specific QA/QC and verification

The quality objectives and the QA/QC and verification plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.2.3. The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives. The bilateral quality meeting 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 MS Excel.

Until the end of 2014, the Finnish Forest Research Institute (Metla) had a management team to guide and supervise the reporting of emissions and removals for the LULUCF sector, which was under Metla's responsibility. The members had 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 were discussed and approved by the management team before they were introduced to the advisory board (see Section 1.2.1). Representatives from Statistics Finland and Agrifood Research Finland were invited to the meetings. The management team met 2-4 times per year. From 2015 onward, a new management team will be set up in Luke.

The general quality control procedures specified in the 2006 IPCC Guidelines 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 2014). 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.

#### *6.10.5.5 Category-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. Also a database of individual fires were obtained that allowed us to estimate wildfire emissions based on two classes, namely clear-cut areas and stocked forests.

#### *6.10.5.6 Category-specific planned improvements*

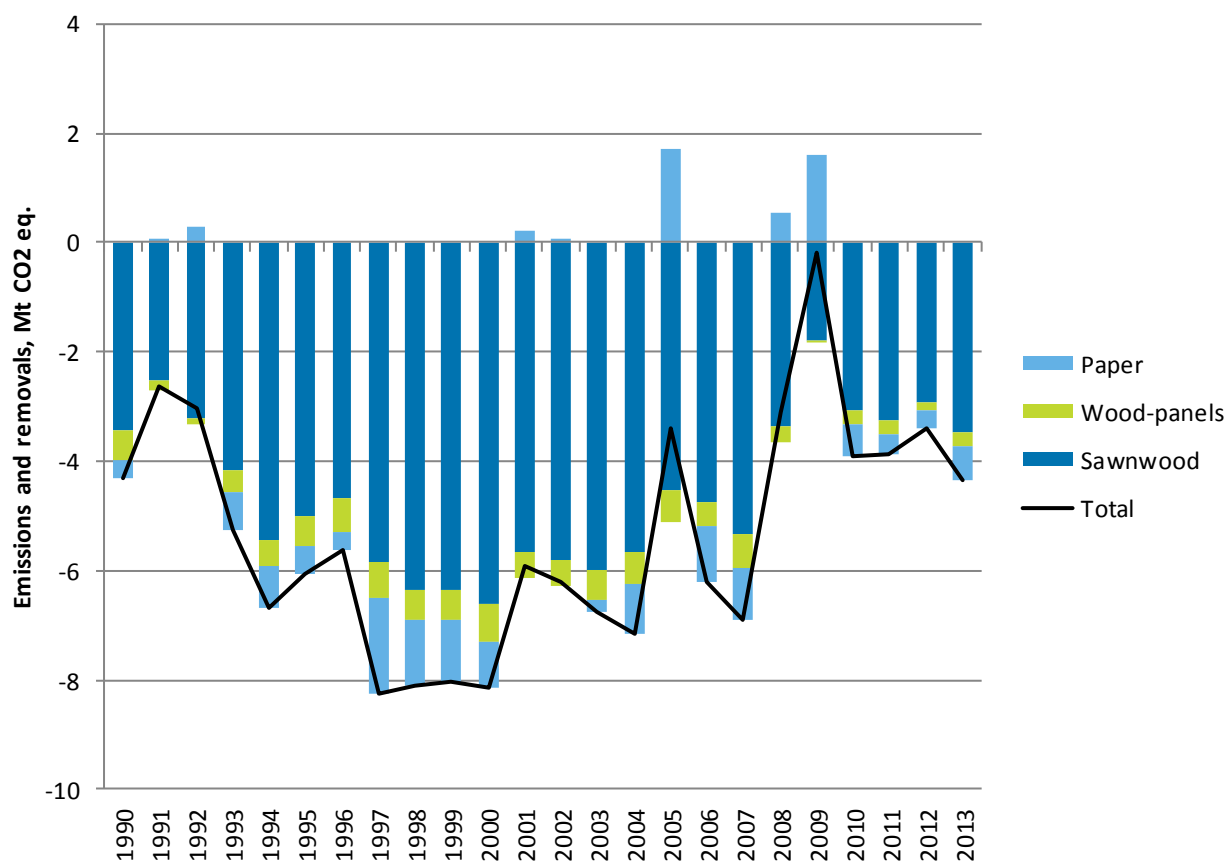
The suitability of the current emission factors to the Finnish conditions of biomass burning will be studied against IPCC 2006 methodology. The results are expected to be ready by the 2017 annual submission.

## 6.11 Harvested Wood Products (CRF 4.G)

### 6.11.1 Category description

Harvested Wood Products (HWP) pool was a net sink of 4.4 Mt CO<sub>2</sub> in 2013 of which 35% came from domestically consumed HWP and 65% from exported HWP. HWP has been a net sink for the whole reported time series. The most important component of the HWP sink was sawn wood. The sink of sawn wood has been at its lowest level in 2009 being 2.0 Mt CO<sub>2</sub> and its highest in 2000 6.6 Mt CO<sub>2</sub>. Wood panels has been a sink in 1990–2013 but less than 0.7 Mt CO<sub>2</sub>. Paper and paperboard has acted both as a sink and as a source. Paper and paperboard category is sensitive to the changes in production, since the lifetime of paper is much shorter than of sawn wood and wood panels (Figure 6.11-1).

HWP is a key category as in trend and a level based on the IPCC Tier 1 methodology.



**Figure 6.11-1** Emissions and removals from HWP categories sawn wood, wood panels and paper products

HWP is reported as a carbon stock change in production based HWP stocks originating from wood harvested in Finland including exported HWP. HWP comprise of solid wood products (sawn wood and wood panels) and paper products (wood pulp). The production quantity of pulp was used as a proxy for paper and paperboard production. In Finland, 98.7% of wood pulp is used for paper and paperboard production, and 1.3% (part of dissolving wood pulp) for textile and hygiene products which are exported (percentages are for 2013)<sup>16</sup>. Wood pulp production for other purposes than paper and paperboard has started mainly in 2012. The annual change of HWP in domestic solid waste disposal sites in (SWDS) and exported products in SWDS was not estimated and is reported as 'NE'.

<sup>16</sup> FAOSTAT: <http://faostat3.fao.org/home/E>  
Customs: <http://uljas.tulli.fi>

## 6.11.2 Methodological issues

### 6.11.2.1 Methods

The Production Approach was used to estimate carbon stock change in HWP (2006 IPCC Guidelines, Vol. 4, Annex 12.A.1). This approach was selected to keep the Convention reporting comparable with the KP reporting. The approach and the reporting scheme encompass domestically produced HWP originating from domestic harvest separately for domestically consumed and exported HWP by HWP categories.

To estimate the HWP contribution, the variables 2A HWP in use, and 2B HWP in SWDS, for which the wood originated from domestic harvest, were needed (2006 IPCC Guidelines, Vol. 4, Table 12.1).

$$\Delta C_{HWP_{DC}} = \Delta C_{HWP_{IU_{DC}}} + \Delta C_{HWP_{SWDS_{DC}}}$$

The carbon stock change in SWDS was assumed to be zero, so the variable 2B ( $\Delta C_{HWP_{SWDS_{DC}}}$ ) was set to zero, and only the variable 2A ( $\Delta C_{HWP_{IU_{DC}}}$ ) was estimated. Method to estimate annual carbon stock change of variable 2A is a Tier 2 method. The annual change in carbon stock in the HWP pool was estimated using a flux-data method with default half-lives and country specific activity data. The decay of HWP is estimated employing the first order decay (FOD) function (Equation 12.1 in the 2006 IPCC Guidelines, Vol. 4).

$$C(i+1) = e^{-k} \times C(i) + \left[ \frac{(1 - e^{-k})}{k} \right] \times Inflow(i)$$

$$\Delta C(i) = C(i+1) - C(i)$$

Where:

$i$  = year

$C(i)$  = the carbon stock in a HWP category at the beginning of year  $i$ , kt C

$k$  = decay constant of FOD for a HWP category,  $\text{yr}^{-1}$  ( $k = \ln(2)/HL$ , where HL is half life of a HWP category)

$Inflow(i)$  = the inflow to a HWP category in year  $i$ , kt C

$\Delta C(i)$  = carbon stock change in a HWP category in year  $i$ , kt C

HWP categories sawn wood, wood panels and wood pulp were used. The estimation started from 1961, since statistical activity data was available since then. The annual inflow to a HWP category originating from domestically produced wood for sawn wood, wood panels and paper products was estimated as:

$$Inflow(i)_{(DH)} = P(i) \times \left[ \frac{RWC(i)_{(DH)}}{RWC(i)_{TOT}} \right]$$

Where:

$Inflow(i)_{DH}$  = carbon in annual production of a HWP category originating from domestic harvest in year  $i$ , kt C

$P(i)$  = carbon in annual production of a HWP category in year  $i$ , kt C

$RWC(i)_{DH}$  = roundwood consumption of domestic harvest by wood or pulp industry in year  $i$ ,  $\text{m}^3$

$RWC(i)_{TOT}$  = total roundwood consumption by wood or pulp industry in year  $i$ ,  $\text{m}^3$

Statistics on total wood consumption and consumption of domestic round wood by wood-products industry and pulp industry were used to estimate the production from domestic harvest. Annual statistics were available for the period of interest, from 1961 onwards. Statistics for the years 1990 onwards are from Finnish Statistical Yearbook of Forestry 2014 and statistics for 1961-1989 are from Finnish Statistical Yearbook of Forestry 2000.

The HWP contribution was computed separately for HWP produced and consumed domestically and HWP produced and exported. The annual carbon stock change was subdivided into these two groups by the proportion of exported products and total production for HWP categories.

$$CSC(i)_{EXP} = CSC(i) \times \frac{P(i)_{EXP}}{P(i)_{TOT}}$$

$$CSC(i)_{DOM} = CSC(i) \times \left[ 1 - \frac{P(i)_{EXP}}{P(i)_{TOT}} \right]$$

Where:

$CSC(i)_{EXP}$  = the carbon stock change in a HWP category produced and exported in year  $i$

$CSC(i)_{DOM}$  = the carbon stock change in a HWP category produced and consumed domestically in year  $i$

$CSC(i)$  = the carbon stock change in a HWP category in year  $i$

$P(i)_{EXP}$  = quantity of exported production of a HWP category in year  $i$

$P(i)_{TOT}$  = total quantity of production of a HWP category in year  $i$

### 6.11.2.2 Activity data

Country-specific data for sawn wood, wood panels and pulp (production, imports and exports) were downloaded from the FAOSTAT database (FAO 2014). The FAOSTAT data were employed since the whole time series of data were easily accessible in the Internet. Activity data downloaded from FAOSTAT database were compared to national statistics compiled by Finnish Forest Research Institute. The FAO data were in agreement with national data.

### 6.11.2.3 Emission factors and other parameters

To convert sawn wood to from volume units to carbon, conversion factor for coniferous sawn wood was used (IPCC KP Supplement, Table 2.8.1). This conversion factor is justifiable since 99% of the wood consumed by sawmilling industry is coniferous. An aggregate conversion factor presented in Table 2.8.1 in the IPCC KP Supplement was used for wood panels. A 10% moisture and 50% carbon content for wood pulp was assumed. The employed conversion factors are given in Table 6.11-1.

The half-lives of HWP categories are as are given in the decision 2/CMP.7 (see Table 6.11-1).

**Table 6.11-1** Conversion factors to convert volume units to carbon and used half-lives

HWP categories	Density	Carbon fraction	C conversion factor	Half-lives
	t m <sup>-3</sup>		t C m <sup>-3</sup>	years
Coniferous sawnwood	0.45	0.5	0.225	35
Wood-based panels	0.595	0.454	0.269	25
Pulp	0.9	0.5	0.45	2

### 6.11.3 Uncertainty and time series' consistency

The uncertainties related to the estimates of the HWP pool are:

- Uncertainty related to the used FOD model which is a simplification of real world e.g. constant decay rates
- Uncertainties related to activity data
- Uncertainties of conversion factors, emission factors and half-lives.

The uncertainty of the HWP is assumed to be  $\pm 50\%$ , as it is given to a Tier 1 method in the 2006 IPCC Guidelines.

### 6.11.4 Category-specific QA/QC and verification

The quality objectives and the QA/QC and verification plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.2.3. The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives. The bilateral quality meeting is held annually between the inventory unit and the sectoral expert.

Until the end of 2014, the Finnish Forest Research Institute (Metla) had a management team to guide and supervise the reporting of emissions and removals for the LULUCF sector, which was under Metla's responsibility. The members had 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 were discussed and approved by the management team before they were introduced to the advisory board (see Section 1.2.1). Representatives from Statistics Finland and Agrifood Research Finland were invited to the meetings. The management team met 2-4 times per year. From 2015 onward, a new management team will be set up in Luke.

Activity data downloaded from FAOSTAT database were compared with national statistics compiled by the Finnish Forest Research Institute. The downloaded data corresponded to national data. Computation was done by SAS.

### 6.11.5 Category-specific recalculations

In previous submissions Finland used the Stock Change Approach to estimate carbon stock change in HWP. The estimation was based on the Finnish wood product inventories, which enabled to produce country-specific half-lives for solid wood products. Since for the second Kyoto Protocol commitment period was decided to use the Production Approach, this approach was chosen to be applied also for the Convention reporting to keep the reporting more comparable.

The main changes were:

- In the 2014 submission, the carbon stock change in only domestically consumed HWP was reported. Now the domestically produced HWP as well as exported HWP are reported.
- In the 2014 submission, the country-specific half-lives for solid wood products were used (for years 1900-1995 14.8 years, for 1995-2000 16.0 years, for 2000-2012 10.5 years). Now the default half-lives used in KP reporting (35 years for sawn wood and 25 years for wood panels) as presented in the Decision 2/CMP.7 were also employed in the Convention reporting.
- The carbon stock estimation is now started from 1961 but in the 2014 submission it was started from 1900.

Recalculation produced higher sinks than the old method (Table 6.11-2). This is because previously only the domestically consumed products were included in the estimates.

**Table 6.11-2** The difference in emissions due to the recalculation in the HWP pool between the 2014 and 2015 submissions

	Carbon stock change, kt CO <sub>2</sub>	
	1990	2014
Submission 2014	-946	1 287
Submission 2015	-4 313	-3 394
Difference 2015-2014	-3 367	-4 681

### 6.11.6 Category-specific planned improvements

Because there is a plan to further improve the HWP estimation for KP reporting, the same improvement subjects stand also for the Convention reporting. The development project started in the end of 2014, and the results will be implemented in GHG inventory earliest in the 2017 submission. The main targets for the project are to develop methodology

- To allocate harvest removals to afforestation and deforestation, and thus to improve also the estimates for Forest Land Remaining Forest Land
- To study the possibilities to use information on timber assortments removed from forest
- To study the possibilities to use country-specific parameters, for example, tree species and HWP category dependent conversion factors.
- To take into account the use of recovered paper in the pulp production

- To estimate carbon stock change in domestic SWDS
- To estimate uncertainties of carbon stock changes of the HWP pool.

## Appendix\_6a

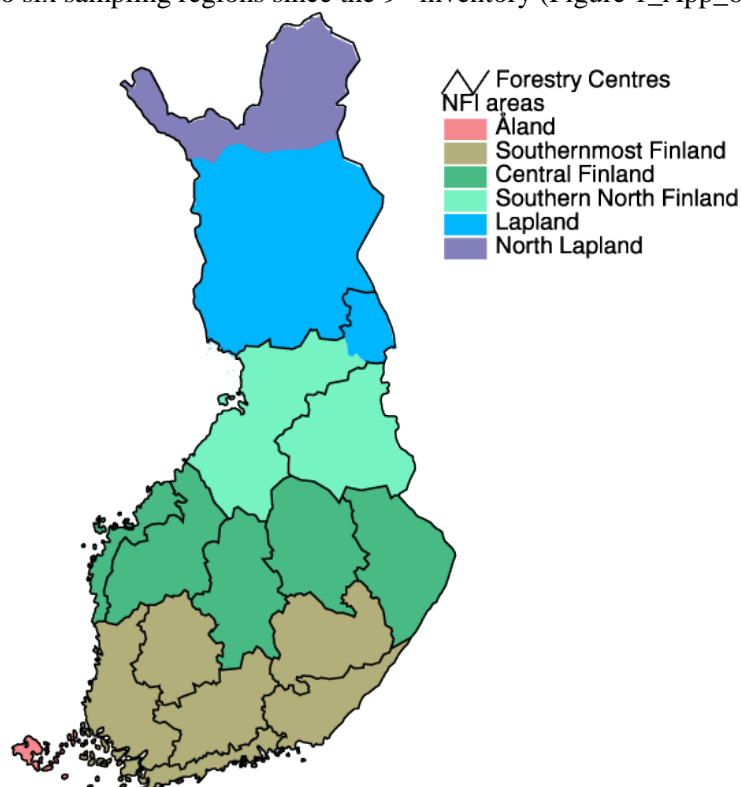
### National forest inventory

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\_6a 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.

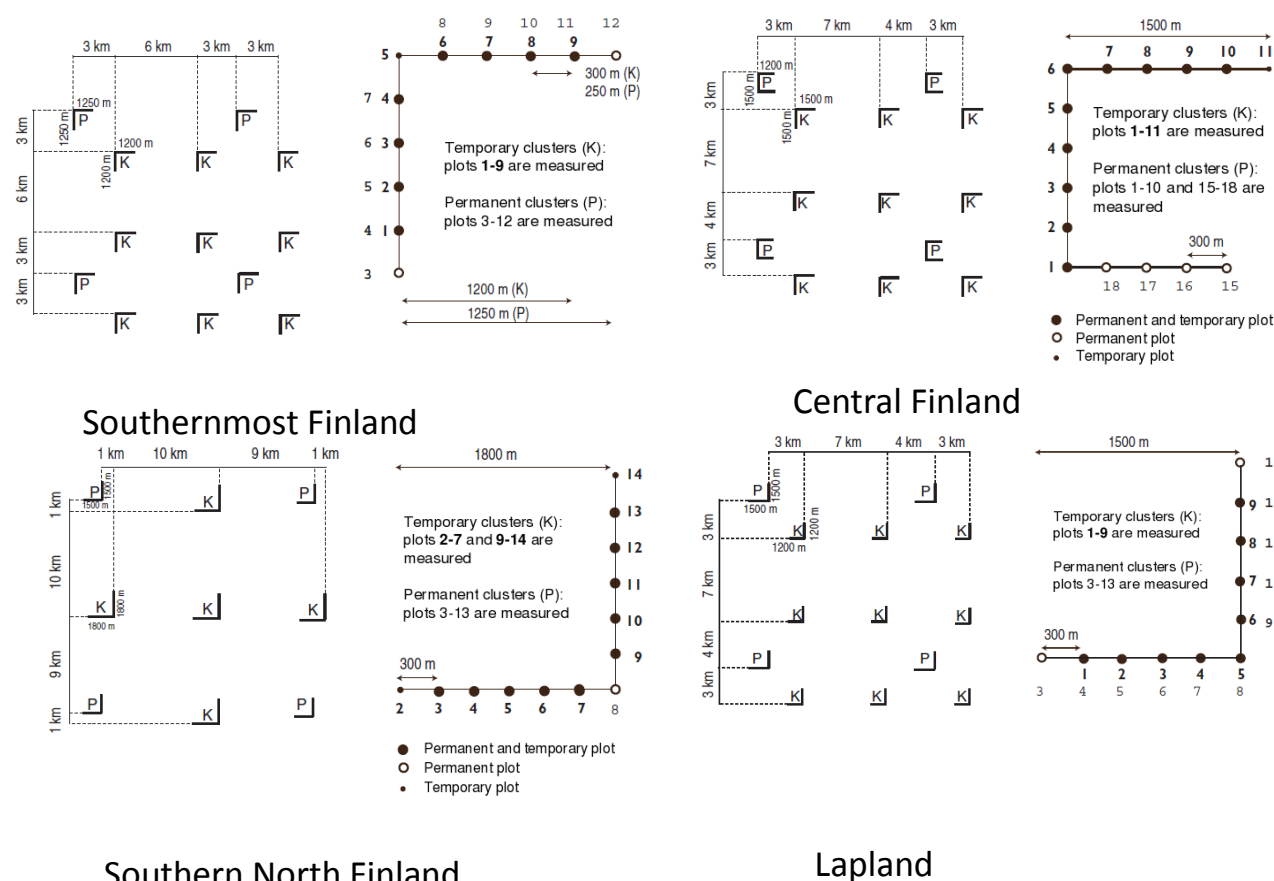
**Table 1\_App\_6a.** The areas of national land classes in the whole country in the 6<sup>th</sup> to 11<sup>th</sup> National Forest Inventories. The land total areas correspond the official land area provided by the National Land Survey of Finland at the time period of each inventory

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	2009-2013	20 268	2 501	3 228	198	26 194	4 195	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 (Figure 1\_App\_6a, Figure 2\_App\_6a).



**Figure 1\_App\_6a.** Six sampling regions (NFI areas) and the boundaries of the regional units of the Public Services at the Finnish Forestry Centres in 2013



**Figure 2\_App\_6a** Sampling design by sampling regions in NFI1

On the sample plots, tree- and stand-level information is assessed and measured. Stand-level variables describe, for example, the forest site type, 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 fertility 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 of 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 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\_6a). 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\_6b

### *Estimation of land-use changes for the years 1990–2013*

Areas of land-use and land-use change are calculated from NFI data. An inventory cycle takes 5 years in NFI, and 1/5 of the plots are measured yearly throughout the country. There is less than 5 years NFI data for the latest years, therefore land-use information of NFI plots was updated by means of remote sensing data and other spatial data.

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 2009–2013 are based on NFI data and updating of the data.

The areas were computed as follows:

- areas on land-use categories for the base year, 2002
- annual areas of land-use changes for years 1990–2012
- areas of land-use categories for the other years, 1990–2001 and 2003–2013.

#### Annual areas of land-use changes

The moving average method was applied to provide annual estimates of land-use changes for the years 1990–2013. 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 1990–2012 at first. These are called as “raw estimates”, calculated directly from NFI or updated 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 2011–2013 because the latest available raw estimate was for the year 2012. Raw estimate for 2013 was not used because 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 Southern Finland and Northern 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 Southern Finland and Northern Finland, 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. The latest years from 2005 onwards were reported by replacing older NFI data with new one, i.e., 2006–2010 measurements were utilized for  $x_t$ ,  $t = 2005$ , 2007–2011 measurements for  $x_t$ ,  $t = 2006, 2008–2012$  measurements for  $x_t$ ,  $t = 2007$  and 2009–2013 measurements for  $x_t$ ,  $t \geq 2008$ . Land-use information of NFI data measured in 2008–2013 was updated. NFI data measured in and after 2010 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 recalculate the whole time series. Hence, for  $t = 2005, 2006, \dots, 2012$ ,

$$x_t = \sum_{i \in c_t} a_{it},$$

where set  $c_t$  contains those plots of SF/NF measured during years  $t + 1, \dots, 2013$ , 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  $t + 1, \dots, 2013$ . Set  $c_t$  for 2009-2013 contain plots of SF/NF measured in 2009-2013 with updated land-use data.

### Moving averages

The final estimates,  $y_t$  for years  $t = 1992, 1993, \dots, 2010$  were computed as simple moving averages,

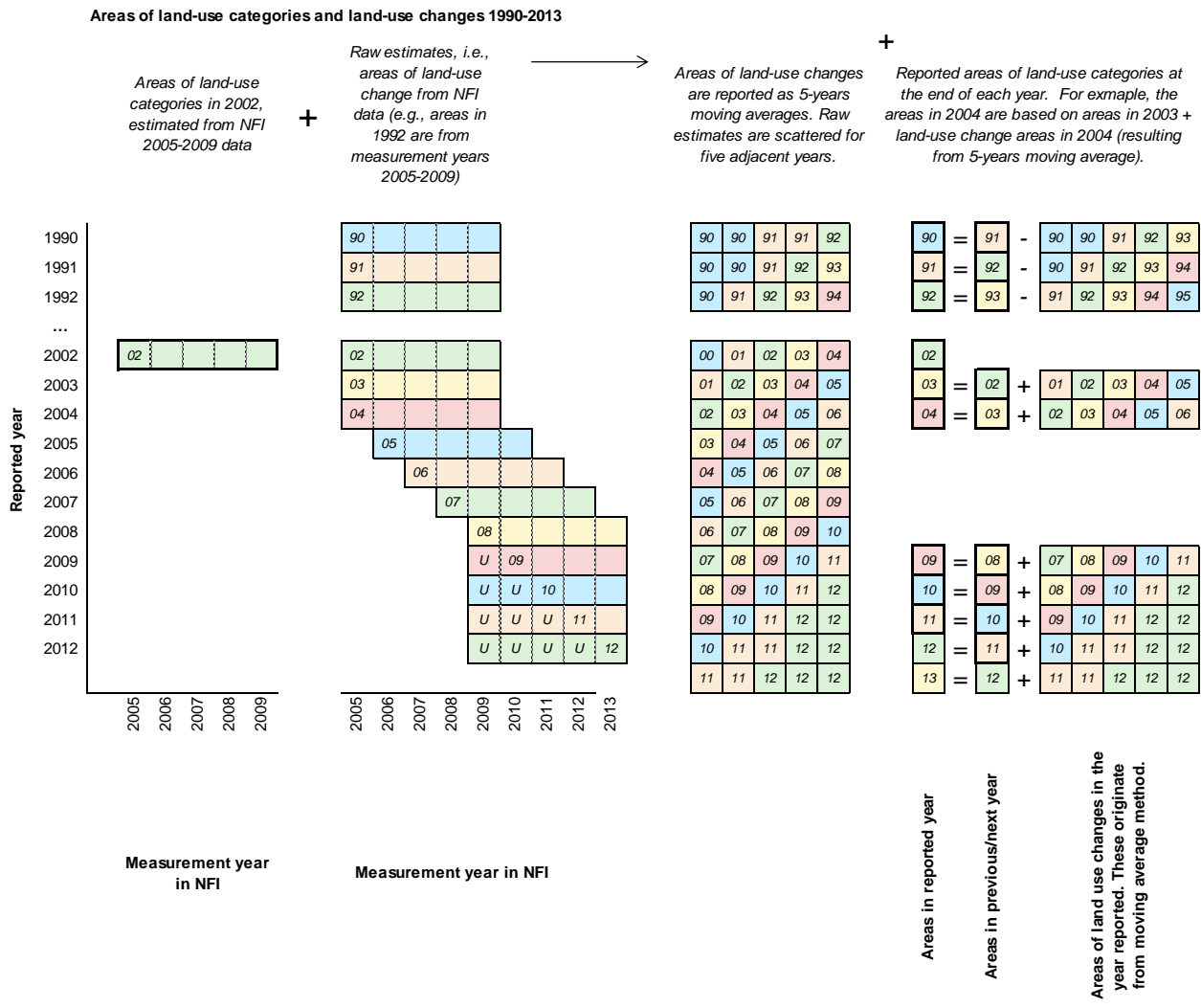
$$y_t = \frac{1}{5} \sum_{s=t-2}^{t+2} x_s,$$

and those for the remaining years near the end-points of the  $x_t$  series as weighted averages,

$$\begin{aligned} y_{1990} &= \frac{2}{5}x_{1990} + \frac{2}{5}x_{1991} + \frac{1}{5}x_{1992} \\ y_{1991} &= \frac{2}{5}x_{1990} + \frac{1}{5}x_{1991} + \frac{1}{5}x_{1992} + \frac{1}{5}x_{1993} \\ y_{2011} &= \frac{1}{5}x_{2009} + \frac{1}{5}x_{2010} + \frac{1}{5}x_{2011} + \frac{2}{5}x_{2012} \\ y_{2012} &= \frac{1}{5}x_{2010} + \frac{2}{5}x_{2011} + \frac{2}{5}x_{2012} \\ y_{2013} &= \frac{2}{5}x_{2011} + \frac{3}{5}x_{2012} \end{aligned}$$

### Annual areas of land-use classes

Land-use class areas in the end of year 2002 were estimated from 2005-9 data by adjusting the estimated areas at the time of the measurement according to estimated cumulative change during the years from 2003 to year before the measurement. End of year 2002 was chosen as fixed point, because new data from year 2010 effects change estimates from year 2003 onwards. Estimates of land-use class areas for other years were computed on the basis of 2002 area estimates and annual change estimates  $y_t$  (Figure 1\_App\_6b).



**Figure 1\_App\_6b** Estimation of the areas of land-use categories and land-use changes in 1990-2013. At first areas of land-use changes are calculated for each year. For these areas a 5-years moving average method is applied where areas are divided equally to 5 adjacent years. Index *U* refers to updated NFI data

## Appendix\_6c

### Estimation of woody biomass stocks, gains and losses

#### Tree biomass stocks in Forest Land

To provide the tree biomass losses for lands converted from Forest land to other land use, and litter input needed in the estimation of carbon stock changes in SOM and DOM pools, the annual stocks of living biomass in tree compartments were estimated using tree-level measurements on field sample plots of the NFI and Finnish biomass models (Repola et al. 2007, Repola 2008, Repola 2009, see Appendix\_6d).

The annual biomass stocks were linearly interpolated based on four National Forest Inventories, NFI8-NFI11 (see Appendix\_6a). The NFI11 data measured in 2013 were made use of except for Åland for which data were not yet available.

The steps of the estimation were:

1. Biomass by tree compartments (c=stem, bark, living branches, dead branches, foliage, stump, roots) and stem volume were computed from sample tree data by tree species group (sp = pine, spruce, broadleaved), soil type (mineral, organic), and region (Southern Finland, Northern Finland). Biomass conversion and expansion factors,  $BCEF_{S,NFI,c,sp,soil,region}$ , were computed separately for each NFI as a ratio of appropriately weighted mean biomass and mean stem volume estimated over the NFI sample trees belonging to the respective strata. The Finnish tree-level biomass models were used for biomass estimation (Repola et al. 2007, Repola 2008, Repola 2009, Appendix\_6d). The ready-estimated sample tree stem volumes in the NFI data were used.
2. The volume of growing stock in forest land was computed separately for each NFI over all trees belonging to the respective strata. Volume of growing stock was converted to biomass using the following equation:

$$C_{S,NFI,sp,soil,region} = V_{NFI,sp,soil,region} \times BCEF_{S,NFI,c,sp,soil,region} \times CF,$$

where subscript S refers to stock and V to stem volume. V is the total stem volume estimated using the standard NFI procedures (see e.g., Tomppo et al. 2011). A default value of 0.5 was used for the carbon fraction CF.

3. Each estimate,  $C_{S,NFI,sp,soil,region}$ , was allocated to the appropriately weighted mean of the measurement dates. The linear trend estimated based on the difference between NFI9 and NFI8 was applied to extrapolate to the years preceding the mean measurement date of NFI8. The trend in total biomass has been increasing for the whole period 1990-2013, but in order to avoid overestimation, the years after the NFI11 mean measurement date were extrapolated as a constant equal to the NFI11 result.

#### Gains in living biomass in Forest Land Remaining Forest Land

The annual gain (growth) in living tree biomass was estimated first to the total forest land and then to lands converted to forest land. Remainder of these two estimates was the biomass growth for Forest Land Remaining Forest Land. The annual biomass increments were linearly interpolated from the estimates based on four National Forest Inventories (NFI8-NFI11) (see Appendix\_6a). The NFI11 data measured in 2013 were made use of except for Åland, for which the 2013 data were not yet available.

The steps of the estimation were:

1. Total stem volume increment and above- and below-ground biomass increments for each NFI were computed by tree species group (sp = pine, spruce, broadleaved), soil type (mineral, organic), and region (Southern Finland, Northern Finland). The estimation of increments was based on tree-level measurements of five-year increments in the breast-height diameter and in the height of the trees, and on the Finnish tree-level biomass models (Appendix\_6d), 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. 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 computed (Repola 2008, Repola 2009, Appendix\_6d).

2. The total increment of growing stock ( $I_V$ ) was estimated using the standard NFI procedures (see e.g., Tomppo et al. 2011). The volume increment was converted to biomass increment using the following equation:

$$\Delta C_{G,NFI,sp,soil,region} = I_{V,NFI,sp,soil,region} \times BCEF_{G,NFI,c,sp,soil,region} \times CF,$$

where subscript G refers to growth and V to stem volume, and subscript c is included to index two biomass compartments (above-ground and below-ground). A default value of 0.5 was used for the carbon fraction CF.

3. 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 1990-2013, but in order to avoid overestimation, the years after the NFI11 mean date were extrapolated as a constant equal to the NFI11 result.

#### *Carbon stock change in living biomass in Cropland Remaining Cropland*

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 allocated to Cropland Remaining Cropland also in cases when cropland was converted to other land-use categories. The following equation is used:

$$\Delta CC_{cc_{LB}} = \sum_i (C_{ai} - C_{di})$$

$$B_{hi} = d_i * w_i * Frac_{Dm} * Frac_C$$

$$G_i = B_{hi} / H_{ci}$$

$$C_{ai} = A_i * G_i$$

$$C_{di} = A_{ci} * B_{hi}$$

where

i denotes the plant species (currants, dwarfish apple trees, vigorously growing apple trees)

$\Delta CC_{cc_{LB}}$  = 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
$Ac_i$	= 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 1\_App\_6c. 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 1\_App\_6c 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. The Information Centre of the Ministry of Agriculture and Forestry collects data for the area on apple trees and currants (Table 2\_App\_6c).

**Table 1\_App\_6c** National coefficients for living apple trees and currants (cropland remaining 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

**Table 2\_App\_6c** Areas of apple trees and currants, ha

	Vigorously-growing apple trees	Dwarfish apple trees	Currants
1990	380	0	1 407
1995	419	0	1 535
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
2013	345	315	1772

#### *Gains in living biomass in Grassland Remaining Grassland*

Since the trees outside forest have been measured only in NFI11 (2009-2013) it was not possible to estimate gains in tree biomass in grassland using the same procedure as was used for forest land. The available information on trees outside forest was tree species and a diameter at the breast height. The stem number per hectare by IPCC land-use class (converted and remaining), tree species (pine, spruce, broadleaved) and diameter class (1 cm) was computed. Then the biomass by tree species and diameter class was computed from forest land sample trees and merged with the stem number data. The growth rates of growing stock reported by NFI and based on NFI10 and NFI11 data were used to compute the biomass growth separately for Southern and Northern Finland (Table 3\_App\_6c).

**Table 3\_App\_6c** Growth rates of tree biomass used to compute gains in tree biomass and applied mean biomass increments by tree species in Grassland Remaining Grassland

Tree species	Southern Finland	Northern Finland
Growth rate, %		
- Pine	4.24	3.88
- Spruce	4.89	3.76
- Broadleaved	5.56	4.33
Annual mean biomass increment, t C ha <sup>-1</sup>		
- Pine	0.025	0.012
- Spruce	0.061	0.011
- Broadleaved	0.422	0.100

#### *Carbon stock change in living biomass in Land Converted to Forest Land*

The method to estimate carbon stock changes in land converted to forest land were estimated employing the information about the amount of biomass on land before the conversion, the amount of biomass on forest land after the conversion, and the number of the years elapsed since the conversion. Land under land-use change was divided in two groups according to the biomass before the conversion. For land converted from cropland, peat extraction or settlements the initial biomass 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 4\_App\_6c). For land changed from grasslands or other wetlands (peatlands) than peat extraction sites there was assumed to be biomass also before the conversion. For these cases, the mean biomass stock per hectare (kg) and the biomass increment rates (%) were estimated to compute the net mean annual increment (Table 5\_App\_6c). The net mean increments were computed from the NFII 1 sample plots belonging to the relevant conversion categories. All estimates were computed by tree species group (pine, spruce, broadleaved), soil type (mineral, organic), land-use change type and region (Southern Finland, Northern Finland) separately for above- and below-ground biomass. The same net mean annual increments were applied throughout the entire time series.

The total 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 Forest Land. This method is valid since the trees of forested sites reach the dimensions of pulpwood about at the age of 20 years and later. The size of trees is not the only criteria for cutting but also the density of a stand. A forest area stays in the converted category for 20 years and hence only a minor part of cutting removals allocated to Forest Land Remaining Forest Land originates from forests converted from other land uses (see Section 6.4.6 Category-specific planned improvements).

**Table 4\_App\_6c** Mean annual biomass increment (t/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	1.735
Cropland	Pine-mineral	0.190
Cropland	Spruce-mineral	0.738
Cropland	Broadleaved-organic	1.108
Cropland	Pine-organic	0.425
Cropland	Spruce-organic	0.400
Peat Extraction	Broadleaved-organic	0.950
Peat Extraction	Pine-organic	0.145
Settlements	Broadleaved-mineral	0.880
Settlements	Pine-mineral	0.814
Settlements	Spruce-mineral	0.224

**Table 5\_App\_6c** Mean annual biomass increment (t/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	2.883
Grassland	Pine-mineral	0.414
Grassland	Spruce-mineral	1.375
Grassland	Broadleaved-organic	2.076
Grassland	Pine-organic	0.256
Grassland	Spruce-organic	0.727
Wetland	Broadleaved-organic	0.855
Wetland	Pine-organic	1.248

#### *Losses in living biomass*

The loss in living tree biomass in Forest Land Remaining 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.

The official statistics on the total drain of growing stock was used to compute the **total losses in living biomass**. 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, including purchased energy wood, are based on the information provided by sampled roundwood purchasers and by Metsähallitus that governs state owned forests. The sample for removal statistics covers over 90% of the industrial roundwood purchases. The non-commercial roundwood removals refer to logs for contract sawing and the fuelwood used in dwellings. The volumes of contract sawing and fuelwood have been investigated in 10-year intervals, the latest information was compiled in 2008-2010. The volume of harvesting losses left on the ground has based until 2008 on the investigations conducted during 1966-1971 (Mikkola 1972). The latest estimates are based on the measurements on the NFI permanent sample plots. On the same NFI data is also based the volume of unrecovered natural losses. The statistics were compiled by the Finnish Forest Research Institute and published in the Finnish Statistical Yearbook of Forestry (2014) (Table 6\_App\_6c).

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 NFI9 (1996-2003) and remeasured in NFI10 (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 NFI9 measurements for those trees in the permanent plots that were harvested or had died between the inventories. The same factors were applied for the whole series of drain volumes.

**Table 6\_App\_6c** The drain in Forest Land Remaining Forest Land 1990-2013 (million m<sup>3</sup>/year)

	Mineral soils			Organic soils			Total
	Pine	Spruce	Broadleaved	Pine	Spruce	Broadleaved	
1990	17.9	19.2	8.7	2.8	2.8	3.0	54.4
1995	20.3	23.4	9.2	3.1	3.3	3.0	62.4
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	22.3	21.4	9.8	3.4	3.0	3.2	63.1
2007	25.7	23.7	10.6	3.9	3.3	3.5	70.7
2008	24.4	19.2	14.4	3.8	2.7	4.7	69.2
2009	19.2	16.4	13.2	3.1	2.3	4.2	58.3
2010	24.4	20.5	14.9	3.8	2.9	4.8	71.1
2011	24.9	20.6	15.1	3.9	2.9	4.8	72.2
2012	25.0	20.5	14.6	3.9	2.8	4.8	71.6
2013	26.6	22.5	16.4	4.2	3.1	5.3	78.0

The **losses in biomass due to the land-use change** were estimated separately for each conversion type and Southern and Northern Finland. First the criteria were set for each conversion type according to the site fertility and soil type and the depth of peat in organic soils. Secondly the mean volumes of corresponding NFI plots were computed. These volumes were assumed to represent the initial state before the conversion. Finally the mean volumes were converted to biomass with the BCEF computed from NFI data (see above section Tree biomass stocks in Forest Land) and multiplied with the corresponding annual conversion area.

The **loss in biomass in Forest Land Remaining Forest Land** was the difference between the total biomass loss and loss in conversion areas.

## Appendix\_6d

### *Biomass models used in estimating the biomass increment and stock*

The applied models are represented in Table 1\_App\_6d. 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 ratio ( $cr$ ). 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\_6d** Biomass models used in estimating the of biomass increment and stock

<b>Scots pine (<i>Pinus sylvestris</i>)</b>				
	<b>Biomass compartment</b>	<b>Biomass function</b>	<b>Reference</b>	<b>Applied in</b>
Repola multivariate models				
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	$\exp(-3.529+9.337*dk/(dk+12)+3.265*h/(h+18)+0.124*i_5+0.001*t_{13}-0.006*bt+(0.003+0.009)/2)$	Repola 2009 (A18)	inc
Repola density model				
	stem wood density	$378.39-78.829*d_a+0.039*dd$	Repola 2007 (52)	inc, stock
Marklund model for needles (estimation of fine roots)				
	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>
<b>Repola multivariate models</b>				
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
<b>Repola density model</b>				
	stem wood density	$442.03-0.904*dk-82.695*d_a$	Repola 2007 (53)	inc, stock
<b>Marklund model for needles (estimation of fine roots)</b>				
	needles	$\exp(9.7809*d/(d+12)-0.4873*\log(h)-1.8551)$	Marklund 1988 (G-16)	stock

**Broadleaved trees**

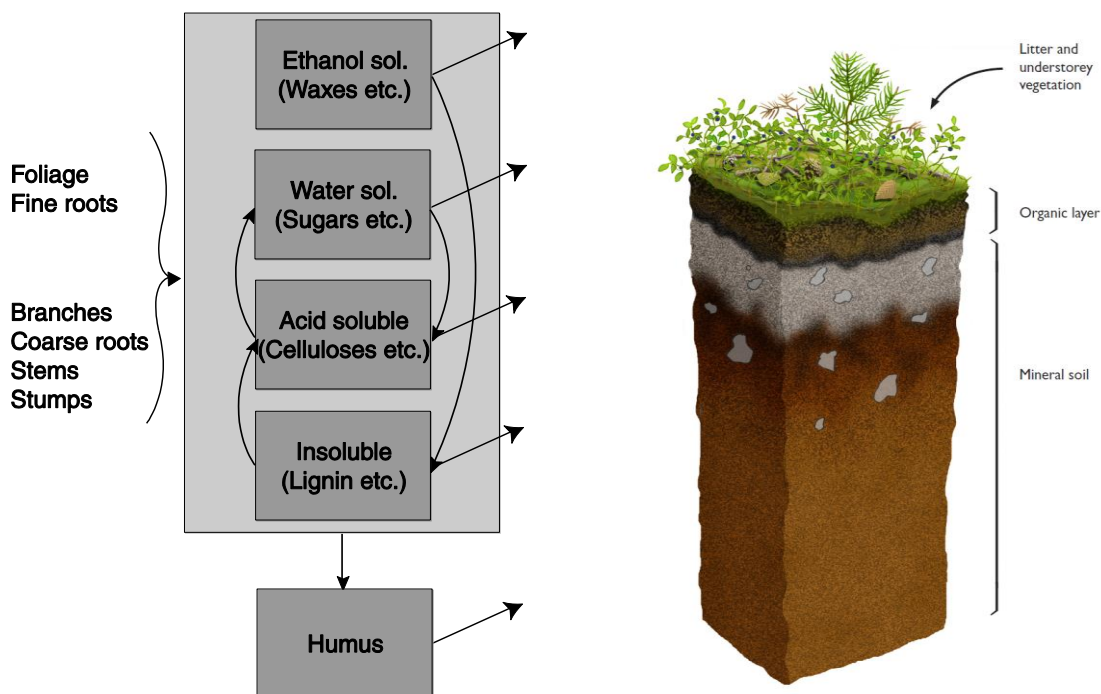
	<b>Biomass compartment</b>	<b>Biomass function</b>	<b>Reference</b>	<b>Applied in</b>
<b>Repola multivariate models</b>				
Model 1	stem wood	$\exp(-4.879+9.651*dk/(dk+12)+1.012*\log(h)+(0.00263+0.00544)/2)$	Repola 2008 (7)	inc
	stem bark	$\exp(-5.401+10.061*dk/(dk+12)+2.657*h/(h+20)+(0.01043+0.04443)/2)$	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
<b>Repola density model</b>				
	stem wood density	$431.43 + 28.054 * \log(dk) - 52.203 * d_a$	Repola 2007 (54)	inc, stock

## Appendix\_6e

### 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\_6e) 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\_6e** 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\_6e and Figure 2\_App\_6e). 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.

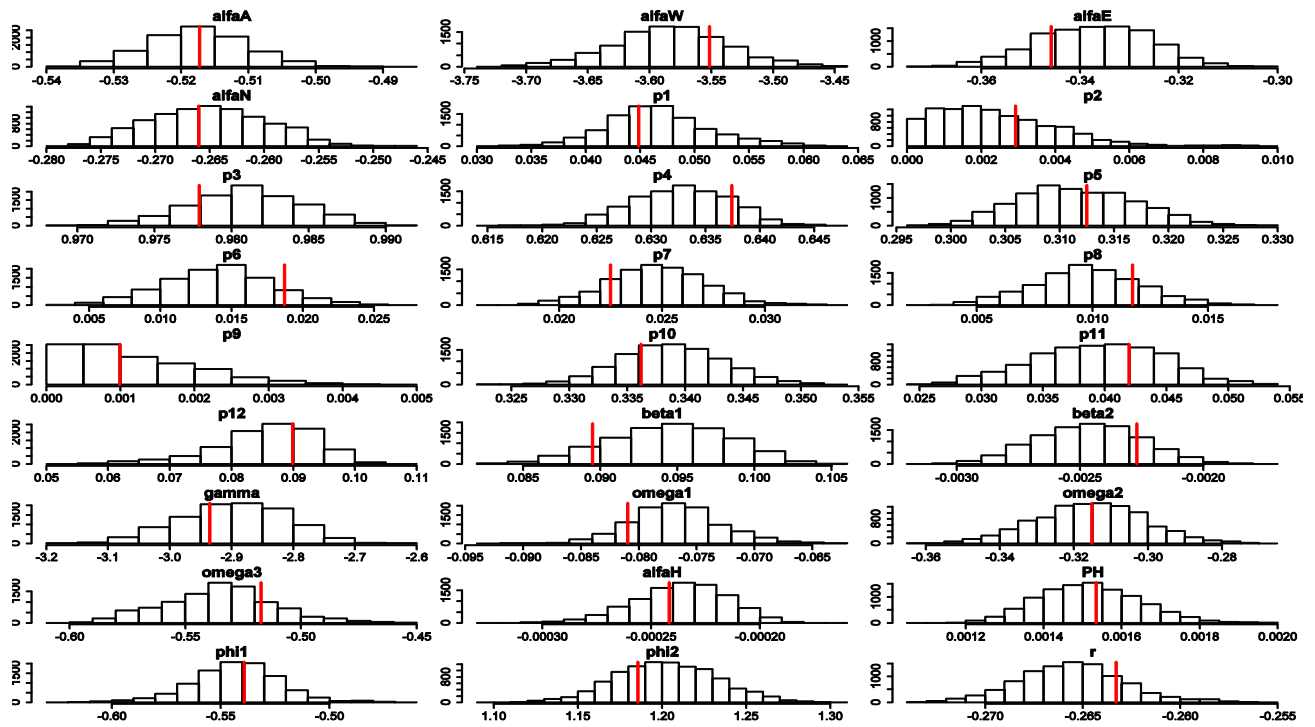
In the Yasso07 model the size of woody material also affects the decomposition rate (Tuomi et al. 2011a). The size-dependent coefficient  $h_s(d)$  multiplies the decomposition factors and, therefore, slows the decomposition of woody material. The size-dependent coefficient  $h_s(d)$  has been defined 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\_6e and Figure 2\_App\_6e). The equation results in a value of one when  $d$  approaches a small value.

**Table 1\_App\_6e** 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\_6e

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
ω <sub>1</sub>	-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\_6e** 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\_6f

### *Emission factors for soil organic matter and dead organic matter for Forest Land remaining Forest Land, for Land converted to Forest Land and for Forest Land converted to Wetlands*

**Table 1\_App\_6f** 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 Southern and Northern 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	0.39	-2.36	-1.23	-0.53	-0.30	0.04
1991	0.13	0.12	-2.03	-0.89	-0.20	0.04	0.38	-2.36	-1.23	-0.53	-0.30	0.04
1992	0.14	0.12	-1.99	-0.85	-0.15	0.08	0.42	-2.33	-1.19	-0.50	-0.26	0.08
1993	0.15	0.12	-1.95	-0.82	-0.12	0.11	0.45	-2.31	-1.17	-0.47	-0.24	0.10
1994	0.17	0.12	-1.90	-0.77	-0.07	0.16	0.50	-2.28	-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	-0.19	0.15
1996	0.22	0.13	-1.87	-0.74	-0.04	0.20	0.53	-2.24	-1.11	-0.41	-0.17	0.16
1997	0.23	0.14	-1.82	-0.69	0.01	0.24	0.58	-2.21	-1.08	-0.38	-0.15	0.19
1998	0.22	0.14	-1.78	-0.65	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	0.29	0.63	-2.16	-1.03	-0.33	-0.10	0.24
2000	0.20	0.16	-1.77	-0.64	0.06	0.29	0.63	-2.14	-1.00	-0.31	-0.07	0.27
2001	0.18	0.16	-1.78	-0.65	0.05	0.28	0.62	-2.11	-0.98	-0.28	-0.05	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	-0.25	-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	0.12	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	-1.79	-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	-0.63	0.07	0.30	0.64	-2.07	-0.93	-0.24	0.00	0.34
2008	0.10	0.16	-1.77	-0.63	0.07	0.30	0.64	-2.04	-0.90	-0.20	0.03	0.37
2009	0.12	0.16	-1.81	-0.68	0.02	0.26	0.59	-2.04	-0.91	-0.21	0.03	0.36
2010	0.10	0.16	-1.78	-0.64	0.06	0.29	0.63	-2.00	-0.86	-0.17	0.07	0.40
2011	0.12	0.14	-1.79	-0.65	0.05	0.28	0.62	-1.98	-0.84	-0.14	0.09	0.43
2012	0.14	0.15	-1.79	-0.66	0.04	0.27	0.61	-1.97	-0.83	-0.14	0.10	0.43
2013	0.14	0.14	-1.76	-0.63	0.07	0.30	0.64	-1.96	-0.82	-0.13	0.11	0.44

**Table 2\_App\_6f** 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	-1.57	-1.38	-1.18	-0.91	0.47	0.63	-3.75	-1.52	-1.46
2	-1.13	-1.00	-0.81	-0.60	0.42	0.57	-3.70	-1.52	-1.45
3	-0.84	-0.76	-0.66	-0.50	0.41	0.55	-3.65	-1.52	-1.43
4	-0.63	-0.57	-0.55	-0.43	0.41	0.54	-3.60	-1.52	-1.41
5	-0.45	-0.41	-0.47	-0.37	0.41	0.53	-3.55	-1.52	-1.40
6	-0.31	-0.27	-0.40	-0.32	0.42	0.54	-3.50	-1.52	-1.38
7	-0.18	-0.16	-0.34	-0.28	0.42	0.54	-3.45	-1.52	-1.36
8	-0.08	-0.06	-0.29	-0.25	0.43	0.54	-3.40	-1.52	-1.35
9	0.01	0.03	-0.25	-0.22	0.43	0.55	-3.35	-1.52	-1.33
10	0.09	0.11	-0.22	-0.19	0.44	0.55	-3.30	-1.52	-1.31
11	0.16	0.18	-0.19	-0.17	0.44	0.55	-3.25	-1.52	-1.30
12	0.21	0.24	-0.16	-0.15	0.45	0.56	-3.20	-1.52	-1.28
13	0.26	0.29	-0.14	-0.13	0.45	0.56	-3.15	-1.52	-1.26
14	0.31	0.34	-0.12	-0.12	0.46	0.56	-3.11	-1.52	-1.25
15	0.34	0.38	-0.10	-0.10	0.46	0.57	-3.06	-1.52	-1.23
16	0.38	0.42	-0.09	-0.09	0.46	0.57	-3.01	-1.52	-1.21
17	0.41	0.46	-0.07	-0.08	0.47	0.57	-2.96	-1.52	-1.20
18	0.43	0.49	-0.06	-0.07	0.47	0.58	-2.91	-1.52	-1.18
19	0.45	0.51	-0.06	-0.06	0.47	0.58	-2.86	-1.52	-1.16
20	0.47	0.54	-0.05	-0.05	0.47	0.58	-2.81	-1.52	-1.15

**Table 3\_App\_6f** 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\_6g

### *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

(A6g.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 (A6g.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\_6h

### *Estimating the uncertainty of mineral soils*

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 6.4.3, Table 1\_App\_6h)

**Table 1\_App\_6h** 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 Southern and Northern 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 6.4.3. Uncertainties of biomass estimates for the different components are given in Table 2\_App\_6h and Table 3\_App\_6h.

**Table 2\_App\_6h** 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\_6h** 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 6e). 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 2013. 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 Southern Finland and 1975 for Northern 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 combinations 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\_6i

### *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\_6i).

**Table 1\_App\_6i** Emission factors for dead wood loss due to deforestation (t C/ha)

Region	Soil	Emission factor
south	mineral	0.530
	organic	0.388
north	mineral	1.280
	organic	0.515

## Appendix\_6j

### Method for estimating C stock changes in croplands and grasslands

#### Estimation of biomass

Aboveground and belowground biomasses of croplands were calculated based on the national yield statistics (yield per hectare) of main crop plants divided in 16 regions (Matilda agricultural statistics service). Yield statistics were converted to biomass using the calculation scheme proposed by (Bolinder et al. 2007) applying national parameters (Table 1\_App\_6j).

**Table 1\_App\_6j** Parameters for calculating plant biomass

		DM	HI	SR/RootDM	TR	LO
Annual crops	Winter wheat	0.86	0.42	5.6	0.41	0.02
	Spring wheat	0.86	0.42	5.6	0.41	0.02
	Rye	0.86	0.40	5.6	0.41	0.02
	Barley	0.86	0.53	5.6	0.41	0.02
	Oats	0.86	0.46	5.6	0.41	0.02
	Turnip rape	0.92	0.35	5.1	0.41	0.02
	Rape	0.92	0.35	5.1	0.41	0.02
	Pea	0.87	0.50	5.0	0.41	0.02
	Potato	0.22	0.55	5.0	0.41	0.02
	Sugar beet	0.21	0.66	5.0	0.41	0.02
Perennial crops	Hay	0.86	0.84	4 036*	0.41	0.10
	Silage	0.34	0.84	4 036*	0.41	0.10

DM= dry matter, HI= harvest index, SR= ratio of shoot and root biomass, RootDM= root dry matter, TR= turnover rate of the roots (i.e. rhizodeposition, root exudates), LO= yield losses

\*In the case of hay and silage a constant root biomass per hectare was assumed.

Yield losses were assumed to take place after harvesting, and therefore yield biomass ( $BM_Y$ ) was calculated from the harvested yield as:

$$BM_Y = Yield * (1 + LO) \times DM$$

Above-ground biomass ( $BM_{AG}$ ) was calculated as follow:

$$BM_{AG} = \frac{BM_Y}{HI}$$

Belowground biomass ( $BM_{BG}$ ) of annual crop plants was calculated as:

$$BM_{BG} = \frac{BM_{AG}}{SR}$$

Fallow and perennial crops were assumed to have the same constant belowground biomass per hectare (Table 1\_App\_6j). Aboveground biomass of fallow was assumed to be 5,375 kg ha<sup>-1</sup> in the south and 4,845 kg ha<sup>-1</sup> in the north. Hectare-based biomasses were weighted with the area of each cultivated crop plants taken from the Land Parcel Identification System of the EU. Since grasslands are mainly abandoned fields, the above- and belowground biomasses of fallow were used for grassland vegetation as well.

#### Nitrogen in crop residues

Nitrogen content of crop residues for estimating the N<sub>2</sub>O emissions for CRF 3 were calculated based on the crop plant biomasses (see above). Nitrogen in above-ground residues ( $N_{AG}$ ) and belowground biomass ( $N_{BG}$ ) were taken into account.

$$N_{AG} = (BM_{AG} - BM_Y) \times NC_{AG}$$

$$N_{BG} = \frac{BM_{BG}}{RL} \times NC_{BG}$$

where  $RL$  is the length (years) of the crop rotation (1 for annual crops and 3.5 for perennial crops) and  $NC_{AG}$  and  $NC_{BG}$  are species/group specific nitrogen contents of above- and belowground biomasses (2006 IPCC Guidelines; Table 11.2).

### Soil carbon input

Soil carbon input consists of plant residues and manure. Carbon input through plant residues were estimated on the basis of plant biomass (see above).

Aboveground carbon input from plant residues was calculated as follow (0.45 refers to carbon content of 45%.):

$$CI_{AG} = (BM_{AG} - BM_Y) \times 0.45$$

Belowground carbon input was calculated as:

$$CI_{BG} = BM_{BG} \times \left( \frac{1}{RL} + TR \right) \times 0.45$$

where  $RL$  is the length (years) of the crop rotation (1 for annual crops and 3.5 for perennial crops) and  $TR$  is the root turnover rate.

Manure-derived carbon ( $CI_{manure}$ ) was calculated based on the regional numbers of livestock and livestock specific rates of volatile solids in manure (Appendix\_5a) and assuming that 50% of the volatile solids is carbon. Total soil carbon input was then obtained as a sum of above ( $CI_{AG}$ ) and belowground plant residues ( $CI_{BG}$ ) and carbon from manure ( $CI_{manure}$ ). The C input was divided in fractions based on its chemical quality (Table 2\_App\_6j)

**Table 2\_App\_6j** Acid, water and ethanol soluble and non-soluble fractions of litter and manure C input for Yasso07 model

Plant litter	A	W	E	Ns
Cereals	0.71	0.08	0.03	0.18
Pea	0.63	0.14	0.02	0.21
Potato	0.23	0.48	0.05	0.24
Sugarbeet	0.26	0.54	0.04	0.16
Oilseed rape	0.40	0.34	0.04	0.22
Turnip rape	0.42	0.27	0.04	0.27
Grasses	0.46	0.32	0.04	0.18
Manure	0.65	0.12	0.07	0.16

### Emission factors

The emissions factors are derived from the model simulation as described in Section 6.5. For cropland remaining cropland, they can be either negative (loss of C) or positive (gain of C) depending on the C input rate of each year (Table 3\_App\_6j). For the land use conversions, they are usually negative with the exception of the conversion of cropland to grassland (Table 4\_App\_6j).

**Table 3\_App\_6j** Emission factors for cropland remaining cropland

Year	South	North
1990	0.006	0.001
1995	-0.105	0.025
2000	0.127	0.024
2001	-0.026	-0.045
2002	0.014	0.062
2003	-0.035	-0.050
2004	-0.039	-0.060
2005	0.047	0.035
2006	-0.131	-0.102
2007	0.086	-0.040
2008	-0.009	-0.190
2009	0.114	0.058
2010	-0.162	-0.009
2011	0.018	0.011
2012	0.021	-0.090
2013	0.047	0.000

**Table 4\_App\_6j** Aggregated emission factors for land conversions of different age (t C ha<sup>-1</sup>)

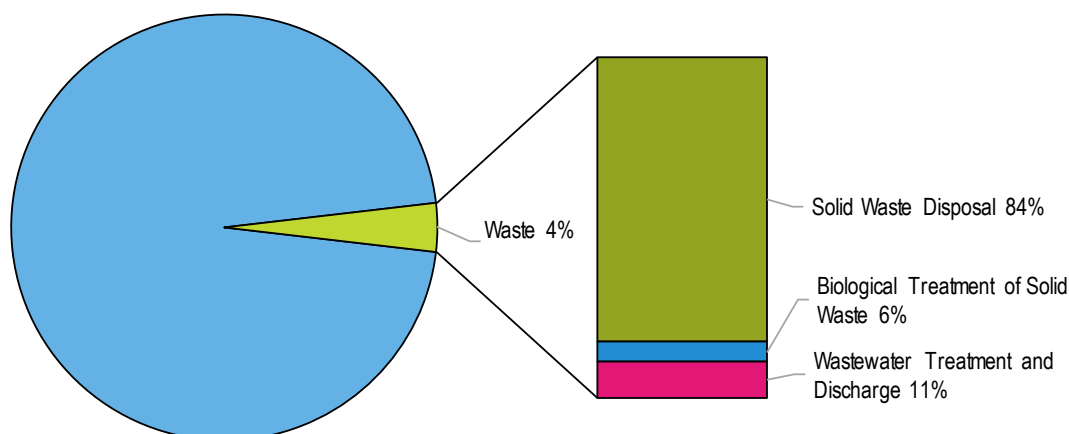
Time since conversion	FL/WL-CL South	FL/WL-CL North	GL-CL South	GL-CL North	FL/WL-GL South	FL/WL-GL North	CL-GL South	CL-GL North
1	-2.18	-1.34	-0.78	-0.69	-1.39	-0.65	0.73	0.63
2	-1.77	-1.10	-0.58	-0.52	-1.19	-0.58	0.54	0.47
3	-1.48	-0.93	-0.47	-0.43	-1.01	-0.50	0.44	0.39
4	-1.28	-0.80	-0.40	-0.36	-0.88	-0.44	0.37	0.33
5	-1.14	-0.71	-0.35	-0.31	-0.79	-0.39	0.32	0.29
6	-1.04	-0.64	-0.31	-0.28	-0.73	-0.36	0.29	0.25
7	-0.96	-0.59	-0.28	-0.26	-0.68	-0.34	0.26	0.23
8	-0.90	-0.56	-0.26	-0.24	-0.64	-0.32	0.24	0.21
9	-0.85	-0.52	-0.25	-0.22	-0.61	-0.30	0.23	0.20
10	-0.81	-0.50	-0.23	-0.21	-0.58	-0.29	0.22	0.19
11	-0.78	-0.48	-0.22	-0.20	-0.55	-0.27	0.21	0.18
12	-0.75	-0.46	-0.21	-0.19	-0.53	-0.26	0.20	0.17
13	-0.72	-0.44	-0.20	-0.19	-0.51	-0.26	0.19	0.17
14	-0.69	-0.43	-0.20	-0.18	-0.50	-0.25	0.18	0.16
15	-0.67	-0.41	-0.19	-0.17	-0.48	-0.24	0.18	0.15
16	-0.65	-0.40	-0.18	-0.17	-0.46	-0.23	0.17	0.15
17	-0.63	-0.39	-0.18	-0.16	-0.45	-0.22	0.17	0.14
18	-0.61	-0.38	-0.17	-0.16	-0.43	-0.22	0.16	0.14
19	-0.59	-0.37	-0.17	-0.15	-0.42	-0.21	0.16	0.14
20	-0.57	-0.36	-0.16	-0.15	-0.41	-0.20	0.15	0.13

## 7 WASTE (CRF 5)

### 7.1 Overview of the sector

Emissions from the waste sector were 2.3 million tonnes of carbon dioxide equivalent (Mt CO<sub>2</sub> eq.) in 2013. This was 4% 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 biological treatment are smaller (Figure 7.1-1). 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 domestic and industrial wastewater treatment plants and uncollected domestic wastewaters and from biological treatment of solid waste (composting and anaerobic digestion). N<sub>2</sub>O emissions are generated from nitrogen input of fish farming as well as domestic and industrial wastewater treatment and from composting.

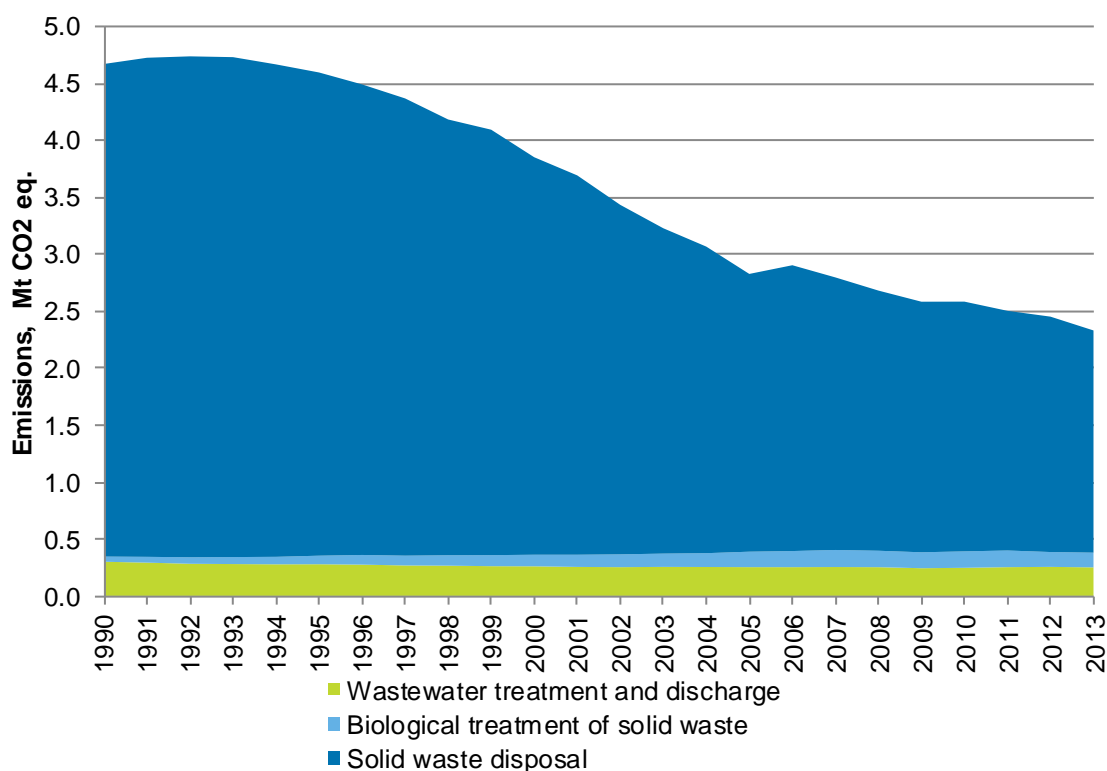
NMVOC emissions from solid waste disposal sites and wastewater handling as well as NMVOC, CH<sub>4</sub> and N<sub>2</sub>O emissions from composting are also estimated in the Finnish inventory. General assessment of completeness could be found in Section 1.7 and more detailed assessment is included in Annex 5.



**Figure 7.1-1** Greenhouse gas emissions from the Waste Sector in 2013 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 treatment about 11% and biological treatment (composting and anaerobic digestion) 6% of this sector's total emissions. Compared to 2012 emissions decreased by 5% in 2013 and since 1990 these emissions have decreased 50%. A small increase in the 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 (Figure 7.1-2). 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 where after the changes in the emissions have been small. Emissions in 2012 and 2013 show a slight decrease compared to the previous years. Anaerobic digestion is a very small but growing source of CH<sub>4</sub> emissions in the waste sector. The CH<sub>4</sub> emissions from this source were less than 0.1 kt CO<sub>2</sub> eq in 1990 and more than 6 kt CO<sub>2</sub> in 2012 and 2013. In addition, the increase of waste incineration has decreased the emissions from landfills from 2008 onwards. The energy produced in waste incineration is

utilised and the emissions are therefore reported in the Energy sector. Implementation of landfill gas recovery has also had a significant decreasing impact on the emissions.

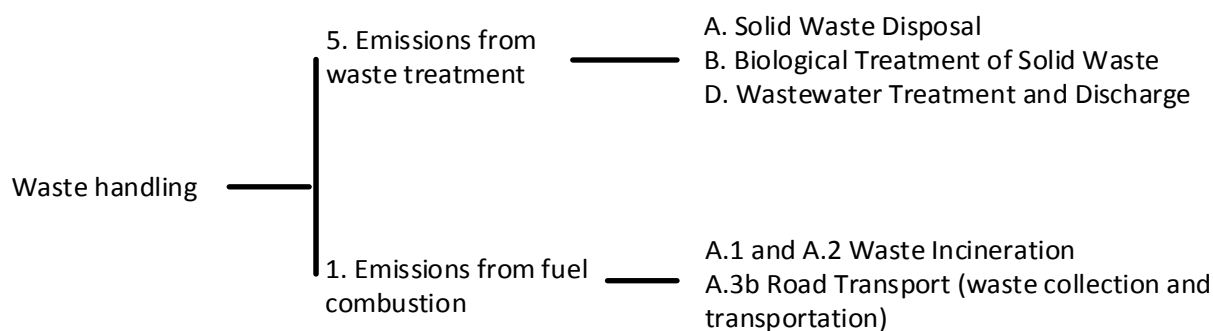


**Figure 7.1-2** Trend in the Waste Sector's emissions (Mt CO<sub>2</sub> eq.)

The emission trend in the Waste Sector by subcategory and gas is presented in Table 7.1-1. Waste handling produces emissions of which only a part is reported in Waste sector. Emissions from waste incineration and emissions from waste collection and transportation are reported in the Energy sector see Figure 7.1-3.

**Table 7.1-1** Emissions in the Waste Sector by source and gas (Mt CO<sub>2</sub> eq.)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<b>Solid waste disposal</b>	<b>4.33</b>	<b>4.25</b>	<b>3.49</b>	<b>3.33</b>	<b>3.07</b>	<b>2.86</b>	<b>2.69</b>	<b>2.44</b>	<b>2.51</b>	<b>2.39</b>	<b>2.29</b>	<b>2.20</b>	<b>2.19</b>	<b>2.11</b>	<b>2.07</b>	<b>1.95</b>
Methane	4.33	4.25	3.49	3.33	3.07	2.86	2.69	2.44	2.51	2.39	2.29	2.20	2.19	2.11	2.07	1.95
<b>Biological treatment of solid waste</b>	<b>0.05</b>	<b>0.08</b>	<b>0.10</b>	<b>0.11</b>	<b>0.11</b>	<b>0.12</b>	<b>0.12</b>	<b>0.14</b>	<b>0.14</b>	<b>0.15</b>	<b>0.14</b>	<b>0.14</b>	<b>0.14</b>	<b>0.15</b>	<b>0.13</b>	<b>0.13</b>
Methane	0.03	0.04	0.06	0.06	0.06	0.07	0.07	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.07	0.07
Nitrous oxide	0.02	0.03	0.04	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05
<b>Wastewater treatment and discharge</b>	<b>0.30</b>	<b>0.28</b>	<b>0.26</b>	<b>0.25</b>	<b>0.25</b>	<b>0.25</b>	<b>0.25</b>	<b>0.25</b>	<b>0.25</b>	<b>0.25</b>	<b>0.25</b>	<b>0.24</b>	<b>0.25</b>	<b>0.25</b>	<b>0.26</b>	<b>0.25</b>
Methane	0.22	0.21	0.19	0.19	0.19	0.19	0.19	0.18	0.18	0.18	0.18	0.17	0.18	0.18	0.18	0.17
Nitrous oxide	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.07	0.08	0.08
<b>Total</b>	<b>4.67</b>	<b>4.60</b>	<b>3.85</b>	<b>3.69</b>	<b>3.44</b>	<b>3.23</b>	<b>3.07</b>	<b>2.83</b>	<b>2.91</b>	<b>2.80</b>	<b>2.68</b>	<b>2.58</b>	<b>2.59</b>	<b>2.50</b>	<b>2.45</b>	<b>2.33</b>



**Figure 7.1-3** Reporting categories of emissions from waste handling in the national greenhouse gas inventory

### *Key categories*

The key categories in the waste sector in 2013 are summarised in Table 7.1-2Table 7.1-2.

**Table 7.1-2** Key categories in Waste Sector (CRF 6) in 2013 (Approach 1)

IPCC category	Gas	Identification criteria
5.A. Solid Waste Disposal	CH <sub>4</sub>	L, T

## 7.2 Solid Waste Disposal (CRF 5.A)

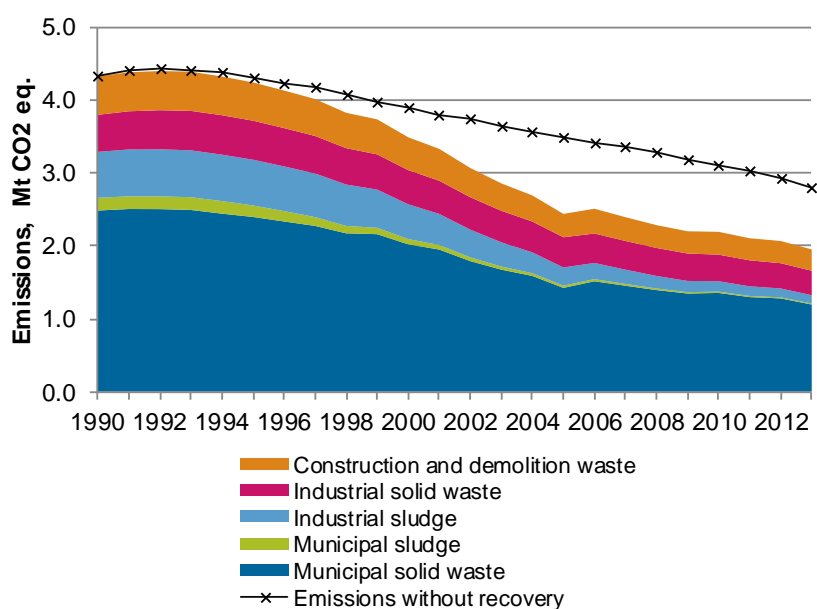
### 7.2.1 Category description

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 7.2-1** Reported emissions calculation methods and types of emission factors for the subcategory Solid Waste Disposal in the Finnish inventory (Unmanaged Waste Disposal Sites are included under Managed Waste Disposal in 1990-2001)

CRF	Source	Emissions reported	Methods	Emission factors
5.A.1	Managed Waste Disposal	CH <sub>4</sub>	T2	CS, D
5.A.2	Unmanaged Waste Disposal Sites	IE, NO	NA	NA

Emissions from solid waste disposal on land have decreased by 55% since 1990 and 6% compared to 2012. The trend in CH<sub>4</sub> emissions from solid waste disposal on land is presented by subcategory in Figure 7.2-1 and Table 7.2-3.



**Figure 7.2-1** Methane emissions from solid waste disposal on land (Mt CO<sub>2</sub> eq.). The figure shows also the amount methane generated (emission without recovery) at solid waste disposal sites.

## 7.2.2 Methodological issues

### 7.2.2.1 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 2006 IPCC Guidelines.

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. The status of the SWDS (managed – unmanaged; covered or not covered) 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 were unmanaged when used) because all the closed landfills have been covered since 2002. The modified equation can be seen in the Appendix\_7a at the end of Chapter 7.

### 7.2.2.2 Emission factors and other parameters

The parameters used in the calculation are mainly the 2006 IPCC Guidelines default values. Some country-specific emission parameters (factors) are used (Table 7.2-2). The choices of the parameters are in full agreement with the information and data ranges given in the 2006 IPCC Guidelines.

**Table 7.2-2** 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	D
F (Fraction of methane in landfill gas)	0.5	D
OX (Oxidation factor)	0.1	D
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 7.2-5.	k1 = 0.185 k2 = 0.03 k3 = 0.1 k4 = 0.06	D/CS 2006 IPCC Guidelines
MCF (Methane correction factor)	In 1990: 0.982 In 1991: 0.985 In 1992-1996: 0.988 In 1997-2001: 0.994 In 2002-2013: 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 7.2-4. Between the years presented in the table MCF is linearly growing. The weighted mean values of the MCF presented in Table 7.2-4 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 7.2-3** CH<sub>4</sub> emissions from solid waste disposal on land by subcategory (Mt CO<sub>2</sub> eq.)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Municipal solid waste	2.49	2.40	2.02	1.95	1.79	1.67	1.59	1.42	1.51	1.45	1.39	1.35	1.35	1.30	1.28	1.20
Municipal sludge	0.17	0.16	0.07	0.06	0.05	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.02	0.01	0.01
Industrial sludge	0.63	0.63	0.48	0.43	0.38	0.33	0.29	0.25	0.22	0.20	0.17	0.15	0.14	0.13	0.12	0.11
Industrial solid waste	0.51	0.54	0.47	0.46	0.45	0.43	0.42	0.41	0.40	0.39	0.38	0.38	0.36	0.36	0.35	0.34
Construction and demolition waste	0.53	0.53	0.45	0.44	0.40	0.38	0.36	0.32	0.34	0.33	0.31	0.31	0.31	0.30	0.30	0.29
<b>Total</b>	<b>4.33</b>	<b>4.25</b>	<b>3.49</b>	<b>3.33</b>	<b>3.07</b>	<b>2.86</b>	<b>2.69</b>	<b>2.44</b>	<b>2.51</b>	<b>2.39</b>	<b>2.29</b>	<b>2.20</b>	<b>2.19</b>	<b>2.11</b>	<b>2.07</b>	<b>1.95</b>

**Table 7.2-4** 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. *OX* is chosen to be 10% of the CH<sub>4</sub> generated at landfills based on international research (e.g. Oonk & Boom 1995).

DOC fractions of different types of waste are based on the 2006 IPCC Guidelines default values and national research data (Isännäinen 1994) and measurements made in industry (DOC value for de-inking sludges) (Huttunen 2008). For MSW 2006 IPCC Guidelines 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 7.2-6. 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 7.2-5** 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	2006 IPCC GLs
Food	0.15	0.185	2006 IPCC GLs
Paper	0.4	0.06	2006 IPCC GLs
Wood	0.43	0.03	2006 IPCC GLs
Garden	0.2	0.1	2006 IPCC GLs
Napkins	0.24	0.1	2006 IPCC GLs
Mixed packaging	0.1	0.06	2006 IPCC GLs
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	2006 IPCC GLs
Food	0.15	0.185	2006 IPCC GLs
Paper	0.4	0.06	2006 IPCC GLs
Wood	0.43	0.03	2006 IPCC GLs
Garden	0.2	0.1	2006 IPCC GLs

Waste group and subgroups	DOC	k	Reference
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
<b>Construction and demolition waste</b>			
Plastics	0		2006 IPCC GLs
Other inert	0		2006 IPCC GLs
Asphalt and tar	0.02	0.06	Expert knowledge
Wood	0.43	0.03	2006 IPCC GLs
Mixed (years 1997-1999)	0.0996	0.03	Perälä & Nippala, 1998
Mixed (years 2000-2013)	0.1384	0.03	Perälä, 2001
Total (years 1990-1996)	0.096-0.106	0.03	Calculated
Paper (packaging)	0.24	0.06	2006 IPCC GLs
Textile (packaging)	0.43	0.06	2006 IPCC GLs
Other (packaging)	0.1	0.06	Expert knowledge
<b>Industrial and municipal inert waste</b>			
Plastics	0		2006 IPCC GLs
Other combustible	0		2006 IPCC GLs
Other non-combustible	0		2006 IPCC GLs
Ash	0		2006 IPCC GLs
Other sludges (mainly from inorganic processes)	0		2006 IPCC GLs
<b>Other inert waste</b>			
Mine	0		2006 IPCC GLs
Soil	0		2006 IPCC GLs

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 2006-2013 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 7.2-6** 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	2008-2013
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 7.2-7** DOC-values of municipal solid waste

	1990 - 1993	1994 - 1996	1997 - 1999	2000	2001	2002	2003	2004	2005	2006	2007	2008 - 2013
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

### 7.2.2.3 Activity data

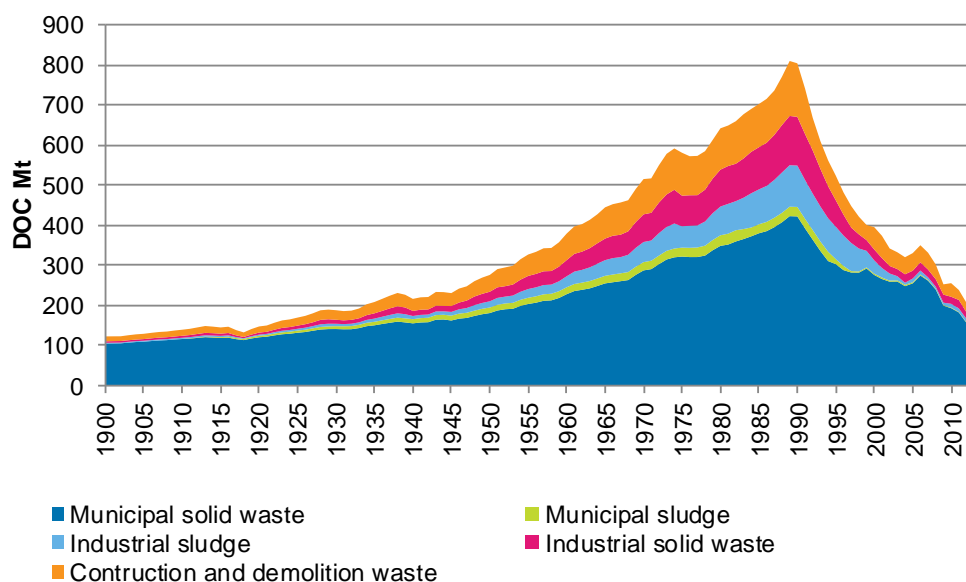
The activity data used in the calculation are taken from the VAHTI system (see Section 1.4 and Annex 6). It includes information on all landfills in Finland excluding Åland, which is estimated according to the population. The VAHTI contains data on the total amounts of waste taken to landfills from 1997 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 data (part of industrial paper waste was classified as municipal 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 the base year, activity data from studies by Isaksson (1993) and Pipatti et al. (1996) are used for construction and demolition waste, by Karhu (1993 for industrial sludges and by Puolamaa et al. (1995) for solid industrial waste.

The amount of landfilled waste in 1990-2013 is presented in Table 7.2-8. The corresponding DOC tonnes are given in Table 7.2-9. 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 7.2-11. The industrial solid waste category consist of several hundreds of EWC-codes (EWC principal groups 02-16 and 18-19). The previous UNFCCC review encouraged Finland to provide information on clinical waste management practices and regulations, in order to improve the transparency of the inventory submission. The industrial EWC-codes include among others the category health service activities including clinical wastes, also. Part of the clinical wastes are landfilled (separately or if non-hazardous among other wastes). These waste amounts are known quite well according to the exact EWC-codes. The burned or incinerated clinical waste amounts are not known so well (part of burned industrial wastes are reported by fuel codes, only). The composition of industrial solid waste is presented according to the DOC and decay groups in Appendix\_7c. 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 increased 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 2010-2013 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 7.2-3.

Data on landfill gas recovery are obtained from the Finnish Biogas Plant Register (Huttunen and Kuittinen 2014) and presented in Table 7.2-10 and in Appendix\_7b (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 7.2-2** The DOC (Mt) of the five waste groups starting from the year 1900

**Table 7.2-8** 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).

Waste group	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Municipal solid waste	2 400	1 682	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	685
Municipal sludge (d.m.)	47	25	6	8	6	6	6	6	5	4	4	3	3	2	3	3
Municipal sludge (wet m.)	498	298	70	79	66	63	58	53	51	39	27	26	22	23	22	22
Industrial sludge (d.m.)	337	260	118	97	65	42	29	48	44	32	15	18	26	27	32	32
Industrial sludge (wet m.)	1 193	881	550	329	209	198	127	161	144	119	49	55	82	78	96	94
Industrial solid waste	2 135	1 519	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	3 175
Constr. and demol. waste	1 262	637	454	457	377	401	373	390	353	336	331	229	342	240	241	196

**Table 7.2-9** Landfilled waste (1 000 DOC t)

Waste group	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Municipal solid waste	422	303	276	266	259	260	248	255	275	262	240	200	193	183	156	121
Municipal sludge	24	12	3	4	3	3	3	3	3	2	2	2	1	1	1	1
Industrial sludge	103	81	33	24	18	10	5	9	10	6	5	6	10	9	8	9
Industrial solid waste	121	66	27	25	19	18	21	19	20	19	19	20	17	21	17	14
Constr. and demol. waste	134	61	56	56	44	42	43	44	43	42	37	26	34	25	24	20

**Table 7.2-10** Landfill CH<sub>4</sub> recovery (kt) and the number of operating CH<sub>4</sub> recovery plants (Huttunen and Kuittinen 2013)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Recovery (kt)	0	2.84	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	34.05
Number	0	4	12	13	26	27	29	33	33	33	33	35	39	39	40	40

**Table 7.2-11** DOC share in landfilled Industrial solid waste without inert industrial wastes (-)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
DOC share (-)	0.189	0.154	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	0.065

### 7.2.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

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 2013. The correlation between uncertainties in emissions in 1990 and 2013 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 an expert estimate.

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 an expert estimate.

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 has minor inconsistencies considering the allocation of these wastes in 2005-2009. 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.

## 7.2.4 Category-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 1.2.3. The QC procedures are performed according to the QA/QC plan in order to attain these quality objectives. The bilateral quality meeting 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 1.2.3.

General Quality Control (QC) procedures were applied in category CRF 5.A according to the IPCC 2006 Guidelines (Vol 1, Chapter 6, Table 6.1):

- 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 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.

### Category-specific QC

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.

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 7.2.2).

### Quality assurance and verification

The guidance in the 2006 IPCC Guidelines (IPCC 2006) for activity data collection in the Waste sector is based on a top-down approach starting from default data on waste generation which is then divided into waste streams by treatment type. In Finland, the activity data for waste treatment is based on bottom-up data collected from waste management operators (main source VAHTI system, see Annex 6). The bottom-up data is more accurate (often measured data based on requirements in environmental permits) than data on estimates on waste generation, which are based on survey data. The QA and verification measures given in Chapter 3.8 of the Waste cannot therefore be applied as such.

The corrected activity data (from the VAHTI system) of the landfilled municipal solid waste used in the submission for the inventory year 2013 delivered to Statistics Finland for comparison with their own observations on the same initial data. The results from this QA procedure are 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.

For example, the total amount of municipal waste generated in Finland in 2013 was estimated to be 2.7 million tonnes and the treatment of the municipal solid waste was divided into the following categories in 2013 (Finland 2014):

- Landfilling 26% (0.7 million tonnes)
- Composting and anaerobic digestion 13%
- Material recycling 19%
- Burning and incineration 42%.

The estimated amounts of landfilled municipal solid waste in the inventory are in good agreement with this figure.

Measurements of landfill gas recovery at the largest solid waste disposal site in Finland have been studied in more detail (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.

### *7.2.5 Category-specific recalculations*

No ordinary recalculation has been made since the previous submission. The implementation of 2006 IPCC Guidelines introduced no changes to the methodology and emission estimates changed due to the new GWPs, only.

### *7.2.6 Category-specific planned improvements*

Specially, in the years 2006-2013 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.

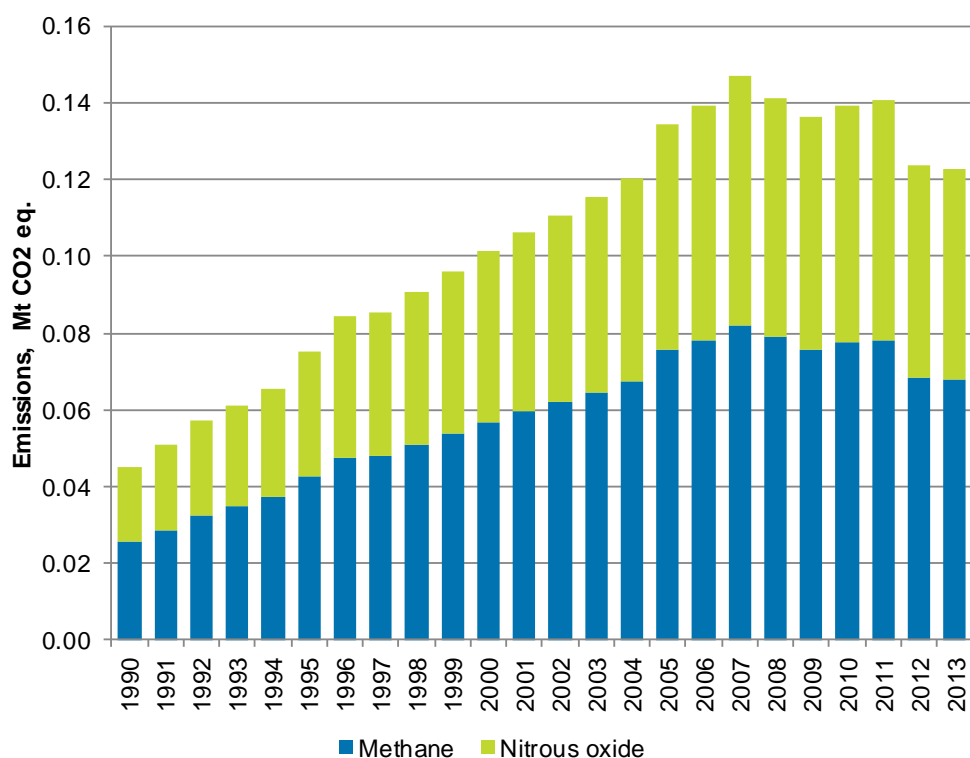
A sample survey for construction and demolition waste was conducted in 2013 by Statistics Finland. The survey was sent to construction companies. Due to a low response rate the results did not give enough new information about the composition of mixed construction and demolition waste to justify a revision of the waste composition.

## 7.3 Biological Treatment of Solid Waste (CRF 5.B)

### 7.3.1 Composting (CRF 5.B 1)

#### 7.3.1.1 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).



**Figure 7.3-1** Greenhouse gas emissions from composting (Mt CO<sub>2</sub> eq.)

**Table 7.3-1** Reported emissions, calculation methods and types of emission factors for the subcategory Composting in the Finnish inventory (D = default)

CRF	Source	Emissions reported	Methods	Emission factors
5.B.1	Composting			
	Municipal solid waste	CH <sub>4</sub> , N <sub>2</sub> O	T1	D
	Municipal sludge	CH <sub>4</sub> , N <sub>2</sub> O	T1	D
	Industrial sludge	CH <sub>4</sub> , N <sub>2</sub> O	T1	D
	Industrial solid waste, constr. waste	CH <sub>4</sub> , N <sub>2</sub> O	T1	D

Emissions from composting have more than doubled since 1990, being 5% of the Waste sector's emissions in 2013. Compared to 2012, emissions declined nearly 1% in 2013. The trend in emissions is presented by subcategory in Table 7.3-3. The waste amounts with degradable auxiliary matter (20%-30%) in composting are presented in Table 7.3-4, correspondingly.

#### 7.3.1.2 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).

$$\text{Emissions (kt CH}_4 \text{ or kt N}_2\text{O)} = AD * EF / 1000000$$

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 7.3-2.

**Table 7.3-2** Emission factors in composting (g CH<sub>4</sub>/kg waste treated, g N<sub>2</sub>O/kg waste treated) (2006 IPCC GLs)

	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 is based on the VAHTI system. 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 (R032) and composting plant code in VAHTI system have been used in data collection for the years 2006-2013. In 2013, the composted municipal sludges are estimated according to the removed outgoing sludges from municipal wastewater plants (the same data source is used in the Agricultural sector, also) and to the share of composted amounts compared to that amount in 2006-2012 data. The classification to the reporting subgroups is based on to the EWC codes of composted wastes (like landfilled wastes with the exception of construction wastes). The amounts of composted sludges have turned down after 2006. In recent years anaerobic digestion plants have been built in Finland, which is probably the main reason for this development.

Degradable auxiliary material used in composting is included in the activity data. The shares have been estimated to be 20% (solid wastes) or 30% (sludges) for the whole time series (Petäjä 2005).

**Table 7.3-3** Emissions from composting by subcategory (Mt CO<sub>2</sub> eq.)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<b>Methane emissions</b>	<b>0.026</b>	<b>0.042</b>	<b>0.057</b>	<b>0.060</b>	<b>0.062</b>	<b>0.065</b>	<b>0.067</b>	<b>0.075</b>	<b>0.078</b>	<b>0.082</b>	<b>0.079</b>	<b>0.076</b>	<b>0.078</b>	<b>0.078</b>	<b>0.069</b>	<b>0.068</b>
Municipal solid waste	0.006	0.010	0.018	0.019	0.020	0.021	0.022	0.023	0.023	0.029	0.028	0.028	0.030	0.032	0.030	0.032
Municipal sludge	0.015	0.027	0.032	0.033	0.033	0.034	0.035	0.040	0.040	0.038	0.039	0.033	0.032	0.030	0.028	0.028
Industrial sludge	0.003	0.003	0.004	0.005	0.005	0.006	0.006	0.008	0.009	0.011	0.008	0.010	0.009	0.008	0.006	0.006
Industrial solid waste	0.001	0.002	0.003	0.003	0.004	0.004	0.004	0.004	0.006	0.005	0.003	0.006	0.006	0.008	0.005	0.003
<b>Nitrous oxide emissions</b>	<b>0.020</b>	<b>0.033</b>	<b>0.045</b>	<b>0.047</b>	<b>0.049</b>	<b>0.051</b>	<b>0.053</b>	<b>0.059</b>	<b>0.061</b>	<b>0.065</b>	<b>0.062</b>	<b>0.060</b>	<b>0.062</b>	<b>0.063</b>	<b>0.055</b>	<b>0.055</b>
Municipal solid waste	0.005	0.009	0.016	0.017	0.018	0.019	0.019	0.021	0.021	0.026	0.025	0.025	0.027	0.029	0.027	0.028
Municipal sludge	0.011	0.020	0.023	0.023	0.024	0.024	0.025	0.028	0.029	0.027	0.028	0.023	0.023	0.021	0.020	0.020
Industrial sludge	0.002	0.002	0.003	0.003	0.004	0.004	0.005	0.006	0.006	0.008	0.006	0.007	0.007	0.006	0.004	0.004
Industrial solid waste	0.001	0.002	0.003	0.003	0.003	0.004	0.004	0.004	0.005	0.005	0.003	0.005	0.005	0.007	0.004	0.003

**Table 7.3-4** Composted waste with degradable auxiliary matter by subcategory (1 000 t)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Municipal solid waste	60	102	180	190	199	209	218	233	232	289	284	281	304	319	304	317
Municipal sludge (d.m.)	60	110	128	131	133	136	138	159	160	151	156	130	127	120	112	111
Industrial sludge (d.m.)	13	12	15	18	21	23	26	32	36	42	33	38	38	33	22	22
Industrial solid waste	12	18	31	34	38	41	45	45	61	52	35	57	60	77	47	31

### 7.3.1.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

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 complementing the activity data and the uncertainties ( $\pm 40$  in 1990,  $\pm 30\%$  in the early 2000's to the  $\pm 25$  in 2013, 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. Manual crosschecking of data has been necessary because there is also the option that the sludges are delivered to be composted outside the handling plant to other companies. For this reason the activity data in 2013 was collected in the way described in the previous section. 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 identified by crosschecking the outgoing wastes and by utilising the report from composting plants (Merilehto and Koskinen 2010). This means that the uncertainties of the activity data will remain on quite a high level in the future also.

The uncertainties of the emissions factors are according to the range variations given in the 2006 IPCC Guidelines default emission factors. The total uncertainty in composting was -52% to +61% in the 2013 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) even if the origin of the activity data varies (see previous section).

#### *7.3.1.4 Category-specific QA/QC and verification*

The QC procedures are performed according to the QA/QC and verification plan in order to attain quality objectives. The bilateral quality meeting 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 system 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 Quality Control (QC) procedures were applied in composting according to the 2006 IPCC Guidelines (Vol 1, Chapter 6, Table 6.1):

- Documentation on activity data and emission factors was crosschecked with the corresponding data in the calculation model.
- A sample of input data from each 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.

The data from Statistics Finland on biological treatment of municipal solid waste in 2013 (see end of Section 7.2.4) is in good agreement with the data used in the inventory.

#### *7.3.1.5 Category-specific recalculations*

The auxiliary matter in composting is calculated in a slightly different manner in 2006-2012 than in the previous submissions. In the previous submission values derived from VAHTI data were used. Now, in every composting plant the share of auxiliary matter is assumed to be 20% (solid wastes) or 30% (sludges). These amounts are estimated according to plant level data from VAHTI system but because the reporting practices of auxiliary matter varies considerably in VAHTI system, the change to use constant data for the whole time series was made. The implementation of 2006 IPCC Guidelines introduced no changes to the methodology. The emission estimates changed due to the treatment of auxiliary matter and due to the new GWPs.

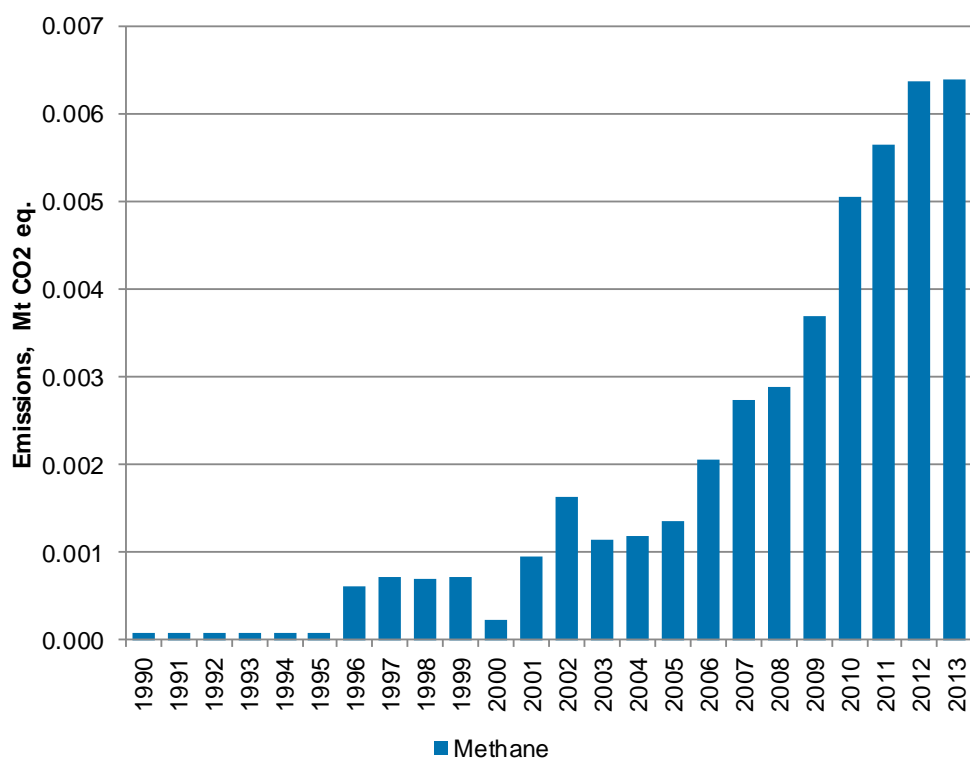
#### *7.3.1.6 Category-specific planned improvements*

There are no planned improvements.

## 7.3.2 Anaerobic digestion at biogas facilities (CRF 5.B 2)

### 7.3.2.1 Category description

Emissions of greenhouse gas CH<sub>4</sub> from biogas facilities are estimated. The emission source includes emissions from anaerobic digestion of biowastes (municipal solid waste, municipal and industrial sludges and industrial solid waste including construction waste).



**Figure 7.3-2** Methane emissions from anaerobic digestion (Mt CO<sub>2</sub> eq.)

**Table 7.3-5** Reported emissions, calculation methods and types of emission factors for the subcategory Anaerobic digestion in the Finnish inventory (D = default)

CRF	Source	Emissions reported	Methods	Emission factors
5.B.2	Anaerobic digestion at biogas facilities			
	Municipal solid waste	CH <sub>4</sub>	T1	D
	Municipal sludge	CH <sub>4</sub>	T1	D
	Industrial sludge	CH <sub>4</sub>	T1	D
	Industrial solid waste incl. constr. waste	CH <sub>4</sub>	T1	D

Emissions from anaerobic digestion have been increased significantly in recent years. Yet, this emission source is very small being 0.3% of the Waste sector's emissions in 2013. The trend in emissions is presented by subcategory in Table 7.3-7 and the waste amounts in anaerobic digestion are presented in Table 7.3-8

### 7.3.2.2 Methodological issues

#### Methods

Emissions from anaerobic digestion have been calculated using the method given in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006).

$$\text{Emissions (kt CH}_4 \text{ or kt N}_2\text{O)} = AD * EF / 1000000$$

where

$AD$  = Waste amount (t)

$EF$  = emission factor (g CH<sub>4</sub> /kg waste treated)

#### Emission factors

Emission factors in anaerobic digestion are presented in Table 7.3-6.

**Table 7.3-6** Emission factors in composting (g CH<sub>4</sub>/kg waste treated) (IPCC, 2006)

	CH <sub>4</sub> emission factor
Municipal solid waste, Industrial solid waste including construction waste	1
Municipal sludge, Industrial sludge (d.m.)	2

#### Activity data

Activity data is based on the VAHTI system and extrapolated data from digestion plants operating in 1990-1995 (using municipal sludges). The classification to the reporting subgroups is based on to the EWC codes of treated wastes. In recent years several anaerobic digestion plants have been built in Finland which has multiplied the waste amounts and emissions from anaerobic digestion since 2005. The waste amounts in anaerobic digestion are presented in Table 7.3-8.

**Table 7.3-7** Emissions from anaerobic digestion by subcategory (kt CO<sub>2</sub> eq.)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<b>Methane emissions</b>	0.09	0.09	0.23	0.96	1.64	1.16	1.19	1.36	2.06	2.74	2.89	3.69	5.05	5.66	6.37	6.40
Municipal solid waste	NO	NO	0.09	0.84	1.52	0.92	0.97	1.06	1.07	1.17	1.24	1.57	1.78	2.28	2.51	2.25
Municipal sludge	0.09	0.09	0.13	0.12	0.12	0.24	0.18	0.14	0.23	0.20	0.49	1.03	1.21	1.41	1.83	1.82
Industrial sludge	NO	NO	NO	NO	NO	0.00	0.00	0.03	0.00	NO	0.04	0.05	0.42	0.42	0.42	0.43
Industrial solid and constr. waste	NO	NO	NO	0.00	0.00	NO	0.03	0.12	0.75	1.37	1.12	1.04	1.65	1.54	1.61	1.90

**Table 7.3-8** Waste amounts in anaerobic digestion by subcategory (1000 t)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Municipal solid waste	NO	NO	3.8	33.5	60.7	36.6	38.9	42.4	43.0	46.7	49.5	62.9	71.0	91.4	100.3	89.9
Municipal sludge (d.m.)	1.8	1.8	2.6	2.4	2.4	4.8	3.6	2.9	4.7	4.0	9.8	20.6	24.2	28.3	36.6	36.4
Industrial sludge (d.m.)	NO	NO	NO	NO	NO	0.001	0.04	0.5	0.002	NO	0.8	0.9	8.3	8.3	8.4	8.7
Industrial solid and constr. waste	NO	NO	NO	0.1	0.1	NO	1.2	5.0	30.1	54.9	44.8	41.5	66.1	61.7	64.4	75.9

### 7.3.2.3 *Uncertainties and time-series consistency*

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

The VAHTI system had no treatment code solely for anaerobic digestion for the years 1996-2005 and the new code for anaerobic digestion was introduced in 2006 and the use of this code might have been slightly unreliable, still. However, the years before 2006 is no major problem because only one digestion plant was operating in these years. Also, anaerobic digestion plants are quite large units being all in VAHTI register. For these reasons the uncertainties ( $\pm 20\%$  in 1990-1995 and after that  $\pm 10\%$ ) are smaller than in composting (Petäjä 2015).

The uncertainties of the emissions factors are according to the range variations of the 2006 IPCC Guidelines default emission factors.

Calculating method for anaerobic digestion is the same through whole time series. Time series for activity data is gathered in a consistent manner (e.g. waste groups).

### 7.3.2.4 *Category-specific QA/QC and verification*

The QC procedures are performed according to the QA/QC and verification plan in order to attain quality objectives. The bilateral quality meeting is held annually between the inventory unit and the sectoral expert.

Anaerobic digestion plants from VAHTI system were compared to the governmental survey from anaerobic digestion (and composting) plants and their environmental permits by Finnish Environment Institute and Ministry of the Environment (Merilehto and Koskinen 2010).

General Quality Control (QC) procedures were applied in anaerobic digestion according to the 2006 IPCC Guidelines (Vol 1, Chapter 6, Table 6.1)

- Documentation on activity data and emission factors was crosschecked with the corresponding data in the calculation model.
- A sample of input data from each 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.

### 7.3.2.5 *Category-specific recalculations*

Anaerobic digestion is a new emission source in the 2015 submission.

### 7.3.2.6 *Category-specific planned improvements*

No planned improvements.

## *7.4 Incineration and open burning of waste (CRF 5.C)*

Emissions of greenhouse gases CO<sub>2</sub>, N<sub>2</sub>O and CH<sub>4</sub> from Waste Incineration (CRF 5.C) are reported in the energy sector (CRF 1.A) in the Finnish inventory. Emission factors are presented in Table 3.2-4, Table 3.2-6 and Table 3.2-7.

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 tonnes. The incineration of paper and paperboard in households is estimated to be 31,000 tonnes together. Hazardous wastes are burned (with energy recovery) mainly in one plant in Finland and the mass of these wastes were approximately 80,000 tons together in 2013. Open burning of waste is not allowed in Finland.

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% the treatment 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 2013 (Statistics Finland 2014). In addition, almost all of the incineration (D10) concerns poor quality waste components which has been burned at with better waste components and the energy efficiency would be over 65% at boiler level.

## 7.5 Wastewater treatment and discharge (CRF 5.D)

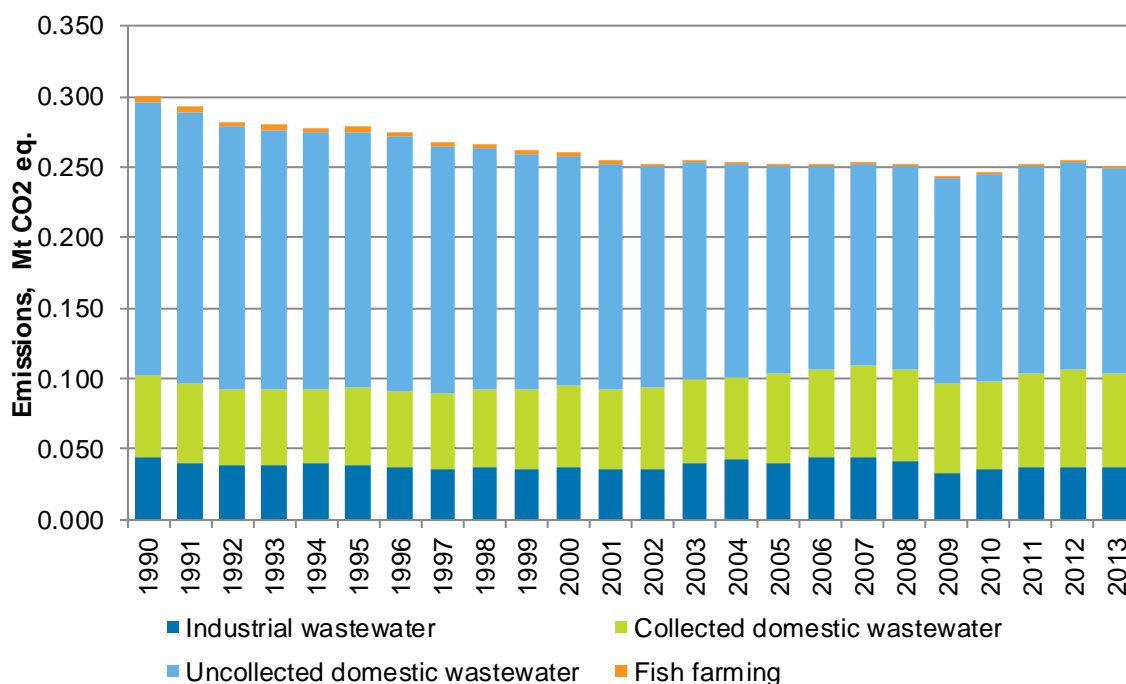
### 7.5.1 Category description

The emission sources cover municipal (domestic) and industrial wastewater treatment 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.

**Table 7.5-1** 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
5.D.1	Domestic Wastewater	CH <sub>4</sub>	CS, T2	CS, D
5.D.1	Domestic Wastewater	N <sub>2</sub> O	CS, T1	D
5.D.2	Industrial Wastewater	CH <sub>4</sub> ,	CS, T2	CS, D
5.D.2	Industrial Wastewater	N <sub>2</sub> O	CS	D
5.D.3	Other (Fish Farming)	N <sub>2</sub> O	CS	D

Emissions from wastewater treatment have been decreased by 15% since 1990 and decreased nearly 2% compared to 2012. Emission trends by sources are presented in Figure 7.5-1. The overall trend in domestic wastewaters (the most significant source) is decreasing due to downward trend of population in uncollected wastewaters (methane). Emission trends from wastewater treatment and discharge by subcategory and gas are presented in Table 7.5-2.



**Figure 7.5-1** Emissions from wastewater handling by emission source (Mt CO<sub>2</sub> eq.)

## 7.5.2 Methodological issues

### Methods

A national methodology that corresponds to the methodology given in the 2006 IPCC Guidelines is used in the estimation of the CH<sub>4</sub> emissions. MCF parameters are defined according to total organics in wastewaters so no subtractions of removed sludges or recovered methane are taken into account. 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).

The equations used for calculating CH<sub>4</sub> emissions from domestic and industrial wastewater treatment are described in the Appendix\_7a.

The MCF parameters for wastewater plants are based on expert opinions (Jouttijärvi et. al. 1999) and they are within the range of the 2006 IPCC Guidelines. 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). 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 fish farming was also taken into account. Also, a difference to IPCC method is that co-discharged protein (factor) from industry is not taken into account but the measured N values from industry are used. Because the measures incoming loads to wastewater treatment plants are used in calculations, no emission from advanced centralised wastewater treatment plants are estimated. The emission factors for industrial wastewater and for fish farming are the same as in domestic wastewater.

The IPCC methodology is very rough and the N input into waterways is based on population data. In Finland, the N input from domestic and industrial wastewaters 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 2014).

$$\text{Emissions (kt N}_2\text{O)} = \text{Nitrogen load (kg)} * EF * 10^{-6} * 44/28$$

Where

*EF* = Emission factor (kg N<sub>2</sub>O-N/kg N load), IPCC default = 0.005

### Emission factors and other parameters

Emission factors for collected domestic wastewaters are IPCC default factors for the maximum methane producing capacity  $B_0 = 0.6 \text{ kg CH}_4/\text{kg BOD}$  and country-specific, based on expert knowledge, for the methane conversion factor  $MCF = 0.01$  (being within the range of the 2006 IPCC Guidelines). For uncollected wastewaters the 2006 IPCC Guidelines default emission factors are used ( $B_0 = 0.6 \text{ kg CH}_4/\text{kg BOD}$  and  $MCF = 0.5$ ).

For the industrial wastewaters the emission factor is the IPCC default for the maximum methane producing capacity  $B_0 = 0.25 \text{ kg CH}_4/\text{kg COD}$  and a country-specific emission factor based on expert knowledge for the methane conversion factor  $MCF = 0.005$  (being within the range of the 2006 IPCC Guidelines).

## Activity data

Activity data are based on

- domestic wastewater: Population (Uncollected wastewater); the BOD (BOD<sub>7</sub>) values and N load values of wastewaters from the VAHTI system.
- industrial wastewater: the COD values of wastewaters from the VAHTI system. 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.

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 2014) and from VAHTI system (the continent of Finland).

The BOD and COD load values and Nitrogen load input values are presented in Table 7.5-3 and Table 7.5-4, respectively. The population having uncollected domestic wastewater handling system and the protein consumption per person are presented in Table 7.5-5.

**Table 7.5-2** Emissions from wastewater treatment by subcategory (Mt CO<sub>2</sub> eq.)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<b>Methane emissions (Total)</b>	<b>0.221</b>	<b>0.209</b>	<b>0.190</b>	<b>0.187</b>	<b>0.187</b>	<b>0.186</b>	<b>0.186</b>	<b>0.181</b>	<b>0.182</b>	<b>0.181</b>	<b>0.179</b>	<b>0.172</b>	<b>0.176</b>	<b>0.179</b>	<b>0.177</b>	<b>0.174</b>
Collected domestic wastewater	0.015	0.015	0.015	0.015	0.016	0.016	0.016	0.017	0.016	0.017	0.017	0.017	0.017	0.017	0.017	0.017
Uncollected domestic wastewater	0.179	0.168	0.150	0.148	0.145	0.142	0.139	0.136	0.133	0.132	0.132	0.134	0.135	0.136	0.135	0.133
Industrial wastewater	0.027	0.026	0.025	0.024	0.026	0.029	0.030	0.028	0.032	0.032	0.029	0.022	0.024	0.025	0.025	0.024
<b>Nitrous oxide emissions (Total)</b>	<b>0.079</b>	<b>0.069</b>	<b>0.070</b>	<b>0.068</b>	<b>0.066</b>	<b>0.069</b>	<b>0.068</b>	<b>0.071</b>	<b>0.071</b>	<b>0.073</b>	<b>0.074</b>	<b>0.071</b>	<b>0.071</b>	<b>0.074</b>	<b>0.078</b>	<b>0.077</b>
Collected domestic wastewater	0.043	0.040	0.043	0.041	0.042	0.044	0.042	0.046	0.046	0.047	0.049	0.047	0.045	0.048	0.052	0.050
Uncollected domestic wastewater	0.015	0.014	0.013	0.013	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012	0.012
Industrial wastewater	0.017	0.013	0.012	0.012	0.011	0.011	0.012	0.012	0.012	0.012	0.012	0.011	0.012	0.012	0.012	0.012
Fish farming	0.004	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.002
<b>Total wastewater</b>	<b>0.300</b>	<b>0.278</b>	<b>0.260</b>	<b>0.255</b>	<b>0.253</b>	<b>0.255</b>	<b>0.254</b>	<b>0.253</b>	<b>0.253</b>	<b>0.254</b>	<b>0.252</b>	<b>0.243</b>	<b>0.247</b>	<b>0.253</b>	<b>0.255</b>	<b>0.251</b>

**Table 7.5-3** BOD and COD loads (1 000 t)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<b>Domestic wastewater</b>																
Collected BOD <sub>7</sub> load	117	114	119	118	126	125	127	132	126	134	134	129	129	133	134	130
Collected BOD <sub>5</sub> load	100	97	101	101	108	107	108	113	108	114	114	110	111	114	114	111
Uncollected BOD <sub>5</sub> load	24	22	20	20	19	19	19	18	18	18	18	18	18	18	18	18
<b>Industrial wastewater</b>																
COD load	852	843	795	758	819	912	965	895	1022	1027	929	709	764	814	809	781

**Table 7.5-4** N load in effluent (1 000 t)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
<b>Domestic wastewater</b>																
Collected N load	24.9	22.9	23.6	23.0	22.9	24.0	23.2	24.7	24.5	25.2	25.8	25.1	24.4	26.0	27.5	26.8
Uncollected N load	6.4	5.8	5.4	5.4	5.2	5.2	5.2	5.1	5.0	5.0	5.0	5.1	5.2	5.3	5.3	5.3
N load in Industrial wastewater	7.2	5.4	5.2	4.9	4.5	4.7	5.3	5.1	5.1	5.1	5.1	4.5	5.3	5.1	5.2	5.1
N load in Fish farming	1.7	1.3	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	0.8

**Table 7.5-5** Population (1000 persons) having collected or uncollected wastewater treatment system and dry closets and protein consumption (g/person/day)

	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Uncollected wastewater	1 092	1 023	915	902	882	863	847	830	812	803	806	814	824	828	819	810
Collected wastewater	3 786	3 983	4 170	4 196	4 231	4 263	4 296	4 333	4 373	4 406	4 427	4 444	4 457	4 477	4 513	4 548
Dry closet	109	102	91	90	88	86	85	83	81	80	81	81	82	83	82	81
Protein consumption (g/person/day)	100.3	97.4	100.4	102.3	101	103.4	105	104.4	104.9	106.7	107.2	107	107.7	109.2	110.1	111.2

### 7.5.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents assumptions made for the analysis. A description uncertainty analysis is provided in Section 1.6.

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 2013 inventory (Section 1.6).

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 (type of activity data and emission factors). 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 estimation (-60% to +100%).

For sparsely populated areas, the activity is based on population and the 2006 IPCC Guidelines default value for BOD<sub>5</sub> in Europe. 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.

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 category. A detailed description of the uncertainty analysis has been presented in Monni & Syri (2003) and Monni (2004).

### 7.5.4 Category-specific QA/QC and verification

General descriptions of quality objectives, QA/QC and verification procedures are presented in Section 1.2.3. The QC procedures are performed according to the QA/QC and verification plan in order to attain these quality objectives. The bilateral quality meeting is held annually between the inventory unit and the sectoral expert.

General Quality Control (QC) procedures applied in category CRF 5.B. according to the 2006 IPCC Guidelines (Vol 1, Chapter 6, Table 6.1):

- Documentation on activity data and emission factors was crosschecked with the corresponding data in the calculation model.
- A sample of input data from each 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.

### *7.5.5 Category-specific recalculations*

The implementation of the 2006 IPCC Guidelines introduce increased activity data to N load but the new emission factor is 50% smaller than in previous submissions resulting in somewhat decreased N<sub>2</sub>O emissions. Excluding the impact of the new GWP, methane emission are on same level as in previous submissions, only emissions in uncollected domestic wastewaters slightly increased due to the 2006 IPCC Guidelines default values compared to the values of Check method in IPCC 2000 Good Practice Guidance. Also, the activity data in VAHTI system was investigated through the whole time series and the substantial mistakes were corrected.

### *7.5.6 Category-specific planned improvements*

There are no planned improvements.

## Appendix\_7a

### *The equations used in calculating emissions from the Waste sector (CRF 5)*

#### Solid waste disposal on land (CRF 5.A)

The modified Equation 5.1 (IPCC 2000) is as follows:

$$\text{CH}_4 \text{ generated in year } t \text{ (kt / year)} = \sum_x [A * k * SW(x) * L_0(x) * e^{-k(t-x)}]$$

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  $x$  (kt / a)

$L_0(x) = MCF(t) * DOC(x) * DOCF * F * 16 / 12$  (kt CH<sub>4</sub> / kt 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  $x$  (kt C / kt 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:

$$\text{CH}_4 \text{ emitted in year } t \text{ (kt / a)} = [\text{CH}_4 \text{ generated in year } t - R(t)] * (1 - OX)$$

where

$R(t)$  = Recovered CH<sub>4</sub> in inventory year  $t$  (kt / a)

$OX$  = Oxidation factor (fraction)

#### Wastewater treatment (CRF 5.D)

Equations used in calculating CH<sub>4</sub> emissions from domestic wastewater and industrial wastewater treatment are as follows:

$$\text{Emissions (kt CH}_4\text{)} = \text{Organic load in wastewaters} * B_0 * MCF / 1000000$$

where

$B_0$  = Maximum methane producing capacity (kg CH<sub>4</sub> / kg BOD or kg COD)

$MCF$  = Methane conversion factor (fraction)

## Appendix\_7b

### *List of landfill gas recovery plants and volume of collected gas in 2013 (Huttunen and Kuittinen 2014)*

Name of a plant	Volume of collected gas, 1 000 m <sup>3</sup>
Vuosaari, Helsinki	870
Seutula, Vantaa	1 020
Kiertokapula, Hyvinkää	1 960
Kiertokapula, Hämeenlinna	1 700
Porvoo	770
Ämmässuo, Espoo	51 388
Mankkaa, Espoo	3 000
Tampere	1 300
Oulu	5 600
Kerava	0
Lappeenranta	300
Lohja	1 000
Joensuu	1 700
Pori	1 072
Simpele	442
Lahti	1 690
Jyväskylä	3 800
Nokia	1 850
Sammalsuo, Kouvola	1 200
Iisalmi	490
Järvenpää	100
Mikkeli	380
Raisio	100
Rovaniemi	400
Turku	2 000
Uusikaupunki	100
Kajaani	1 000
Myllykoski Paper, Anjalankoski	400
Silmäsuo, Kuopio	600
Heinälamminrinne, Kuopio	2 800
Keltakangas, Anjalankoski	400
Keltakangas2, Kouvola	1 069
Vaasa	700
Imatra	620
Savonlinna	740
Salo	200
Stormossen, Mustasaari	77
Heinsuo, Kotka	510
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 2013 because of reparation of landfill structures.

## Appendix\_7c

### 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	2013
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	0.065
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	2013
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	3.1
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	0.3
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	1 612
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	728
Sludges	521	521	521	426	331	237	142	47	297	516	465	402	320	303	826	834	799	887	864	813	125	223	606	620
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	NO
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	9.3
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	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	2013
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	7.3
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	0.4
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	NO	NO	NO	NO	NO	NO
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	1.4
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	101
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	1.5
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	87

## 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	2013
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	3.1
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	0.3
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	1 612

## 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	2013
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	728
Sludges	521	521	521	426	331	237	142	47	297	516	465	402	320	303	826	834	799	887	864	813	125	223	606	620
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	NO
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	9.3
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	2.0
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	7.3
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	0.4
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	NO	NO	NO	NO	NO	NO
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	1.4
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	101
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	1.5
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	87

## 8 *OTHER (CRF 6)*

Finland does not report any emissions under the Other sector.

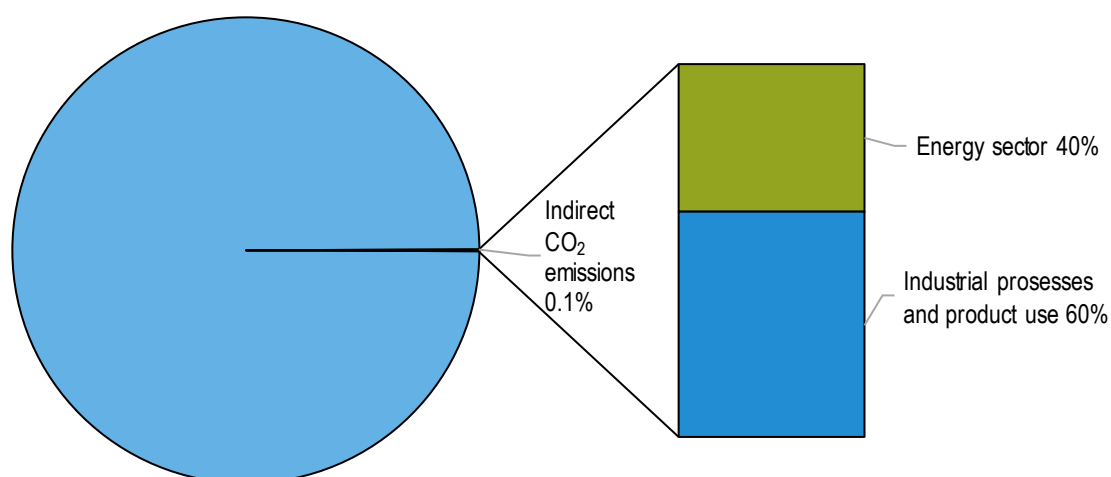
## 9 INDIRECT CO<sub>2</sub> AND NITROUS OXIDE EMISSIONS

### 9.1 Description of sources of indirect emissions in GHG inventory

Finland reports as memo item indirect N<sub>2</sub>O emissions from nitrogen deposition caused by NO<sub>x</sub> emissions from other than the agriculture and LULUCF sources. These estimates are not included in national totals. In addition, indirect CO<sub>2</sub> emissions due to atmospheric oxidation of CH<sub>4</sub> and NMVOCs have been calculated. Finland's national total emissions include the indirect CO<sub>2</sub> emissions but are presented in the CRF tables with and without indirect CO<sub>2</sub>.

Indirect N<sub>2</sub>O emissions totaled 192 kt in 2013. Emissions declined 54% compared to 1990 and nearly 2% compared to 2012. These estimates are not included in national totals but reported as memo items.

Indirect CO<sub>2</sub> emissions totaled 81 kt in 2013. Emissions declined 69% compared to 1990 and 4% compared to 2012. In 2013, 40% of the indirect CO<sub>2</sub> emissions originated from the energy sector (CRF 1) and 60% from the industrial processes and other product use sector (CRF 2). In industrial processes and other product use only 0.0005% of indirect CO<sub>2</sub> emissions were from CH<sub>4</sub>.



**Figure 9.1-1** Indirect CO<sub>2</sub> emissions from energy sector and industrial processes and product use compared with total emissions in 2013

#### 9.1.1 Indirect N<sub>2</sub>O emissions

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. Indirect N<sub>2</sub>O emissions caused from N deposition by total NO<sub>x</sub> emissions from other than the agriculture and LULUCF sources in Finland are reported as a memo item. The main source for the NO<sub>x</sub> emissions is fuel combustion in the Energy sector, with transportation being the most significant category. The indirect N<sub>2</sub>O emissions from agricultural sources (mainly from NH<sub>3</sub> emissions) are included in the Agriculture sectors. Indirect emissions from nitrogen deposition due to industrial NH<sub>3</sub> emissions are estimated to be of small, if not negligible, significance.

### 9.1.2 Indirect CO<sub>2</sub> emissions

The inventory of indirect greenhouse gas emissions (NMVOCs) and also indirect CO<sub>2</sub> emissions from NMVOC emissions from fugitive emissions from fuels as well as from industrial processes and solvent use sectors 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. Documentation of the calculation is presented in Finland's Informative Inventory Report under the UNECE CLRTAP (Finnish Environment Institute, 2014)

Fugitive emissions from fuels include emissions from oil refineries as well as storage of chemicals at the refineries, road traffic evaporative emissions from cars, the gasoline distribution network and refueling of cars, ships and aircraft. NMVOC emissions from fugitive emissions from fuels are reported under CFR 1.B.2d category. Indirect CO<sub>2</sub> emissions from NMVOCs are reported aggregated in national totals.

NMVOC and also indirect CO<sub>2</sub> emission sources from industrial processes and solvent use sectors are presented in Table 9.1-1. Also the CRF categories in which NMVOC emissions are reported is presented in Table 9.1-1.

**Table 9.1-1** CRF categories and description of NMVOC emissions sources under production processes and solvent use sectors

CRF category	Description	Indirect CO <sub>2</sub>
2.B.10	Chemical industry and storage of chemicals	yes
2.C.7	Metal production	yes
	-Iron and steel production	
	-Non-ferrous metal production	
2.D.3	Road paving with asphalt	yes
	Asphalt roofing	yes
	Cement production	yes
	Use of paints in industry and households (paint application)	yes
	Degreasing in metal and electronics industries and dry cleaning activities	yes
	Chemical products, manufacture and processing	
	-Pharmaceutical, textile, leather and plastic industries	yes
	-Rubber conversion	
	-Manufacture of paint, inks and glues	
	Other production	
	-Printing industry	yes
	-Domestic solvent use	
	-Solvent extraction of edible oils	
	-Production of glass and mineral wool	
	-Impregnation of wood	
	-Use of pesticides	
2.H.1	Pulp and paper production	no
2.H.2	Food and drink production	no

### 9.1.3 Indirect CO<sub>2</sub> emissions from CH<sub>4</sub>

In the Finnish inventory indirect CO<sub>2</sub> emissions have been calculated from CH<sub>4</sub> emissions from oil refineries (1.B.2a), natural gas transmission and distribution (1.B.2b) as well as from coke production (2.C.1f). Indirect CO<sub>2</sub> emissions have been calculated from CH<sub>4</sub> emissions for the whole time series and reported aggregated in national totals.

## 9.2 Methodological issues

### 9.2.1 Indirect N<sub>2</sub>O emissions

The indirect N<sub>2</sub>O emissions from other than agriculture and LULUCF sectors 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.

### 9.2.2 NMVOC emissions

#### 9.2.2.1 Fugitive emissions from fuels

NMVOC emissions from oil refineries and storage are based on emission data from the VAHTI system (detailed information in Annex 6). Evaporative emissions from cars are based on expert estimation at VTT Technical Research Centre of Finland Ltd (Mäkelä K. 2014) and emissions from the gasoline distribution chain and refueling of vehicles based on information from the Finnish Petroleum Federation for the years 1990-2013 (Pohjolainen, 2008 and Finnish Petroleum Federation, 2014).

#### 9.2.2.2 Production processes and solvent use

NMVOC emissions from chemical industry are estimated based on emission data from the VAHTI system (detailed information in Annex 6). NMVOC emissions from iron and steel and non-ferrous metals production are calculated 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 2013. NMVOC emissions from cement production are based on VAHTI system. The activity data and emission factors used in the calculations for asphalt roofing and road paving with asphalt are from Nynas Oy (Blomberg, T. 2014) and Finland Custom Statistics (ULTIKA/ULJAS). The sources of activity data have been changed since the inventory of 2006.

Emissions from paint application 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.

Emissions from degreasing and dry-cleaning 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 to the VAHTI system. 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.

NMVOC emissions from printing industry are based on emission data reported by the plants to the VAHTI system 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 (Kotiranta. S. 2014) and amount of used pesticides (Savela M. 2014). Information from Finnish Cosmetics, Toiletry and Detergents Association are used to estimate emissions from domestic solvent use

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 based on VAHTI system and on different statics and emission factors.

More information on the calculation of these NMVOC emissions can be found in Finland's Informative Inventory Report under the UNECE CLRTAP (Finnish Environment Institute, 2014).

### 9.2.3 Indirect CO<sub>2</sub> emissions

Indirect CO<sub>2</sub> emissions were calculated from NMVOC emissions for the time series 1990-2013 using the equation below.

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

It was assumed for years 1990-2013 that the average carbon content is 80% by mass based on 2006 IPCC Guidelines is used for following sectors:

- fugitive emissions from oil and natural gas
- chemical industry
- cement production
- asphalt roofing
- road paving with asphalt

According to the 2006 IPCC Guidelines used fossil carbon content fraction of NMVOC for years 1990-2013 is based on the NMVOC speciation profile provided in the EMEP/CORINAIR Emission Inventory Guidebook 2000 Section B4610-6.

It was assumed for years 1990-2013 that the average carbon content is 60% by mass is used for following sectors according to the 2006 IPCC Guidelines.

- paint application
- degreasing and dry cleaning
- manufacture and processing chemical products
- other production

As described in the Guidelines, the used fossil carbon content fraction of NMVOC is based on limited published national analyses of speciation profile.

For fugitive emissions from fuels 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 2011-2013.

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.

### 9.2.4 Indirect CO<sub>2</sub> emissions from CH<sub>4</sub>

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 and coke production. Indirect CO<sub>2</sub> emissions from methane emissions were calculated using the equation below.

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

### 9.3 *Uncertainties and time-series consistency*

Quantitative estimates of uncertainty are provided in Annex 2. The annex also documents assumptions made for the analysis. A description of uncertainty analysis is included in Section 1.6.

Uncertainty for activity data is  $\pm 100\%$  and for emission factors  $\pm 10\%$  is used in following sectors: paint application, degreasing and dry cleaning, chemical products and other production. For fugitive emissions from fuels and chemical industry uncertainty for activity data is  $\pm 100\%$  and for emission factors  $\pm 20\%$ . In iron and steel industry and road paving and asphalt sectors uncertainty  $\pm 85\%$  for activity data and for emission factors  $\pm 20\%$  is used. 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.

### 9.4 *Category-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 1.2.3. The QC procedures are performed according to the QA/QC plan in the sector which emit indirect CO<sub>2</sub> emissions in order to attain these quality objectives. The bilateral quality meeting is held annually between the inventory unit and the sectoral experts.

In the calculation of NMVOCs and indirect CO<sub>2</sub> emissions general inventory QC procedures mentioned in the 2006 IPCC Guidelines (Chapter 1.6, Table 6) 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 system. There is no data available to compare with emission factors in the EMEP EEA Emission Inventory Guidebook.

### 9.5 *Category-specific recalculations*

The time series of indirect N<sub>2</sub>O emissions is recalculated due to changed NO<sub>2</sub> emissions. These estimates are not included in national totals.

Time series of indirect CO<sub>2</sub> emissions from CH<sub>4</sub> emissions in industrial processes and product use were recalculated due to implementation of 2006 IPCC Guidelines as default emission factor to calculate CH<sub>4</sub> emissions from coke production were used.

The time series of indirect CO<sub>2</sub> emissions from CH<sub>4</sub> emissions in oil refining were recalculated as CH<sub>4</sub> emissions were recalculated using default emission factor from 2006 IPCC Guidelines.

### 9.6 *Category-specific planned improvements*

No planned improvements.

## 10 RECALCULATIONS AND IMPROVEMENTS

### *10.1 Explanations and justifications for recalculations, including in response to the review process*

The main driver for recalculations in Finland's greenhouse gas inventory submission 2015 has been the implementation of the guidance given in the 2006 IPCC Guidelines. The recommendations from the previous UNFCCC inventory reviews have been taken into account to the extent they are applicable taking into account the implementation of the revised UNFCCC reporting guidelines and the 2006 IPCC Guidelines. The significance of the sources based on the results of the key category and uncertainty analyses are considered when prioritising improvements to be made in the inventory calculations. The recalculations made since the previous inventory submission are described also in the sector Chapters 3-9.

There were some recalculations in **the Energy sector (1.A)** as a response to the reviews. The most important was the revision of time series for refinery gases. Data before and after the starting of EU ETS (2005) were not fully consistent. In one plant the activity data was re-estimated based on the output production data. The plant specific NCVs and CO<sub>2</sub> EFs for 1990-2004 were re-estimated using the measured data taken from ETS (2005-2013) and reasoning based on discussions with the refinery staff.

CO<sub>2</sub> emission factor for hard coal for 2005-2007 was also re-estimated as a response to the reviews.

Oxidation factors for liquid and gaseous fuels were changed due to implementation of 2006 IPCC Guidelines, as well as the CO<sub>2</sub> emission factor for coke.

Some recalculations were made to correct errors in the plant level data. 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.

Due to the implementation of the 2006 IPCC Guidelines off-road vehicles and other machinery in commercial, institutional and residential sectors were reallocated to 1.A 4 from 1.A 3e and emissions from lubricants were reallocated from 1.A 5 to sector 2.D 1. In addition indirect N<sub>2</sub>O emissions from NO<sub>x</sub> are reported now as a memo item and these emissions are not included in category 1.A 5.

Due to the revision of calculation models for transport (LIPASTO) emissions have been recalculated in sectors 1.A 3b (road transportation), 1.A 3c (railway transportation), 1.A 3d (domestic navigation) and in 1.A 2gvii, 1.A 4aii, 1.A 4bii, 1.A 4cii (off-road vehicles and other machinery).

In the **Fugitive emissions from fuels (CRF 1.B)** emissions from oil refining are calculated using default emission factor from the 2006 IPCC Guidelines. Also emissions from distribution of so called town gas in the beginning of the time series are included in the inventory.

Under **Industrial Processes and Product use (CRF 2)** most of the recalculations are in reality reallocations which were done due to implementation of the 2006 IPCC Guidelines. For ammonia and coke production emissions were recalculated using default emission factors from the 2006 IPCC Guidelines. Also emissions from zinc, copper and nickel production are now included in the inventory as they are new sources in the EU-ETS. Emissions from use of urea based catalysts are included in the inventory for years 2006-2013. In chemical production emissions of one company was added to the inventory for the whole time series.

In the **F-gases category** the most significant recalculations were made in categories 2.E.1, 2.F.1, 2.F.2 and 2.G.1. HFC, PFC and SF<sub>6</sub> emissions from 2.E.1 Integrated Circuit or Semiconductor were recalculated for the years 1990-2012 due to revision of some IPCC default emission factors in the 2006 IPCC Guidelines. Due to confidentiality, the emissions are reported in 2.H.3 Grouped confidential data of halocarbons and SF<sub>6</sub>.

HFC and PFC emissions from category 2.F.1 Refrigeration and Air conditioning were recalculated for the years 1990-2012 in the level of subcategories 2.F.1.a-f. Previously the emissions from 2.F.1 were reported as

a single figure for all the subcategories. Emissions from 2000 on are calculated with the Tier 2b mass balance method of the 2006 IPCC Guidelines. The methodology for estimating the original total charge of retiring equipment was changed to answer the methodology presented in the 2006 IPCC Guidelines in Section 7.5.2.3 (box 7.3 in page 7.54). HFC emissions from 2.F.2 Foam Blowing Agents were recalculated for the years 1998-2012 due to revision of some IPCC default emission factors in the 2006 IPCC Guidelines.

SF<sub>6</sub> emissions from category 2.G.1 Electrical equipment were recalculated for the years 1990-2012 due to change in emission estimation methodology from the Tier 3 mass balance method to the Tier 2 national emission factor method.

In the **Agriculture sector** (CRF 3), many changes were made due to the 2006 IPCC Guidelines and some changes as country-specific improvements. Changes to animal numbers (2012) and animal waste management systems data (AWMS) had some impact to every emission category of Agriculture. For enteric fermentation coefficients for NEm and Ym changed (the 2006 IPCC Guidelines), DE are now country-specific (each cattle subgroup have their own specific DE), NEa share of pasture was updated (it is the same as in N mass flow model), NEp share of cows giving birth updated (previously assumed 100%). The number of fur animals was updated for the year 2012 as data was now available and numbers of horses and ponies for 2012 corrected. For manure management emissions e.g. MCFs and N<sub>2</sub>O EFs changed due to the 2006 IPCC Guidelines. AWMS data was updated and refinements were made to ammonia volatilization parameters. NO and N<sub>2</sub> emissions were added. For agricultural soils new emission groups are mineralization and organic Grassland, crop residue calculation changed and EFs changed, e.g. for direct emissions (the 2006 IPCC Guidelines). Organic soil EFs for annual and perennial crops were updated (IPCC Wetlands Supplement) and organic grassland has a country-specific EF. Area of organic soils diminished as the area of Dystric gleysols was excluded.

In the **LULUCF sector** (CRF 4), the areas of land-use categories and sub-categories (converted/remaining, mineral/organic soil, drained/undrained peatlands) were recalculated. Reason was to employ the latest NFI data measured in 2013. 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 2013 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. The implementation of new IPCC guidelines increased the coverage of the sources. According to the 2006 IPCC Guidelines, the off-site CO<sub>2</sub> emissions from use of horticultural peat are reported, as well the N<sub>2</sub>O emissions from N mineralisation due to the land-use changes. CH<sub>4</sub> emissions from drained organic forest soils are reported according to the IPCC Wetlands Supplement. Carbon stock changes in Harvested Wood Products pool were recalculated. The approach was changed from Stock Change Approach to Production Approach to have one method for estimation of the HWP contribution (see paragraph below KP-LULUCF).

In cropland and grassland the time series of the areas were updated and all soil and biomass emissions were recalculated. The area of cropland organic soils diminished by 100 000 ha due to the exclusion of Dystric gleysols from this class. The method for cropland remaining cropland was changed from Tier 1 to Tier 3. The emission factors for organic soils were changed to those from IPCC 2013 for cropland and to those from Maljanen et al. 2010 for grassland. The C stock changes of grassland remaining grassland were reported as “not occurring” due to the method change from Tier 1 to Tier 3 and the assumption that no management changes occur in such areas.

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. The new sources were included in the KP reporting compatible with the Convention reporting. The HWP is a new reported pool as the Decision 2/CMP.7 requires.

In the **Waste sector** (CRF 5) recalculations have been made in composting because the auxiliary matter is calculated in a slightly different manner in 2006-2012 compared to previous submissions. In addition, in domestic and in industrial wastewaters the implementation of the 2006 IPCC Guidelines introduced increased N load activity data and changes to emission factors. Also, the largest mistakes in wastewater activity data from VAHTI system was corrected. Anaerobic digestion is a new emission source in the 2015 submission.

**Table 10.1-1** Recalculations made for the 2015 inventory submission by CRF category and their implications to the emission level in 1990 and 2012

CRF Category	Recalculation	Reason for the recalculation	Implication to the CRF category level (kt CO <sub>2</sub> eq.)		Implication to the Total emission level without LULUCF (%)	
			in 1990	in 2012	in 1990	in 2012
<b>1. Energy</b>			<b>-412.6</b>	<b>-5.9</b>	<b>-0.39</b>	<b>0.01</b>
1.A. Fuel combustion activities	Reallocations, corrections in activity data	2006 IPCC GLs, corrections in erroneous or preliminary activity data	-398.0	14.0	-0.56	0.02
1. Energy industries	Corrections in activity data	Revised source data	-209.9	30.6	-0.29	0.05
2. Manufacturing industries and construction	Reallocation of off-road mobile machinery; revised calculation models for transport (LIPASTO); revised time series for refinery gases	2006 IPCC GLs; erroneous refinery gases data (activity, NCV, CO <sub>2</sub> EF) 1990	318.0	313.8	0.45	0.50
3. Transport	Reallocation of off-road mobile machinery; revised calculation models for transport (LIPASTO)	2006 IPCC GLs	-667.6	-465.6	-0.94	-0.75
4. Other sectors	Reallocation of off-road mobile machinery	2006 IPCC GLs	366.5	351.8	0.51	0.56
5. Other	Reallocation of lubricants, reallocation of indirect N <sub>2</sub> O emissions from NO <sub>x</sub>	2006 IPCC GLs	-204.9	-216.7	-0.29	-0.35
1.B. Fugitive emissions from fuels	Revised default EF is used to calculate emissions from oil refining and emissions from distribution of town gas in 1990 are included.	2006 IPCC GLs, new information on town gas	-14.7	-7.3	-0.02	-0.01
<b>2. Industrial processes and product use</b>			<b>287.3</b>	<b>623.0</b>	<b>0.40</b>	<b>1.00</b>
A. Mineral industry	Some of the limestone and dolomite use is reallocated to chemical and metal industry.	2006 IPCC GLs	-70.6	-82.8	-0.10	-0.13
B. Chemical industry	Some of the limestone and dolomite use is reallocated to chemical and metal industry. For 1990 new default EF is used to calculate emissions from ammonia production. Emissions of a hydrogen producing plant was included to the inventory.	2006 IPCC GLs, new plant from EU ETS was included	142.7	114.6	0.20	0.18

CRF Category	Recalculation	Reason for the recalculation	Implication to the CRF category level (kt CO <sub>2</sub> eq.)		Implication to the Total emission level without LULUCF (%)	
			in 1990	in 2012	in 1990	in 2012
C. Metal industry	Some of the limestone and dolomite use is reallocated to chemical and metal industry. New default EF is used to calculate emissions from coke production. New emission category is included in the inventory.	2006 IPCC GLs and new sources have been introduced to ETS.	38.0	-2.2	0.05	0.00
D. Non-energy products from fuels and solvent use	Emissions from lubricant use are now included in 2.D. Emissions from paraffin wax and urea-based catalysts use are for the first time included in the inventory.	2006 IPCC GLs	219.7	85.5	0.31	0.14
E. Electronics Industry	HFC, PFC and SF <sub>6</sub> emissions from 2.E.1 for the years 1990-2012. Emissions are reported in 2.H.3 due to confidentiality.	Revision of some IPCC default emission factors in 2006 IPCC GLs.				
F. Product uses as substitutes for ODS	HFC emissions from 2.F.1 for the years 1990-2012. PFC emissions from 2.F.1 for the years 1990-2012. HFC emissions from 2.F.2 for the years 1994-2012.	HFC and PFC emissions from 2.F.1: introduction of the calculation of emissions in the level of subcategories 2.F.1.a-f and minor methodological changes. HFC emissions from 2.F.2: Revision of some IPCC default emission factors in 2006 IPCC GLs.	0.001	470.6	0.002	0.75
G. Other product manufacture and use	SF <sub>6</sub> emissions from 2.G.1 for the years 1990-2012.	Introduction of a new emission estimation methodology.	49.9	15.1	0.07	0.02
H. Other	HFC, PFC and SF <sub>6</sub> emissions from 2.E.1 for the years 1990-2012. Emissions are reported in 2.H.3 due to confidentiality.	Revision of some IPCC default emission factors in 2006 IPCC GLs.	7.7	20.2	0.01	0.03
<b>3. Agriculture</b>			<b>692.6</b>	<b>418.2</b>	<b>0.97</b>	<b>0.67</b>
A. Enteric fermentation	Coefficients for NEm and Ym changed, DE country-specific, NEa share of pasture updated, NEp share of cows giving birth updated, number of fur animals was updated (2012), numbers of horses and ponies corrected (2012)	2006 IPCC GLs, specific DE now available for each cattle subgroup, better data available, errors corrected	244.2	225.3	0.34	0.36

CRF Category	Recalculation	Reason for the recalculation	Implication to the CRF category level (kt CO <sub>2</sub> eq.)		Implication to the Total emission level without LULUCF (%)	
			in 1990	in 2012	in 1990	in 2012
B. Manure management	e.g. MCF, N <sub>2</sub> O EFs changed, animal waste management data updated (and dry lot & bedding added), updates to ammonia volatilisation, N <sub>2</sub> and NO emissions added, corrections to animal numbers	2006 IPCC GLs, better data available for AWMS	-57.2	42.2	-0.08	0.07
D. Agricultural soils	Direct EF changed, the area of Dystric gleysols was excluded, new EFs for organic soil and Grassland included, crop residue calculation changed, mineralization in mineral soil added, AWMS updates, corrections to animal numbers	2006 IPCC GLs, IPCC Wetlands Supplement, better data available	-114.1	-36.7	-0.16	-0.06
F. Field burning of agricultural residues	Fraction burned updated, quantity of residue updated	better data available	1.3	2.1	0.00	0.00
G. Liming	New emission group, previously in LULUCF sector	2006 IPCC GLs	617.9	194.2	0.86	0.31
H. Urea application	New emission group	2006 IPCC GLs	0.7	0.3	0.00	0.00
<b>4. Land use, Land Use Change and Forestry</b>			<b>-2 125.7</b>	<b>-1 829.2</b>		
A. Forest land	Carbon stock changes in living biomass, litter, dead wood and soil organic carbon. N <sub>2</sub> O and CH <sub>4</sub> emissions from drained forest lands. N <sub>2</sub> O emission from N fertilization.	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 2013 were added to climate average calculation, producing also new steady state estimation for soil carbon. CH <sub>4</sub> emissions from drained organic soils were estimated and reported first time. EF to estimate N <sub>2</sub> O emissions from N fertilization was updated according to 2006 IPCC GLs.	1 423.5	2 220.1		
B. Cropland	Area data	Improved accuracy	-482.8	-235.1		

CRF Category	Recalculation	Reason for the recalculation	Implication to the CRF category level (kt CO <sub>2</sub> eq.)		Implication to the Total emission level without LULUCF (%)	
			in 1990	in 2012	in 1990	in 2012
C. Grassland	Organic soil EFs	More data behind the EFs				
	CL remaining CL Tier3	Method better representing national conditions				
D. Wetlands	Area data	Improved accuracy	106.8	301.6		
	Organic soil EFs	More data behind the EFs				
E Settlements	C stock change in GL remaining GL not occurring	Method better representing national conditions				
	Carbon stock change in living biomass, SOM, DOM, CH <sub>4</sub> and N <sub>2</sub> O emissions from organic soils.	Activity data recalculated (area estimates). Latest NFI data applied for biomass estimates. Off-site emissions from horticultural peat were estimated and reported.	134.4	364.25		
G. Harvested wood products	Carbon stock change in living biomass, SOM, DOM. Emissions from N mineralisation.	Activity data recalculated (area estimates). Latest NFI data applied for biomass estimates. Emissions from N mineralisation were estimated and reported.	59.9	201.2		
		New method was applied	-3 367.5	-4 681.2		
<b>6. Waste</b>			<b>-20.8</b>	<b>28.0</b>	<b>-0.03</b>	<b>0.04</b>
A. Solid waste disposal			0	0	0.00	0.00
B. Biological treatment of solid waste	Emissions from anaerobic digestion	New emission source	0.1	4.20	0.00	0.01
C. Incineration and open burning of waste	Activity data (auxiliary matter)	More reliable and accurate data				
D. Wastewater treatment and discharge	DC values	More accurate activity data	-20.9	23.8	-0.03	0.04
	N load values	Implementation of the 2006 IPCC GLs				
	Emission factors	Implementation of the 2006 IPCC GLs				

CRF Category	Recalculation	Reason for the recalculation	Implication to the CRF category level (kt CO <sub>2</sub> eq.)		Implication to the Total emission level without LULUCF (%)	
			in 1990	in 2012	in 1990	in 2012
KP-LULUCF						
KP A. Article 3.3	Carbon stock change in living biomass, SOM, DOM. CH <sub>4</sub> , N <sub>2</sub> O emissions from soils.	The areas of ARD activities were recalculated due to updated NFI data. The latest NFI data were applied to estimate biomass increments, -stocks and litter production for soil model. Weather data from 2013 were added to climate average calculation, producing also new steady state estimation for soil carbon. Emissions from N mineralisation were estimated and reported. Off-site emissions from horticultural peat were estimated and reported. CH <sub>4</sub> emissions from drained organic soils were estimated and reported. CSC in AR under D were estimated and reported.				
KP B. Article 3.4	Carbon stock change in living biomass, SOM, DOM, HWP. CO <sub>2</sub> , CH <sub>4</sub> , N <sub>2</sub> O emissions from biomass burning. N <sub>2</sub> O emission from N fertilization.	The areas of FM activities were recalculated due to updated NFI data. The latest NFI data were applied to estimate biomass increments, -stocks and litter production for soil model. Weather data from 2013 were added to climate average calculation, producing also new steady state estimation for soil carbon. CSC in HWP pool were estimated and reported. New activity data and biomass estimates applied for biomass burning estimates. EF to estimate N <sub>2</sub> O emissions from N fertilization was updated according to the 2006 IPCC Guidelines.				

## *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 Planned improvements, including response to the review process

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 evaluates the need for significant improvements, horizontal development projects, and discusses and gives advice on how to find resources for significant development projects.

The development of the greenhouse gas inventory aims to improve the calculation of the emissions/removals and the 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 the different sectors. The planned or proposed improvement measures are compiled in a yearly inventory improvement plan. The inventory improvement plan is discussed by the advisory board 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 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
CRF 1	Systematic review and update of EFs in the energy sector Next phases: fossil gasoline, wood fuels; comparison of non-CO2 emission factors in aviation (previously used national model vs. Eurocontrol data)	2013 plan, thereafter continuous
CRF 1 A 4	Review of CH <sub>4</sub> EF small combustion	2017
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 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. This work is also related to the method development of HWP estimates e.g. to have separate estimates for AR and FM.	2017
CRF 4	Estimation and/or improvement of estimation of tree biomass gains for remaining Cropland, Grassland Wetlands and Settlements	2017

Table 10.4-2 summarises Finland's responses to the review of the 2014 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 2014 inventory submission

CRF	Comment	Finland's response	Where in NIR
1B	17. Although the Finnish inventory for the energy sector is well elaborated and concise, transparency can still be improved. Some parts of the text presented in the NIR have not been updated from the previous annual submission, which may lead to misinterpretations of the current NIR, such as in page 131, where the recalculations section indicates that no recalculations have been done, although the immediately preceding paragraph indicates that "[a]fter the latest recalculations (see below), the bunker fuel volumes in the GHG inventory deviate slightly from the IEA data...". In another example, the ERT noted that Finland reported AD for oil venting (13,672.12 kt oil refined for 2012 in CRF table 1.B.2), but the corresponding emissions were reported as "NO". In response to a question raised by the ERT during the review, the Party clarified that the AD refer only to oil refining/storage and should not have been reported under oil venting. Finland further explained that the oil venting emissions were reported together with the flaring emissions and that it checked with the operator and that the information received is that oil venting should not exist and that all process gases during normal function are routed to the refinery's fuel gas system and burned in different process heaters and boilers, and are thus reported as fuel combustion. Finland further explained that other types of oil venting emissions occur, such as venting of oil storage and drainage systems, and are reported as non-methane volatile organic compound (NMVOC) emissions. The ERT recommends that Finland thoroughly review the next annual submission as part of its quality assurance/quality control (QA/QC) processes in order to ensure that parts of the text from the previous annual submission are not incorrectly carried over to the current annual submission. The ERT also recommends that the Party review the reporting in the CRF tables with respect to oil venting to ensure that there is no duplication of information on AD and that an explanation is provided in the documentation box to clarify that NMVOC emissions are related to oil venting. Finally, the ERT recommends that the Party include in the NIR all information provided to the ERT during the review with regard to oil venting and flaring, in order to increase the transparency of the reporting.	Regarding reporting of emissions from oil venting and flaring have been checked and information given during the review have been added to the NIR. Also incorrect AD in oil venting have been removed from the CRF.  QA/QC procedures have been improved.	Section 3.3.2.1
1B	19. With regard to natural gas distribution, the CH <sub>4</sub> emissions have not been estimated for 1990. In response to observations made during earlier stages of the review, the Party indicated that it does not expect emissions from natural gas distribution to have occurred because natural gas was only distributed in the newer parts of the pipeline in 1990. Further, in response to an earlier draft of this report, Finland referred to page 65 of the NIR, which states that town gas distributed in 1990 did not include CH <sub>4</sub> , thus the fugitive CH <sub>4</sub> emissions were zero. The Party also noted that, according to information received from the distributor, there were no CH <sub>4</sub> emissions from distribution in Finland in 1990. However, the ERT is of the view that it is unlikely that no emissions occurred, and not considering these emissions leads to a time-series consistency issue and a potential lack of completeness for 1990. The ERT further notes that, in its NIR, Finland also suggests that there could be some CH <sub>4</sub> from this gas, indicating on page 124 that this town gas "did not contain substantial amounts of methane". The ERT recommends that the Party address these issues and provide any additional information in the NIR to prove that consistency of the time series and completeness for 1990 are ensured. If minor emissions, in 1990, cannot be excluded, the ERT recommends that Finland either estimate those emissions or report the notation key "NE" (not estimated).	Emissions from town gas have now been reported.	Section 3.3.2.2
1A	20. In previous review reports, the ERTs noted that the AD for the energy sector presented in the NIR were aggregated both in terms of categories and fuels. In response to recommendations made in previous review reports, Finland has made improvements in the reporting of disaggregated fuel consumption data in the energy sector. Although the ERT believes that the aggregation of AD does not affect the emission estimates, some further improvement would increase the transparency of emission calculations. Therefore the ERT recommends that Finland make efforts to provide disaggregated AD, to the extent possible, especially for those fuels for which the aggregation would imply the use of very different EFs (e.g. other solid fuels in manufacturing industries and construction, other fuels in energy industries), to improve the transparency of its reporting.	Annual fuel specific CO <sub>2</sub> emission factors and total activities are disaggregated at the level of 35 fuel types in Appendix_3b. This should give enough transparency to follow development of emission factors. In sectoral tables (Table 3.2-8 and Table 3.2-9) activity data are more aggregated due to confidentiality, but this should not be a problem, because	Appendix_3b

CRF	Comment	Finland's response	Where in NIR
		CO <sub>2</sub> emission factors are not depending on the sectors.	
RA	22. As shown in table 5 above, the difference in energy consumption between the reference approach and the sectoral approach, in 2012, was –7.8 per cent (–4.3 per cent for CO <sub>2</sub> emissions. According to CRF table 1.A(c), the relatively high difference in liquid fuels is caused by statistical differences in the oil balance. The discrepancy is also addressed in the NIR, where it is stated that there are no obvious reasons for the differences and any final conclusions cannot be made without further, resource demanding, investigations. The ERT recommends that Finland continue to explore the reasons for the difference between the sectoral and reference approach, especially for those years where the differences are significant, and provide additional explanation in its NIR in order to increase the transparency of its reporting.	There have been relatively high differences in the last two years. For 2012 the reason was erroneous import data in customs statistics. At the moment we are concentrating on the reasons of the latest years' differences.	Section 3.2.1
RA	23. The difference in apparent consumption between the reference approach and the data reported to the International Energy Agency (IEA) was 1.5 per cent in 2012. However, the growth rate of total apparent consumption in the period 1990–2012 shows a discrepancy between the two sources of data of –14.1 per cent in the CRF tables and –7.1 per cent in the IEA data. In response to observations made during earlier stages of the review, Finland explained that the IEA time series has been updated for the years 2000–2012 by Statistics Finland and that some errors occur in the earlier years of the time series, especially with regard to the oil balance data. The Party has reported in its NIR that a check and review of the official oil balance data for the period 1990–1997 would be needed in order to clarify the differences between the reference approach and the sectoral approach, specifically for the years 1992 and 1993, which would require cooperation between different stakeholders and an update of the IEA time series data. This would also mean that a recalculation of the energy balance for that period would be required, as well as an important investment. In view of the need for improvement in other areas of the inventory, Finland considered that such research was not a priority. The ERT acknowledges that the issue was not a priority in 2014, but recommends that the Party address the errors identified in the early years of the time series in the next annual submission.	There are significant statistical differences (errors?) in the IEA data in especially in early 1990's. Because these errors have been at least partly corrected in the RA, differences are inevitable. This subject has been discussed during every review. We have no possibility to open 1990's energy balance sheets in the IEA data. Instead of single years, the subject should be studied over a longer period (for example average on 5 years), to smoothen annual statistical differences. At the moment it is not possible to check the original data.	Section 3.2.1
1A	25. Apart from the issue of fuel allocation between domestic and international navigation described above, total residual fuel oil reported in the CRF tables, taking into account domestic navigation and international marine bunkers, is 6.7 per cent lower than the data reported to IEA for 2012. In response to a question raised by the ERT during the review, Finland provided detailed calculations that explain the difference in total fuel reported in the CRF tables and to IEA, which is mainly due to the fact that the "Åland-correction" is taken into account in domestic navigation only in the IEA data. The ERT is satisfied with the explanation provided and recommends that the Party include this rationale in the NIR.	Explanations added.	Section 3.2.2
1A	27. In previous review reports, the ERT highlighted the issue of the time-series consistency of the CO <sub>2</sub> IEF for coal used in public electricity and heat production owing to the rapid decrease between 2007 (93.72 t/TJ) and 2008 (92.76 t/TJ) and the possibility of an overestimation of emissions in the preceding years. In response to questions raised during previous reviews, Finland informed the ERT that the applicability of the default EF (94.60 t/TJ) for the years 2004–2007 could be further investigated, but that the Party would not prioritize this matter over more urgent development needs. Finland has reported in its current NIR that in 2014 other needs, such as the implementation of the Intergovernmental Panel on Climate Change (IPCC) 2006 IPCC Guidelines for National Greenhouse Gas Inventories (hereinafter referred to as the 2006 IPCC Guidelines), have been prioritized. The ERT accepts Finland's explanation and recommends that the Party take this opportunity, with the implementation of the 2006 IPCC Guidelines, to ensure time-series consistency.	We are testing a method to estimate CO <sub>2</sub> EF for the years 2004–2007 based on the data we have available. It requires still some study and test calculations. The results will be reported in the following submission.	Section 3.2.4.6
1A	29. There are significant inter-annual changes in the CH <sub>4</sub> IEF for liquid fuels in road transportation for several years of the time series. For example, in 2012 the CH <sub>4</sub> IEF reported for gasoline (13.69 kg/TJ) is 11.2 per cent lower than in 2011 (15.42 kg/TJ) and exhibits the	Time series have been recalculated.	Section 3.2.5.4

CRF	Comment	Finland's response	Where in NIR
	<p>second largest decrease among reporting Parties. In response to questions raised during earlier stages of the review, Finland indicated that annual changes in the share of diesel, gasoline, biodiesel and biogasoline could explain the variation in the IEF. Table 3-3-3 of the NIR shows that, from 2011 to 2012, there has been a decrease in the consumption of gasoline, diesel oil and natural gas, whereas an increase in liquid and gaseous biofuels is observed. For the same period, table 3-3-5 of the NIR shows an increase of bio-components of liquid fuels for gasoline, diesel oil and biogas. The Party also clarified that the transport calculation system is under review for the next annual submission. In response to a further question raised by the ERT during the review, Finland also explained that the model for road transport emissions will be totally revised, especially with regard to the distances travelled (in kilometres) associated with different types of vehicles and fuels. Changes in fuel totals should be very small. The ERT recommends that the Party include all relevant information with regard to the calculation of CH<sub>4</sub> emissions in the submission, including the results of the improved model and its impact on the CH<sub>4</sub> IEF, in order to improve transparency.</p>		
1A	<p>30. The ERT noted that the CH<sub>4</sub> IEF for several industries has exhibited an unusual trend. For pulp, paper and print, for example, the CH<sub>4</sub> IEF for biomass (ranging from 1.30 kg/TJ to 1.44 kg/TJ) is the lowest of reporting Parties (ranging from 1.30 to 284.12 kg/TJ) and lower than the IPCC default value (30 kg/TJ). In response to questions raised by the ERT during the review, Finland explained that the non-CO<sub>2</sub> EFs used are based on studies which include plant-level measurements made in selected plant types. The Party has reported in its NIR that the CH<sub>4</sub> EFs were originally taken from a research study conducted in 1992 and 1994 and updated by studies conducted in 2005 and 2006. The Party has expanded the database to include a more detailed classification of boilers and expert judgement has been applied when data for new boilers were not available. Measurements were also made in several power plants in Finland in 2005. Similar trends have been observed for food processing, beverages and tobacco for other fuels, as well as for the category other (manufacturing industries and construction) for gaseous fuels. In both cases, the Party explained that annual changes in individual boiler data are responsible for the trend observed in the CH<sub>4</sub> IEFs. In response to a question raised by the ERT during the review, Finland confirmed that, in the case of food processing, beverages and tobacco, plants have different CH<sub>4</sub> EFs. The Party indicated that any changes in individual plant boiler data would impact the IEFs and that it is not possible to report every change or correction in the plant-level data in the NIR for practical reasons and to maintain confidentiality, but that further information may be provided upon request. The ERT recommends that the Party include a paragraph about the changes in boiler data and the impact of these changes on the CH<sub>4</sub> IEFs in the NIR and update the text annually in order to improve transparency.</p>	<p>A text concerning this issue has been added.</p>	<p>Section 3.2.4.2</p>
1A	<p>31. Finland has reported in its NIR that fugitive emissions have decreased by 25.5 per cent since 1990 owing to changes in oil refining processes, especially in flaring (NIR page 65). However, in CRF table 1.B.2 a comparison of the values for 1990 (9,884.00 kt) and 2012 (13,672.12 kt) shows that the amount of oil refined/stored rose by 38.3 per cent (CO<sub>2</sub> and CH<sub>4</sub> emissions rose by 37.5 per cent and 38.3 per cent, respectively). CO<sub>2</sub> emissions from oil flaring decreased by 17.6 per cent in the period 1990–2012 (from 121.93 Gg in 1990 to 100.48 Gg in 2012), in spite of a 35.9 per cent increase in the AD (from 1,131.60 kt in 1990 to 1,537.75 kt in 2012), and a 39.4 per cent reduction was observed in the CO<sub>2</sub> IEF between 1990 (107,753.12 kg CO<sub>2</sub>/kt) and 2012 (65,345.46 kg CO<sub>2</sub>/kt). In response to a question raised by the ERT during the review regarding the reason for the decrease in emissions from oil flaring, given that the AD showed an increase in the amount flared, Finland explained that some plants have reported both CO<sub>2</sub> emissions and flared gas, whereas other plants have reported oil flaring including CO<sub>2</sub> emissions only (but not AD), which cannot be inferred solely from the IEF. Finland informed the ERT that it will try to obtain specific data from the plant operators for the next annual submission in order to disaggregate the contribution of CO<sub>2</sub> emissions in the CO<sub>2</sub> IEF and isolate it from other interferences. The ERT recommends that Finland include all relevant information provided during the review in the NIR.</p>	<p>We have studied carefully plant-level data of refinery gases and noticed some erroneous data in one plant. The activity data, NCV and CO<sub>2</sub> EF had to be re-estimated for the early years of time series. The results were available too late to be included in this submission, thus they will be reported in the next submission.</p>	<p>Section 3.2.4.6</p>
3	<p>38. The ERT identified some cases of errors and inconsistencies in the NIR. For example, there were errors in NIR tables 6.3-3 and 6.4-7 (where data on the area of cultivated organic soils for the latest inventory year incorrectly copied the data for the year 1990 and did not match the CRF tables). In response to questions raised by the ERT during the review, the Party stated that the correct values have been used in the calculations and are reported in the CRF tables but errors arose when transferring the data to the NIR. Further, the ERT</p>	<p>Errors in NIR tables are corrected and Appendix_5a is updated. More effort was put to accuracy when entering data to NIR, including this table.</p>	<p>Appendix_5a, Table 5.3-3, Table 5.4-6, Table 10.4-2</p>

CRF	Comment	Finland's response	Where in NIR
	noted that appendix 6a of the NIR, entitled "The equations used in the calculation of greenhouse gas emissions from the agriculture sector", was not updated to reflect the recalculations undertaken for this sector, and incorrect information was found in NIR table 10.4-2 regarding the Party's response to previous reviews. The ERT recommends that the Party enhance its QC procedures to ensure that the NIR is updated with the correct data and information for every new annual submission.		
3A	39. In response to recommendations made in the previous review report that Finland review the livestock characterization data and ensure consistency between the nitrogen (N) excretion model and the enteric fermentation model used, the Party has made recalculations for CH <sub>4</sub> emissions from enteric fermentation for cattle and swine. For cattle, the daily weight gains have been updated to ensure the consistency of data inputs and assumptions between manure management and enteric fermentation. Concerning swine, the Party now estimates the emissions based on an enhanced characterization of different swine categories. The ERT commends the Party for these efforts. However, the description in the NIR of how the country-specific EFs for the different swine categories were developed was not transparent, the values for mature weight for heifers and calves were missing in NIR table 6.2-5, and the formula to calculate the average weight gain in appendix 6a to the NIR was not updated. In response to questions raised by the ERT during the review, the Party provided additional information on the underlying data supporting the development of the country-specific EFs for swine. The ERT recommends that the Party include a description in the NIR of how the EFs for the different swine categories were compiled, complete NIR table 6.2-5 and update appendix 6a of the NIR in order to improve transparency.	a) The description of swine EFs was improved. b) Mature weights for heifers and calves were added. c) Average weight gains were updated	a) Section 5.2.2 and Appendix_5a b) Table 5.2-5 c) Appendix_5a
3B	40. In the previous review report, the ERT recommended that Finland provide a reference to the ratio used to divide N between the dung part and urine part of the manure for the calculation of the weighted N <sub>2</sub> O EF for solid storage. A reference to this parameter has still not been provided in the NIR of the 2014 annual submission. In NIR table 10.4-2, Finland states that "[t]he 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". The ERT reiterates the recommendation made in the previous review report that Finland include this reference in the NIR.	The share of urine is 55% of the separated urine & dung nitrogen (according to a generalisation made in N mass flow model based on cattle manure qualities). The N <sub>2</sub> O EF for solid storage is now 0.005 according to GL2006 and includes separated urine in Finnish inventory.	Section 5.3.2
3	41. In the previous review report, the ERT noted that Finland changed its reporting of the fraction of crop biomass that is N (FracNCRBF) from a value in the 2012 annual submission (0.04 in 2010) to the notation key "NA" in the 2013 annual submission. In response to questions raised during the previous review, Finland had indicated that reporting a value for FracNCRBF would not accurately reflect the calculations, and therefore the Party reported it as "NA". The previous ERT recommended that Finland continue to report this fraction in the CRF tables in the form of a weighted average. In its 2014 annual submission, Finland indicates in NIR table 10.4-2 that these values are now reported in the NIR, table 6.5-2. However, this fraction is not reported in NIR table 6.5-2, nor is it reported in the CRF tables. The ERT notes that Finland's decision not to report FracNCRBF does not impact the emission calculations, and therefore the ERT finds Finland's approach acceptable for the current annual submission. Nevertheless, the ERT recommends that the Party improve its QC procedures to ensure that the correct information is provided in NIR table 10.4-2.	More effort was put to accuracy when entering data to NIR, including this table.	Table 10.4-2
3	42. The previous ERT noted that the total of all 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 questions raised during the previous review, Finland had responded that agricultural production changed considerably in the beginning of the 1990s. Many farms ceased operating and the area of fallow more than doubled between 1990 and 1991. The recommendation in the previous review report was that Finland include the explanation for the sudden decrease in total crop yield after 1990 in its annual submission. The current ERT notes that Finland has reported in table 10.4-2 of the NIR that in section 6.1.1, "[m]ore text on the trend variations was added". However, section 6.1.1 contains no significant changes on this topic between the 2013 and the 2014 annual submissions. The ERT reiterates the recommendation made in the previous review report that Finland provide this explanation in the NIR, and further recommends that the Party improve its QC procedures to ensure that the correct information is provided in NIR table 10.4-2.	The text: "Agricultural production changed considerably 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 .." was added to NIR	Section 5.4.1

CRF	Comment	Finland's response	Where in NIR
3	43. Finland uses a country-specific methane conversion factor (MCF) of 10 per cent for deep litter, referring to a paper by Dustan (2002). <sup>6</sup> The ERT was of the view that this reference alone does not provide sufficient support for the use of the MCF for deep litter, as opposed to the value provided in the IPCC <i>Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories</i> (hereinafter referred to as the IPCC good practice guidance) of 39.0 per cent for cool climates. The ERT notes that the IPCC reference states that although the current default value of 39.0 per cent may be too high, an alternative value is not specifically provided. In response to further questions raised by the ERT during the review, Finland noted that in addition to Dustan and the 2006 IPCC Guidelines, which indicate that the current IPCC default value is too high, the IPCC good practice guidance comments that the MCFs for deep litter are similar to those for liquid/slurry (IPCC good practice guidance, page 4.37). For example, the MCF for liquid manure and deep litter are exactly the same for all climates in both the IPCC good practice guidance and the 2006 IPCC Guidelines. This, in combination with the paper by Dustan which justifies the use of an MCF of 10 per cent for storage of liquid manure in countries with a climate such as Finland's, as well as the ERT's knowledge of recent scientific literature indicating that the IPCC default EF for deep litter may be too high, lead the ERT to accept Finland's use of the same MCF for liquid manure and deep litter. However, the ERT recommends that Finland improve the justification of the use of the country-specific MCF for deep litter in the annual submission.	Finland no longer uses country-specific deep litter MCF as Guidelines 2006 was taken into use.	
4	46. The ERT noted some discrepancies between the CRF tables and the NIR data. The ERT noted that, for example, the areas of land converted to grassland in CRF table 5.C, both for organic and mineral soils (21.56 kha and 62.51 kha, respectively, for 2012), are different from those reported in the NIR (approximately 20 kha and 60 kha, respectively, for 2012). In response to a question raised by the ERT during the review, Finland explained that the discrepancies are due to errors affecting the NIR, resulting in the inclusion in the NIR tables of the areas related only to southern Finland. The ERT recommends that Finland ensure the consistency of the reported data by enhancing the QA/QC procedures.	The figures have been corrected and QA/QC procedures have been improved	Section 6.6.2.2
4	47. Finland assesses the land-use categories and land-use changes on the basis of the National Forest Inventory (NFI); for the period 2007–2012, land-use information on the NFI sample plots has been updated with orthophoto interpretation. In response to a question raised by the ERT during the review regarding land representation, Finland provided additional information on the total forest area assessed by the NFI and on the use of ancillary data sources to detect the land-use changes occurring before and after the NFI measurements. The ERT recommends that Finland increase the transparency of the NIR by including this information in the annual submission.	The description in the NIR has been improved	Section 6.3, Appendix_6a, Appendix_6b
4	48. Finland has reported the carbon stock changes in living biomass as "NE" in CRF table 5.C. The ERT considers that this reporting is not in accordance with the IPCC <i>Good Practice Guidance for Land Use, Land-Use Change and Forestry</i> (hereinafter referred to as the IPCC good practice guidance for LULUCF). In response to a question raised by the ERT during the review, Finland explained that the pool will be reported in the next annual submission, on the basis of a currently ongoing study. The ERT reiterates the recommendation made in the previous review report that Finland report the carbon stock changes associated with the living biomass pool in its annual submission.	These carbon stock changes are reported.	Section 6.6 and Appendix_6c
4	49. The ERT noted that the area of land converted to cropland reported in CRF table 5(III) (114.94 kha) is different from the area reported in CRF table 5.B (115.97 kha). In response to a question raised by the ERT during the review, Finland informed the ERT that an error had occurred in CRF table 5(III), and further explained that the error affected the AD only. The ERT recommends that Finland accurately report these figures in its annual submission and enhance its QA/QC procedures.	The figures have been corrected and QA/QC procedures have been improved	Table 6.5-4
4	50. Finland has reported biomass burning in land converted to cropland, grassland remaining grassland (wildfires only), land converted to grassland, and settlements as "NE" for the entire time series. In response to an earlier draft of this report, Finland stated that according to fire statistics, there were no fires on croplands or grasslands between 1995 and 2012. There are no data available on fires on croplands or grasslands for earlier years, or on settlements for the entire time series and the Party also stated that there probably would be no additional data for the 2015 annual submission. The ERT considers that this reporting is not in accordance with the IPCC	The problem to allocate wildfires according to IPCC land-use classes to Cropland, Grassland and Settlements will be solved due to additional data obtained. Emissions will be allocated	Section 6.10.5.1

CRF	Comment	Finland's response	Where in NIR
	good practice guidance for LULUCF. The ERT recommends that Finland report emissions related to biomass burning from the above-mentioned categories in its annual submission.	as needed for the 2016 annual submission. Considering croplands and grasslands, it is stated in the fire statistics that no woody biomass was burned in 1995-2012. It is reasonable to suppose that this is true also for 1990-1994 and 2013 since orchards are not a common land use type in Finland.	
5	58. The Party reported N <sub>2</sub> O emissions from human sewage as 0.25 Gg of N <sub>2</sub> O instead of 0.53 Gg (which would be the value for emissions estimated using the default EF of 0.01 kg provided in the <i>Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories</i> (hereinafter referred to as the Revised 1996 IPCC Guidelines). In response to a question raised by the ERT during the review, the Party explained that the lower emissions are a result of the purification technology Finland uses for human sewage wastewater. The Party responded that the N <sub>2</sub> O emissions consist of collected and uncollected wastewater. The default protein values are used only for uncollected wastewater. The measured N values are used for collected wastewater which leads to lower human sewage emissions. The EF of 0.01 kg of N <sub>2</sub> O-N/kg sewage-N produced for the wastewater before purification is constant throughout the time series and for collected and uncollected wastewater. The IEF reported in CRF table 6.B (0.005 kg of N <sub>2</sub> O-N/kg sewage-N) is different because the N load per person from collected wastewater is smaller owing to purification than the N load per person from uncollected wastewater (which is calculated according to protein consumption and population). The N purification (nitrification and denitrification) reduces the N load to the waterways, which equates to lower emissions. The ERT recommends that the Party improve the transparency of its reporting by including a clear description of the methodology used for the purification of sewage wastewater in its NIR.	Purification of sewage wastewater has anymore no effect on emissions because the calculation method is according to 2006 IPCC Guidelines	Section 7.5.2
5	59. CH <sub>4</sub> emissions from composting steadily increased from 1.03 Gg in 1990 to 3.27 Gg in 2007, then slightly decreased to 2.78 Gg in 2012. While noting that it is not mandatory to report CH <sub>4</sub> and N <sub>2</sub> O emissions from other (waste), the ERT reiterates the recommendation made in the previous review report that Finland improve the transparency of the composting category by enhancing the descriptions in the NIR on the AD for composted waste and the destination of industrial waste and sludge from wastewater handling plants.	The whole time series of AD divided in subgroups is presented in the NIR. The description of getting AD data from VAHTI system in general and especially data for municipal sludge is in the NIR.	Section 7.3.1.2 (under Activity data). Table 7.2.-4
KP	63. The ERT noted some discrepancies between the KP-LULUCF CRF tables and the NIR data. The ERT noted, for example, inconsistencies between NIR tables ES.4-1 and 2.5-2 and KP-LULUCF CRF table 5(KP-I)B.1 (which report net CO <sub>2</sub> removals from forest management as 36,788 Gg and 36,790.69 Gg, respectively). In response to a question raised by the ERT during the review, Finland explained that the discrepancies are due to errors affecting the NIR and the Party provided additional information to better explain the data reported. The ERT recommends that Finland ensure the consistency of the reported data, by enhancing the QA/QC procedures. The ERT also encourages Finland to increase the transparency of the NIR by including the information provided to the ERT during the review in its NIR.	QA/QC procedures have been improved	
KP	64. The ERT noted a large recalculation for afforestation and reforestation when comparing the 2014 and 2013 annual submissions (an average increase in removals of approximately 146 per cent). In response to a question raised by the ERT during the review, Finland explained that the recalculation was due to the update of biomass values used in the estimation of the carbon stock changes. Finland stated that the new NF111 data (covering the period 2009–2012) were used because they more accurately represent the first commitment period than the previous NF110 data (covering the period 2005–2008), and provided additional information to explain the	The description in the NIR has been improved	Section 11.3.1.1 and Appendix_6c

CRF	Comment	Finland's response	Where in NIR
	changes that had occurred. The ERT recommends that Finland increase the transparency of the NIR by including information on recalculations in its annual submission.		
KP	65. Finland reported emissions from the conversion of forest land to wetlands (peat lands) for the litter pool as "IE". In response to a question raised by the ERT during the review, Finland explained that the decomposition of litter is included in the emissions from stock piles (the EFs for peat extraction include emissions from production fields, stock piles and ditches). The emissions due to decomposition of fine dead roots (litter in peat) are included in the EFs for peat production fields. The ERT accepts the explanation provided by Finland, but recommends that the Party increase the transparency of the NIR by including this information in its annual submission.	The description in the NIR has been improved under Land converted to Wetlands section where the method is described in more detail	Section 6.7.2.2
	74. Finland has reported its commitment period reserve in its 2014 annual submission. The Party reported that its commitment period reserve has not changed since the initial report review (319,515,790 t CO <sub>2</sub> eq) as it is based on the assigned amount and not the most recently reviewed inventory. The ERT disagrees with this figure. The ERT's calculation of the commitment period reserve is 304,828,656 t CO <sub>2</sub> eq based on 100 per cent of five times the most recent inventory, which is lower than 90 per cent of the assigned amount. In response to a question raised by the ERT during the review, Finland agreed with this figure. The ERT recommends that Finland include the correct information on its commitment period reserve in its annual submission.	<p>The commitment period reserve for the first commitment period (CP1) is calculated as five times 100% of the 2012 inventory as this results in a lower value than 90 % of the assigned amount for CP1.</p> <p>The commitment period reserve for the second commitment period (CP2) is calculated as 90 % of the assigned amount for CP2 allocated to Finland in the EU's, its Member States and Iceland agreement on joint fulfilment of the QELRC – this value is lower than 100 per cent of the most recent inventory times five.</p>	Chapter 12

# 11 KP-LULUCF

## 11.1 General information

In this Chapter, Finland provides supplementary information under Article 7, of the Kyoto Protocol (KP) from the LULUCF activities. Provided information on anthropogenic greenhouse gas emissions by sources and removals by sinks under Article 3, paragraphs 3 and 4, of the Kyoto Protocol is in accordance with the relevant CMP decisions and the 2006 IPCC Guidelines (IPCC 2006) and IPCC KP Supplement (IPCC 2014a). Methodologies presented in the IPCC Wetlands Supplement (IPCC 2014b) are applied to the purpose to estimate certain emissions and removals for drained organic soils.

Under Article 3, paragraph 3, Finland reports emissions and removals from activities Afforestation/Reforestation (AR) and Deforestation (D), and under Article 3, paragraph 4, from Forest Management (FM). Reporting and accounting of these activities are mandatory for the second commitment period (CP). Forest Management was elected as an additional activity for the first commitment period. Other additional activities under Article 3, paragraph 4, are not elected for the second commitment period, as were not for the first commitment period. Finland has elected accounting of each activity under Article 3, paragraphs 3 and 4, for the entire commitment period. Finland will apply the natural disturbance provision under FM if needed, but not under AR.

In 2013, Article 3.3 activities acted as a net source of 2.4 Mt CO<sub>2</sub> eq. (Table 11.1-1, Table 11.1-2), of which a net emission of 2.92 Mt CO<sub>2</sub> eq. was from Deforestation and a net removal of 0.54 Mt CO<sub>2</sub> eq. from Afforestation and Reforestation (Figure 11.1-1, Table 11.1-1). Article 3.4 Forest Management was a net sink of 46 Mt CO<sub>2</sub> eq. (Table 11.1-1). About a half of the FM sink resulted from the forest-related activities and the other half of the carbon stock change in the Harvested Wood Products pool (HWP).

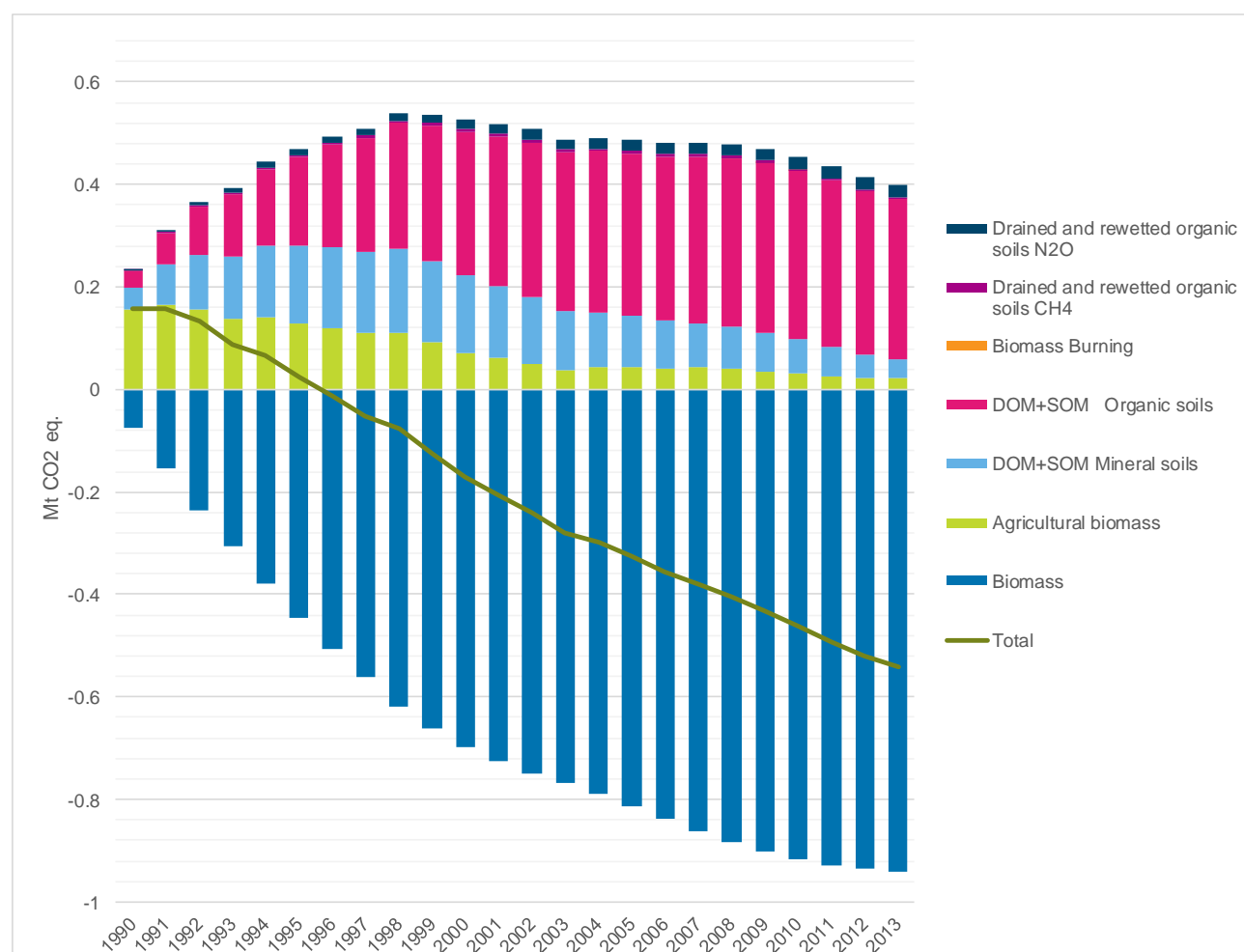
In the end of 2013, the area of AR activity was 167,882 ha. It is small compared to the total KP-forest area (0.8%). In the 1990's, the AR area increased more than 10,000 ha per year, but since then the annual increase in the area has decreased continuously being just 1,000 ha in 2013. One reason to this development is that since 2008 the state subsidies are not paid anymore for the new projects for forestation of arable lands. The land area under D activity in 2013 was 354,648 ha, of which 1,419 ha were reforested, and hence actually forest. The deforestation rate was in its highest in the first decennial of the 2000's. The economic downturn is presumably the main reason to the reduced deforestation area during the latest years (Table 11.4-1).

The area of FM has decreased 2% since 1990. The inter-annual variation in the sink is more a reflection of the changes in commercial round wood markets and the economic situation than change in area of FM land.

There is no overlapping with the reported emissions and removals under Articles 3.3 and 3.4, and the emissions from the sources listed in Annex A to the KP:

- Energy: Tree biomass removed for bio-energy use is reported as losses in biomass under KP-LULUCF and under the Energy sector the CO<sub>2</sub> emissions are not included in the totals but reported as an information item. Non-tree biomass and litter removed from a site cleared for peat extraction are either included in KP-LULUCF emissions, or if transported to power plants, in the Energy sector.
- Agriculture: N<sub>2</sub>O emissions from drained organic soils are included in Agriculture sector and not reported under KP-LULUCF. N<sub>2</sub>O emissions from N fertilisation in land converted from Forest Land to Cropland and Grassland are included in Agriculture totals which otherwise are reported under Deforestation activity. CO<sub>2</sub> emissions from urea applied to soil in D and FM lands are reported under Agriculture sector. N<sub>2</sub>O emissions from N mineralisation due to the conversion from Forest Land to Cropland are reported under Deforestation. CO<sub>2</sub> emissions from liming are reported under Agriculture.
- Waste: CO<sub>2</sub> emissions from HWP in solid wood disposal sites are not reported under Waste sector but are reported under FM (assumed to be zero). CH<sub>4</sub> and N<sub>2</sub>O emissions from HWP in SWDS are reported under Waste sector.
- There are no common sources with other sectors.

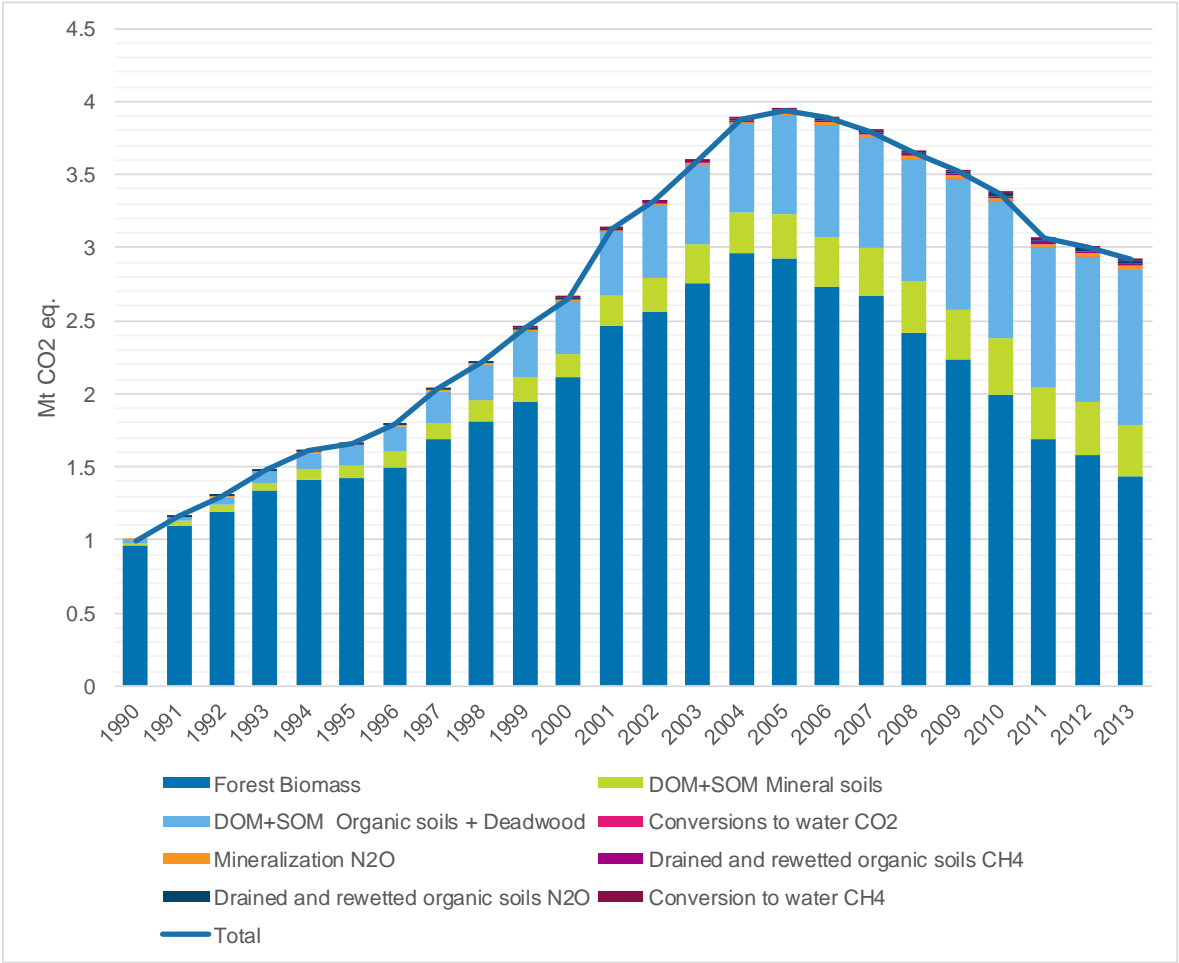
The estimates for the non-CO<sub>2</sub> emissions from drained and rewetted organic soils allocated according to geographical location (Region 1 and Region 2) have been provided as additional information in the NIR because there is no place for them in the reporting tables under the Kyoto Protocol (Table 11.1-2).



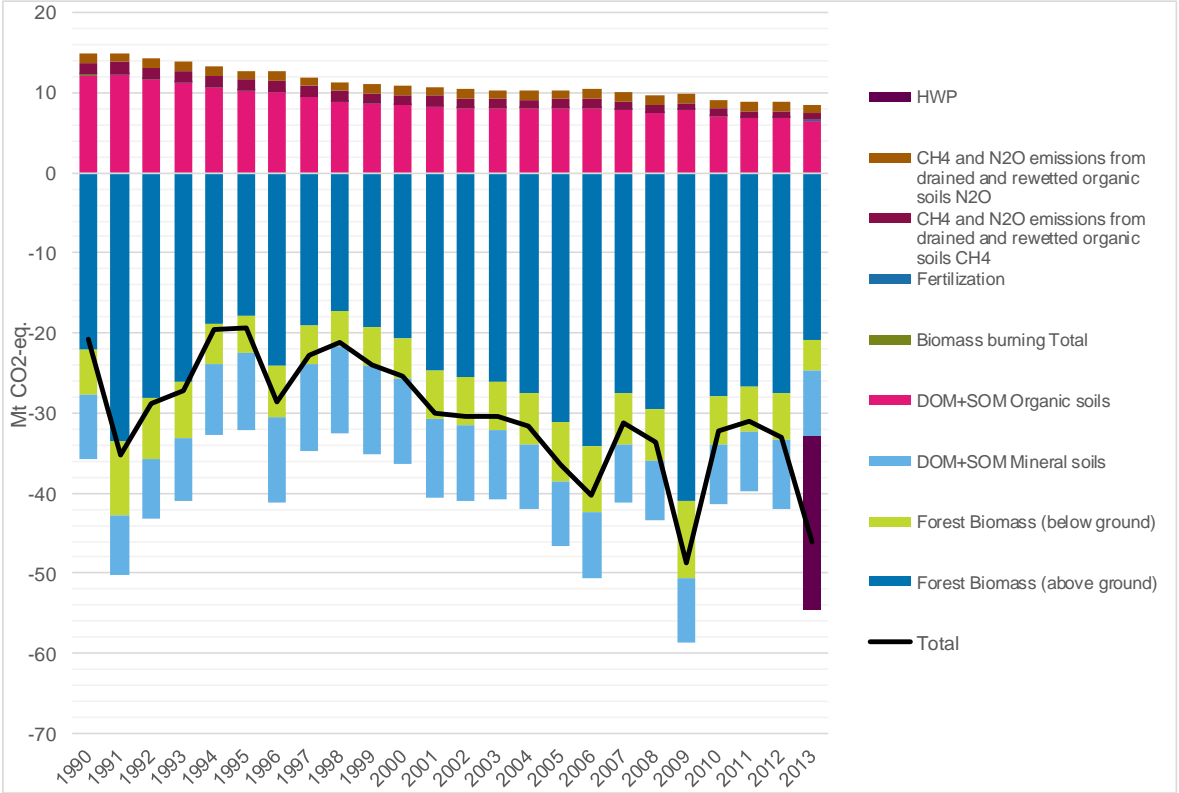
**Figure 11.1-1** Net emissions and removals from Afforestation and Reforestation in 1990-2013, Mt CO<sub>2</sub> eq.

**Table 11.1-1** Net emissions and removals from Afforestation, Reforestation, Deforestation and Forest Management in 2013, kt CO<sub>2</sub> eq.

		AR	D	FM
Region 1	CO <sub>2</sub>	-456	2 425	-10 276
	CH <sub>4</sub>	-1	11	312
	N <sub>2</sub> O	14	37	625
	Total	-443	2 473	-9 339
Region 2	CO <sub>2</sub>	-114	433	-16 105
	CH <sub>4</sub>	6	4	524
	N <sub>2</sub> O	10	8	485
	Total	-98	445	-15 097
HWP	CO <sub>2</sub>			-21 617
Total		-542	2 917	-46 053



**Figure 11.1-2** Net emissions and removals from Deforestation in 1990-2013, Mt CO<sub>2</sub> eq.



**Figure 11.1-3** Net emissions and removals from Forest Management in 1990-2013, Mt CO<sub>2</sub> eq.

**Table 11.1-2** Non-CO<sub>2</sub> emissions from drained and rewetted AR, D and FM lands (organic soils) by geographical locations Region 1 and Region 2 (kt CO<sub>2</sub> eq.)

			2013
<b>AR</b>	CH <sub>4</sub>	Region 1	-1.2
		Region 2	6.3
	N <sub>2</sub> O	Region 1	13.8
		Region 2	9.7
<b>D</b>	CH <sub>4</sub>	Region 1	10.8
		Region 2	4.1
	N <sub>2</sub> O	Region 1	16.2
		Region 2	5.6
<b>FM</b>	CH <sub>4</sub>	Region 1	311.2
		Region 2	523.2
	N <sub>2</sub> O	Region 1	615.4
		Region 2	481.0

### 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 planted forests that have yet to reach a crown density of 10% or a tree height of 5 m are included in forest, as are areas normally forming a part of the forest area that are temporarily unstocked as a result of clear cutting 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 in forest Table 11.1-3.

**Table 11.1-3** Parameters of the forest definition

Parameter	Selected value
Minimum area	0.5 ha
Minimum tree crown cover	10%
Minimum tree height	5 m
Minimum width	20 m

The 2006 IPCC Guidelines define forest as a land with woody vegetation consistent with the selected parameters to define forest land in the national GHG inventory. In Finland, forest definition is outlined to species which traditionally are considered forest tree species, hence fruit orchards are excluded. In Finnish GHG inventory fruit orchards are included in croplands. The area of apple trees, which could reach to the forest definition, has been less than 500 ha. Land with tree cover is excluded from forest land if the land is predominantly under agricultural or urban land use. Areas reserved for forest preservation are accounted as forest. This definition of forest is applied also in the FRA assessments conducted by FAO. Finland employed the same forest definition in the first commitment period.

In the Finnish NFI, the national definitions for land-use categories are applied for domestic purposes and for international reporting lands are classified according the FAO definitions complemented with the minimum area criteria. The national classification is based on the growth potential of trees and site index, but also the use or possible use of land for forestry is considered. The minimum area for land-use categories is not normatively set. Guidance is given for a stand, for example, as a unit of forestry measures. Especially, if a stand's land use differs from the surroundings, a smaller minimum area is accepted. Guidance is, if a small patch of forest is inside other land-use classes, it is included in the surrounding land use if the land cannot be

regarded as forestry land. This rule involves the minimum area and the minimum width. Usually a forest stand is a part of a large forest consisting of several stands and the criteria for minimum forest area is fulfilled.

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 the national criteria for a minimum area of 0.25 ha to cover all forest land (see Sections 6.2 and 6.4.1). These forests are tended for forestry purposes, and difficult to include in the other land-use categories. 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.

#### **Exclusion of small forests (area less than 0.5 ha)**

The NFI sample plots that were located in the small forests have been identified using GIS analysis. The numerical vector map data from the National Land Survey (2014b) 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\_6a, Figure 1\_App\_6a). The minimum area for forest land and poorly productive forest land is not exact, but, rather, a guide of 0.25 ha for Southern Finland and 0.5 ha for Northern Finland is given. The diverse total land areas are presented in Table 11.1-4. Due to 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 (1,000 ha) 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)	22 081	21 993	21 918	30 391	30 389	30 388
UNFCCC (Forest land)	22 110	22 025	21 950	30 391	30 389	30 388
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>	22 769 <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: Natural Resources Institute Finland (Luke) / National Forest Inventory).

<sup>3</sup> NFI11, measurement years 2009-2013 (Source: Natural Resources Institute Finland (Luke) / National Forest Inventory). 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 not elected to account for any additional activities under Article 3, paragraph 4, of the Kyoto Protocol in the second commitment period.

### 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

Definitions for ARD and FM, as they are in Annex to the Decision 16/CMP.1, were implemented in the first commitment period and they will be applied similarly in the second CP. Article 3.3 activities are defined as human induced land-use changes between forest land and other land uses. In Table 11.1-5 are the conversion types, which are included in ARD activities. The way how land-use categories are defined and the reasons to consistent application of land-use categories are described in Sections 6.2 and 6.3.

**Table 11.1-5** Land-use changes types reported under Article 3.3

Activity	Human induced land-use change from / to	Subdivision	Abbreviation in CRF Tables
<b>Afforestation/Reforestation</b>	Cropland	Mineral soil	CLmin
	Cropland	Organic soil	CLorg
	Grassland	Mineral soil	GLmin
	Grassland	Organic soil	GLorg
	Wetlands	Peat extraction	WLpeat
	Wetlands	Other wetlands	WLorg
	Settlement	-	Set
<b>Deforestation</b>	Cropland	Mineral soil	CLmin
	Cropland	Organic soil	CLorg
	Grassland	Mineral soil	GLmin
	Grassland	Organic soil	GLorg
	Wetlands	Peat extraction	WLpeat
	Wetlands	Other wetlands	WLorg
	Wetlands	Inland water	WLwaters
	Settlement	-	Set
	Forest land	-	AR_under_D

Afforestation/Reforestation and Deforestation (ARD) areas have been estimated from the data based on the 10<sup>th</sup> and 11<sup>th</sup> forest inventories (NFI10 and NFI11). Data consist of sample plot data, stand-level data and measured tree-level 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 other spatial 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 second and subsequent commitment periods. The forests, other land uses and land-use changes will be monitored in field every year throughout the whole country, excluding the northernmost part of Lapland and the Åland Islands. Åland is monitored in NFI once every five years, northernmost part of Lapland every other inventory cycle. Regardless of that, the land-use conversions are worked out for GHG inventory purposes. Spatial data are used for updating the land use on NFI sample plots.

Finland interprets the definition for forest management applying the *broad approach* (IPCC KP Supplement, p. 1.10, p. 2.87). FM is a system of practices that occur within two identified areas, Region 1 and Region 2 (Figure 11.2-1). FM includes forests under silvicultural measures, either intensively managed or inactively use, and protected forests. FM activities are not identified at either a stand-level or a landscape-level for the GHG inventory purposes; rather, they are identified for two larger land areas subject to forest management and for which geographical boundaries are defined and reported.

The time series for the FM area have been estimated using the same NFI and auxiliary data as for the ARD areas. The forest area was computed in the same way as for the Convention reporting. The FM area in each year is derived from the total forest land area and from the annual AR and D areas. The total forest land area under KP is the sum of FM and AR areas. 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\_6b. 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*

Since Finland will not account any electable activities, it can be said the lands not falling into AR, D or FM are under an activity 'other'. In the first commitment period, for the purpose to detect lands under different activities and for area estimation, every NFI sample plot (plot center stand) was classified into one activity according to the applied definition of an activity in question. Each plot could belong to only one activity in the end of a year. The sum of the activities AR, D, FM and 'other' constitute the total area of Finland. The history of the land use and land-use changes were investigated for years 1990 to 2012. Monitoring of these sample plots continues during the second CP. This approach confirms that the land once included will stay in the accounting and only new lands from 'other' activities can be entered in the accounting.

## 11.2 Land-related information

Finland implements Reporting Method 1 for lands subject to Article 3.3 and Article 3.4 activities (IPCC KP Supplement, page 2.15). The area of Finland is divided into two regions: Region 1 covers Southern Finland and Region 2 Northern 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 6a, Figure 1\_App\_6a). These areas include lands subject to ARD activities and FM activity. 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 (IPCC KP Supplement Table 2.2.1). The approach is applicable as the spatial resolution of the utilized data is fine enough to represent the minimum forest area.

The base data source for land use and land-use changes was the National Forest Inventory (NFI) complemented with auxiliary data for land use. The NFI is a sampling based inventory system that covers all land-use categories, not only forestry land. The sampling unit for area estimation is a point. In a sample plot, the point is the midpoint of the plot. The midpoint stand 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 land under Article 3.3 is the minimum area to detect land-use changes. Information on land-use transfers is based on NFI plot and stand-level data. When land use of a plot center (plot center stand) has been changed, it can be detected (see also 11.1.1 and 11.2). Thus, land-use changes do not have any minimum size. However, a forest area where the plot is located should have an area of 0.5 ha at a minimum.

### 11.2.2 Methodology used to develop the land-use transition matrix

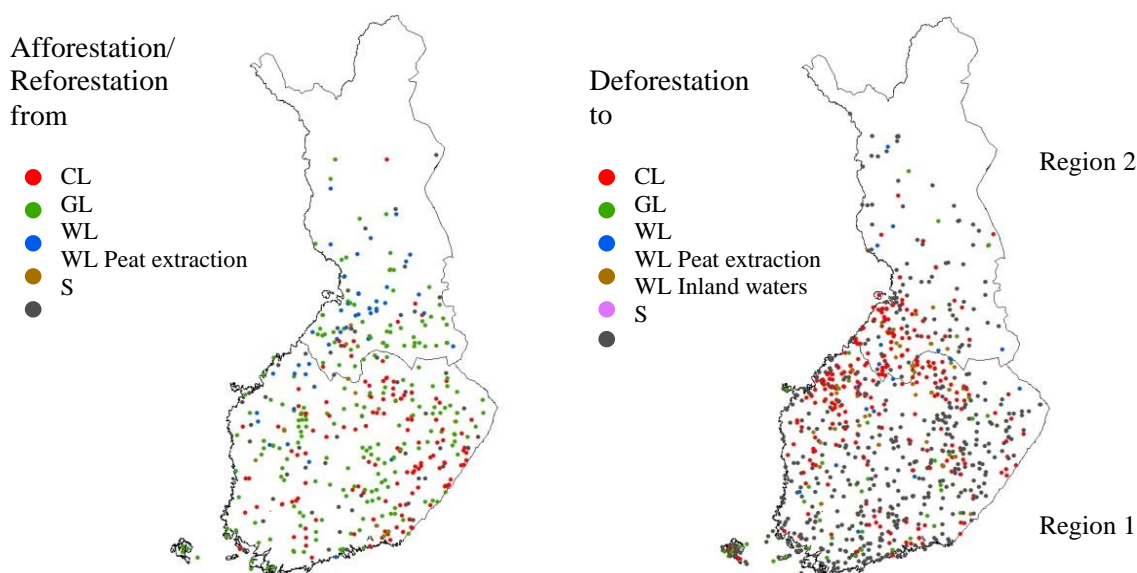
The NFI contain information to derive the IPCC land use and the land-use change category for each sample plot. The data were measured in 2005-2013. The land use history for all sample plots was investigated enabling to calculate the annual land-use change areas for the years 1990-2013. The data and method are consistent with UNFCCC reporting and are described in Section 6.2. FM area was developed by subtracting D areas from total forest area calculated from NFI. The matrix in the Table 11.2-1 contains cumulative ARD areas from 1 January 1990 to 31 December 2012 and areas of ARD activities in 2013 (Table 11.2-1).

**Table 11.2-1** Land-use transition matrix for 2013 (1,000 ha)

2013		Article 3.3 activities		Article 3.4 activities				Other	Total
		A/R	D	FM	CM	GM	RV	W	
Article 3.3 activities	A/R	166	1						167
	D		344						344
	FM		10	21 722					21 731
Article 3.4 activities	CM	NA		NA	NA	NA	NA	NA	NA
	GM	NA		NA	NA	NA	NA	NA	NA
	RV	NA		NA	NA	NA	NA	NA	NA
	W	NA		NA	NA	NA	NA	NA	NA
Other		2	NA	NA	NA	NA	NA	NA	11 599
Total		168	355	21 722	NA	NA	NA	NA	33 843

### 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 where upon it was possible to place them in the appropriate regions. Remotely sensed and other spatial data are also spatially explicit. NFI data were merged with additional spatial data for land-use change detection. Remotely sensed data included aerial images with 0.5 m spatial resolution, satellite images and other raster data (20-25 m) and LPIS data on fields with location accuracy better than 2.5.



**Figure 11.2-1** Geographical locations of the two reporting regions and their identification codes. The sample plots under ARD activities for the years 1990-2013 are plotted on the map. Different land-use conversions from or to forest land are presented in different colors

## 11.3 Activity-specific information

### 11.3.1 Methods for carbon stock change and GHG emission and removal estimates

The 2006 IPCC Guidelines and IPCC KP Supplement are implemented for the preparation of the emission and removal estimates. The definitions of Decision 16/CMP.1 are applied as in the first commitment period. For more information about forest definition see Section 11.1.1. Methodology in the IPCC Wetlands Supplement was partly employed, but Finland does not intend to implement the entire Guideline. The same methodologies as were used for UNFCCC reporting were also employed for KP reporting.

#### 11.3.1.1 Description of the methodologies and the underlying assumptions used

##### *Carbon stock changes*

##### **Carbon stock change 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 6.4.2.1).

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 6.4.2.2). 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 6.5.2.2, 6.6.2.2, 6.7.2.2 and 6.8.2.2

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 conversion 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\_6f) 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 6.4.2.1 and for Land Converted to Forest Land in Section 6.4.2.2. For more on deforestation as a result of Forest Land being converted to other land uses, see Sections 6.5.2.2, 6.6.2.2, 6.7.2.2 and 6.8.2.2 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 thinning 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 6.4.2.1). 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.

### **Harvested wood products**

A carbon stock change (CSC) in the HWP pool was estimated on the basis of the Production Approach (2006 IPCC Guidelines, Vol. 4, Annex 12.A.1). Used method is Tier 2 method, the first-order decay function with default half-lives for sawn wood (35 yr.), wood panels (25 yr.) and paper (2 yr.) (IPCC 2014a). Applied method is corresponding to the method described in Section 6.11. The inherited emissions before 2013 were excluded from the estimates. This is applicable procedure for Finland, since the emissions due to the removed trees from FM forests were accounted in the first commitment period. The CSC in paper and paperboard subcategory was not directly estimated but the production volume of pulp from domestic harvest was used. This is considered to give a valid estimate for paper and paperboard, because the use of pulp as a raw material for other commodities is rare.

An aggregate estimate of carbon stock changes in HWP is reported for AR (for which IE is reported), reforested D (for which IE is reported) and FM under the FM category, because at the moment it is not possible to differentiate the harvest between AR and FM (IPCC KP Supplement, p. 2.118). Ongoing development project will enable the differentiation in the future. Also the year, from which the inherited emissions are included, will be revisited.

Tier 1 method instantaneous oxidation was used to estimate CSC under Deforestation and under FM/AR for wood products in solid waste disposal sites and harvested wood used for energy purposes.

### *Non-CO<sub>2</sub> 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 on 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 4(I) Category (Section 6.10.1). The sales statistics do not allocate the sales between Southern and Northern Finland (Region 1 and 2). In order to allocate the total amount, statistics on forest fertilisation areas were used to obtain a ratio for Southern and Northern Finland for each year of the time series. It was assumed that the same amount of fertiliser is applied per hectare in both Southern and Northern 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 2000-2013 the Finnish Statistical Yearbook of Forestry (2014) divided forest

fertilisation area into remedial fertilisation and fertilisation for growth. 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 deduced that remedial fertilisations are nitrogen-free.

N fertilisers are 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 and CH<sub>4</sub> emissions from drained and rewetted organic soils**

N<sub>2</sub>O and CH<sub>4</sub> 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 6.10.2. Both CH<sub>4</sub> and N<sub>2</sub>O emissions from drained organic forest soils have been reported according to the 2006 IPCC guidelines (IPCC 2006) and IPCC Wetlands Supplement (IPCC 2014b). N<sub>2</sub>O emissions from drained organic soils were estimated according fertility class based on emissions factor from Ojanen et al. (2010). CH<sub>4</sub> emissions were estimated for drained organic forest soils with EFs that vary according to drainage situation (Ojanen et al. 2010), while CH<sub>4</sub> emissions from ditches were estimates by applying IPCC default emission factor according to the IPCC Wetlands Supplement (IPCC 2014b) for that land area. Similarly, CH<sub>4</sub> and N<sub>2</sub>O emissions from afforestation, reforestation and deforestation on drained organic lands were estimated as in the reporting under convention (for details see Forest Land and Wetlands section of the NIR).

### **N<sub>2</sub>O emissions from N mineralization due to carbon loss/gain associated with land-use conversion and management change in mineral soils**

N<sub>2</sub>O emissions from mineralisation due to deforestation, forest land converted to cropland or settlements, are reported using the methodology followed that given in the 2006 IPCC Guidelines. The method is described in Vol. 4, Section 6.10.3.

### **Biomass burning**

GHG emissions from biomass burning in FM areas were estimated using the same method as described in Section 6.10.5. CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O emissions are 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 2011-2013 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 6.10.5).

Biomass burning on D areas is not reported since residue burning is not a common practice when clearing new fields or grasslands.

## ***11.3.2 Justification when omitting any carbon pool or GHG emissions/removals from activities under Article 3.3 and Forest Management under Article 3.4***

Under AR, the N<sub>2</sub>O emissions from N fertilisation are reported as NA. 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.

Under FM and AR, the N<sub>2</sub>O emissions from drained mineral soils are reported as NA. In general, upland forest soils in Finland are not water logging and are nitrogen limited. Therefore, soil textures are not water saturated and there is no long lasting flooding on upland forest soils. Also Finnish forest soils typically have high C:N ratios and low atmospheric nitrogen deposition, both factors decreasing the potential for N<sub>2</sub>O production. Recent research states that N<sub>2</sub>O emissions are typically very low, unless there is a significant input of organic or inorganic nitrogen from runoff. Furthermore, the area of drained mineral soils is minor in the Finnish context, 7% of forest land on mineral soils. The area has been constant for last 15 years, indicating that most of the drainage was done in the 1980's and the 1990's and the soils are dry.

Although the recent Finnish study by Tupek et al. (2014), did not include forests on drained mineral soil, its results can be used as an approximation of conditions in drained mineral soils. In our conditions, ditching drains forests on mineral soil quite effectively and thus the drained sites are not waterlogged from time to time or seasonally. Tupek et al. studied upland forest on podzols that have been managed earlier in 60s and 70s and report that the level of water table did not affect N<sub>2</sub>O emissions. The results of Tupek et al. are also in line with earlier results by Pihlatie et al. (2007), Korhonen et al. (2013), Schindlbacher et al. (2004), Pilegaard et al. (2006) on close to zero N<sub>2</sub>O emissions with high relative uncertainties, indicating that these sites can be either sinks or sources depending on years. As N<sub>2</sub>O emission research from Finland reports constantly close to zero emissions and substantial errors, meaning that likely emission factor can be zero, N<sub>2</sub>O emissions from drained mineral soils was omitted. Pihlatie et al. (2007) report "The chamber N<sub>2</sub>O fluxes varied from a small uptake to a small emission", see Fig 2, where fluxes are with error bars. In this study annual cumulative mean was 0.003 g N m<sup>-2</sup> yr<sup>-1</sup>. Also Korhonen et al. (2013) reports annual mean cumulative emission of 0.02 g N m<sup>-2</sup> yr<sup>-1</sup> for a well-drained managed sites in Finland (same site as Pihlatie et al. (2007)). Both, Pihlatie et al. (2007) and Korhonen et al. (2013) report marginal background emissions levels of N<sub>2</sub>O for Hyytiälä site with high relative uncertainties, indicating that these sites can be either sinks or sources depending on years (note that Hyytiälä is a managed Scots pine site where water flows through soil rapidly). Also a paper by Schindlbacher et al. (2004) reports N<sub>2</sub>O emission potentials based on data from Finland and other European countries. According to this paper Finnish N<sub>2</sub>O fluxes are only 5-20% out of those measured in other countries that locate more south. Schindlbacher et al. (2004) agrees well with Pilegaard et al. (2006) that illustrates well close to zero N<sub>2</sub>O emissions of Hyytiälä compared to more southern European sites.

### *11.3.3 Information on whether or not indirect and natural GHG emissions and removals have been factored out*

Finland has not factored out from the reported estimates the 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. It can be hypothesized that in the accounting of FM these effects are factored out, when the emissions and removals occurred in the commitment period are compared to the FMRL which also includes the same effects.

### *11.3.4 Changes in data and methods since the previous submission (recalculations)*

The areas of Article 3.3 activities and Forest Management were recalculated. Updating procedure of NFI land-use parameters was run through with new spatial data and the latest NFI11 data measured in 2013 were employed. Thus the areas were recalculated since the previous submission. Found errors in the data and calculations were also corrected.

Other recalculations were:

- Tree biomass gains and losses: recalculated activity data, new NFI tree data, errors corrected in computations (ARD, FM)
- Harvested wood products: new carbon pool under the KP (FM, AR)
- N<sub>2</sub>O emissions from N fertilization: EF change according to the 2006 IPCC Guidelines, see Section 6.10.1.5 (FM)

- N<sub>2</sub>O emissions from mineralization: enhancement of the coverage of inventory according to the 2006 IPCC Guidelines, see Section 6.10.3
- Off-site emissions (CO<sub>2</sub>) from peat removed for environmental and horticultural use: new source according to the 2006 IPCC Guidelines, see Section 6.7.2.1 (D)
- CH<sub>4</sub> emissions from drained organic soils: new source according to the IPCC Wetlands Supplement, see Sections 6.10.2 (FM, AR, D)
- Biomass burning/ wildfires (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O): new activity data and biomass estimates, see Section 6.10.5 (FM, AR)

### 11.3.5 Uncertainty estimates

It was assumed that uncertainty estimates developed for the Convention reporting apply also for lands under the Kyoto Protocol reporting (see Section 6.4.3 for carbon stock changes in Forest land, Section 6.7.3 for carbon stock changes in Wetlands, Section 6.10.1.3 for N fertilisation, Section 6.10.2.3 for non-CO<sub>2</sub> emissions from drainage, Section 6.10.5.3 for biomass burning, Section 6.11 for HWP). 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 were 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\_6e and Appendix\_6h). 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 Land Converted to Forest Land. Hence the uncertainty assessment in Section 6.4.3.4 applies also here. The uncertainty of 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 Approach 2 uncertainty analysis for KP reporting were same as those for UNFCCC reporting, but the aggregation of uncertainties of the subcategories between these two reporting differs.

The uncertainty for HWP was not computed but the UC for tier 1 method was used. The UC is 50% for HWP. It is difficult to estimate the UC for HWP since, for example, the UC for the default half-lives is not known.

**Table 11.3-1** Relative uncertainties estimated using Approach 2 methods for Kyoto Protocol activities 3.3 and 3.4

	Emission 2013, kt CO <sub>2</sub> eq.	Emission uncertainty
KP 3.3 ARD	2 376	±78%
KP 3.3.a AR	-542	±60%
KP 3.3.b. D	2 918	-63 - +62%
KP 3.4 FM	-46 053	-32 - +31%
KP 3.4. FM (exl. HWP)	-24 436	±40%
KP 3.4 HWP	-21 617	±50%

### 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 2014). 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, part of the difference is related to the uncertainty of estimates.

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 2014). 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 2014).

**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
1995	8.7	12.1	4.1
2000	4.9	6.7	5.8
2001	4.1	5.3	6
2002	3.4	4.4	2.7
2003	2.5	3.4	2
2004	3	4.1	2.4
2005	3	3.9	2.3
2006	2.7	3.8	2.3
2007	2.9	4.1	3.1
2008	2.8	3.7	3.5
2009	2.3	2.8	3.6
2010	2.1	2.5	2.9
2011	1.8	2.1	2.2
2012	1.5	1.7	1.7
2013	1.4	1.6	1.6
<b>All</b>	127.1	169.5	140.4
<b>all AR-D</b>	125.5	167.9	140.4

**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	7.0	4.1	2.9
1995	11.1	5.7	5.4
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	22.4	14.7	7.7
2005	22.4	8.8	13.6
2006	21.2	9.6	11.6
2007	20.4	9.7	10.7
2008	18.7	10.7	8.0
2009	16.9	12.8	4.1
2010	14.6	27.3	-12.7
2011	12.3	15.2	-2.9
2012	11.3	17.5	-6.2
2013	10.3	14.0	-3.7
All	354.6	243.2	111.5

### 11.3.6 Information on other methodological issues

Other methodologies were not used than those explained above.

### 11.3.7 The year of the onset of an activity, if after 2008

The onset of all the activities Finland reports and accounts for under the KP is before 2008.

## 11.4 Article 3.3

Emissions and removals from ARD activities in 1990-2013 are given in Appendix\_11b.

Lands that were subject to D activities since 1990 and on which subsequent regrowth of forests occur continue to be reported under D as a sub-category '*AR\_under\_D*'. The area of these lands was 1,419 ha in 2013. The previous land use of these lands was settlement; gravel pits or other build-up areas.

The cumulative sum of areas afforested/reforested and deforested since 1990 is provided in Table 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	10 185	3 334	13 519	5 579	1 392	6 971
1995	55 481	22 710	78 191	43 766	12 082	55 848
2000	88 307	37 714	126 021	94 893	30 895	125 788
2001	91 901	39 429	131 330	108 351	35 816	144 167
2002	94 993	40 781	135 774	122 001	41 505	163 506
2003	97 629	41 584	139 213	136 571	47 512	184 083
2004	100 773	42 559	143 332	151 721	54 756	206 477
2005	103 889	43 390	147 279	166 498	62 414	228 912
2006	107 113	44 016	151 129	180 236	69 854	250 090
2007	110 293	44 893	155 186	194 257	76 239	270 496
2008	113 251	45 620	158 871	206 745	82 460	289 205
2009	115 547	46 040	161 587	218 763	87 313	306 076
2010	117 450	46 460	163 910	229 794	90 921	320 715
2011	118 815	46 796	165 611	239 230	93 774	333 004
2012	119 913	46 964	166 877	247 936	96 376	344 312
2013	120 750	47 132	167 882	255 922	98 726	354 648

### 11.4.1 Information that demonstrates that the activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2013 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 and with other auxiliary data. 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 and not accounted under the KP, occur when due to the land lift seawater turns to land and, thereafter, gradually into forest. In addition, the conversion from land-use category 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 land 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 (WLog). That type of conversion is in contrast to land being converted from wetlands to forest (WLog). 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.

Forests are clear cut as a silvicultural measure and a first phase of the artificial regeneration. When a clear-cut area is located in a 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 surroundings 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. In the case the land-use change occurs after a clear-cut, this can be taken into account by classifying the sample plot as non-forest.

#### *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*

Cutting areas in 2013 are given in Table 11.4-2 (Finnish Statistical Yearbook of Forestry 2014).

**Table 11.4-2** Clear-cut forest areas (1,000 ha)

	2013
Region 1	102.2
Region 2	37.7
Total	139.9

#### *11.4.4 Natural disturbance provisions*

The natural disturbance provision will not be applied for AR.

## 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

Finland interprets the definition for forest management using a broad approach described in the IPCC KP Supplement. 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 revised Forest act (Forest Act 1093/1996) became effective in 2014 with, for example, amendments to increase the variability in methods of managing the forests and to enhance the biodiversity. The National Forest Programme 2015 (Finnish Ministry of Agriculture and Forestry 2011), 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.

Forest area, AR and D area were calculated for the years 1990-2013 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 or AR under D, and therefore all FM activities have occurred in or after 1990 and have been human-induced.

### 11.5.2 Information relating to Forest Management

Emissions and removals from FM activity in 1990-2013 are given in Appendix\_11c. The area under forest management for the years 1989-2013 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
1990	11 572	10 496	22 068
1995	11 534	10 485	22 019
2000	11 482	10 466	21 949
2001	11 469	10 461	21 930
2002	11 455	10 456	21 911
2003	11 441	10 450	21 890
2004	11 426	10 442	21 868
2005	11 411	10 435	21 846
2006	11 397	10 427	21 824
2007	11 383	10 421	21 804
2008	11 371	10 415	21 785
2009	11 359	10 410	21 769
2010	11 348	10 406	21 754
2011	11 339	10 404	21 742
2012	11 330	10 401	21 731
2013	11 322	10 399	21 722

### 11.5.2.1 Information that FM conforms with the forest definition

Forest management activity is practised in forest areas as defined above. All forests fulfilling the definition of forest (See Section 11.1.1) are considered managed and are under forest management. 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 Information on reporting of Forest Management in relation to the Forest Management Reference Level

The value of Finland's FMRL is -19,300 kt CO<sub>2</sub> eq. without HWP and -20,466 kt CO<sub>2</sub> eq. with HWP as they are in Annex to the Decision 2/CMP.7. The FMRL was constructed in 2011 and since then several changes have been done to the applied data and methods (Table 11.5-2).

**Table 11.5-2** Changes in methods, additions and modifications in the GHG inventory since the submission of FMRL

Additions to / modifications in the GHG inventory	FMRL technical correction
New NFI data are used to estimate FM and D areas for 1990-2009	FM area for 2009 was used as an initial FM area from which the annual deforestation rate was subtracted to have the FM area in 2013-2020. The new annual deforestation rate for 2013-2020 is an average of D areas of 2004-2008.
New biomass conversion and expansion factors have been estimated from the NFI data for tree biomass increment and drain (harvest and natural losses)	The old BCEFs were used for the construction of FMRL. New BCEFs are used to convert predicted increment, harvest and natural losses expressed as stem volume to biomass.
Yasso07 soil model and new Scandinavian parameters were implemented	Yasso model with global parameters were used for FMRL. The change to the new model version was taken into account in the computation of the TC as a proportional difference in estimates between these two model versions in 1990-2009. The predicted soil sink was adjusted by +10% compared to the sink included in FMRL.
Recalculated CO <sub>2</sub> emissions from drained organic soils	The effect of new BCEFs were estimated as a proportional change compared to estimates used for construction of FMRL (about 1% lower emissions now)
CH <sub>4</sub> emissions from drained organic soils were included in the GHG inventory	New gas, not included in FMRL. An average of emissions in 2004-2008 was used for 2013-2020 (1,093 kt CO <sub>2</sub> eq. yr <sup>-1</sup> ).
N <sub>2</sub> O emission from drained organic soils were included in the GHGI	New gas, not included in FMRL. An average of emissions in 2004-2008 was used for 2013-2020 (1,122 kt CO <sub>2</sub> eq. yr <sup>-1</sup> ).
CH <sub>4</sub> and N <sub>2</sub> O emissions from controlled burning were re-estimated with new biomass data	New average of annual emissions from prescribed burning in 2004-2008 was used for 2013-2020 (1 kt CO <sub>2</sub> eq. yr <sup>-1</sup> ).
N <sub>2</sub> O emissions from N fertilization were re-estimated	New average of annual emissions from N fertilization in 2004-2008 was used for 2013-2020 (14 kt CO <sub>2</sub> yr <sup>-1</sup> ).
New GWP values were implemented	For N <sub>2</sub> O and CH <sub>4</sub> emissions
Carbon stock changes in the HWP carbon pool are estimated according to the Decision 2/CMP.7 and included in the GHGI under the KP	For FMRL, the HWP contribution was estimated from domestic harvest, domestically consumed HWP, from 1900 to 2020, including the first CP. Now the initial year is 2013 and also exported HWP are included. Same policy assumptions about the volumes of production were used for TC as was used for FMRL. HWP contribution to the corrected FMRL is -13,492 kt CO <sub>2</sub> yr <sup>-1</sup> .

Additions to / modifications in the GHG inventory	FMRL technical correction
Natural disturbance	Finland intends to apply the ND provision. The background level of ND (532 kt CO <sub>2</sub> eq. yr <sup>-1</sup> ) was taken in account in the TC.

In the technical assessment report over Finland's FMRL submission, two issues were brought out expressing possible inconsistency between the projected FMRL and historical emissions and removals from FM, namely the predicted increment of growing stock and amount of natural losses. Both remarks apply to the estimates produced by models. These issues were not yet processed for this submission. After the adoption of FMRL, further research to develop these models was started and it is expected that the results will resolve the possible problems. Results are expected to be ready to be implemented in GHG inventory within three years.

In the construction of the corrected FMRL, the effects of the changes in estimation of carbon stock changes in mineral and organic forest soils were assessed as a proportional change in estimates. Other emissions and removals were estimated employing the same methods as was used for the construction of the FMRL.

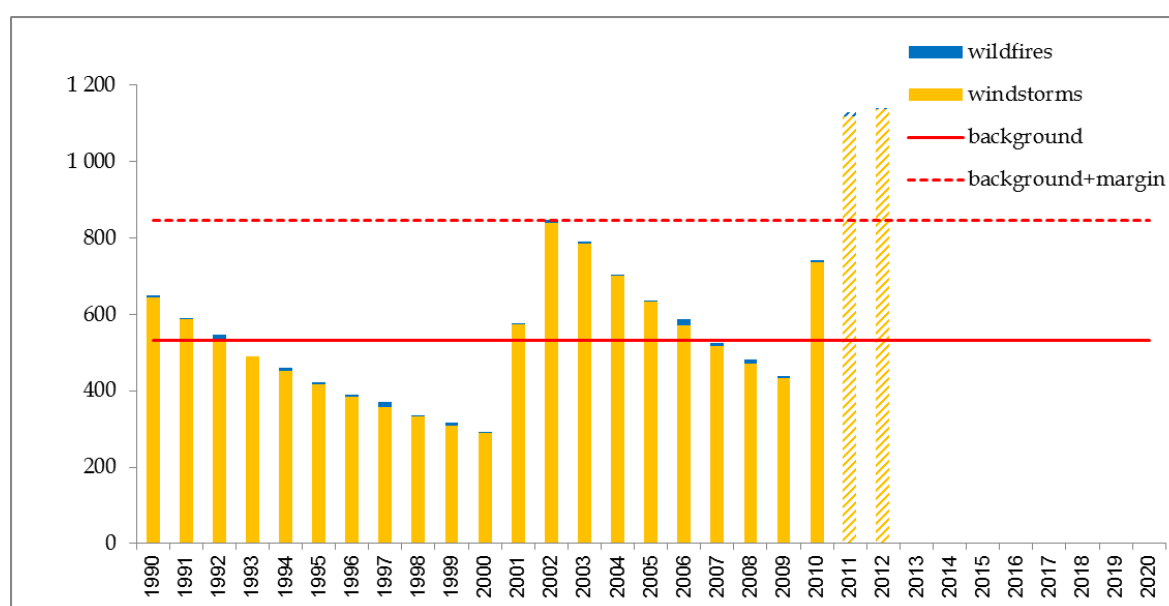
Based on the above mentioned changes the technical correction to FMRL including HWP is -11,020 kt CO<sub>2</sub> eq.

#### 11.5.2.3 Natural disturbance provisions: Indication of use, occurrence of natural disturbances and description of methods including background level and how net credits or debits will be avoided

Finland will apply the natural disturbance provision for accounting of Forest Management under Article 3, paragraph 4, during the second commitment period if needed. Finland wishes to exclude windstorms, insect attacks and wildfires from accounting under the natural disturbance provisions.

#### Occurrence of natural disturbances in Finland and obtained background level and margin

Natural disturbances in Finland are usually small-scale and the forests are in general in good condition. In the recent years storms have caused the most damage. Fire control is effective and areas of forest fires have been small. The emissions from natural disturbances during the calibration period 1990-2012 and the obtained background level and background level+margin are presented in Figure 11.5-1. The background level is 532 kt CO<sub>2</sub> eq and the margin 314 kt CO<sub>2</sub> eq.



**Figure 11.5-1** Emissions from natural disturbances in 1990-2012 (kt CO<sub>2</sub> eq.) and obtained background level and margin. Outliers are marked with diagonal-lined bars

### **Methodology to estimate emissions, background level and margin**

GHG emissions from decay of wood felled during windstorms and transferred into DOM pool in FM areas were estimated using a Tier2 method (See Section 2.2.1, Chapter 2, 2006 IPCC Guidelines). Decomposition rates were obtained from Yasso07 soil carbon model similarly as for DOM pool under Forest Management. The model is described in detail in Section 6.4.2.1 and Appendix\_6e. The model was applied to all windstorms and it was assumed that these lands were on mineral soils.

Annual volume of trees damaged due to windstorms was derived from forest disturbance reports (Finnish Forest Research Institute 2014). The proportions of damages by tree species were derived from permanent sample plots of the NFI10 data and damage information on sample trees. The volumes by tree species were needed as an input for the model. Trees harvested due to salvage logging were excluded from the emission calculations. The proportion of salvage loggings was estimated to be 70% of the total stem volume damaged in windstorms (Ihalainen et al. 2003). Salvage logging did not include foliage, branches, stumps or roots. The model initialisation was done using average windstorm data from the calibration period, which is justified to remove any effect of trends or any assumption of the historical data. Emissions from wildfires were estimated as described in Sections 6.10.5 and 11.3.1.1. The IPCC default method was used when developing the background level and margin (IPCC 2014a). The insect attacks were insignificant and the emissions were assumed zero during calibration period.

### **Avoiding the expectations of net credits or net debits**

- No trend was observed in natural disturbance emissions during the calibration period or is expected during the commitment period (see Figure 11.5-1).
- The background level of emissions for FM included in the FMRL after technical correction is equal to the average of annual emissions from natural disturbances during the calibration period which are in the background group.
- A test application of the constructed background level and the margin to the annual emissions in the calibration period leads automatically to the same background group as used during the construction of the background level, because the default method was applied

#### ***11.5.2.4 Information on how all emissions arising from the conversion of natural forests to planted forests are accounted for***

The emissions from conversion from natural forest to planted forest are included in the emissions/removals from FM. Natural forests are defined as the primary forests reported to the FAO for FRA 2015 Assessment (not yet published). Primary forests are naturally regenerated forest of native species, where there are no clearly visible indications of human activities and the ecological processes are not significantly disturbed. The area of these forests is 230,000 ha. Planted forest is defined as a forest established through planting or seeding with native or introduced tree species. No conversion from natural forest to planted forest has occurred in 2013.

## *11.6 Other information*

### *11.6.1 Key category analysis for Article 3.3 activities and activities under Article 3.4*

Key category analysis for KP-LULUCF was performed according to the 2006 IPCC Guidelines. The results of the key category analysis for KP LULUCF activities for the inventory year 2013 are included in the CRF Tables and in Table 1.5-2. Carbon stock changes under ARD and FM and CH<sub>4</sub> and N<sub>2</sub>O emissions from drainage of soils are identified as key sources for the KP-LULUCF activities. Identification of the associated category as a key category in the UNFCCC inventory is used as a criterion for the identification of key categories for KP-LULUCF.

## *11.7 Information relating Article 6*

There are no lands subject to Article 3.3 and Article 3.4 activities which are also subject to projects under Article 6.

## Appendix\_11a

### Identification of ARD Activities

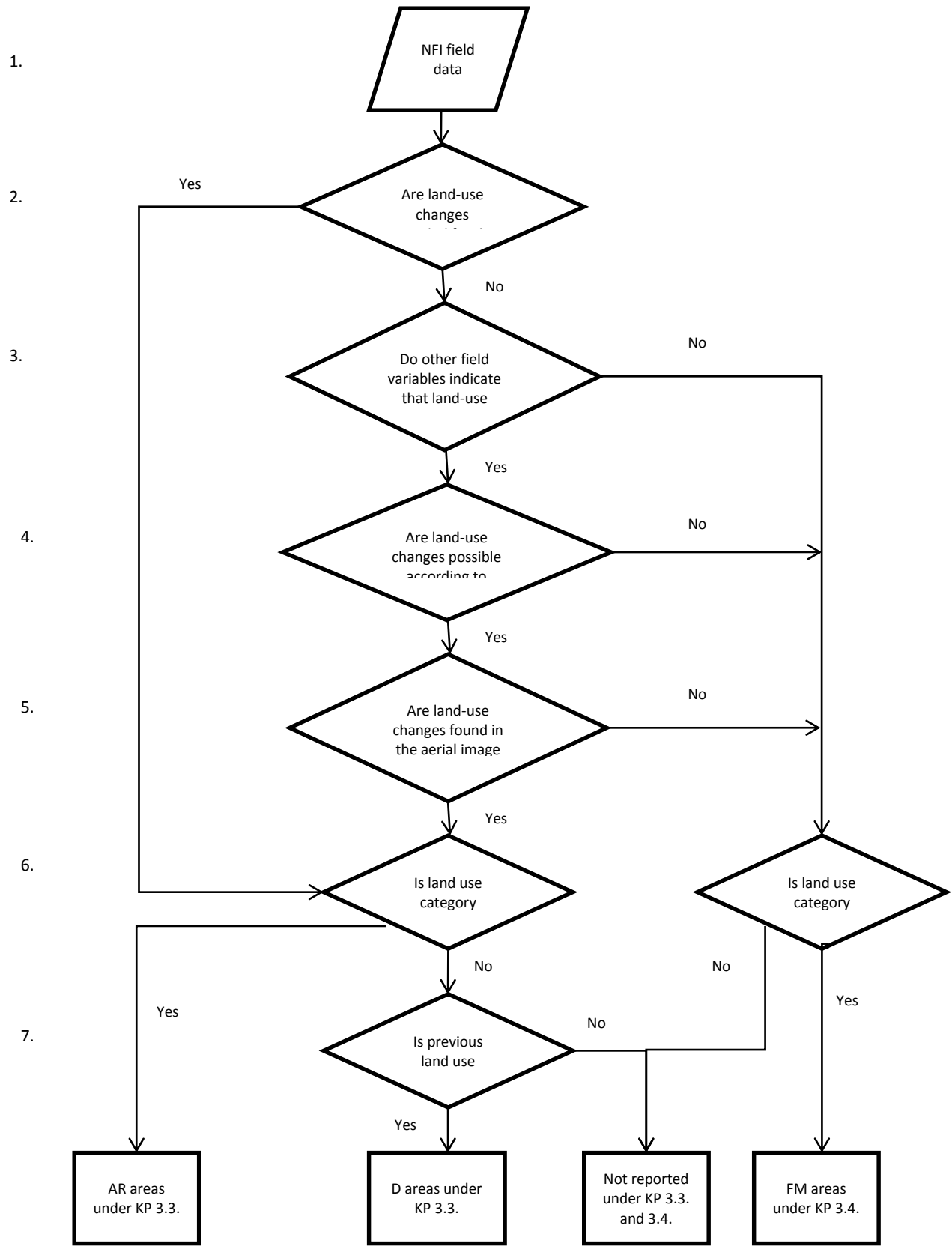
The areas of ARD activities were calculated using National Forest Inventory data (NFI), which included 10<sup>th</sup> and 11<sup>th</sup> NFI data measured in 2005-2008 (NFI10) and 2009-2013 (NFI11). The field measurements are carried out in five-year cycles for NFI plots and combined NFI10 and NFI11 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 spatial data and aerial photo interpretation to the end of 2013. The images used in the interpretation were the newest possible aerial photos made freely available by Land Survey of Finland (Land Survey of Finland 2014 b). There were also other data sources for the updating, i.e., digital maps, Landsat images and land parcel identification system data (LPIS) 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. NFI data and its update were used for calculation of FM, AR and D areas.
2. NFI plots with recordings of AR and D activities were used in the area calculations.
3. In addition, NFI plots which were recorded as unchanged in the field were checked for possible land-use changes by means of other NFI parameters like stand age, soil type, land use etc.
4. If NFI plot parameters showed that land-use changes were possible, coarse scale image interpretation was carried out for those plots, it included satellite images, thematical maps, LPIS data, numerical maps from different years.
5. At the final stage, aerial image interpretation was carried out for the plots selected after the steps 1-4 to detect land-use changes. The aerial images had a 0.5 meter resolution and they were from around the year 1990 (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

## Appendix\_11b

### Net emissions and removals from the activities under Articles 3.3

**Table 1\_App\_11b** Net emissions and removals from Afforestation and Reforestation, kt CO<sub>2</sub> eq.

	Biomass	DOM+SOM Mineral soils	DOM+SOM Organic soils	Biomass Burning	Drained organic soils N <sub>2</sub> O	Drained orgainc soils CH <sub>4</sub>	HWP	Total
	kt CO <sub>2</sub> eq							
1990	81	43	31	NO	2.1	0.8	IE	159
1991	10	79	63	NO	4.3	1.4	IE	157
1992	-77	106	94	NO	6.4	2.2	IE	132
1993	-168	122	123	NO	8.3	2.8	IE	88
1994	-236	138	151	NO	10.1	3.3	IE	67
1995	-315	150	175	NO	11.7	3.7	IE	25
1996	-387	155	201	NO	13.3	4.3	IE	-13
1997	-452	158	222	NO	14.7	4.6	IE	-53
1998	-506	162	245	NO	16.0	4.9	IE	-77
1999	-572	160	264	NO	17.1	5.2	IE	-126
2000	-626	151	281	NO	18.1	5.4	IE	-171
2001	-665	141	293	NO	18.9	5.5	IE	-207
2002	-699	129	303	NO	19.6	5.5	IE	-241
2003	-730	116	308	NO	20.1	5.4	IE	-280
2004	-746	107	314	NO	20.6	5.4	IE	-299
2005	-769	98	319	NO	21.1	5.4	IE	-326
2006	-796	93	321	NO	21.4	5.4	IE	-355
2007	-818	87	325	NO	21.9	5.4	IE	-379
2008	-843	82	328	0.07	22.3	5.3	IE	-405
2009	-867	76	331	0.04	22.6	5.3	IE	-433
2010	-886	67	327	0.04	22.9	5.2	IE	-463
2011	-901	57	323	NO	23.1	5.1	IE	-492
2012	-913	47	317	NO	23.3	5.1	IE	-520
2013	-920	38	312	NO	23.4	5.0	IE	-542

**Table 2\_App\_11b** Net emissions and removals from Deforestation, kt CO<sub>2</sub> eq.

	Forest Biomass	DOM+SOM Mineral soils	DOM+SOM Organic soils +Deadwood	Conversion to water CO <sub>2</sub> kt CO <sub>2</sub> eq	Mineralizati on	Drained and rewetted organic soils CH <sub>4</sub>	Drained and rewetted organic soils N <sub>2</sub> O	HWP	Total	Conversion to water CH <sub>4</sub> <sup>1</sup> CH <sub>4</sub>
1990	959	14	20	NO	1.0	0.0	0.0	IO	995	NO
1991	1 100	29	32	NO	1.7	0.2	0.4	IO	1 163	NO
1992	1 199	46	50	NO	3.1	0.6	1.0	IO	1 299	NO
1993	1 333	59	75	NO	4.0	1.3	1.9	IO	1 475	NO
1994	1 412	74	111	NO	5.0	2.0	2.9	IO	1 607	NO
1995	1 424	90	136	NO	5.9	2.7	4.1	IO	1 663	NO
1996	1 501	102	173	NO	6.7	3.3	5.0	IO	1 791	NO
1997	1 689	109	222	NO	7.7	3.8	5.6	IO	2 037	NO
1998	1 805	149	241	NO	9.8	4.1	6.0	IO	2 215	NO
1999	1 950	166	314	0.16	11.0	4.5	6.5	IO	2 451	0.03
2000	2 109	169	353	0.31	11.2	4.9	7.1	IO	2 654	0.06
2001	2 468	206	430	0.47	13.3	5.3	7.6	IO	3 130	0.09
2002	2 567	227	496	0.63	15.0	5.7	8.2	IO	3 319	0.11
2003	2 755	263	547	0.79	17.0	6.3	9.0	IO	3 598	0.14
2004	2 957	290	596	0.79	18.8	6.8	9.8	IO	3 879	0.14
2005	2 932	299	672	0.79	19.9	7.6	11.0	IO	3 942	0.14
2006	2 734	342	765	0.79	22.2	8.5	12.4	IO	3 884	0.14
2007	2 669	327	756	0.79	21.6	9.9	14.4	IO	3 798	0.14
2008	2 417	355	830	0.79	23.6	11.1	16.3	IO	3 653	0.14
2009	2 233	341	895	0.63	23.3	12.3	18.0	IO	3 522	0.14
2010	1 993	386	935	0.47	26.0	13.2	19.3	IO	3 374	0.14
2011	1 688	357	959	0.31	24.1	14.1	20.6	IO	3 064	0.14
2012	1 578	362	1 002	0.16	24.0	14.5	21.3	IO	3 002	0.14
2013	1 435	353	1 070	0	23.5	14.9	21.9	IO	2 918	0.14

<sup>1</sup>Not in CRF-reporter

## Appendix\_11c

### Net emissions and removals from the activities under Article 3.4

**Table 1\_App\_11c** Net emissions and removals from Forest Management, kt CO<sub>2</sub> eq.

	Biomass	DOM+SOM		Biomass burning			Fertilization	Drained organic soils	Drained organic soils	HWP	Total
		mineral soils	organic soils	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O					
1990	-27 799	-7 852	12 200	3.9	4.83	0.40	20.6	1 137	1 486	NA	-20 799
1991	-42 681	-7 470	12 348	2.0	2.06	0.17	15.6	1 137	1 467	NA	-35 179
1992	-35 666	-7 582	11 734	9.8	3.67	0.30	6.6	1 138	1 448	NA	-28 906
1993	-33 030	-7 941	11 277	0.0	1.31	0.11	2.6	1 139	1 429	NA	-27 122
1994	-23 922	-8 830	10 644	7.4	2.89	0.24	8.9	1 139	1 410	NA	-19 539
1995	-22 380	-9 737	10 203	5.0	2.40	0.20	5.0	1 140	1 391	NA	-19 371
1996	-30 425	-10 745	10 095	4.1	1.67	0.14	5.9	1 140	1 372	NA	-28 551
1997	-23 934	-10 897	9 470	11.1	2.57	0.21	9.7	1 140	1 353	NA	-22 843
1998	-21 598	-10 871	8 895	1.4	0.95	0.08	10.3	1 141	1 334	NA	-21 086
1999	-24 034	-11 060	8 648	6.3	2.36	0.19	7.3	1 140	1 305	NA	-23 984
2000	-25 623	-10 635	8 458	2.8	0.98	0.08	7.4	1 140	1 275	NA	-25 374
2001	-30 755	-9 901	8 342	1.9	3.04	0.25	8.4	1 140	1 246	NA	-29 914
2002	-31 548	-9 346	8 101	5.9	3.25	0.27	8.9	1 136	1 216	NA	-30 422
2003	-32 124	-8 626	8 004	5.9	2.26	0.19	8.7	1 133	1 187	NA	-30 410
2004	-33 899	-8 023	7 991	3.7	0.69	0.06	9.2	1 129	1 158	NA	-31 631
2005	-38 485	-8 188	8 055	5.1	1.77	0.15	8.4	1 126	1 128	NA	-36 348
2006	-42 414	-8 292	8 145	15.1	2.82	0.23	14.0	1 122	1 099	NA	-40 307
2007	-33 984	-7 207	7 859	5.7	1.23	0.10	12.8	1 119	1 070	NA	-31 123
2008	-35 853	-7 511	7 493	9.1	1.57	0.13	27.2	1 113	1 011	NA	-33 709
2009	-50 594	-8 011	7 804	5.4	1.37	0.11	19.1	1 108	952	NA	-48 715
2010	-33 867	-7 460	7 084	5.3	0.83	0.07	17.4	1 103	894	NA	-32 222
2011	-32 365	-7 493	6 866	12.1	1.94	0.16	16.3	1 098	835	NA	-31 028
2012	-33 408	-8 468	6 891	1.1	0.52	0.04	11.5	1 097	835	NA	-33 040
2013	-24 622	-8 325	6 562	5.1	1.10	0.09	13.1	1 096	834	-21 617	-46 053

## 12 INFORMATION ON ACCOUNTING OF KYOTO UNITS

### 12.1 Information relevant to the first commitment period

#### 12.1.1 Background information

The standard electronic format tables are included in the submission (see RREG1\_FI\_2014.xlsx). The SEF tables include information on the AAU, ERU, CER, t-CER, l-CER and RMU in the Finnish registry 31.12.2014 as well as information on transfers of the units in 2014, to and from other Parties of the Kyoto Protocol.

#### 12.1.2 Summary of information reported in the SEF tables

The total number of AAU units in the registry at the end of the year 2014 corresponded to 326,415,793 tonnes CO<sub>2</sub> eq.

The number of units of ERU in registry corresponded to 6,321,416 tonnes CO<sub>2</sub> eq.

The units of CERs in the registry corresponded to 16,314,015 tonnes CO<sub>2</sub> eq.

The units of t-CERs in the registry corresponded to 17,712 tonnes CO<sub>2</sub> eq.

The registry did not contain any RMUs 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 349,068,936 tonnes CO<sub>2</sub> eq. Finland's assigned amount is 355,017,545 tonnes CO<sub>2</sub> eq.

#### 12.1.3 Discrepancies and notifications

The Finnish national registry does not hold units in 2014 that are not valid for use towards compliance with commitments under Article 3, paragraph 1 pursuant to paragraph 43 (b) of the annex to decision 13/ CMP.1.

#### 12.1.4 Publicly accessible information

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:

- **Public information required by Decision 13/CMP.1:**
  - Legal Entities
  - 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)
- **Public information in accordance with the Commission regulation (EU) N:o 1123/2013:**
- Decision given by Energy Authority at 24th of January 2014 on international credit entitlements during period 2008-2020 (Dnro 1159/320/2013) (only in Finnish)
- Correction given by Energy Authority at 6th of March 2014 to the original decision made at 24th of January 2014 (Dnro 1159/320/2013) (only in Finnish)
- **Other public information:**
- Decisions given by Ministry of Employment and the Economy on free allocation of emission allowances during emissions trading period 2013-2020

In addition, “Kyoto Protocol Public Reports” are also available on the Finnish part of the Union registry web site: <https://ets-registry.webgate.ec.europa.eu/euregistry/FI/public/reports/publicReports.xhtml>

### *12.1.5 Calculation of the commitment period reserve (CPR)*

The commitment period reserve for the first commitment period is calculated as 100 per cent times the total national emissions without the LULUCF sector in 2012 in the most recent inventory applicable to the first commitment period (the reviewed 2014 inventory submission) and amounts to 304,828,656 tonnes CO<sub>2</sub> eq.

Finland’s assigned amount for the first commitment period is 355,017,545 tonnes of CO<sub>2</sub> eq. and a commitment period reserve value, calculated as 90% of the assigned amount would amount to 319,515,790 tonnes of CO<sub>2</sub> eq, which is higher than the one given above and calculated as 100 per cent times the most recently reviewed inventory for the first commitment period.

### *12.1.6 KP-LULUCF accounting*

Finland elected accounting of all KP-LULUCF activities at the end of the first commitment period. The review of the last inventory submission (2014 submission) was finalised in February 2015. No information on the accounting of the KP-LULUCF is therefore included in the SEF tables for 2014.

In Table 12.1-1 data on accounting for the KP-LULUCF activities based on cumulative data for the years 2008 - 2012 are given. According to this information Finland shall issue 476,368 RMU units for the activity afforestation and reforestation, cancel 14,516,159 AAUs, ERUs, CERs or RMU units for the activity deforestation and issue 16,973,124 RMU unit for the activity forest management.

Finland has implemented these transactions in April 2015. For the activity afforestation and reforestation Finland cancelled 14,516,159 AAUs.

**Table 12.1-1** Information table on final accounting for activities under Articles 3.3 and 3.4 for the first commitment period of the Kyoto Protocol, t CO<sub>2</sub> eq. (2014 annual submission<sup>1</sup>)

	As reported	Revised estimates	Final accounting quantity <sup>2</sup>
Afforestation and reforestation			
Non-harvested land	-476 368		-476 368
Harvested land	NA		NA
Deforestation	14 516 159		14 516 159
Forest management	-16 973 124		-16 973 124
Article 3.3 offset	-14 039 791		-14 037 791
Forest management cap	-2 933 333		-2 933 333
Cropland management	NA		NA
Grazing land management	NA		NA
Revegetation	NA		NA

<sup>1</sup> The values included under the 2014 annual submission are the cumulative accounting values for 2008, 2009, 2010, 2011 and 2012, as reported in the accounting table of the KP-LULUCF CRF tables for the inventory year 2012

<sup>2</sup> The "final accounting quantity" is the quantity of Kyoto Protocol units that the Party shall issue or cancel under each activity under Article 3, paragraph 3, and paragraph 4, if relevant, based on the final accounting quantity in the 2014 annual submission

## *12.2 Information for the second commitment period*

### *12.2.1 Background information*

The standard electronic format tables (SEF) will be included in the first inventory submission for the second commitment period of the Kyoto Protocol. However, in the sections below a summary of the information to be included in the SEF tables is given.

### *12.2.2 Summary of information reported in the SEF tables*

The registry contained only CER units at the end of year 2014. The units of CERs in the registry corresponded to 113,213 tonnes CO<sub>2</sub> eq.

The registry did not contain any AAUs, ERUs, RMUs, t-CERs or l-CERs. No units were in the retirement account. The total number of units in the registry at the end of the year 2014 corresponded to 113,213 tonnes CO<sub>2</sub> eq.

### *12.2.3 Discrepancies and notifications*

The Finnish national registry does not hold units in 2014 that are not valid for use towards compliance with commitments under Article 3, paragraph 1 pursuant to paragraph 43 (b) of the annex to decision 13/ CMP.1.

### *12.2.4 Publicly accessible information*

The publicly available information is described in Section 12.1.4 above.

### *12.2.5 Calculation of the commitment period reserve (CPR)*

Finland's assigned amount is 240,544,599 tonnes of CO<sub>2</sub> eq. and the commitment period reserve is 216,490,139 tonnes of CO<sub>2</sub> eq. calculated as 90% of the assigned amount would amount tonnes of CO<sub>2</sub> eq.

A commitment period reserve calculated as 100 per cent times the most recently reviewed inventory would result in a higher value.

### *12.2.6 Accounting under the Kyoto Protocol*

The EU, its Member States, including Finland, and Iceland are fulfilling their quantified emission reduction targets for the second commitment period of the Kyoto Protocol jointly. The level of emissions allocated to Finland is equal to Finland's national total emissions without the LULUCF sector minus the emissions included in the EU ETS including the CO<sub>2</sub> emissions from civil aviation assigned amount under the Kyoto Protocol covers. Finland's assigned amount is fixed in the agreement on the burden sharing between the EU, its Member States and Iceland, to 240,544,599 tonnes CO<sub>2</sub> eq.

In 2013 Finland's total national emissions without LULUCF were 63,069,302 tonnes CO<sub>2</sub> eq, the EU ETS emissions were 31,496,743 tonnes CO<sub>2</sub> eq and the CO<sub>2</sub> emissions from civil aviation were 192,190 tonnes CO<sub>2</sub> eq, which means that the accountable emissions amounted to 31,380,369 tonnes CO<sub>2</sub> eq.

In addition, Finland is responsible for any credits/debits resulting from emissions/removals from the KP LULUCF activities. 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 for the second commitment period.

In Table 12.2-1 data on accounting for the KP-LULUCF activities based on the reporting for the year 2013 are given. According to this information, Finland would at the end of the commitment period be able to issue RMUs corresponding to the net amount of -13,356,983 tonnes CO<sub>2</sub> eq.

**Table 12.2-1** Information table on accounting for activities under Articles 3.3 and 3.4 for the second commitment period of the Kyoto Protocol, kt CO<sub>2</sub> eq.

<b>Article 3.3 net emissions</b>	<b>2 375 953</b>
Article 3.4 net removals (FM)	-46 052 936
Finland's FMRL	-19 300 000
Technical correction to the FMRL	-11 020 000
<b>FM net removals minus FMRL and the technical correction</b>	<b>-15 732 936</b>
Article 3.4 cap	-19 971 700
<b>Estimate of net additions/subtractions to the assigned amount from Article 3.3 and 3.4<sup>1)</sup></b>	<b>13 356 983</b>

- 1) Sum of ADR net emissions and FM net removals minus FMRL and the technical correction (the sign has been changed to positive to indicate that this amount (net) will be added to the assigned amount)

## 13 INFORMATION ON CHANGES IN NATIONAL SYSTEM

No changes were implemented in Finland's national system during 2014. In 2015, the Climate Law was adopted by naming Statistics Finland as the national entity for national greenhouse gas inventory system. The Climate Law enforces Statistics Finland's role as the national entity responsible for the greenhouse gas inventory. In 2015, also the agreements between Statistics Finland and the ministries and expert organisations involved in the inventory preparation will be updated. The new agreements will implement changes in the accounting and reporting requirements for the second commitment period of the Protocol, and also the EU MMR but no other substantial changes in the organisation or functions of the national system have been made. The national systems has been described in the Section 1.2.

# 14 INFORMATION ON CHANGES IN NATIONAL REGISTRY

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.

Chapter 14 has been updated for this submission to incorporate the changes in the registry since the 2014 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.

**Table 14.1-1** Changes to the national registry of Finland (Table will be updated in the next submission)

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.
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. Versions of the CSEUR released after 6.1.7.1 (the production version at the time of the last Chapter 14 submission) introduced changes in the structure of the database. These changes 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 since version 6.1.7.1 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 2015 and the test report is attached as Annex H. 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.

Reporting Item				Description
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				<p>The indication of the Commitment Period for relevant accounts has been included in the public table of account information on the web site:  <a href="http://www.energiavirasto.fi/en/web/energy-authority/public-reports">http://www.energiavirasto.fi/en/web/energy-authority/public-reports</a></p> <p>The statements have been added on the public web site:  <a href="http://www.energiavirasto.fi/en/web/energy-authority/public-reports">http://www.energiavirasto.fi/en/web/energy-authority/public-reports</a></p> <p>“This document does not contain information considered confidential under the Article 110 of the Commission Regulation (EU) N:o 389/2013. Therefore, the following information is not disclosed in the document: account number, representative identifier, representative name and all the contact information including the full name, mailing address, telephone number, facsimile number and e-mail address of the representative of the account holder”</p> <p>“These documents do not contain information considered confidential under the Article 110 of the Commission Regulation (EU) N:o 389/2013. Under the Article 110 information held in the EUTL, the Union Registry and any other KP registry shall be considered confidential with very limited exceptions due to EU law or national law. Article 110 contains a non-exhaustive list on such classified information, including the holdings of all accounts, all transactions made, the unique unit identification code of the allowances and the unique numeric value of the unit serial number of the Kyoto units held or affected by a transaction. Therefore, the documents contain only information on a general level and the detailed information on holding and transaction of the units is not disclosed in the documents”</p>
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.
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				<p>Changes introduced since version 6.1.7.1 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.</p> <p>Annex H testing was carried out in February 2015 and the test report is attached as Annex H.</p>
The previous recommendations	Annual	Review	<p>P2.4.2.1: In response to questions raised by the assessor during the review 2014, “ Finnish national registry does not hold units in 2013 that are not valid for use towards compliance with commitments under Article 3, paragraph 1 pursuant to paragraph 43 (b) of the annex to decision 13/ CMP.1.</p> <p>P2.4.2.2 and P2.4.2.3: See the response in the above reporting item: 15/CMP.1 annex II.E paragraph 32.(g)</p> <p>P2.4.2.4: In response to questions raised by the ERT during the review 2014, “Finland provided in 2013 the additional description of database structure and the complete reporting of test results to the secretariat.”</p>	

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 Annex 8.

## 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 provided in Finland's 6th National Communication and the previous inventory are incorporated into this inventory report. The main principles of minimizing 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 the Mekong Region, southern and eastern Africa, and the Andean Region.

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, ultra-critical 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.	<p>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.</p>
(f) Assisting developing country Parties that are highly dependent on the export and consumption of fossil fuels in diversifying their economies.	<p>Action has been undertaken both through support by international organisations such as UNCTAD (United Nations Conference on Trade and Development) and through bilateral partnerships.</p>

Action	Implementation in Finnish policy
	<p>Examples on bilateral partnerships include capacity-building 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 access to clean energy and renewable energy business opportunities through the Energy and Environment Partnership (EEP) Programme, launched during the United Nations World Summit on Sustainable Development in 2002 and currently implemented in 3 regions: the Mekong Region covering Lao PDR, Cambodia, Vietnam, Myanmar and Thailand; Southern and Eastern Africa covering 13 countries: Botswana, Burundi, Kenya, Lesotho, Mozambique, Namibia, Rwanda, Seychelles, South Africa, Swaziland, Tanzania, Uganda, Zambia; and the Andean Region covering Bolivia, Colombia, Peru and Ecuador. EEP programmes in Central America and Indonesia have been successfully completed.</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 feasibility studies and pilot and demonstration projects as well as innovative business models. 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. The level of disaggregation is based on the recommendation in 2006 GLs.

Key categories analysis according to Approach 1 (2006 IPCC Guidelines) is done by CRF Reporter. The results are presented in CRF table 7 and also here below in Table 1.

**Table 1.** Key categories identified using Approach 1 level and trend assessment

Category		Gas	Level		Trend
			Base year	Year 2013	
1A1 Energy Industries	Liquid	CO2	Yes	Yes	Yes
1A1 Energy Industries	Solid	CO2	Yes	Yes	Yes
1A1 Energy Industries	Gaseous	CO2	Yes	Yes	Yes
1A1 Energy Industries	Other fossil	CO2		Yes	Yes
1A1 Energy Industries	Peat	CO2	Yes	Yes	Yes
1A1 Energy Industries	Biomass	N2O			Yes
1A2 Manufacturing Industries and Construction	Liquid	CO2	Yes	Yes	Yes
1A2 Manufacturing Industries and Construction	Solid	CO2	Yes	Yes	Yes
1A2 Manufacturing Industries and Construction	Gaseous	CO2	Yes	Yes	Yes
1A2 Manufacturing Industries and Construction	Other fossil	CO2		Yes	Yes
1A2 Manufacturing Industries and Construction	Peat	CO2	Yes	Yes	Yes
1A3b Road Transportation		CO2	Yes	Yes	Yes
1A3c Railways		CO2			Yes
1A3d Domestic Navigation	Liquid	CO2		Yes	Yes
1A4 Other Sectors	Liquid	CO2	Yes	Yes	Yes
1A4 Other Sectors	Peat	CO2			Yes
1A4 Other Sectors	Biomass	CH4		Yes	Yes
1A5 Other	Liquid	CO2	Yes	Yes	Yes
1A5 Other	Gaseous	CO2			Yes
2A1 Cement Production		CO2	Yes	Yes	Yes
2A2 Lime Production		CO2		Yes	Yes
2A4 Other Process Uses of Carbonates		CO2			Yes
2B2 Nitric Acid Production		N2O	Yes		Yes
2B10 Other		CO2		Yes	Yes
2C1 Iron and Steel Production		CO2	Yes	Yes	Yes
2D Non-energy Products from Fuels and Solvent Use		CO2			Yes
2F1 Refrigeration and Air Conditioning		Agg. F-gases		Yes	Yes
3A Enteric Fermentation		CH4	Yes	Yes	Yes
3B Manure Management		CH4		Yes	Yes
3B Manure Management		N2O		Yes	
3D1 Direct N2O Emissions From Managed Soils		N2O	Yes	Yes	Yes
3D2 Indirect N2O Emissions From Managed Soils		N2O	Yes	Yes	
3G Liming		CO2	Yes		Yes
4A1 Forest Land Remaining Forest Land		CO2	Yes	Yes	Yes
4A2 Land Converted to Forest Land		CO2		Yes	Yes
4B1 Cropland Remaining Cropland		CO2	Yes	Yes	Yes
4B2 Land Converted to Cropland		CO2	Yes	Yes	Yes
4C1 Grassland Remaining Grassland		CO2	Yes		
4D11 Peat Extraction Remaining Peat Extraction		CO2	Yes	Yes	Yes
4D13 Other Wetlands Remaining Other Wetlands		CO2			Yes
4D2 Land converted to Wetlands		CO2			Yes
4E2 Land converted to Settlements		CO2	Yes	Yes	Yes
4G Harvested Wood Products		CO2	Yes	Yes	Yes
4(II) Drainage and rewetting and other management of soils		CH4	Yes	Yes	Yes
4(II) Drainage and rewetting and other management of soils		N2O	Yes	Yes	Yes
5.A. Solid Waste Disposal		CH4	Yes	Yes	Yes

## ANNEX 2. Assessment of uncertainty

**Table 1.** Approach 2 uncertainty assessment

Category	CFR fuel	Gas	Emissions/ removals 1990	Emissions/ removals 2013	Activity data uncertainty 2013		Emission factor/ implied EF uncertainty 2013		Uncertainty in emissions 2013		Share of total uc in emissions 2013	Category trend 1990-2013	Uncertainty in trend 2013	
			Gg CO <sub>2</sub> -eq	Gg CO <sub>2</sub> -eq	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	%	%	(-) %	(+) %
0I Indirect emissions		CO <sub>2</sub>	261.6	80.4					14	14	0.01	-69	3	4
1A1 Energy Industries	Liquid	CO <sub>2</sub>	2 613.0	2 130.4	1	1	3	3	3	3	0.05	-18	4	5
1A1 Energy Industries	Liquid	CH <sub>4</sub>	1.1	1.0	1	1	36	36	36	36	0.00	-7	16	21
1A1 Energy Industries	Liquid	N <sub>2</sub> O	23.3	21.6	1	1	39	39	39	39	0.01	-7	19	23
1A1 Energy Industries	Solid	CO <sub>2</sub>	9 640.1	10 664.8	1	1	1	1	1	1	0.13	11	5	5
1A1 Energy Industries	Solid	CH <sub>4</sub>	2.7	3.3	1	1	57	57	57	57	0.00	19	73	197
1A1 Energy Industries	Solid	N <sub>2</sub> O	41.7	66.5	1	1	57	57	57	57	0.04	59	99	262
1A1 Energy Industries	Gaseous	CO <sub>2</sub>	2 636.2	3 877.1	1	1	0	0	1	1	0.03	47	3	3
1A1 Energy Industries	Gaseous	CH <sub>4</sub>	1.2	1.9	1	1	48	49	48	49	0.00	57	82	170
1A1 Energy Industries	Gaseous	N <sub>2</sub> O	15.0	23.2	1	1	47	46	47	46	0.01	54	76	151
1A1 Energy Industries	Peat	CO <sub>2</sub>	3 951.6	4 794.3	2	2	2	2	3	3	0.13	21	9	10
1A1 Energy Industries	Peat	CH <sub>4</sub>	3.0	5.3	2	2	60	60	60	60	0.00	79	115	308
1A1 Energy Industries	Peat	N <sub>2</sub> O	33.4	61.3	2	2	60	60	60	60	0.03	84	117	324
1A1 Energy Industries	Biomass	CH <sub>4</sub>	1.7	13.0	3	3	57	57	57	57	0.01	661	475	1 347
1A1 Energy Industries	Biomass	N <sub>2</sub> O	2.9	119.4	3	3	56	56	56	56	0.06	3 993	2 508	7 305
1A1 Energy Industries	Other fossil	CO <sub>2</sub>	1.0	279.7	5	5	15	15	16	16	0.04	27 837	10 675	30 375
1A1 Energy Industries	Other fossil	CH <sub>4</sub>	0.0	0.4	5	5	60	60	60	60	0.00	21 664	14 505	51 906
1A1 Energy Industries	Other fossil	N <sub>2</sub> O	0.0	4.4	5	5	60	60	60	60	0.00	88 007	58 481	211 635
1A2 Manufacturing industries and construction	Liquid	CO <sub>2</sub>	4 855.5	3 261.2	6	6	1	1	6	6	0.19	-33	6	7
1A2 Manufacturing industries and construction	Liquid	CH <sub>4</sub>	3.9	3.5	6	6	30	31	31	33	0.00	-11	31	43
1A2 Manufacturing industries and construction	Liquid	N <sub>2</sub> O	38.2	22.6	6	6	29	48	29	49	0.01	-41	22	37
1A2 Manufacturing industries and construction	Solid	CO <sub>2</sub>	4 841.6	2 171.9	2	2	4	4	4	4	0.08	-55	2	3
1A2 Manufacturing industries and construction	Solid	CH <sub>4</sub>	1.6	0.5	2	2	27	27	27	27	0.00	-70	10	16
1A2 Manufacturing industries and construction	Solid	N <sub>2</sub> O	44.9	8.6	2	2	26	26	26	26	0.00	-81	6	11
1A2 Manufacturing industries and construction	Gaseous	CO <sub>2</sub>	2 198.6	1 652.9	2	2	0	0	2	2	0.03	-25	2	2
1A2 Manufacturing industries and construction	Gaseous	CH <sub>4</sub>	1.2	0.9	2	2	44	44	44	44	0.00	-22	39	83
1A2 Manufacturing industries and construction	Gaseous	N <sub>2</sub> O	14.6	11.1	2	2	48	48	48	48	0.00	-24	40	81
1A2 Manufacturing industries and construction	Peat	CO <sub>2</sub>	1 475.9	1 004.8	2	2	2	2	3	3	0.02	-32	6	7
1A2 Manufacturing industries and construction	Peat	CH <sub>4</sub>	1.1	0.7	2	2	54	54	54	54	0.00	-34	37	59
1A2 Manufacturing industries and construction	Peat	N <sub>2</sub> O	15.4	8.3	2	2	54	54	54	54	0.00	-46	31	53
1A2 Manufacturing industries and construction	Biomass	CH <sub>4</sub>	8.3	14.9	2	2	31	32	31	32	0.00	81	69	121
1A2 Manufacturing industries and construction	Biomass	N <sub>2</sub> O	54.7	77.7	2	2	40	39	40	39	0.03	42	64	114
1A2 Manufacturing industries and construction	Other fossil	CO <sub>2</sub>	125.2	416.9	3	3	7	7	8	8	0.03	233	57	75
1A2 Manufacturing industries and construction	Other fossil	CH <sub>4</sub>	0.1	0.4	3	3	36	36	36	36	0.00	172	129	363
1A2 Manufacturing industries and construction	Other fossil	N <sub>2</sub> O	0.6	3.7	3	3	27	27	27	27	0.00	471	218	446

Category	CFR fuel	Gas	Emissions/ removals 1990	Emissions/ removals 2013	Activity data uncertainty 2013		Emission factor/ implied EF uncertainty 2013		Uncertainty in emissions 2013		Share of total uc in emissions 2013	Category trend 1990-2013	Uncertainty in trend 2013	
			Gg CO2-eq	Gg CO2-eq	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	%	%	(-) %	(+) %
1A3a Civil aviation	Liquid	CO2	385.1	192.2	20	20	2	2	20	20	0.04	-50	11	12
1A3a Civil aviation	Liquid	CH4	0.3	0.2	20	20	99	100	99	106	0.00	-43	97	318
1A3a Civil aviation	Liquid	N2O	4.7	2.5	20	20	69	150	70	153	0.00	-45	42	186
1A3b Road transportation	Diesel oil	CO2	4 923.5	7 056.6	1	1	1	2	2	2	0.12	43	4	4
1A3b Road transportation	Diesel oil	CH4	13.7	3.8	1	1	50	50	50	50	0.00	-72	15	34
1A3b Road transportation	Diesel oil	N2O	65.5	46.3	1	1	70	149	70	149	0.06	-29	55	243
1A3b Road transportation	Motbr gasoline	CO2	5 882.5	4 162.5	2	2	2	2	3	3	0.11	-29	3	3
1A3b Road transportation	Motbr gasoline	CH4	93.2	14.4	2	2	50	50	50	50	0.01	-85	8	19
1A3b Road transportation	Motbr gasoline	N2O	88.3	19.5	2	2	70	151	70	151	0.03	-78	17	77
1A3b Road transportation	Gaseous	CO2		6.1	3	3	1	1	3	3	0.00			
1A3b Road transportation	Gaseous	CH4		0.1	3	3	50	50	50	50	0.00			
1A3b Road transportation	Gaseous	N2O		0.1	3	3	70	149	70	149	0.00			
1A3b Road transportation	Biomass	CH4		1.0	1	1	75	75	75	75	0.00			
1A3b Road transportation	Biomass	N2O		4.1	1	1	59	117	59	117	0.00			
1A3c Railways	Liquid	CO2	191.1	92.7	5	5	1	2	5	5	0.00	-51	3	4
1A3c Railways	Liquid	CH4	0.3	0.1	5	5	50	50	50	50	0.00	-52	27	59
1A3c Railways	Liquid	N2O	1.5	0.4	5	5	70	149	70	150	0.00	-70	24	106
1A3d Navigation	Liquid	CO2	441.3	475.8	6	6	1	1	6	6	0.03	8	9	10
1A3d Navigation	Liquid	CH4	5.4	3.3	6	6	80	81	80	81	0.00	-40	57	279
1A3d Navigation	Liquid	N2O	2.8	3.4	6	6	53	94	53	94	0.00	21	77	207
1A3d Navigation	Biomass	CH4		0.1	11	11	96	98	96	100	0.00			
1A3d Navigation	Biomass	N2O		0.0	11	11	66	117	67	118	0.00			
1A3e Other Transportation	Gaseous	CO2	2.2	13.4	10	10	0	0	10	10	0.00	510	81	93
1A3e Other Transportation	Gaseous	CH4	0.0	0.0	10	10	60	60	60	61	0.00	1 743	1 184	3 254
1A3e Other Transportation	Gaseous	N2O	0.0	0.1	10	10	60	60	60	62	0.00	508	391	1 078

Category	CFR fuel	Gas	Emissions/ removals 1990	Emissions/ removals 2013	Activity data uncertainty 2013		Emission factor/ implied EF uncertainty 2013		Uncertainty in emissions 2013		Share of total uc in emissions 2013	Category trend 1990-2013	Uncertainty in trend 2013	
			Gg CO2-eq	Gg CO2-eq	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	%	%	(-) %	(+) %
1A4 Other sectors	Liquid	CO2	6 995.8	3 605.4	7	7	1	1	7	7	0.23	-48	6	7
1A4 Other sectors	Liquid	CH4	26.3	17.4	7	7	27	28	27	29	0.00	-34	23	38
1A4 Other sectors	Liquid	N2O	55.0	25.6	7	7	44	37	45	39	0.01	-53	23	36
1A4 Other sectors	Solid	CO2	46.5	9.3	9	9	1	1	9	9	0.00	-80	3	4
1A4 Other sectors	Solid	CH4	2.8	0.1	9	9	70	74	70	75	0.00	-96	3	11
1A4 Other sectors	Solid	N2O	0.6	0.1	9	9	42	42	43	44	0.00	-83	8	15
1A4 Other sectors	Gaseous	CO2	102.3	160.3	3	3	0	0	3	3	0.01	57	10	11
1A4 Other sectors	Gaseous	CH4	0.3	0.2	3	3	51	51	51	52	0.00	-20	45	106
1A4 Other sectors	Gaseous	N2O	0.6	0.9	3	3	33	34	34	34	0.00	55	60	91
1A4 Other sectors	Peat	CO2	121.6	241.6	9	9	2	2	9	9	0.02	99	35	49
1A4 Other sectors	Peat	CH4	1.5	2.9	9	9	44	44	44	46	0.00	98	97	155
1A4 Other sectors	Peat	N2O	1.4	2.8	9	9	63	133	63	133	0.00	96	138	420
1A4 Other sectors	Biomass	CH4	192.0	274.8	8	8	69	138	70	139	0.35	43	120	748
1A4 Other sectors	Biomass	N2O	26.7	37.5	8	8	61	125	61	126	0.04	41	99	342
1A4 Other sectors	Other fossil	CO2	0.2									-100		
1A4 Other sectors	Other fossil	CH4	0.0									-100		
1A4 Other sectors	Other fossil	N2O	0.0									-100		
1A5 Other energy	Liquid	CO2	1 045.6	825.1	15	15	2	2	16	16	0.12	-21	22	39
1A5 Other energy	Liquid	CH4	3.0	1.9	15	15	41	42	42	49	0.00	-36	33	76
1A5 Other energy	Liquid	N2O	8.0	6.6	15	15	38	51	40	54	0.00	-17	41	93
1A5 Other energy	Solid	CO2	1.2									-100		
1A5 Other energy	Solid	CH4	0.0									-100		
1A5 Other energy	Solid	N2O	0.0									-100		
1A5 Other energy	Gaseous	CO2	55.9	196.1	37	37	1	0	37	37	0.07	251	3 125	2 983
1A5 Other energy	Gaseous	CH4	0.1	0.3	37	37	60	60	64	78	0.00	250	3 477	3 613
1A5 Other energy	Gaseous	N2O	0.3	1.1	37	37	60	61	64	78	0.00	251	3 461	3 608
1A5 Other energy	Peat	CO2	24.0									-100		
1A5 Other energy	Peat	CH4	0.3									-100		
1A5 Other energy	Peat	N2O	0.1									-100		
1A5 Other energy	Biomass	CH4	0.3	0.9	10	10	60	60	60	62	0.00	166	171	474
1A5 Other energy	Biomass	N2O	0.3	0.2	10	10	59	59	59	61	0.00	-26	47	131
1A5 Other energy	Other fossil	CO2												
1A5 Other energy	Other fossil	CH4												
1A5 Other energy	Other fossil	N2O												

Category	CFR fuel	Gas	Emissions/ removals 1990	Emissions/ removals 2013	Activity data uncertainty 2013		Emission factor/ implied EF uncertainty 2013		Uncertainty in emissions 2013		Share of total uc in emissions 2013	Category trend 1990-2013	Uncertainty in trend 2013	
			Gg CO2-eq	Gg CO2-eq	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	%	%	(-) %	(+) %
1B2 Oil and Natural gas and other emissions from energy production		CO2	111.5	79.3					50	50	0.04	-29	39	85
1B2 Oil and Natural gas and other emissions from energy production		CH4	10.9	40.0					20	20	0.01	268	141	409
1B2 Oil and Natural gas and other emissions from energy production		N2O	0.7	0.9					50	50	0.00	37	76	167
2A1 Cement production		CO2	733.6	485.7	2	2	5	5	5	5	0.02	-34	2	2
2A2 Lime production		CO2	382.6	401.1	2	2	3	3	4	4	0.01	5	5	5
2A3 Limestone and dolomite use		CO2	20.9	2.0	5	5	3	3	6	6	0.00	-90	1	1
2A4 Other process uses of carbonates		CO2	40.6	137.4	4	4	3	3	5	5	0.01	239	21	22
2B1 Ammonia production		CO2	93.0								0.00	-100		
2B2 Nitric acid production		N2O	1 591.6	211.1	3	3	15	15	15	15	0.03	-87	9	72
2B10a Phosphoric acid production		CO2	24.5	41.6					7	7	0.00	69	25	32
2B10b Hydrogen production		CO2	116.2	793.3	5	5	3	3	6	6	0.04	583	74	88
2B10c Limestone and dolomite use		CO2	35.4	75.1	5	5	3	3	6	6	0.00	112	17	19
2C1 Iron and steel production		CO2	1 966.7	2 073.2					7	7	0.13	5	24	43
2C1 Iron and steel production		CH4	0.0	0.0	3	3	20	20	20	20	0.00	80	7	8
2C7 Other Metal Industry		CO2	8.9	21.5					5	5	0.00	142	0	0
2D1 Lubricant use		CO2	207.5	72.6	20	20	7	7	21	22	0.01	-65	9	12
2D1 Lubricant use		CH4	0.3	0.1	20	20	59	60	61	66	0.00	-65	9	12
2D1 Lubricant use		N2O	1.7	0.6	20	20	60	60	61	67	0.00	-65	9	12
2D2 Paraffin wax use		CO2	10.2	18.9	20	20	100	100	100	106	0.02	86	47	62
2D3 Other non energy products		CO2		4.8					10	10	0.00			
2F1 Refrigeration and air conditioning		HFCs	0.0	1 477.0					10	10	0.14	10 833 175	5 088 819	32 101 068
2F1 Refrigeration and air conditioning		PFCs		3.5					20	20	0.00			
2F2 Foam blowing agents		HFCs		12.0					20	20	0.00			
2F4 Aerosols		HFCs		66.2					30	30	0.02			
2G1 Electrical equipment		SF6	45.0	10.0					60	60	0.01	-78	21	116
2G3 N2O from product uses		N2O	64.5	27.5	10	10	0	0	10	10	0.00	-57	11	19
2H3 Other Industrial process and product se		HFCs	0.0	1.7					14	14	0.00	16 446	35 197	86 606
2H3 Other Industrial process and product se		PFCs	0.2	2.9					20	20	0.00	1 303	939	7 242
2H3 Other Industrial process and product se		SF6	7.5	20.7					19	19	0.00	177	647	1 439

Category	CFR fuel	Gas	Emissions/ removals 1990	Emissions/ removals 2013	Activity data uncertainty 2013		Emission factor/ implied EF uncertainty 2013		Uncertainty in emissions 2013		Share of total uc in emissions 2013	Category trend 1990-2013	Uncertainty in trend 2013	
			Gg CO2-eq	Gg CO2-eq	(-) %	(+) %	(-) %	(+) %	(-) %	(+) %	%	%	(-) %	(+) %
3A Enteric fermentation		CH4	2 425.0	2 063.4					18	18	0.34	-15	10	13
3B Manure management		CH4	367.7	455.5					34	34	0.14	24	27	35
3B Manure management		N2O	284.0	284.7					42	146	0.39	0	39	76
3D1 Direct soil emissions		N2O	3 277.3	2 958.2					60	112	3.06	-10	51	118
3D2 Indirect emissions		N2O	478.9	378.8					96	386	1.35	-21	76	1 704
3F Field burning of agricultural residues		CH4	3.1	2.1					46	54	0.00	-32	29	53
3F Field burning of agricultural residues		N2O	1.0	0.6					38	44	0.00	-32	17	23
3G Liming		CO2	617.9	194.2					20	20	0.04	-69	0	2 200
3H Urea Application		CO2	0.7	0.3					30	30	0.00	-50	0	2 200
4A1 ForestLand remaining ForestLand		CO2	-22 886.1	-27 968.1					29	41	10.47	22	57	224
4A2 Land converted to ForestLand		CO2	-155.1	-448.3					55	85	0.35	189	1 692	1 365
4B1 Cropland remaining Cropland		CO2	4 160.1	4 222.5					76	161	6.27	1	71	212
4B2 Land converted to Cropland		CO2	1 310.5	2 208.3					49	96	1.97	69	82	161
4C1 Grassland remaining Grassland		CO2	620.8	382.3					142	256	0.90	-38	266	435
4C2 Land converted to Grassland		CO2	242.0	225.3					72	152	0.32	-7	63	232
4D1 Wetlands remaining Wetlands		CO2	1 367.9	2 004.8					70	150	2.77	47	114	515
4D2 Land converted to Wetlands		CO2	72.1	222.9					45	92	0.19	209	175	547
4E1 Settlements remaining Settlements		CO2												
4E2 Land converted to Settlements		CO2	975.6	947.2					30	38	0.33	-3	35	57
4G Harvested Wood Products		CO2	-4 313.2	-4 356.6					50	50	2.01	1	55	122
4(i) N fertilization		N2O	20.6	13.1	10	10	70	200	70	202	0.02	-37	8	10
4(ii) Drainage, rewetting and other management soils		CH4	1 535.2	921.1					99	100	0.85	-40	108	337
4(ii) Drainage, rewetting and other management soils		N2O	1 216.1	1 208.2					100	100	1.12	-1	191	551
4(iii) Mineralization		N2O	23.2	28.8					50	101	0.03	24	0	0
4(iv) Indirect N2O emissions		N2O	2.1	2.7					50	100	0.00	27	70	362
4(v) Biomass Burning		CO2	3.9	5.1	10	10	70	71	70	72	0.00	31	97	324
4(v) Biomass Burning		CH4	4.8	1.1	10	10	70	70	70	72	0.00	-77	17	57
4(v) Biomass Burning		N2O	0.4	0.1	10	10	70	69	70	71	0.00	-77	17	57
5A Solid Waste Disposal		CH4	4 327.8	1 952.2	30	30	30	30	39	46	0.83	-55	20	52
5B Biological Treatment of Solid Waste		CH4	25.8	74.4	17	17	65	67	65	70	0.05	189	118	291
5B Biological Treatment of Solid Waste		N2O	19.6	54.9	19	19	63	101	64	104	0.05	179	107	249
5D Wastewater Treatment and Discharge		CH4	221.0	174.1	13	13	28	33	28	30	0.05	-21	18	24
5D Wastewater Treatment and Discharge		N2O	79.1	76.6	8	8	95	410	95	411	0.29	-3	36	18

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 2013 emissions/removals are zero, all uncertainty columns are left blank. When either 1990 or 2013 emissions are zero, trend uncertainty columns are left blank.

### *ANNEX 3. Detailed methodological descriptions for individual source or sink categories*

The detailed methodological description are given in the sectoral chapters.

## ANNEX 4. The national energy balance for the most recent inventory year

### Energy Balance Sheet 2013, 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	–	–	–	–	6 151	1 171	1 697	0	8 117	–	399	<b>17 536</b>
Recycled oil	–	–	682	0	–	–	–	106	–	–	–	<b>920</b>
Imports	3 400	12 088	6 142	2 857	–	–	10	0	74	1 513	–	<b>26 083</b>
Exports	-49	–	-9 155	–	–	–	0	–	-45	-161	–	<b>-9 411</b>
International marine bunkers	–	–	-131	–	–	–	–	–	–	–	–	<b>-131</b>
Stock Changes	442	-56	-773	–	–	–	-390	–	–	–	–	<b>-777</b>
<b>Total Primary Energy Supply</b>	<b>3 793</b>	<b>12 032</b>	<b>-3 235</b>	<b>2 860</b>	<b>6 151</b>	<b>1 171</b>	<b>1 316</b>	<b>106</b>	<b>8 146</b>	<b>1 351</b>	<b>399</b>	<b>34 220</b>
Statistical Difference	17	-1 003	-830	1	–	–	-43	0	0	0	0	<b>-1 857</b>
Electricity generation	-1 438	–	-36	-32	-6 151	-1 171	-185	-19	-356	3 870	–	<b>-5 528</b>
Combined district heat and power	-1 229	–	-27	-1 045	–	–	-749	-1	-1 700	1 328	2 801	<b>-652</b>
Cogeneration electricity in industry	-12	–	-32	-195	–	–	-47	-29	-785	678	327	<b>-155</b>
District heat production	-144	–	-147	-318	–	–	-144	-10	-580	–	1 255	<b>-119</b>
Oil refinery	–	-13 035	11 972	–	–	–	–	–	–	–	–	<b>-1 063</b>
Coal transformation	-508	–	–	–	–	–	–	–	–	–	–	<b>-508</b>
Energy sector's own consumption	0	–	–	–	–	–	–	–	–	–	–	
Transmission and distributions losses	-47	–	-37	–	–	–	–	–	–	-224	-315	<b>-623</b>
<b>TFC (total final consumption)</b>	<b>398</b>	<b>–</b>	<b>8 992</b>	<b>1 268</b>	<b>–</b>	<b>–</b>	<b>233</b>	<b>47</b>	<b>4 955</b>	<b>7 003</b>	<b>4 468</b>	<b>27 362</b>
Industry	394	–	1 886	884	–	–	177	29	3 219	3 458	1 492	<b>11 608</b>
Transport	–	–	4 544	7	–	–	–	–	223	63	–	<b>4 837</b>
Residential	0	–	389	30	–	–	4	0	1 248	1 850	1 941	<b>5 462</b>
Agriculture	2	–	443	9	–	–	49	0	184	129	14	<b>830</b>
Commerce and public services	–	–	263	34	–	–	3	0	76	1 503	1 021	<b>2 900</b>
Other consumption	–	–	200	–	–	–	–	18	–	0	–	<b>223</b>
Non-energy use	–	–	1 267	302	–	–	–	0	–	–	–	<b>1 569</b>
Blast furnace oil (subtracted from TFC industry)												

## Energy Balance Sheet 2013, TJ

	Coal	Crude oil & NGL	Petroleum products	Natural gas	Nuclear energy	Hydro & wind power	Peat fuel	Recycled fuels	Wood fuels + biofuels	Other	Electricity	Heat sold & heat pumps	Total
	1	2	3	4	5	6	7		8		9	10	11
Indigenous production	-	-	-	-	257 520	49 025	71 061	0	339 854		-	16 722	<b>734 182</b>
Recycled oil and other	-	-	28 553	0	-	-	-	4 434	113	5 428	-	-	<b>38 529</b>
Imports	142 352	506 102	257 160	119 611	-	-	398	0	3 094		63 328	-	<b>1 092 045</b>
Exports	-2 051	0	-383 297	-	-	-	-20	-	-1 888		-6 754	-	<b>-394 010</b>
International marine bunkers	-	-	-5 498	-	-	-	-	-	-		-	-	<b>-5 498</b>
Stock Changes	18 506	-2 346	-32 364	-	-	-	-16 331	-	-		-	-	<b>-32 535</b>
<b>Total Primary Energy Supply</b>	<b>158 807</b>	<b>503 755</b>	<b>-135 444</b>	<b>119 724</b>	<b>257 520</b>	<b>49 025</b>	<b>55 108</b>	<b>4 434</b>	<b>341 060</b>	<b>5 428</b>	<b>56 574</b>	<b>16 722</b>	<b>1 432 713</b>
Statistical Difference	732	-41 990	-34 758	47	-	-	-1 784	0	0	0	4	0	<b>-77 749</b>
Electricity generation	-60 205	-	-1 506	-1 355	-257 520	-49 025	-7 747	-805	-14 904	-424	162 029	-	<b>-231 462</b>
Combined district heat and power	-51 461	-	-1 151	-43 733	-	-	-31 362	-55	-71 196	-1 216	55 595	117 270	<b>-27 308</b>
Cogeneration electricity in industry	-522	-	-1 330	-8 165	-	-	-1 980	-1 219	-32 864	-2 484	28 382	13 681	<b>-6 500</b>
District heat production	-6 027	-	-6 139	-13 334	-	-	-6 044	-404	-24 289	-1 305	-	52 556	<b>-4 987</b>
Oil refinery	-	-545 745	501 227	-	-	-	-	-	-	-	-	-	<b>-44 518</b>
Coal transformation	-21 249	-	-	-	-	-	-	-	-	-	-	-	<b>-21 249</b>
Energy sector's own consumption	0												<b>0</b>
Transmission and distributions losses	-1 968	-	-1 540	-	-	-	-	-	-		-9 392	-13 172	<b>-26 072</b>
<b>TFC (total final consumption)</b>	<b>16 644</b>	<b>-</b>	<b>376 476</b>	<b>53 090</b>	<b>-</b>	<b>-</b>	<b>9 758</b>	<b>1 947</b>	<b>207 442</b>		<b>293 184</b>	<b>187 057</b>	<b>1 145 598</b>
Industry	16 501	-	78 964	37 022	-	-	7 410	1 198	134 770		144 778	62 465	<b>485 988</b>
Transport	-	-	190 243	275	-	-	-	0	9 347		2 639	-	<b>202 504</b>
Residential	14	-	16 287	1 246	-	-	174	0	52 230		77 454	81 262	<b>228 667</b>
Agriculture	100	-	18 556	358	-	-	2 062	0	7 721		5 382	570	<b>34 748</b>
Commerce and public services	-	-	10 997	1 443	-	-	112	0	3 176		62 932	42 760	<b>121 419</b>
Other consumption	-	-	8 387	-	-	-	-	749	199		0	-	<b>9 335</b>
Non-energy use	29	-	53 042	12 632	-	-	-	-	-		-	-	<b>65 703</b>
Blast furnace oil (subtracted from TFC industry)			2 880										

## Energy Balance Sheet 2013, TJ

Comparison to CRF categories:							Total excluding biomass	including biomass	CRF2015_v1.1 sector totals excl. biomass	difference CRF/EB
Data from energy balance	Coal	Oil products	Natural gas	Peat	Recycled fuels and other	Wood fuels + biofuels				
Transformation (CRF 1A1)	118 214	56 184	66 587	47 134	2 483	143 253	289 361	433 855	268 494	-7.2 %
Industry (CRF 1A2)	16 501	78 964	37 022	7 410	1 198	134 770	140 496	275 865	109 373	-22.2 %
Transport (CRF 1A3) excl. bunker	–	163 614	275	–	0	9 347	163 890	173 237	163 988	0.1 %
Commerce and public services (CRF 1A4a)	–	10 997	1 443	112	0	3 176	12 552	15 727	14 524	15.7 %
Residential (CRF 1A4b)	14	16 287	1 246	174	0	52 230	17 721	69 951	20 214	14.1 %
Agriculture (CRF 1A4c)	100	18 556	358	2 062	0	7 721	21 075	28 796	19 290	-8.5 %
Other (CRF 1A5)	–	8 387	–	–	749	199	8 762	9 335	15 038	71.6 %
<b>Totals by fuel</b>	<b>134 829</b>	<b>379 618</b>	<b>106 932</b>	<b>56 892</b>	<b>4 430</b>	<b>350 695</b>	<b>678 270</b>	1 033 396		
Aviation bunkers correction		-26 629								
<b>Totals</b>	<b>134 829</b>	<b>352 989</b>	<b>106 932</b>	<b>56 892</b>	<b>4 430</b>	<b>350 695</b>	<b>656 071</b>	<b>1 006 767</b>	<b>610 922</b>	-6.9 %
	Solid fuels	Liquid fuels	Gaseous fuels	Peat	Other	Biomass				
<b>CRF totals by fuel</b>	<b>130 986</b>	<b>307 189</b>	<b>107 005</b>	<b>56 900</b>	<b>8 842</b>	<b>362 407</b>	<b>610 922</b>	<b>973 329</b>		
difference CRF/EB	-2.9 %	-13.0 %	0.1 %	0.0 %	99.6 %	3.3 %	-6.9 %	-3.3 %		

## Energy Balance Sheet 2013, kt 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	Other	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	7 544	0	36 035		–	0	7 544	43 579
Recycled oil	–	–	2 036	0	–	–	–	176	–		–	–	2 211	2 211
Imports	13 962	36 790	18 336	6 568	–	–	–	–	328		0	–	75 655	75 983
Exports	-201	–	-27 329	–	–	–	-2	–	–		0	–	-27 532	-27 532
International marine bunkers	–	–	-392	–	–	–	–	–	–		–	–	-392	-392
Stock Changes	1 815	-171	-2 308	–	–	–	-1 734	–	–		–	–	-2 397	-2 397
<b>Total Primary Energy Supply</b>	<b>15 576</b>	<b>36 619</b>	<b>-9 657</b>	<b>6 568</b>	<b>0</b>	<b>0</b>	<b>5 808</b>	<b>176</b>	<b>36 363</b>		<b>0</b>	<b>0</b>	<b>55 089</b>	<b>91 452</b>
Statistical Difference	–	–	-2 478	3	–	–	–	–	–		–	–	-2 476	-2 476
Electricity generation	5 905	–	107	74	0	0	822	32	1 580		0	–	6 941	8 521
Combined district heat and power	5 047	–	82	2 401	–	–	3 329	2	7 549		0	0	10 862	18 411
Cogeneration electricity in industry	51	–	95	448	–	–	210	48	3 485		0	–	853	4 337
District heat production	591	–	438	732	–	–	642	16	2 575		–	0	2 419	4 994
Oil refinery	–	39 672	-35 737	–	–	–	–	–	–		–	–	3 934	3 934
Coal transformation	2 084	–	–	–	–	–	–	–	–		–	–	2 084	2 084
Energy sector's own consumption	0	–	–	–	–	–	–	–	–		–	–	0	0
Transmission and distributions losses	193	–	110	–	–	–	–	–	–		0	0	303	303
<b>TFC (total final energy)</b>	<b>1 620</b>	<b>–</b>	<b>23 061</b>	<b>2 215</b>	<b>–</b>	<b>–</b>	<b>1 036</b>	<b>77</b>	<b>21 353</b>		<b>0</b>	<b>0</b>	<b>27 932</b>	<b>49 362</b>
Industry	1 618	–	5 630	2 033	–	–	787	47	14 290		0	0	10 068	24 405
Transport	–	–	13 564	15	–	–	–	–	370		–	–	13 579	13 950
Residential	1	–	1 161	68	–	–	18	0	5 538		0	0	1 249	6 787
Agriculture	–	–	1 323	20	–	–	219	0	819		0	0	1 562	2 380
Commerce and public services	–	–	784	79	–	–	12	0	337		0	0	875	1 212
Other consumption	–	–	598	–	–	–	–	30	–		0	–	598	628
Non-energy use	–	–	3 782	694	–	–	–	–	–		–	–	4 476	4 476
<b>Total CO<sub>2</sub> emissions</b>	<b>13 214</b>		<b>23 061</b>	<b>5 872</b>			<b>6 040</b>	<b>175</b>	<b>36 542</b>				<b>52 941</b>	<b>89 560</b>
(excluding non-energy use)														
CO <sub>2</sub> emission factor g/MJ	99.1	73.1	71.7	55.19	0.0	0.0	107.2	40.0	107.1		0.0	0.0		
oxidation factor	0.99	0.995	0.995	0.995	0.00	0.00	0.99	0.99	0.99		0.00	0.00		

## Energy Balance Sheet 2013, kt CO<sub>2</sub>

Comparison to CRF categories:							Total excluding biomass	including biomass	CRF2015_v1.1 sector totals difference excl. biomass CRF/EB	
<b>Data from energy balance</b>										
Transformation (CRF 1A1)	11 594	4 766	3 656	5 004	98	15 189	<b>25 021</b>	40 308	<b>21 745</b>	-13.1 %
Industry (CRF 1A2)	1 618	5 630	2 033	787	47	14 290	<b>10 068</b>	24 405	<b>8 509</b>	-15.5 %
Transport (CRF 1A3) excl. bunker	–	<b>11 615</b>	15	–	0	370	<b>11 630</b>	12 000	<b>11 999</b>	3.2 %
Commerce and public services (CRF 1A4a)	–	784	79	12	0	337	<b>875</b>	1 212	<b>1 055</b>	20.5 %
Residential (CRF 1A4b)	1	1 161	68	18	0	5 538	<b>1 249</b>	6 787	<b>1 476</b>	18.1 %
Agriculture (CRF 1A4c)	–	1 323	20	219	0	819	<b>1 562</b>	2 380	<b>1 486</b>	-4.8 %
Other (CRF 1A5)	–	598	–	–	30	–	<b>598</b>	628	<b>1 021</b>	70.8 %
Totals by fuel	<b>13 214</b>	<b>27 827</b>	<b>5 872</b>	<b>6 040</b>	<b>175</b>	<b>36 542</b>	<b>53 128</b>	89 670		
Aviation bunkers correction		<b>-1 949</b>								
<b>Totals</b>	<b>13 214</b>	<b>25 878</b>	<b>5 872</b>	<b>6 040</b>	<b>175</b>	<b>36 542</b>	<b>51 003</b>	<b>87 721</b>	<b>47 291</b>	-7.3 %
<b>CRF totals by fuel</b>	<b>12 846</b>	<b>21 802</b>	<b>5 905</b>	<b>6 041</b>	<b>698</b>	<b>38 388</b>	<b>47 291</b>	<b>85 679</b>		
difference CRF/EB	-2.8 %	-15.8 %	0.6 %	0.0 %	297.8 %	5.1 %	-7.3 %	-2.3 %		

## ANNEX 5. Assessment of completeness and (potential) sources and sinks of greenhouse gas emissions and removals excluded

Completeness of the Finnish inventory submission 2015 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) and emission categories according to the detailed CRF-classification.

Emission sources which are judged as insignificant are reported in Table 2.

### 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

**Table 1 Completeness of Finnish inventory by gases and emission categories**

### 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		Transferred CO <sub>2</sub> is included (subtracted from emissions) in this category.
e. Food Processing, Beverages and Tobacco	X	X	X		
f. Non-metallic minerals	X	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
g. Other:					
Off-road vehicles and other machinery	X	X	X		
Other manufacturing industries	X	X	X		
<b>3. Transport</b>					
a. Domestic Aviation	X	X	X		
b. Road Transportation	X	X	X		
c. Railways	X	X	X		
d. Domestic Navigation	X	X	X		
e. Other Transportation					
Pipeline Transport	X	X	X		
<b>4. Other Sectors</b>					
a. Commercial/Institutional	X	X	X		
b. Residential	X	X	X		
c. Agriculture/Forestry/ Fishing	X	X	X		
<b>5. Other</b>					
a. Stationary					
Other non-specified	X	X	X		
b. Mobile	X	X	X		

### **Energy, Fugitive emissions from fuels (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 and Handling	NO	NO	NO		
b. Solid Fuel Transformation	NO	NO	NO		
c. Other	NO	NO	NO		
<b>2. Oil and Natural Gas and Other Emissions from Energy Production</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
a. Oil	X	X	NO		
b. Natural Gas	X	X			
c. Venting and Flaring	X	X	X	Only flaring, since there is no venting, all process gases are routed to a fuel gas system, not vented.	
d. Other Distribution of town gas	X	X	NO	Only for years 1990-1993.	

### **Energy, CO<sub>2</sub> transport and storage (CRF 1.C)**

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.C. CO<sub>2</sub> transport and storage</b>					
Transport of CO <sub>2</sub>	NO				
Injection and storage	NO				

### **Industrial Processes and Product Use (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
<b>2. Industrial Processes and Product Use</b>					
<b>A. Mineral Products</b>					
1. Cement Production	X				
2. Lime Production	X				
3. Glass Production	X				
4. Other Process Uses of Carbonates					
a. Ceramics	X				
b. Other Uses of Soda Ash	X				
c. Non-metallurgical Magnesium Production	NO				
d. Other	X				
<b>B. Chemical Industry</b>					
1. Ammonia Production	X	NO	NO		No ammonia production in Finland after 1992.
2. Nitric Acid Production			X		Includes also N <sub>2</sub> O emissions from fertiliser production.

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
3. Adipic Acid Production	NO		NO		
4. Caprolactam, Glyoxal and Glyoxylic Acid Production	NO		NO		
5. Carbide Production	NO	NO			
6. Titanium Dioxide Production	IE			CO <sub>2</sub> emissions are from wastewater treatment 2.A.4d.	Production method is sulphate route process which does not give rise to process greenhouse gas emissions
7. Soda Ash Production	NO				
8. Petrochemical and Carbon Black Production					
a. Methanol	NO	NO			
b. Ethylene	NO	NO			
c. Ethylene Dichloride and Vinyl Chloride Monomer	NO	NO			
d. Ethylene Oxide	NO	NO			
e. Acrylonitrile	NO	NO			
f. Carbon Black	NO	NO			
g. Other	NO	NO			
9. Fluorochemical production					
a. By-Product Emissions				No production in Finland (no F gases emissions)	
b. Fugitive Emissions					
10. Other					
Phosphoric Acid Production	X	NO	NO		
Hydrogen Production	X	NO	NO		
Limestone and Dolomite Use	X	NO	NO		
Chemicals Production	NO	NO	NO		Only NMVOC emissions.
<b>C. Metal Production</b>					
1. Iron and Steel Production	X	X			Includes CO <sub>2</sub> emissions from integrated ferrochromium and stainless steel plant. Also CO <sub>2</sub> emissions from limestone use in steel plants and CH <sub>4</sub> emissions from coke production are included in this category
2. Ferroalloys Production	IE	NO		Emissions from integrated ferrochromium and stainless steel plant have been allocated to 2.C 1 Iron and steel production.	
3. Aluminium Production	NO	NO			
4. Magnesium Production	NO			SF <sub>6</sub> emissions are included in 2.H.3	

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. Lead Production	NO			Emissions are included in 2.C.7 Other due to confidentiality reasons.	Includes CO <sub>2</sub> emissions from zinc, copper and nickel production and NMVOC emissions from metal production.
6. Zinc Production	C				
7. Other	X				
D. Non-energy Products from Fuels and Solvent Use					
1. Lubricant Use	X	X	X		
2. Paraffin Wax Use	X			NMVOC emissions are included in Road paving with asphalt.	Includes also use of paraffin candles.
3. Other					
Solvent Use	NO				
Road paving with asphalt	NO				
Asphalt roofing	NO				
Use of urea-based catalysts	X				
G. Other Product Manufacture and Use					
3. N <sub>2</sub> O from Products Uses			X		
H. Other					
1. Pulp and paper					NMVOC emissions only.
2. Food and beverages industry					NMVOC emissions only.

### **F-gases (CRF 2.E, CRF 2.F, CRF 2.G and CRF 2.H)**

Greenhouse gas source and sink categories	HFC <sub>s</sub>	PFC <sub>s</sub>	SF <sub>6</sub>	NF <sub>3</sub>	Explanation, -if not estimated -if included elsewhere	Notes
<b>2. Industrial Processes and Product Use</b>						
<b>E. Electronics Industry</b>						
1. Integrated Circuit of Semiconductor	C	C	C	NO	C included in 2.H.3.	
2. TFT Flat Panel Display	NO	NO	NO	NO		
3. Photovoltaics	NO	NO	NO	NO		
4. Heat Transfer Fluid	NO	NO	NO	NO		

Greenhouse gas source and sink categories	HFC <sub>s</sub>	PFC <sub>s</sub>	SF <sub>6</sub>	NF <sub>3</sub>	Explanation, -if not estimated -if included elsewhere	Notes
5. Other	NO	NO	NO	NO		
<b>F. Consumption of Halocarbons and SF<sub>6</sub></b>						
1. Refrigeration and Air Conditioning Equipment	X	X	NO	NO		
2. Foam Blowing Agents	X	NO	NO	NO		Excl. one component foam.
3. Fire Protection	X, C	NO	NO	NO	C included in 2.H.3.	
4. Aerosols	X	NO	NO	NO		Incl. one component foam.
5. Solvents	NO	NO	NO	NO		
6. Other applications	NO	NO	NO	NO		
<b>G. Other Product Manufacture and Use</b>						
1. . Electrical Equipment	NO	NO	X	NO		
2. SF <sub>6</sub> and PFCs from Other Product Use		NO	NO	NO		
4. Other	NO	NO	NO	NO		
<b>H. Other</b>						
3. Grouped confidential data of halocarbons and SF <sub>6</sub>	X	X	X	NO		

### **Agriculture (CRF 3)**

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. Agriculture</b>					
<b>3.1 Livestock</b>					
<b>A. Enteric fermentation</b>					
1. Cattle					
Dairy Cattle		X			
Non-Dairy Cattle		X			
2. Sheep		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
3. Swine		X			
4. Other Livestock					
Poultry		NE		No methodology in the 2006 IPCC Guidelines	
Horses		X			
Goats		X			
Reindeer		X			
Fur-bearing Animals		X			
<b>B. Manure Management</b>					
1. Cattle		X	X	Emissions from composting and anaerobic digestion of manure regarded as insignificant	
Dairy Cattle		X	X		
Non-Dairy Cattle		X	X		
2. Sheep		X	X		
3. Swine		X	X		
4. Other Livestock					
Poultry		X	X		
Horses		X	X		
Goats		X	X		
Reindeer		X	NO		
Fur-bearing Animals		X	X		
5. Indirect N <sub>2</sub> O Emissions			X		
<b>C. Rice Cultivation</b>					
1. Irrigated		NO			
2. Rainfed		NO			
3. Deep Water		NO			
4. Other		NO			
<b>D. Agricultural Soils</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	
1. Direct N <sub>2</sub> O Emissions From Managed Soils						
1. Inorganic N Fertilisers			X			
2. Organic N Fertilisers			X			
3. Urine and Dung Deposited by Grazing Animals			X			
4. Crop Residues			X			
5. Mineralisation/Immobilisation Associated with Loss/Gain of Soil Organic Matter			X			
6. Cultivation of Organic Soils			X			
7. Other			NO			
2. Indirect N <sub>2</sub> O Emissions From Managed Soils						
1. Atmospheric Deposition				X		
2. Nitrogen Leaching and Run-off				X		
E. Prescribed Burning of Savannas						
Forest land		NO	NO			
Grassland		NO	NO			
F. Field Burning of Agricultural Residues						
1. Cereals		X	X			
2. Pulses		NO	NO			
3. Tubers and Roots		NO	NO			
4. Sugar Cane		NO	NO			
5. Other		NO	NO			
G. Liming						
1. Limestone CaCO <sub>3</sub>	X					
2. Dolomite CaMg(CO <sub>3</sub> ) <sub>2</sub>	X					
H. Urea Application						
1. Urea application	X					
I. Other Carbon-containing Fertilisers (no emissions)						
J. Other (no emissions)						

**Land Use Land Use Change and Forestry (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. Land use, Land use change and Forestry					
A. Forest land					
1. Forest land remaining forest land					
Carbon stock change	X, IE			IE: Litter and dead wood are reported under soil organic matter	See NIR 6.4.2
2. Land converted to forest land					
Carbon stock change					
- Cropland converted	X, IE, NO			IE: Litter and dead wood are reported under soil organic matter, Losses in living biomass are included in gains, the method gives an estimate for a net change	See NIR 6.4.2, Appendix_6c
- Grassland converted	X, IE, NO				
- Wetlands converted	X, IE, NO				
- Settlements converted	X, IE, NO				
- Other land converted	X, NO				
B. Cropland					
1. Cropland remaining cropland					
Carbon stock change	X, NE			NE: Emissions from DOM are considered insignificant.	See NIR 6.5.2
2. Land converted to cropland					
Carbon stock change					
- Forest land converted	X				
- Grassland converted	X				
- Wetlands converted	X				
- Settlements converted	NO, NE				
- Other land converted	NO				
C. Grassland					
1. Grassland remaining grassland					
Carbon stock change	X, NE			NE: Emissions from DOM are considered insignificant.	See NIR 6.6.2
2. Land converted to grassland					
Carbon stock change					
- Forest land converted	X				
- Cropland converted	X				
- Wetlands converted	X, NO				
- Settlements converted	NO, NE				
- Other land converted	NO				
D. Wetlands					
1. Wetlands remaining wetlands					

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
Carbon stock change					
1. Peat Extraction remaining peat extraction	X				
2. Flooded Land remaining flooded land	X				
3. Other Wetlands remaining other wetlands	X, NA				
2. Land converted to wetlands					
Carbon stock change					
1. Land converted for peat extraction					
Forest land	X				
Cropland	X, NA				
Grassland	X, NA				
2. Land converted to Flooded land					
Forest land converted	X, NA				
Cropland converted	X, NA				
Grassland converted	X, NA				
Settlements converted	X, NA				
Other land converted	X, NA				
3. Land converted to Other Wetlands					
Forest land converted	X, NA				
Grassland converted	NA				
Settlements converted	NA				
<b>E. Settlements</b>					
1. Settlements remaining settlements					
Carbon stock change	NA				
2. Land converted to settlements					
Carbon stock change					
Forest land converted	X, NA				
Cropland converted	X, NA				
Grassland converted	X, NA				
Wetlands converted	X, NA				
Other land converted	NA				
<b>F. Other land</b>					
1. Other land remaining other land					
Carbon stock change	NA				
2. Land converted to other land					

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
Carbon stock change					
Forest land converted	NA				
Cropland converted	NO				
Grassland converted	NO				
Wetlands converted	NO				
Settlements converted	NA				
<b>G. Other</b>					
Harvested wood products	X				
<b>4 (I) Direct N<sub>2</sub>O emissions from N Inputs to Managed Soils</b>			X		
<b>4(II) Emissions and removals from drainage and rewetting and other management of organic and mineral soils</b>	IE, NA	X, NA	X, NA	IE: CO <sub>2</sub> emissions are reported under Tables 4.A to 4.E	See NIR 6.10.2
<b>4(III) Direct N<sub>2</sub>O emissions from N Mineralisation/Immobilisation</b>			X, NA		
<b>4(IV) Indirect N<sub>2</sub>O emissions from managed soils</b>			X		
<b>4(V) Biomass Burning</b>					
Controlled Burning	IE, NO	X, IE, NO	X, IE, NO	IE: CO <sub>2</sub> emissions from controlled burning are included in carbon stock change in dead organic matter as cutting waste (category 4.A.1). IE for Wildfires: wildfires on Wetlands and Settlements are included in Forest land.	See NIR 6.10.5
Wildfires	X, NA, IE	X, NA, IE	X, NA, IE		

## **Waste (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
<b>5. Waste</b>					
<b>A. Solid Waste Disposal</b>					
<b>1. Managed Waste Disposal Sites</b>					
Anaerobic	NO	X			
Semi-aerobic	NO	NO			
<b>2. Unmanaged Waste Disposal Sites</b>	NO	IE		Unmanaged waste disposal, which occurred in early 1990's, is included under managed waste disposal.	
<b>3. Uncategorized Waste Disposal Sites</b>	NO	NO			

**B. Biological Treatment of Solid Waste**

1. Composting			
Municipal Solid Waste		X	X
Other			
Municipal Sludge		X	X
Industrial Sludge		X	X
Industrial solid waste and construction waste		X	X
2. Anaerobic Digestion at Biogas Facilities			
Municipal Solid Waste		X, NO	NE
Other			
Municipal Sludge		X	NE
Industrial Sludge		X, NO	NE
Industrial solid waste and construction waste		X, NO	NE

**C. Incineration and Open Burning of Waste**

1. Waste incineration				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.).
Biogenic	IE	IE	IE	
Non-biogenic	IE, NO	IE, NO	IE, NO	
2. Open Burning of Waste				
Biogenic	NO, NE	NO, NE		
Non-biogenic	NO, NE	NO, NE		

**D. Wastewater treatment**

1. Domestic Wastewater		X	X
2. Industrial Wastewater		X	X
3. Other			
Fish farming		NO	X
<b>E. Other</b>	NO	NO	NO

## **Land Use, Land-Use Change and Forestry Activities under the Kyoto Protocol (CRF 4(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
4(KP) Land use, land-use change and forestry activities under the Kyoto Protocol					
4(KP-I) Carbon stock changes and net CO <sub>2</sub> emissions and removals					
A.1 Afforestation and reforestation					
above-ground biomass	X, IE			Biomass: The method used for tree biomass estimation produces a combined estimate for gains and losses. 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 DOM and soil organic matter (SOM)	In NIR the description of the method is in Sections 6.4.2, 11.3.1.1
below-ground biomass	X, IE				
litter	IE				
dead wood	IE				
soil	X				
A.2 Deforestation					
above-ground biomass	X, NO, NA, IE			Biomass: Losses from AR under D are included in gains Litter: litter is included in SOM or in energy sector as peat combustion. Dead wood: if IE is reported, dead wood is included in SOM.	In NIR the description of the method is in Sections 6.5.2, 6.6.2, 6.7.2, 6.8.2, Appendix_6c, 11.3.1.1
below-ground biomass	X, NO, NA, IE				
litter	IE				
dead wood	X, IE, NA				
soil	X, NO, NA				
B.1 Forest management					
above-ground biomass	X			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 DOM and soil organic matter (SOM)	In NIR the description of the method is in Sections 6.4.2, 11.3.1.1
below-ground biomass	X				
litter	IE				
dead wood	IE				
soil	X				
4(KP-I)C. Harvested wood products					
A.1.1 Afforestation and reforestation	IE			HWP from AR areas are included in HWP from FM areas	See NIR 11.3.1.1
A.2 Deforestation	IO, IE			IO:Instant oxidation for HWP from deforestation action, IE: for reforested lands reported under D	
B.1 Forest management	X				
4(KP-II)1. Direct N <sub>2</sub> O emissions from N fertilisation					
A.1.1 Afforestation and reforestation			NA		
A.2 Deforestation			IE	IE: Emissions from N fertilization on CL and GL are included in	
B.1 Forest management			X		
4(KP-II)2. CH <sub>4</sub> and N <sub>2</sub> O emissions from drained and rewetted organic soils					
A.1.1 Afforestation and reforestation		X, NA	X, 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
A.2 Deforestation		X, NA	X, NA		
B.1 Forest management		X, NA	X, NA		
4(KP-II)3. N <sub>2</sub> O emissions from N mineralisation/ immobilisation					
A.1.1 Afforestation and reforestation			NA		
A.2 Deforestation			X		
B.1 Forest management			NA		
4(KP-II)5. GHG emissions from biomass burning					
A.1.1 Afforestation and reforestation	X, NA	X, NA	X, NA		
A.2 Deforestation	NA	NA	NA		
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.	See NIR 11.3.1.1

### Emissions reported as insignificant in the Finnish inventory

Finland has not provided estimates for sources listed in the table below. The individual sources for which estimates have not been provided are estimated to have emissions below the threshold 0.05 per cent of the national total emissions and the likely total aggregate estimate of these sources is below 0.1 per cent of the national total emissions. Estimates for the insignificant sources have not been provided in earlier inventory submissions.

Emissions/removals from dead organic matter (DOM) in cropland remaining cropland and in grassland remaining grassland are also considered insignificant. Quantitative estimates for these categories have not yet been made. DOM in grassland remaining grassland is likely a small sink because the areas where trees exist are on their way to slowly becoming forested and thus the biomass is increasing. The amount of tree biomass on grassland remaining grassland is however very small so it is justified to say that the increase in DOM is insignificant.

Finland total emissions in 2013 were 63.1 Mt CO<sub>2</sub> eq, hence 0.05 and 0.1 per cent of the total national emissions amount to 31.5 kt and 63.1 kt, respectively.

**Table 2.** Summary of insignificant sources

Greenhouse gas source and sink categories	CO <sub>2</sub>	CH <sub>4</sub>	N <sub>2</sub> O	F-gases	Likely emission level	Notes
Industrial processes and product use Use of NF <sub>3</sub> in production of semiconductors				C, NE	< 0.1 kt (2003)	NF <sub>3</sub> used only in 2003, See NIR 4.6.2.1
Agriculture Composting	NO	NE	NE		< 7 kt CO <sub>2</sub> eq. around 0	See NIR 5.3.2.2
Anaerobic digestion	NO	NE	NO			

## ANNEX 6. 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 2013

Activity	Water	Air	Waste
Energy production and industrial installations	1 146	657	787
Municipalities	451	5	264
Fish farms	180	-	21
Others	108	448	1531

### 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>17</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

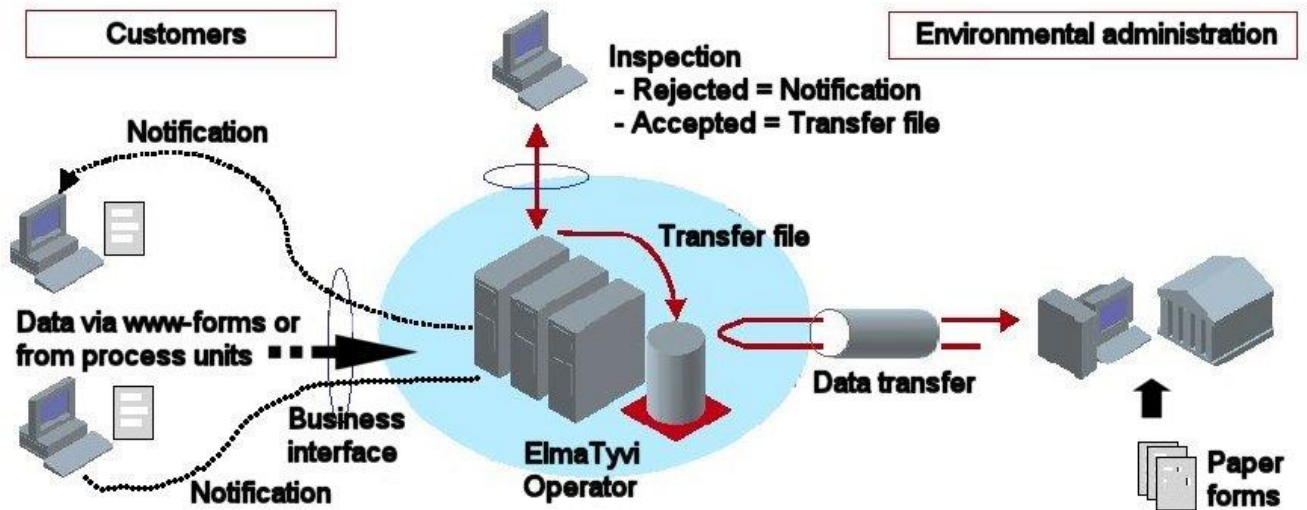
When receiving the emission report from the operator the supervising authority checks whether the data are produced according to the methods agreed in the permit or in a separate monitoring programme for the plant. The methods usually include use of international standards or approved in-house methods. 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>18</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>17</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>18</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 Juha Lahtela, Ministry of the Environment (email: [firstname.surname@ymparisto.fi](mailto:firstname.surname@ymparisto.fi))

## *ANNEX 7. 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) and in Vol 2, Table 2.2, p.2.16 in 2006 IPCC Guidelines. 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,

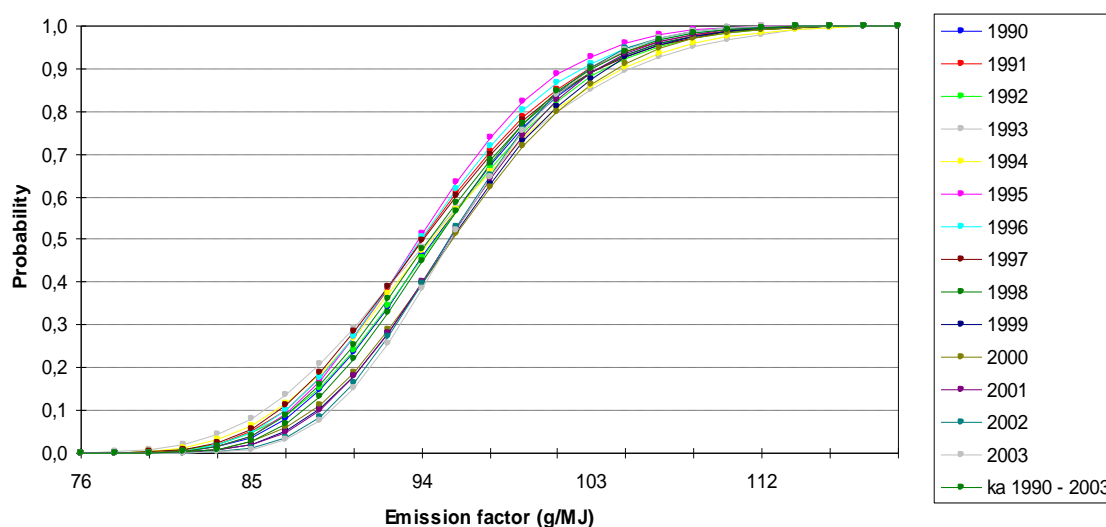
maximum and the mean. In case of the most important countries of coal origin, such as Poland and Russia, hundreds of measurements were available. This was the case for the net calorific value and water content. Measurements of carbon content were scarcer ranging from a few to tens of measurements, depending 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 ( $1000 \text{ t}/2 = 500 \text{ t}$ ).

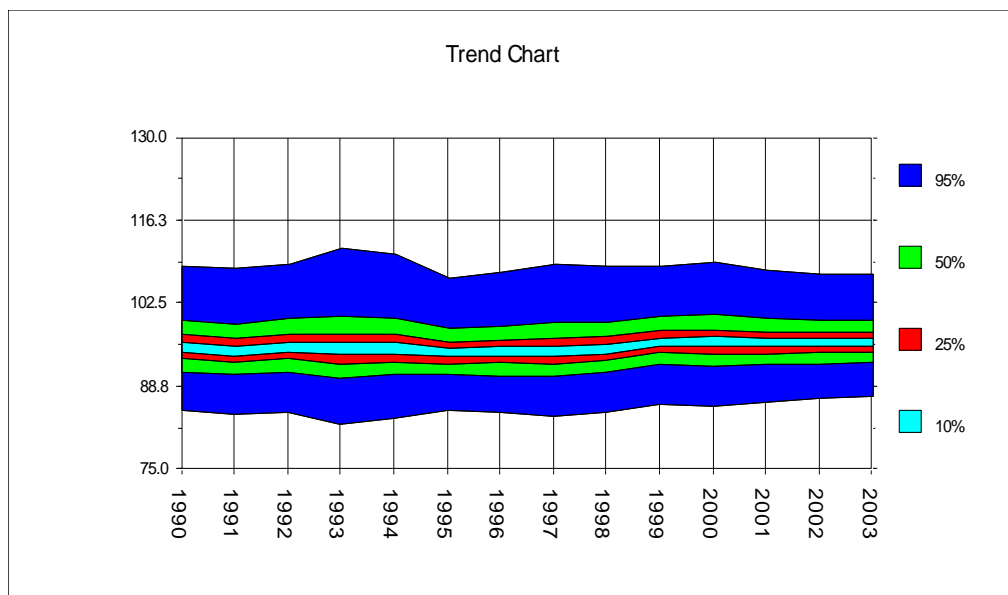
## Results and discussion

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.



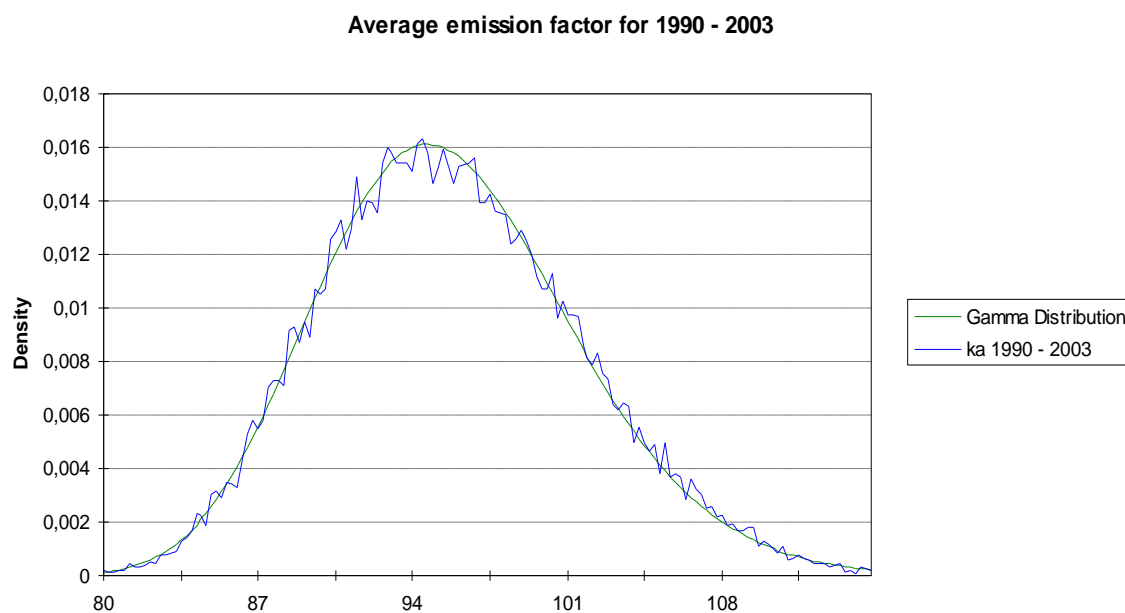
**Figure 1.** Uncertainty and year-to-year variability in the average coal emission factor

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.



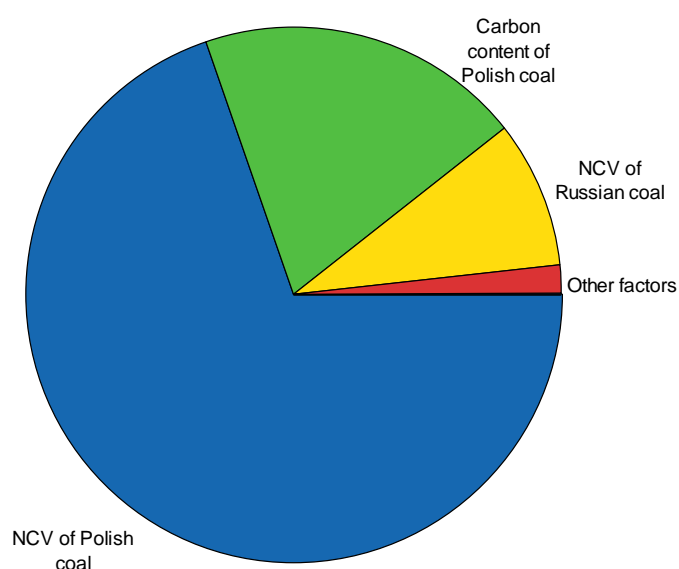
**Figure 2.** Uncertainty in the coal emission factor over time

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 8. 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*

Legal entity	Reason for authorization
Adven Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Ahlstrom Tampere Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Boliden Harjavalta 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
Ekenäs Energi Ab	Operator (company with a legally binding emission ceiling under the EU ETS)
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)
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)
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)

Legal entity	Reason for authorization
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)
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)
Keitele Timber 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)
Kemira Chemicals 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)
Leppäkosken Sähkö 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)
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)
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)
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)
Nivalan Kaukolämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Nordea Pankki Suomi Oyj	Approval and authorisation from the Ministry of the Environment
Nordic Carbon Fund Ky	Authorisation for CDM and JI projects

Legal entity	Reason for authorization
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 Perhoniemi Ab	Operator (company with a legally binding emission ceiling under the EU ETS)
Oy SCA Hygiene Products 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)
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)
Raisio Kaaren 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)
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
Sachtleben Pigments Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
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)
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)
Tampereen Energiantuotanto Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
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)
Tuoke Finland Oy	Operator (company with a legally binding emission ceiling under the EU ETS)

Legal entity	Reason for authorization
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)
Westas Raunio 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)
Wiitaseudun Energia 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)

## ANNEX 9. Information related to additional reporting requirements under EU MMR (525/2013)

### Additional information on the national system

#### Reporting information referred to in Article 5, paragraphs 2 of the EU MMR

According to Article 5 of the EU MMR Member States shall ensure that their competent inventory authorities have access to data reported under the Union's emissions trading scheme (EU ETS), data collected on fluorinated gases under the regulation (EC) 842/2006 and regulation (EC) 166/2006 on data and methodologies reported by facilities, and data reported under the energy statistics regulation. The Finnish national systems has continuous access to all these data. The access is ensured by law, administrative arrangements (Finnish Environment Institute, which performs the F gas calculations for the inventory is the competent authority for the F gas regulation and Statistics Finland is responsible for both the GHG inventory and the energy statistics) and/or agreements under the national system.

### Comparisons with other international reportings

#### Reporting information referred to in Article 7(1)(m), subparagraph iii of Regulation No 525/2013/EU

Quantitative information and explanations for differences of more than +/- 2% in apparent consumption at aggregate level for the reference approach.

In Finland, the difference at aggregate level was 2.0 per cent in 2013. The reasons for differences in the greenhouse gas inventory data compared to the energy statistics data are explained below.

FUEL TYPES			Apparent consumption reported in GHG inventory	Apparent consumption using data reported pursuant to Regulation (EC) No 1099/2008	Absolute difference (1)	Relative difference (2)	Explanations for differences
			(TJ) (3)	(TJ) (3)	(TJ) (3)	%	
Liquid fossil	Primary fuels	Crude oil	473 014	473 483	-469.3	-0.1 %	
		Orimulsion					
		Natural gas liquids	23 198	31 098	-7 899.7	-25.4 %	different allocation of products (in stock changes data)
	Secondary fuels	Gasoline	-108 274	-109 736	1 462.0	-1.3 %	
		Jet kerosene	-21 909	-21 910	0.5	0.0 %	
		Other kerosene	8 060	8 063	-3.7	0.0 %	
		Shale oil					
		Gas/diesel oil	-52 745	-64 068	11 323.1	-17.7 %	customers' stock changes are not included in IEA data

FUEL TYPES			Apparent consumption reported in GHG inventory	Apparent consumption using data reported pursuant to Regulation (EC) No 1099/2008	Absolute difference (1)	Relative difference (2)	Explanations for differences
		Residual fuel oil	-15 358	-16 276	918.0	-5.6 %	different NCV value used in inventory and IEA data. NCV revised in the inventory after data reported to IEA
		Liquefied petroleum gases (LPG)	13 860	13 860	0.0	0.0 %	
		Ethane					
		Naptha	3 810	3 810	0.0	0.0 %	
		Bitumen	-1 327	-1 327	0.0	0.0 %	
		Lubricants	-10 814	-10 814	0.0	0.0 %	
		Petroleum coke	1 139	1 128	10.7	0.9 %	
		Refinery feedstocks	2 697		2 696.6		different allocation of products
		Other oil	13 079	12 376	703.7	5.7 %	different set of products, different allocation
Other liquid fossil							
Liquid fossil totals			328 430	319 689	8 741.8	2.7 %	
Solid fossil	Primary fuels	Anthracite <sup>(3)</sup>					
		Coking coal	35 025	35 349	-323.9	-0.9 %	
		Other bituminous coal	116 447	113 394	3 053.1	2.7 %	different NCV value used in inventory and IEA data.
		Sub-bituminous coal					
		Lignite					
		Oil shale and tar sand					
	Secondary fuels	BKB <sup>(4)</sup> and patent fuel					
		Coke oven/gas coke	7 635	7 970	-334.3	-4.2 %	different NCV value used in inventory and IEA data.
		Coal tar					
Other solid fossil							
Solid fossil totals			159 107	156 713	2 394.9	1.5 %	
Gaseous fossil		Natural gas (dry)	119 622	119 414	207.9	0.2 %	
Other gaseous fossil							
Gaseous fossil totals			119 622	119 414	207.9	0.2 %	
Waste (non-biomass fraction)			8 842	8 758	84.3	1.0 %	reported under other fossil fuels in the inventory
Other fossil fuels							
Peat			57 298	55 412	1 886.2	3.4 %	
Total			673 300	659 985	13 315.2	2.0 %	

(1) Apparent consumption reported in GHG inventory minus apparent consumption using data reported pursuant to Regulation (EC) No 1099/2008

(2) Absolute difference divided by apparent consumption reported in GHG inventory

(3) Data with one decimal point for kt and one decimal point for % values

**Reporting information referred to in Article 7(1)(m)(i) of Regulation No 525/2013/EU**

Quantitative information and explanations for differences of more than +/- 5% in total emissions excluding LULUCF of any of the air pollutants CO, SO<sub>2</sub>, NO<sub>x</sub> and NMVOC reported in the national greenhouse gas inventory and under the **NEC Directive and the CLRTAP inventory**

2013								
EMISSION CATEGORIES	Emissions for pollutants reported in GHG inventory (in kt)	Emissions for pollutants reported in NEC, resubmission 27 Feb 2015 (in kt)	Absolute difference in kt (1)	Relative difference in % (2)	Emissions for pollutants reported in CLRTAP inventory, resubmission 27 February 2015 (in kt)	Absolute difference in kt (1)	Relative difference in % (2)	Explanations for differences
Total (Net Emissions) (NO <sub>x</sub> )	149.9	144.9	5.0	3.3	144.9	5.1	3.4	
Total (Net Emissions) (NMVOC)	94.1	94.6	-0.5	-0.5	94.6	-0.5	-0.5	
Total (Net Emissions) (SO <sub>x</sub> as SO <sub>2</sub> )	47.7	47.4	0.3	0.6	47.4	0.3	0.7	
Total (Net Emissions) (NH <sub>3</sub> )	NE	37.1			37.1			
Total (Net Emissions) (CO)	357.7	NA			369.1	-11.4	-3.2	

(1) Emissions reported in GHG inventory minus emissions reported in NEC/CLRTAP inventory

(2) Difference in kt divided by emissions reported in GHG inventory

NA = not applicable

**Reporting information referred to in Articles 7(1)(k) of Regulation No 525/2013/EU**

Ratio of verified emissions reported by installations and operators under Directive 2003/87/EC to the total reported GHG inventory

Allocation of verified emissions reported by installations and operators under Directive 2003/87/EC to source categories of the national greenhouse gas inventory				
Country: Finland				
Reporting year: 2013				
Basis for data: verified ETS emissions as reported in the EUTL and greenhouse gas emissions as reported in inventory submission for the year 2013				
	Total emissions (CO <sub>2</sub> -eq)			
	Greenhouse gas inventory emissions [kt CO <sub>2</sub> eq]	Verified emissions under Directive 2003/87/EC [kt CO <sub>2</sub> eq]	Ratio in % (Verified emissions/ inventory emissions)	Comment
Greenhouse gas emissions (total emissions without LULUCF for GHG inventory and without emissions from 1A3a Civil aviation, total emissions from installations under Article 3h of Directive 2003/87/EC)	62 877.11	31 496.74	-49.91%	
CO <sub>2</sub> emissions (total CO <sub>2</sub> emissions without LULUCF for GHG inventory and without emissions from 1A3a Civil aviation, total emissions from installations under Article 3h of Directive 2003/87/EC)	51 580.22	31 337.20	-39.25%	

### **Reporting information referred to in Articles 7(1)(m), subparagraph ii of Regulation No 525/2013/EU**

The use and handling of F-gases is controlled by the EU Regulation on certain fluorinated greenhouse gases (517/2014/EU) and the Directive relating to emissions from air conditioning systems in motor vehicles (40/2006/EC). The new F-gas Regulation (517/2014/EU) which applies from 1 January 2015 replaced the original F-gas Regulation (842/2006/EC). The original Regulation placed requirements on the proper recovery of equipment, containment, labelling and reporting of F-gases as well as the training and certification of personnel handling the gases. The Regulation also included specific bans for certain F-gases containing applications. The new F-gas Regulation strengthens the existing measures and also introduces a number of bans on the use of F-gases. The main driver of the move towards more climate-friendly technologies will be a phase down of the quantities of HFCs that can be placed on the EU market. The phase down is applied to the aggregate amount of HFCs (measured in equivalent tonnes of CO<sub>2</sub>) and takes place in a series of steps, starting with a cap in 2015 and reaching a 79% cut in 2030. The phase down is accompanied by a quota system that will specify the amounts of HFCs that individual companies can place on the market, based on sales reported under the existing F-gas Regulation plus an allowance for new entrants. Production or import of HFCs into the EU requires a quota.

Each producer, importer and exporter of fluorinated greenhouse gases report their activity for the previous calendar year annually before 31 March to the European Environment Agency (EEA) if the amount exceed one metric tonne or 100 tonnes of CO<sub>2</sub> equivalent fluorinated greenhouse gases. In addition the reporting obligation applies to undertakings that destroyed one metric tonne or 1000 tonnes of CO<sub>2</sub> equivalent or more of F-gases, undertakings that used 1000 tonnes of CO<sub>2</sub> equivalent of F- gases as feedstock, undertakings that placed 500 tonnes of CO<sub>2</sub> equivalent of F-gases or gases contained in products or equipment on the market (no obligation to report if these gases were bought on the EU market or imported as bulk before being put in the equipment), undertakings that placed on the market pre-charged refrigeration, air conditioning and heat pump equipment where HFCs contained in this equipment have not previously been placed on the EU market. Reported imports and exports of F-gases include only quantities imported from, or exported to, countries outside the European Union. Reporting is performed via the Business Data Repository (BDR) in the EEA's Eionet web service. It is not necessary to send the report additionally to the Commission and to the Competent Authority in the Member State. They have access to the relevant reports in BDR. Finnish Environment Institute acts as the competent authority of the F-gas Regulation in Finland. Data collected through this reporting system is available when preparing Finnish national greenhouse gas inventory. In Finland F-gases are not produced and the amount of imported or exported F-gases to or from the Community did not exceed the limit set for reporting in 2013. Therefore, the use of reporting system of F-gas Regulation pursuant to Article 5(3) of Regulation (EC) No 525/2013 is not currently relevant for Finland / for this submission. However in the future it may become relevant because of the new, lower reporting thresholds set out in the new F-gas regulation.

## *Reporting on the use of flexible mechanisms*

**Questionnaire: Information on the extent to which the Member State's action constitutes a significant element of the efforts undertaken at national level as well as the extent to which the projected use of joint implementation, of the clean development mechanism and of international emissions trading is supplemental to domestic action**

### **Questionnaire on the use of the Kyoto Protocol mechanisms in meeting the 2013-2020 targets**

- 
1. Does your Member State intend to use joint implementation (JI), the clean development mechanism (CDM) and international emissions trading (IET) under the Kyoto Protocol (the Kyoto mechanisms) to meet its quantified limitation or reduction commitment pursuant to the Kyoto Protocol? If so, what progress has been made with the implementing provisions (operational programmes, institutional decisions) and any related domestic legislation?

No decision on the use of Kyoto mechanisms for compliance purposes in CP2 of the Kyoto Protocol has been made. Finland's Kyoto mechanism purchase program covers the period 2006-2020. In the first Kyoto commitment period Finland procured approximately 6 Mt of project units. These will be carried over to CP2. The Kyoto mechanisms purchase program will continue to deliver project units during CP2 through existing investments in carbon funds and two bilateral CDM projects. These are expected to deliver about 4 Mt of project units during CP2.

The Act on the use of the Kyoto mechanisms (109/2007) lays out the administrative framework that enables both the State and other entities to participate in project activities in accordance with the Kyoto mechanisms and in emissions trading pursuant to the Kyoto Protocol, and the acquisition of the Kyoto emission units with these mechanisms. The Act came into force on 12 February 2007. The rights and obligations of the operators concerning the use of CERs and ERUs deriving from the Linking Directive (2004/101/EC) have been implemented in connection with amendments to the Emissions Trading Act (108/2007).

The Act on the use of the Kyoto mechanisms also stipulates that the emission trading registry already established by the Emissions Trading Act acts as a national registry which keeps a record of the emission units as required by the implementation of the Kyoto Protocol. This Act prescribes with which preconditions the Finnish Government's authorisation and approval are given to a project. The Act contains detailed provisions on which authority gives authorisation and approval with respect to each mechanism, and by which preconditions this authority can revoke the given authorisation or approval.

The decree on Joint Implementation (913/2007) entered into force on November 1st 2007. In addition to the regulations on national Track I procedures, the decree on Joint Implementation includes guidance on the contents of applications for Joint Implementation project approvals and authorisations as well as for approvals of domestic JI project verifiers. A decree on the Clean Development Mechanism (915/2007) entered into force simultaneously with the decree on Joint Implementation. The decree on the Clean Development Mechanism includes guidance on the contents of applications for Clean Development Mechanism project approvals and authorisations

The Ministry of Employment and the Economy is responsible for the coordination of Finland's mechanism policy, legislation and budgetary appropriations for the purchase programme. The Ministry of the Environment is the holder of the national account of emission units and responsible for JI operations and international emissions trading. The Ministry for Foreign Affairs is responsible for CDM operations. The national registry and its activities pertain to the Energy Authority, which is part of the result-oriented management of the Ministry of Employment and the Economy.

2. What quantitative contributions to the fulfilment of the quantified emission limitation or reduction commitment pursuant to Article X of Decision Y (Ratification decision) and the Kyoto Protocol does your Member State expect from the Kyoto mechanisms during the second quantified emission limitation and reduction commitment period, from 2013 to 2020? (Please use the table)

No decision on the use of Kyoto mechanisms for compliance purposes in CP2 of the Kyoto Protocol has been made.

**3. Specify the budget in euro for the total use of the Kyoto mechanisms and, where possible, per mechanism and initiative, programme or fund, including the time over which the budget will be spent.**

The overall budget for the procurement of project units from the Kyoto mechanisms has been approximately 70 million euros. Approximately 20 million euros were invested during the CDM/JI pilot programme, which operated from 1999 until early 2006. The rest were allocated in years 2005-2012.

Finland committed about 12.2 million Euros through 10 bilateral projects for the purchase of project units during the prompt start phase and the first commitment period of the Kyoto Protocol. Two of these projects continue in CP2. Beside these bilateral projects, Finland invested in multilateral funds. These funds were: World Bank's Prototype Carbon Fund (PCF), Nordic Environmental Financing Corporation's (NEFCO) Testing Ground Facility (TGF), European Bank for Reconstruction and Development's Multilateral Carbon Credit Fund (MCCF), Asian Development Bank's Asia Pacific Carbon Fund, Nordic Environment Finance Corporations NEFCO Carbon Fund and Asian Development Bank's Future Carbon Fund.

**4. With which countries has your Member State closed bilateral or multilateral agreements, or agreed memorandums of understanding or contracts for the implementation of project based activities?**

Finland has a Memorandum of Understanding with Brazil, China, Costa Rica, El Salvador, Hungary, Latvia, Lithuania, Nicaragua, Poland and Ukraine. In addition, Finland has signed inter-governmental agreements on JI co-operation with Bulgaria, Estonia and Romania.

**5. For each planned, ongoing and completed clean development mechanism and joint implementation project activity in which your Member State participates, provide the following information:**

**Finland currently has two bilateral CDM projects in its procurement portfolio**

- a) Project title and category (JI/CDM)  
**Reduction of Methane Emissions from Ruseifeh Landfill (CDM Reference 2487)**
  - b) Host country: Jordan
  - c) Financing: Public-private partnership
  - d) Project type:  
Waste, landfill methane recovery (use of landfill gas for power generation and flaring)
  - e) Status: in operation
  - f) Lifetime:
    - date of official approval: 11.12.2009, CDM reference 2487
    - date of project initiation (operation starts): 1.6.2006
    - expected date of project termination (lifetime): The project is estimated to generate gas until 2033.
    - crediting period (for what years will ERUs or CERs be generated): 11.12.2009- 11.12.2019
  - h) Projected total and annual emissions reductions that accrue until the end of the second commitment period.  
Projected annual emission reductions according to PDD 46,452 CER/a. Total of 464,520 for 10-year crediting period.
  - i) Total Amount to Finland: 101,585 CERs in first commitment period, 115,000 CERs in second commitment period
  - j) Credits accrued until the end of reporting year:  
Situation as at 31 January 2015: 101,585 CP1 CERs issued; 36,432 CP2 CERs monitored
- 
- a) Project title and category (JI/CDM)  
**Ningxia Federal Solar Cooker Project (CDM reference 2924)**
  - b) Host country: China
  - c) Financing: Private
  - d) Project type:  
Thermal energy for the user with or without electricity
  - e) Status: in operation

- f) Lifetime:
- date of official approval: 12.02.2010; CDM reference 2924
  - date of project initiation (operation starts): 1.3.2010
  - expected date of project termination (lifetime): 2020
  - crediting period (for what years will ERUs or CERs be generated): 12.2.2010 – 11.1. 2020
- h) Projected total and annual emissions reductions that accrue until the end of the second commitment period.  
Projected annual emission reductions according to PDD 40,702 CER/a. Total of 407,020 for 10-year crediting period.
- i) Total Amount to Finland: 122 439 CERs in first commitment period, 127,561 in second commitment period.
- j) Credits accrued until the end of reporting year:  
Situation as at 31 January 2015: 122,439 CP1 CERs issued; 66,326 CP2 CERs issued
- 

<sup>(1)</sup> Member States must select from the following sectors: energy supply (comprising extraction, transmission, distribution and storage of fuels as well as energy and electricity production), energy consumption (comprising consumption of fuels and electricity by end users such as households, services, industry and agriculture), transport, industrial processes (comprising industrial activities that chemically or physically transform materials leading to greenhouse gas emissions, use of greenhouse gases in products and non-energy uses of fossil fuel carbon), agriculture, forestry/LULUCF, waste management/waste, cross-cutting, other sectors.

<sup>(2)</sup> Member States must select from the following GHGs (more than one GHG can be selected): carbon dioxide (CO<sub>2</sub>), methane (CH<sub>4</sub>), nitrous oxide (N<sub>2</sub>O), hydrofluorocarbons (HFC), perfluorocarbons (PFC), sulphur hexafluoride (SF<sub>6</sub>), nitrogen trifluoride (NF<sub>3</sub>).

<sup>(3)</sup> Member States must select from the following objectives (more than one objective can be selected, additional objectives could be added and specified under 'other'):

For **energy supply** — increase in renewable energy; switch to less carbon-intensive fuels; enhanced non-renewable low carbon generation (nuclear); reduction of losses; efficiency improvement in the energy and transformation sector; carbon capture and storage; control of fugitive emissions from energy production; other energy supply.

For **energy consumption** — efficiency improvements of buildings; efficiency improvement of appliances; efficiency improvement in services/tertiary sector, efficiency improvement in industrial end-use sectors, demand management/reduction; other energy consumption.

For **transport** — efficiency improvements of vehicles; modal shift to public transport or non-motorized transport; low carbon fuels/electric cars; demand management/reduction; improved behaviour; improved transport infrastructure; other transport.

For **industrial processes** — installation of abatement technologies; reduction of emissions of fluorinated gases; replacement of fluorinated gases by other substances; improved control of fugitive emissions from industrial processes; other industrial processes.

For **waste management/waste** — demand management/reduction; enhanced recycling; enhanced CH<sub>4</sub> collection and use; improved treatment technologies; improved landfill management; waste incineration with energy use; improved wastewater management systems; reduced landfilling; other waste.

For **agriculture** — reduction of fertilizer/manure use on cropland; other activities improving cropland management, improved livestock management, improved animal waste management systems; activities improving grazing land or grassland management, improved management of organic soils; other agriculture.

For **forestry/LULUCF** — afforestation and reforestation; conservation of carbon in existing forests, enhancing production in existing forests, increasing the harvested wood products pool, enhanced forest management, prevention of deforestation, strengthening protection against natural disturbances, substitution of GHG intensive feedstocks and materials with harvested wood products; prevention of drainage or rewetting of wetlands, restoration of degraded lands, other LULUCF.

For **cross-cutting** — framework policy, multi-sectoral policy, other cross-cutting.

For **Other** Member States must provide a brief description of the objective.

<sup>(4)</sup> Member States must include the figure(s) if the objective(s) is(are) quantified.

<sup>(5)</sup> Member States must indicate in the description if a policy or measure is envisaged with a view to limiting GHG emissions beyond Member State commitments under Decision No 4 06/2009/EC in accordance with Article 6(1)(d) of Decision No 406/2009/EC.

<sup>(6)</sup> Member States must select from the following policy types: economic; fiscal; voluntary/negotiated agreements; regulatory; information; education; research; planning; other.

<sup>(7)</sup> Union policy implemented through the national policy or where national policies are aimed directly at meeting objectives of Union policies. Member State should select a policy from a list provided in the electronic version of the tabular format

<sup>(8)</sup> Secondary Union policy: Member State must indicate any Union policy not listed in the previous column or an additional Union policy if the national policy or measure relates to several Union policies.

<sup>(9)</sup> Member States must select from the following categories: planned; adopted; implemented; expired.

Expired policies and measures must be reported in the template only if they have an effect, or they are expected to continue to have an effect, on greenhouse gas emissions

<sup>(10)</sup> Member States must enter the name/s of entities responsible for implementing the policy or measure under the relevant headings of: National government; Regional entities; Local government; Companies/businesses/industrial associations; Research institutions; Others not listed (more than one entity can be selected)..

<sup>(11)</sup> Member States must provide any indicator used and values for such indicators that they use to monitor and evaluate progress of policies and measures. Those values can be either *ex-post* or *ex-ante* values and Member States must specify the year for which the value applies.

<sup>(12)</sup> — Member States are to include all the policies and measures or their groups of policies and measures for which such assessment is available.

Notation: t signifies the first future year ending with 0 or 5 immediately following the reporting year

## *ANNEX 10. Information related to the reporting under the EU LULUCF Decision 529/2013/EU*

### *1 General information*

Under the EU LULUCF Decision 529/2013/EU Finland reports emissions by sources and removals by sinks from Afforestation and Reforestation (AR), Deforestation (D) and Forest Management (FM) in accordance with Article 3(1), and from Cropland Management (CM) and Grazing land Management (GM) in accordance with Article 3(2). Information related to reporting of AR, D and FM is given in Chapter 11 of the NIR.

CM and GM activities have been estimated using the same methods as emissions and removals were estimated for Cropland and Grassland in the LULUCF and KP reporting. The base year for CM and GM is 1990.

### *2 Land-related information*

CM areas were calculated in a same manner as AR, D and FM (see Sections 11.2.2 and 11.4.1 in the NIR). CM areas are consistent with FM, AR and D areas since they are calculated from the same data and FM, AR and D areas were excluded from CM areas. Otherwise lands that were CM in the base year remained in the category. The areas were calculated for the base year at first. In addition to that, lands converted to CM since 1990 were calculated excluding AR and D. New CM areas were mostly converted from WL. Changes between CM and GM were not taken into account in determining the areas. There was no hierarchy between CM and GM but they were separated from each other on the bases of recorded land-use class and its subclass in the data. CM included all lands under annual and perennial crops, and all fallow lands.

GM areas were calculated the same way as CM areas and FM, AR and D were excluded from GM. The areas were calculated for the base year and also lands converted to GM since 1990 were calculated. However, changes between CM and GM were not taken into account. Lands under GM included herbaceous perennial vegetation for harvest by grazing, and extensive grass. Other grassland subclasses were excluded from GM areas, i.e., abandoned fields, ditches associated with agricultural land, areas of bioenergy plants.

### *3 Activity-specific information*

#### *3.1 Cropland management*

##### *Carbon stock changes in biomass*

The biomass of apple trees and currants are taken into account when calculating the carbon stock change in woody living biomass of CM. The method corresponds to the Tier 2 method of the IPCC (IPCC 2006). See Section 6.5.2.1 for details. Although the areas converted between CM and GM did not change reporting class, the related changes in biomass cover were calculated as C stock changes within the class CM as described in Section 6.5.3. The removal of biomass after the conversion of grazing land to cropland was 4.1 t C/ha and the increase in the carbon stock during the first year after the conversion from grazing land to cropland was 4 t C/ha which are national values of mean crop biomasses based on yields.

##### *Carbon stock changes in soil and dead organic matter*

The changes in mineral soil carbon stock were estimated using a model based Tier 3 approach (Yasso07). Emissions from organic soils were calculated using the method from IPCC (2006) and emission factors from IPCC (2013). The emission factors are 5.7 t C ha<sup>-1</sup> for grass and 7.9 t C ha<sup>-1</sup> for annual crops. See details for the methods in Section 6.5. The carbon stock change in dead organic matter was considered insignificant.

## 3.2 Grazing land management

### *Carbon stock changes in biomass*

It was assumed that no woody biomass exists on grazing land but changes in biomass cover related to land use changes was estimated. Although the areas converted between CM and GM did not change reporting class, the related changes in biomass cover were calculated as C stock changes within the class GM as described in Section 6.5.3. The removal of biomass after the conversion of cropland to grazing land was 4 t C/ha and the increase in the carbon stock during the first year after the conversion from cropland to grazing land was 4.1 t C/ha which are national values of mean crop biomasses based on yields.

### *Carbon stock changes in soil and dead organic matter*

No carbon stock changes in mineral soils of grazing land were expected unless there was a land use change. The C stock changes of land converted to grazing land on mineral soils were estimated using the Yasso07 model (Appendix\_6e).

The emissions from organic grazing land were calculated using the emission factor for the cultivation of grass on organic soils (5.7 t C ha<sup>-1</sup>) (IPCC 2013).

The carbon stock change in dead organic matter was considered insignificant.

### *Information that demonstrates that the activities have occurred since 1 January 1990 and are human-induced*

CM and GM are systems of management practices that occur within two identified areas: Region 1 and Region 2. Areas of CM and GM were calculated for the years 1990—2013 using the NFI data (see Sections 11.2.2 and 11.4.1 in the NIR). Lands that were croplands on 1 January 1990 were included under CM except the FM, AR and D areas. Grazing lands are the areas within grasslands that are related to animal production, only abandoned fields, ditches associated with agricultural land, areas of bioenergy plants, FM, AR and D areas are left out. All croplands and grazing lands are considered managed and the activities are human-induced.