

GREENHOUSE GAS EMISSIONS IN FINLAND
1990-2008

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

25 May 2010

PREFACE

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

- Part 1 Finland's national greenhouse gas emission inventory report (NIR) prepared using the reporting guidelines (UNFCCC 2006) and the Guidelines for the preparation of the information required under Article 7, paragraph 1 of the Kyoto Protocol.
- Part 2 CRF (Common Reporting Format) data tables of Finland's greenhouse gas emissions for the years 1990-2008 including KP-LULUCF data tables. The CFR tables are compiled with the UNFCCC CRF Reporter software (version 3.4.3).
- Part 3 SEF (Standard Electronic Tables) for reporting of Kyoto units (AAU, ERU, CER, t-CER, l-CER, RMU) in the registry 31.12.2009 and transfers of the units during the year 2009.

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Statistics Finland is the National Entity with the overall responsibility of 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 EC, UNFCCC and the Kyoto Protocol independently.

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

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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 mechanism for monitoring European Community greenhouse gas emissions and for implementing the Kyoto Protocol (EU monitoring mechanism, Decision 280/2004/EC of the European Parliament and the Council). This report aims at fulfilling the reporting commitments under all above-mentioned agreements.

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

In accordance with the Government resolution of 30 January 2003 on the organisation of climate policy activities of Government authorities in Finland, Statistics Finland assumed the responsibilities of the National Entity for Finland's greenhouse gas inventory from the beginning of 2005. Statistics Finland as the general authority of the official statistics of Finland is independently responsible for greenhouse gas inventory submissions under the UNFCCC, the Kyoto Protocol and the EU monitoring mechanism. Besides Statistics Finland, the Finnish Environment Institute, MTT Agrifood Research Finland and the Finnish Forest Research Institute take part in the inventory preparation. Statistics Finland acquires also parts of the inventory calculations as purchased services from VTT (Technical Research Centre of Finland) and Finavia (formerly Civil Aviation Administration).

In Finland the national system, as intended in the Kyoto Protocol (Article 5.1), is based, besides regulations concerning Statistics Finland, on agreements on the production of emission/removal estimations and reports between the inventory unit at Statistics Finland and the expert organisations mentioned above. Statistics Finland has also agreements with the responsible ministries defining the responsibilities and collaboration in relation to the reporting requirements under the UNFCCC and Kyoto Protocol, as well as the EU monitoring mechanism. A short description on the National Greenhouse Gas Inventory System in Finland is provided in Section 1.2. A more detailed description can be found from the report "National Greenhouse Gas Inventory System in Finland" which is available on the web: <http://stat.fi/greenhousegases>.

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

ES.2 Summary of trends in national emissions and removals

In 2008, Finland's greenhouse gas emissions totalled 70.1 Tg CO₂ eq. (million tonnes of CO₂ equivalent). The total emissions in 2008 were approximately 1% (~0.9Tg) under the level of the base year (1990 for CO₂, CH₄ and N₂O, and 1995 for HFCs, PFCs and SF₆) – the level to which Finland should limit its emissions during the Kyoto Protocol's first commitment period between 2008 and 2012. Compared the year 2007, the emissions decreased with more than 10%.

A summary of the Finnish national emissions and removals for 1990-2008 is presented in Table ES.2-1.

Table ES.2-1 Finnish greenhouse gas emissions and removals in 1990-2008. The base year of the Kyoto Protocol is 1990 except for F-gases 1995.

Tg CO ₂ equivalent	Base year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Energy	54.7	54.5	53.1	52.4	54.3	59.5	56.1	61.8	60.2	57.0	56.4	54.4	59.7	62.2	69.7	65.6	54.0	65.2	63.2	55.0
Industrial processes (excluding F-gases)	5.0	5.0	4.6	4.3	4.4	4.6	4.5	4.7	4.9	4.8	4.9	4.9	4.9	4.9	5.2	5.4	5.3	5.4	5.7	6.0
F- gases	0.10	0.09	0.07	0.04	0.03	0.04	0.10	0.15	0.24	0.30	0.40	0.57	0.72	0.53	0.72	0.74	0.91	0.80	0.95	1.05
Solvent and other product use	0.18	0.18	0.17	0.16	0.15	0.15	0.14	0.14	0.14	0.14	0.14	0.12	0.12	0.11	0.10	0.11	0.11	0.10	0.10	0.09
Agriculture	7.1	6.6	6.2	5.8	5.9	5.9	6.0	6.0	6.0	5.8	5.7	5.8	5.8	5.8	5.8	5.7	5.7	5.7	5.7	5.8
Waste	4.0	4.0	4.0	4.0	4.0	4.0	3.9	3.8	3.7	3.6	3.5	3.3	3.1	2.9	2.8	2.6	2.4	2.5	2.4	2.2
TOTAL	71.0	70.4	68.2	66.7	68.8	74.2	70.8	76.6	75.2	71.7	71.0	69.1	74.4	76.5	84.2	80.2	68.4	79.7	78.1	70.1
Land use, land-use change and forestry	NA	-16.0	-29.5	-22.7	-20.2	-12.7	-14.1	-24.0	-20.3	-18.4	-21.3	-22.6	-26.3	-26.9	-27.4	-28.9	-32.8	-37.9	-30.7	-35.4

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

Energy related CO₂ 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 1.42 terajoules (TJ) in 2008, which was 4.2 per cent less than in 2007. Contraction of industrial output and mild weather brought the consumption of energy down from the previous year. The replacement of coal condensing power with hydro power in the production of electricity also reduced significantly the total consumption of primary energy and carbon dioxide emissions. The share of renewable energy rose by nearly three percentage points and amounted to 28 per cent of total energy consumption in 2008.

In Norway and Sweden the water reservoirs fell below their long-term average towards the end of the year, which reduced electricity imports from these countries. At the end of 2008 Finland was a net seller on the Nordic electricity market. However, electricity imports from Russia and Estonia increased, and the net imports of electricity grew slightly compared to the previous year. The net imports of electricity covered 15 per cent of total electricity consumption (Energy Statistics, Yearbook 2009).

Emissions in the Industrial Processes sector show a growing trend, in the beginning of the time-series several plants were closed down due to economic recession. Since 1993 the emissions from industrial processes have been growing. 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 in 1990-2008 as the removals in the sector exceed the emissions. Most of the removals in the LULUCF sector come from forest growth; the tree volume increment exceeds annual harvesting and natural mortality. The increment of the growing stock has increased in Finland since 1990. Annual variations in the drain (forest harvesting and natural losses) have been considerable. Also, the dead organic matter pool has been a significant sink during the reporting period. The largest emissions in the LULUCF sector come from changes in soil organic carbon in organic forest and agricultural soils.

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

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

The composition of Finnish greenhouse gas emissions in 2008 is presented in Figure ES.3-1.

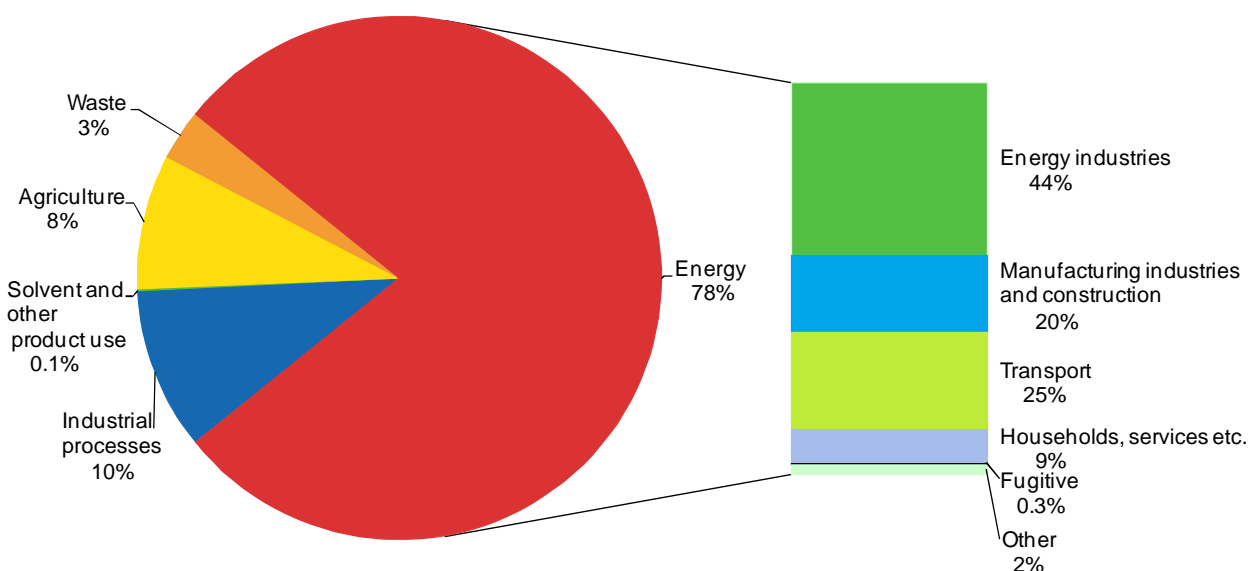


Figure ES.3-1 The composition of Finnish greenhouse gas emissions in 2008 (LULUCF sector excluded). Due to independent rounding the sums do not add up.

The energy sector is the most significant source of greenhouse gas emissions in Finland with an around 78% share of the total emissions in 2008. 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 CO₂ emissions vary mainly according to the economic trend, the energy supply structure and climate conditions. The total primary energy supply decreased in 2008 by 4% compared with the previous year.

The emissions from industrial processes (referred to as non-energy related ones), including CO₂, CH₄, N₂O and F-gases, were 10% of total greenhouse gas emissions in Finland in 2008, being the second largest source of greenhouse gas emissions. Emissions from the process industry have increased by about 41% (~2.0 Tg CO₂ eq.) since 1990, but their share from the total greenhouse gas emissions has remained relatively constant (6 to 10 per cent of total emissions). The increase in the emissions from industrial processes is largely consistent with the economic trend, even if the factors influencing the emissions are more diverse.

Agriculture is the third most significant source of greenhouse gas emissions in Finland. In 2008 agricultural emissions accounted for approximately 8% (5.8 Tg CO₂ eq.) of total emissions. Emissions from agriculture include CH₄ and N₂O emissions. The total emissions from agriculture have a clearly decreasing trend. The annual emissions have reduced by 12% since 1990 due to decreases in the cultivation of organic soils, 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 waste sector accounted for 3% (2.2 Tg CO₂ eq.) of total Finnish greenhouse gas emissions in 2008. Emissions from the waste sector consist of CH₄ and N₂O emissions and they have had a decreasing trend since 1990. Overall, the annual emissions in the waste sector have decreased by almost 45% since the 1990 level. The decrease has been mainly due to the implementation of the Waste Act introduced in 1993, which requires increased recycling and recovery of waste as material or energy.

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

Indirect N₂O emissions caused from N deposition of NO_x emissions are reported in the category Energy in the Finnish inventory. These contribute less than 0.3% to the total emissions.

The LULUCF sector is a net sink in Finland. The net sink in the LULUCF sector has varied from approximately 20% to 50% of the annual emissions from the other sectors during 1990-2008 (Figure ES.3-3). Most of the removals in the LULUCF sector come from forest growth. The annual increment of trees has increased steadily for which reason the CO₂ uptake has also grown. The total drain of trees is very much affected by commercial fellings and the global market situation. In 2007 commercial roundwood fellings were at exceptional high level of nearly 58 million m³. The increase in fellings compared to the earlier year was 14% (Finnish Forest Research Institute, 2008). This is main reason for decrease in net sink of LULUCF sector in 2007.

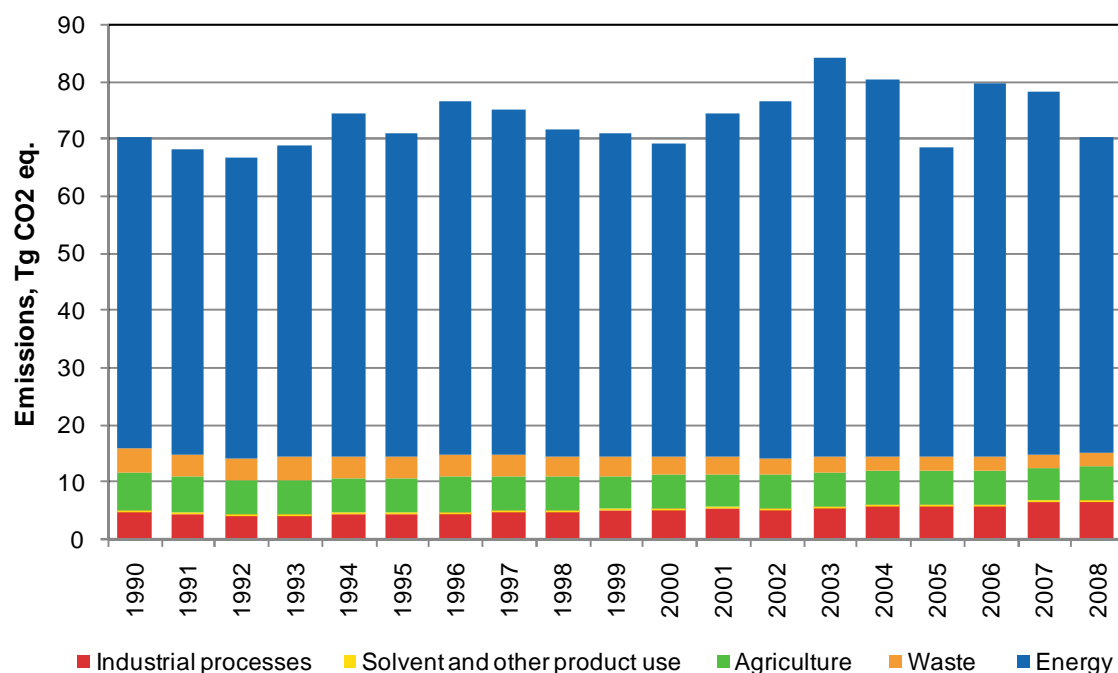


Figure ES.3-2 Greenhouse gas emissions in Finland in 1990-2008 by reporting sector (Tg CO₂ eq.).

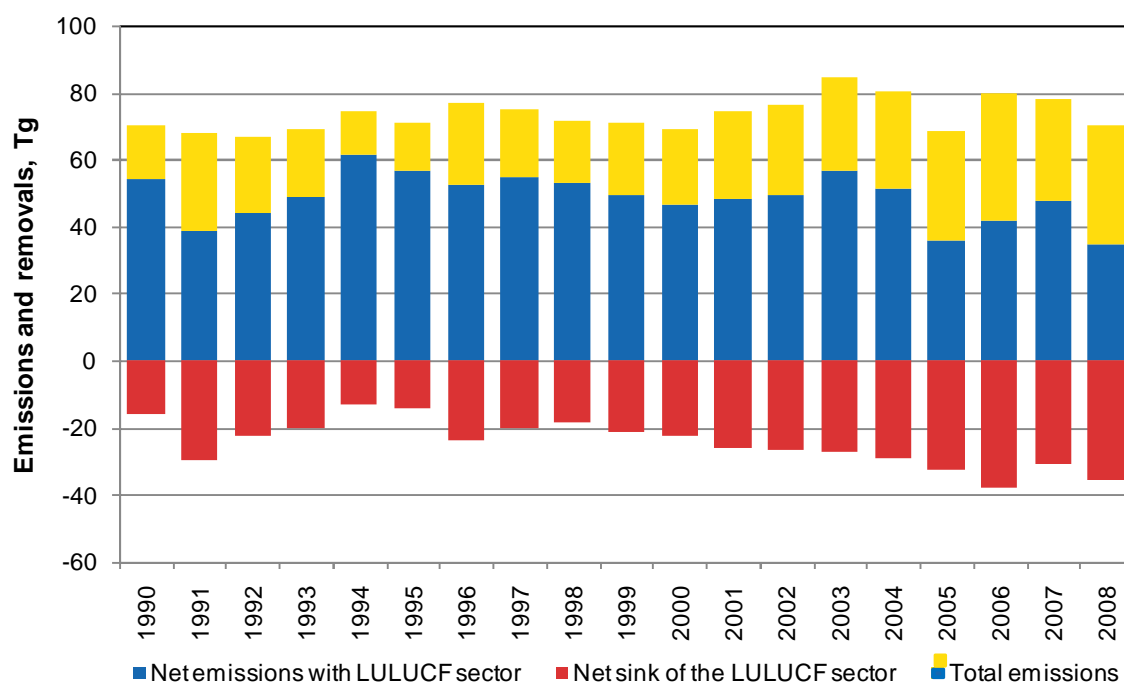


Figure ES.3-3 Net CO₂ equivalent emissions of greenhouse gases in 1990-2008 (emissions plus removals). Emissions are positive and removals negative quantities.

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

Finland's emission limitation target for the Kyoto Protocol's first commitment period (CP, 2008-2012) is to limit its greenhouse gas emissions to the same average level as the emissions in the base year. Finland's base year is 1990, except for F-gas emissions for which the year 1995 was selected. The assigned amount for the first CP is 355,017,545 tonnes CO₂ equivalents, which is approximately 71 million tonnes CO₂ eq. annually on average.

For the LULUCF activities under Article 3 paragraphs 3 and 4, of Kyoto Protocol Finland has chosen commitment period accounting. Article 3.3 covers direct, human induced afforestation (A), reforestation (R) and deforestation (D) activities, and accounting of these activities is mandatory. Under Article 3.4 Finland has elected the activity Forest Management (FM) for optional accounting of the first CP. Net removals from FM activity can be used to compensate net emissions from activities under Article 3.3, and through the issuance of removal units (RMUs) up to a cap value. Finland's cap value for the CP is 2,933,333 tonnes CO₂ equivalents.

Net emissions from ARD activities in 2008 were 1.82 million tonnes CO₂ eq., and net removals from FM activity were 39.9 million tonnes CO₂ eq. (Table ES.4-1). CH₄ and N₂O emissions from biomass burning of AR activities are included under FM, data for analysing burned areas concerning AR activities separately from FM activity were not available. Based on the estimates for the first year of the CP Finland would be able to issue RMUs 0.58 million tonnes CO₂ eq. (cap value divided by 5) for this year at the end of the CP.

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

GREENHOUSE GAS SOURCE AND SINK ACTIVITIES ^{1,2}	Net CO ₂ emissions/removals	CH ₄	N ₂ O	Net CO ₂ eq. emissions/removals
		(Gg)		
A. Article 3.3 activities				1 816
A.1. Afforestation and Reforestation	-1 077			-1 077
A.1.1. Units of land not harvested since the beginning of the commitment period	-1 077	IE	IE	-1 077
A.1.2. Units of land harvested since the beginning of the commitment period	NA	NA	NA	NA
A.2. Deforestation	2 886	NA	0.02	2 893
B. Article 3.4 activities				-39 891
B.1. Forest Management	-39 927	0.06	0.11	-39 891
B.2. Cropland Management	NA	NA	NA	NA
B.3. Grazing Land Management	NA	NA	NA	NA
B.4. Revegetation	NA	NA	NA	NA

¹ IE (included elsewhere), NA (not applicable)

² the signs for removals are negative (-) and for emissions positive (+)

1 INTRODUCTION

1.1 Background information on greenhouse gas inventories and climate change

1.1.1 Greenhouse gas inventories

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

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

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

This National Inventory Report (NIR) of Finland for the 2010 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 (CO₂), methane (CH₄), nitrous oxide (N₂O), perfluorocarbons (PFCs), hydrofluorocarbons (HFCs) and sulphur hexafluoride (SF₆).

Indirect CO₂ emissions resulting from atmospheric oxidation of CH₄ and NMVOC emissions from non-biogenic sources are also included in the inventory. These have been separately estimated for fugitive emissions in the Energy sector and sources in the Industrial Process and Solvent and Other Product Use sectors using the methodology given in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006, see Section 7.2.1.5). For fossil fuel combustion, indirect emissions are included in the methodology to estimate CO₂ emissions. The estimation and reporting of indirect CO₂ emissions are also addressed in the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 1997) and the UNFCCC reporting guidelines on annual inventories (UNFCCC 2006).

The NIR includes also estimates of so-called indirect greenhouse gases (carbon monoxide (CO), nitrogen oxides (NO_x) and non-methane volatile organic compounds (NMVOCs) and sulphur dioxide (SO₂ meaning sulphur oxides and other sulphur emissions calculated as SO₂). Indirect greenhouse gases and sulphur dioxide do not have a direct warming effect, but influence on the formation or destruction of direct greenhouse gases, such as tropospheric ozone. These gases are not included in Annex A of the Kyoto Protocol.

The emission estimates and removals are presented by gas and by source category and refer to the year 2008. Full time series of the emissions and removals from 1990 to 2008 are included in the submission.

The structure of this NIR follows the UNFCCC reporting guidelines on annual inventories (UNFCCC 2006). The annotated outline of the NIR, and the guidance contained therein, developed by the UNFCCC secretariat in 2009, has been followed only partly. Chapter 1 provides an introduction to the background of greenhouse gas inventories and the inventory preparation process and Chapter 2 presents the overall emission trend in Finland from the year 1990 to the year 2008. In Chapters 3–9 more detailed information of GHG emission estimates are given for the seven sectors: (i) energy, (ii) industrial processes, (iii) solvent and other product use, (iv) agriculture, (v) land use, land-use change and forestry, (vi) waste, and (vii) other. In Chapter 10 improvements

and recalculations since the previous submission are summarised. Chapter 11 provides description of KP-LULUCF, Chapter 12 information on accounting of KYOTO units, Chapter 13 information on changes in national system and Chapter 14 information on changes in national registry. Chapter 15 gives information on minimisation of adverse impacts in accordance with Article 3, paragraph 14. Annex 1 contains the mandatory key category reporting tables, the information which is also provided in summary form in Section 1.5 and CRF table 7. In Annex 2 the VAHTI emission database of Finland's environmental administration is described. Annex 3 discusses the applicability of the IPCC default CO₂ emission factor for coal to Finnish circumstances. A national reference calculation for CO₂ emissions from energy combustion will be included in Annex 4 (Comparison of CO₂ emissions calculated from the Energy balance with fuel combustion emissions as reported in the CRF tables) in the 2011 submission. Assessment of completeness and (potential) sources and sinks of greenhouse gas emissions and removals excluded is included in Annex 5. Annex 6 contains the mandatory uncertainty reporting table (table 6.1 of Good Practice Guidance 2000), and additional information on Tier 2 uncertainty analysis as well as sensitivity analysis. Annex 7 includes additional information to be considered as part of the annual inventory submission and the supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol or other useful reference information.

1.1.2 Climate change

Over the past century, atmospheric concentrations of carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O) 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 Fourth Assessment Report of the International Panel of Climate Change (IPCC 2007), the atmospheric concentrations of CO₂ have increased by 35%, CH₄ concentrations have more than doubled and N₂O concentration has risen by 18%, 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, ecosystem 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. According to Finland's National Strategy for adaptation to climate change from the year 2005 (Ilmastonmuutoksen kansallinen sopeutumisstrategia 2005) the average temperature in Finland could rise by about 4-6°C and the average precipitation grow by 15%–25% by the year 2080. Extreme weather events, such as storms, droughts and heavy rains, are likely to increase.

1.1.3 International agreements

Finland has made a commitment 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 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 1990¹.*

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.

¹ 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.

Under the UNFCCC and the Kyoto Protocol, Finland is required to submit annually to secretariat of the Convention a national greenhouse gas inventory covering emissions and removals of direct greenhouse gases from the six sectors (Energy, Industrial processes, Solvent and other product use, Agriculture, Land use, Land-use change and Forestry and Waste) and for all years from the base year or period to the most recent year. The preparation and reporting of the inventories are guided by the UNFCCC guidelines (UNFCCC 2006) and are based on the following IPCC methodologies to ensure the comparability, accuracy and completeness of the inventories;

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

The EU's greenhouse gas monitoring mechanism (280/2004/EC) combines information on annual emission inventories, the climate strategy and the evaluation of the effects of the policy measures and planning of new measures into a dynamic process. The Commission decisions on the implementing provisions and rules of the monitoring mechanism (29 October 2004 and 10 February 2005) specify in detail the content of the reports to be submitted to the Commission. The 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 Community and its Member States to meet their commitments under the UNFCCC and the Kyoto Protocol.

1.2 A description of the institutional arrangement for inventory preparation

1.2.1 National Greenhouse Gas Inventory System in Finland

According to the Government resolution of 30 January 2003 on the organisation of climate policy activities of Government authorities, Statistics Finland assumes the responsibilities of the National Authority for Finland's greenhouse gas inventory from the beginning of 2005. In Finland the National System is established on a permanent footing and it guides the development of emission calculation in the manner required by the agreements. The national system is based on regulations concerning Statistics Finland, on agreements between the inventory unit and expert organisations on the production of emission estimates and reports as well as on co-operation between the responsible ministries. The National System is designed and operated to ensure the transparency, consistency, comparability, completeness, accuracy and timeliness of greenhouse gas emission inventories. The quality requirements are fulfilled by implementing consistently the inventory quality management procedures. The National System for the Greenhouse Gas Inventory in Finland is presented in Figure 1.2-1 below². Changes in national system since the previous submission are addressed in Chapter 13.

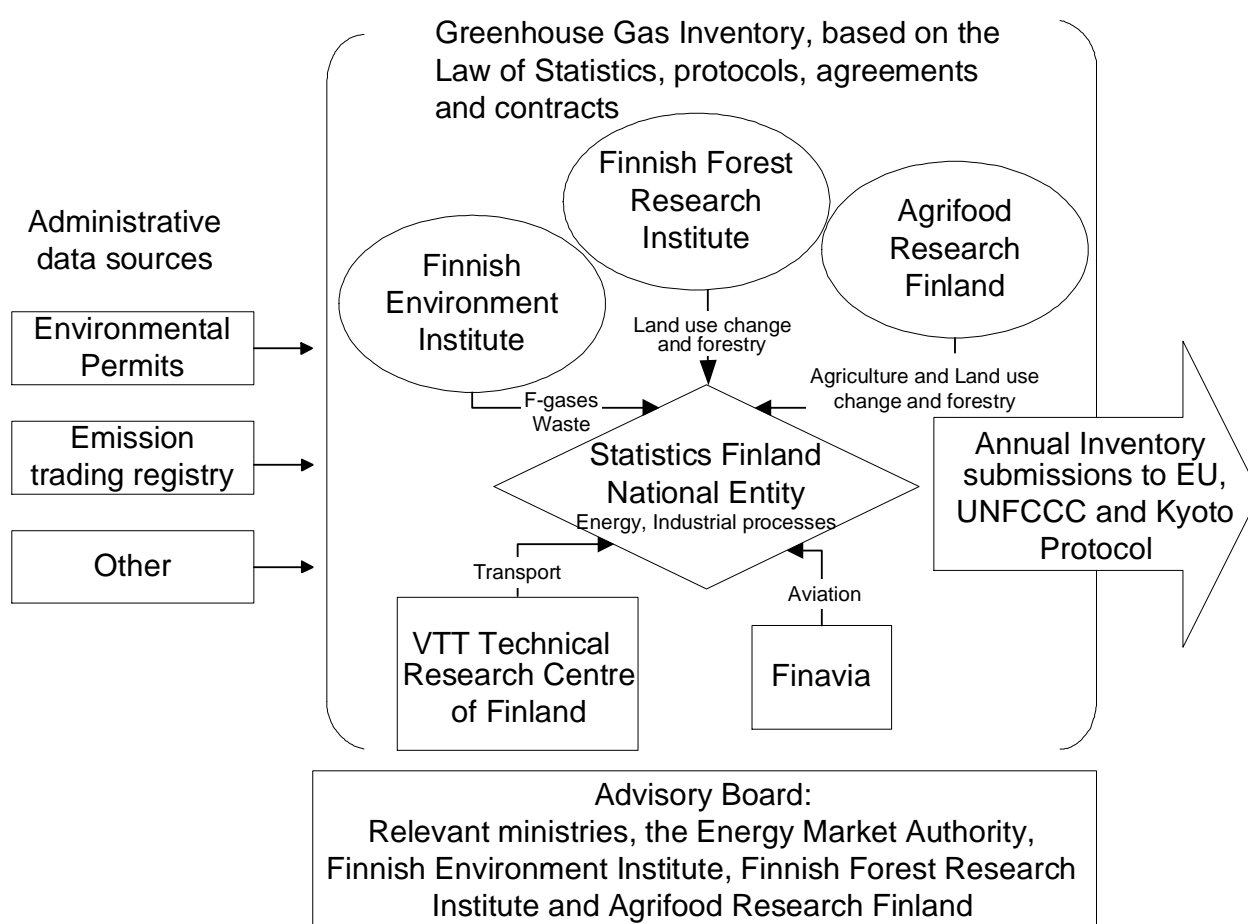


Figure 1.2-1 The National System for the Greenhouse Gas Inventory in Finland.

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

Statistics Finland as the National Authority for the inventory

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

Statistics Finland defines the placement of the inventory functions in its working order. The advisory board of the greenhouse gas inventory set up by the Statistics Finland ensures collaboration and information exchange in issues related to the reporting of greenhouse gas emissions under the UNFCCC and the Kyoto Protocol. The advisory board reviews the achieved quality of the inventory and decides about changes to the inventory's division of labour as agreed for the reporting sectors. In addition, the advisory board promotes longer term research and review projects related to the development of the inventory and reporting, as well as the responsibilities of 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 Authority Statistics Finland also bears the responsibility for the general administration of the inventory and communication with the UNFCCC, co-ordinates participation in the review of the inventory, and publishes and archives the inventory results.

Responsibilities of expert organisations

Finland's inventory system includes in addition to Statistics Finland the expert organisations that have previously taken part in the emission calculation. With regard to this co-operation, separate agreements are made with the Finnish Environment Institute, MTT Agrifood Research Finland and the Finnish Forest Research Institute. Statistics Finland also acquires parts of the inventory as purchased services from VTT (Technical Research Centre of Finland) and Finavia (former Civil Aviation Administration).

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

Table 1.2-1 Reporting protocols and their responsible organisations.

Reporting protocols	Responsible organisations
A. Stationary sources - fuel combustion in point sources, such as power plants, heating boilers, industrial combustion plants and processes	Statistics Finland
B. Mobile sources (transport and off-road machinery)	VTT Technical Research Centre of Finland, Finavia (as a purchased service)
C. Other fuel combustion (agriculture, households, services, public sector, etc.)	Statistics Finland
D. Fugitive emissions from energy production and distribution	Statistics Finland
E. Emissions from industrial processes	Statistics Finland
F. Emissions of F-gases	Finnish Environment Institute
G. Non-methane volatile organic compounds, NMVOC	Finnish Environment Institute
H. Emissions from agriculture	MTT Agrifood Research Finland
I. Emissions from land use, land-use change and forestry	Finnish Forest Research Institute, MTT Agrifood Research Finland
J. Emissions from waste treatment	Finnish Environment Institute
L. Activities under Article 3, paragraphs 3 and 4 of the Kyoto Protocol (ARD and FM)	Finnish Forest Research Institute, MTT Agrifood Research Finland

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

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

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

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

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

In accordance with the Government resolution, the ministries produce the data needed for international reporting on the content, enforcement and effects of the climate strategy. Statistics Finland assists in the technical preparation of the policy reporting. Statistics Finland also compiles technically the National Communications under the UNFCCC and the Kyoto Protocol. Separate agreements have been made on the division of responsibilities and co-operation between Statistics Finland and the ministries. The agreement between Statistics Finland and the Ministry of the Environment were updated in 2008. The agreements between Statistics Finland and the Ministry of Employment and the Economy and between Statistics Finland and the Ministry of Transport and Communications Finland will be updated in 2010.

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

1.2.2 National Registry

Finland's registry is described in Chapter 14 (the description can also be found at <http://stat.fi/greenhosuegases>). The registry was connected to the international transaction log (ITL) of the UNFCCC secretariat in October 2008. Changes in the national registry in 2009 are addressed in Chapter 14.

The Energy Market Authority is responsible for national registry, the internal reporting system and database management. The registry administrator, senior Engineer (D.Sc.) Jouko Hepola in the Energy Market Authority is responsible for the registry system. The company WM-data is responsible for hosting the registry production servers (network connectivity and VPN devices) and providing data communication services to the production environment. Innofactor Ltd. is responsible for application-level management, including core software, localization and environment and registry test/preproduction servers.

The Energy Market Authority is committed to produce 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 has been done using so-called standard electronic tables (SEF), which are also addressed in Chapter 14.

1.3 Brief description of the process of inventory preparation

The UNFCCC, the Kyoto Protocol and the EU's greenhouse gas monitoring mechanism require Finland to submit annually a National Inventory Report (NIR) and Common Reporting Format (CRF) tables. The annual submission contains emission estimates for the second but last year, so that the 2010 submission contains estimates for the calendar year 2008.

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

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

1.4 Brief general description of the methodologies and data sources used

The methodologies used for the Finnish greenhouse gas inventory are consistent with the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 1997) and IPCC Good Practice Guidance (IPCC 2000) and IPCC Good Practice Guidance for Land Use, Land Use Change and Forestry (IPCC 2003). Detailed descriptions of the methodologies used can be found as sector specific from Chapters 3 to 9.

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

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

Sector	Main data sources
1.A Energy: Fuel combustion	VAHTI system Energy Statistics, Yearbook 2009 (Statistics Finland) Surveys: electricity production, district heating plants, energy consumption of the manufacturing industry LIPASTO and TYKO models of VTT, Finavia Energy Market Authority (ETS emission data)
1.B Fugitive emissions	VAHTI system Energy Statistics, Yearbook 2009 (Statistics Finland) Individual companies
2. (I) Industrial processes	Energy Market Authority (ETS emission data) Industrial statistics database VAHTI system Individual production plants
2. (II) Industrial processes (F-gases)	Surveys of the Finnish Environment Institute
3. Solvents and other product use	VAHTI system ULTIKA/ULJAS, import statistics of Finland Association of Finnish Paint Industry Individual companies Published literature
4. Agriculture	Matilda database of the Ministry of Agriculture and Forestry Yearbook of Farm Statistics Finnish Trotting and Breeding Association MTT Agrifood Research Finland Finnish Environment Institute (SYKE) Published literature
5. LULUCF	NFI (National Forest Inventory) Finnish Statistical Yearbook of Forestry Yearbook of Farm Statistics Association of Finnish Peat Industry VAHTI system Published literature
6. Waste	VAHTI system Water and Sewage Works Register Register for Industrial Water Pollution Control

The VAHTI system of Finland's environmental administration is one of the main data sources used in the inventory (especially in the Energy and Waste sectors). The VAHTI system functions as a tool for the 15 Centres for Economic Development, Transport and the Environment in their work on processing and monitoring environmental permits. The data system contains information on the clients (more than 31,000) required by the environmental permits, such as:

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

A more detailed description of VAHTI is included in Annex 2.

The EU ETS data obtained from the Energy Market 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 CO₂ emissions of specific installations (mainly energy emissions). During 2005–2007, Finland has 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 is applied to CO₂ 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 CO₂ into the atmosphere. The issuance of permits lies with the Energy Market Authority. In Finland, the number of installations needing a permit has been around 530 during the first period of the EU ETS.

The Commission has specified the interpretation of the Directive's scope for the second period in its guidelines concerning the period 2008–2012. According to that the scope of emissions trading will expand in Finland to involve petrochemical cracking installations and mineral wool production. There is no carbon black production referred to by the Commission in Finland. At the moment there are about 600 installations, which need a permit.

1.5 *Brief description of the key categories*

1.5.1 *GHG inventory*

This section provides an overview of key categories. The detailed reporting tables required by the official UNFCCC reporting guidelines are provided in Annex 1 of this report. All of the reporting tables are structured following IPCC (2003).

Using tables 7.1 and 5.4.1 of IPCC (2000) and IPCC (2003) as a basis, the key category analysis consists of 154 category-gas combinations. This is a more detailed categorisation than suggested, but it better reflects the methodologies used and the national circumstances. One exception is the energy sector, where the disaggregation for CO₂ emissions from stationary combustion is down to the level where CRF fuels types (liquid, gaseous, solid, and other fuels) are distinguished. A detailed discussion of and justification for the disaggregation is provided in Monni (2004).

Finland reports the results of the Tier 2 key category analysis (IPCC 2000, 2003), which means that the analysis accounts for uncertainties. The goal is to screen the long list of category-gas combinations, 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 on the quality of the estimates and assessing needs for improvements with the sectoral experts. The discussions take place during annual quality meetings, and result in potential candidates for closer scrutiny (see Section 1.7). The key categories are also subject to more detailed documentation and quality control.

IPCC (2000, 2003) also suggest identifying key categories based on qualitative criteria. However, none were identified for the present submission.

The key categories of Table 1.5-1 are also found in CRF table 7.

1.5.2 *KP-LULUCF inventory*

Key category analysis for KP-LULUCF was performed according to section 5.4 of the IPCC good practice guidance for LULUCF (IPCC 2003). The results are reported in Section 11.6.1 and CRF table NIR.3.

Table 1.5-1 Key categories identified using Tier 2 methodology. Detailed reporting tables can be found in Annex 1.

IPCC Greenhouse Gas Source and Sink Categories	Direct greenhouse gas	Key category	Criteria for identification	Comments
1.A. Fuel Combustion - gaseous fuels	CO2	Yes	Trend	..
1.A. Fuel Combustion - liquid fuels	CO2	Yes	Level (1990, 2008), trend	..
1.A. Fuel Combustion - other fuels	CO2	Yes	Level (1990, 2008), trend	..
1.A. Fuel Combustion - solid fuels	CO2	Yes	Level (1990, 2008), trend	..
1.A.1 Energy Industries - biomass	CH4	Yes	Trend	..
1.A.1 Energy Industries - other fuels	CH4	Yes	Trend	..
1.A.3.b. Road Transportation - diesel	N2O	Yes	Level (2008), trend	..
1.A.3.b. Road Transportation - gasoline - cars with catalytic converters	N2O	Yes	Level (1990, 2008)	..
1.A.4. Other Sectors - biomass	CH4	Yes	Level (1990, 2008), trend	..
1.A.5 Other - other fuels (mostly indirect N2O from NOx)	N2O	Yes	Level (1990, 2008)	..
2.B.2 Nitric Acid Production	N2O	Yes	Level (1990, 2008), trend	..
2.B.5 Other: Hydrogen Production	CO2	Yes	Trend	..
2.C.1 Iron and Steel production	CO2	Yes	Level (2008), trend	..
2.F.1. Refrigeration and Air Conditioning Equipment	HFCs, PFCs	Yes	Level (2008), trend	..
2.F.8 Electrical Equipment	SF6	Yes	Trend	..
4.A. Enteric fermentation	CH4	Yes	Level (1990, 2008), trend	..
4.B. Manure management	CH4	Yes	Level (1990, 2008), trend	..
4.D. Agricultural soils: direct emissions, animal production and sludge spreading	N2O	Yes	Level (1990, 2008), trend	..
4.D. Agricultural soils: indirect emissions	N2O	Yes	Level (1990, 2008), trend	..
5.A.1. Forest Land remaining Forest Land - net carbon stock change in living biomass	CO2	Yes	Level (1990), trend	..
5.A.1. Forest Land remaining Forest Land - net carbon stock change in mineral soils	CO2	Yes	Level (1990, 2008), trend	..
5.A.1. Forest Land remaining Forest Land - net carbon stock change in organic soils	CO2	Yes	Level (1990, 2008), trend	..
5.A.2. Cropland converted to Forest Land - net carbon stock change in organic soils	CO2	Yes	Level (1990), trend	..
5.A.2. Grassland converted to Forest Land - net carbon stock change in living biomass	CO2	Yes	Trend	..
5.A.2. Grassland converted to Forest Land - net carbon stock change in organic soils	CO2	Yes	Level (2008), trend	..
5.A.2. Settlements converted to Forest Land - net carbon stock change in mineral soils	CO2	Yes	Level (1990, 2008), trend	..
5.A.2. Wetlands converted to Forest Land / drained-WL - organic soils	CO2	Yes	Level (2008), trend	..
5.B.1. Cropland Remaining Cropland - net carbon stock change in mineral soils	CO2	Yes	Level (1990, 2008), trend	..
5.B.1. Cropland Remaining Cropland - net carbon stock change in organic soils	CO2	Yes	Level (1990, 2008), trend	..
5.B.2 Forest Land converted to Cropland / organic soils - net carbon stock change in organic soils	CO2	Yes	Level (2008), trend	..
6.A. Solid Waste disposal on Land	CH4	Yes	Level (1990, 2008), trend	..
6.B.2 Domestic and Commercial Wastewater - densely populated areas	N2O	Yes	Level (1990, 2008)	..
6.D Other: compost production	CH4	Yes	Trend	..

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

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

1.6.1 Quality management is implemented in a structured way

The objective of Finland's GHG inventory system is to produce high-quality GHG inventories. As a national statistical office Statistics Finland and its Greenhouse gas inventory unit are committed to quality. The quality framework based on the European Statistics Code of Practice and Statistics Finland's Guidelines on Professional Ethics (the documents are available on the web: http://tilastokeskus.fi/org/periaatteet/index_en.html) supports the GHG inventory quality management.

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

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

Issues related to QA/QC are discussed at the meetings of the inventory working group (4-7 meetings per year) and at the bilateral quality meetings between the inventory unit and the expert organisations (once a year). The main findings and conclusions concerning the inventory's quality and improvement needs are communicated to the advisory board.

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

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

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

1.6.2 Inventory process

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

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

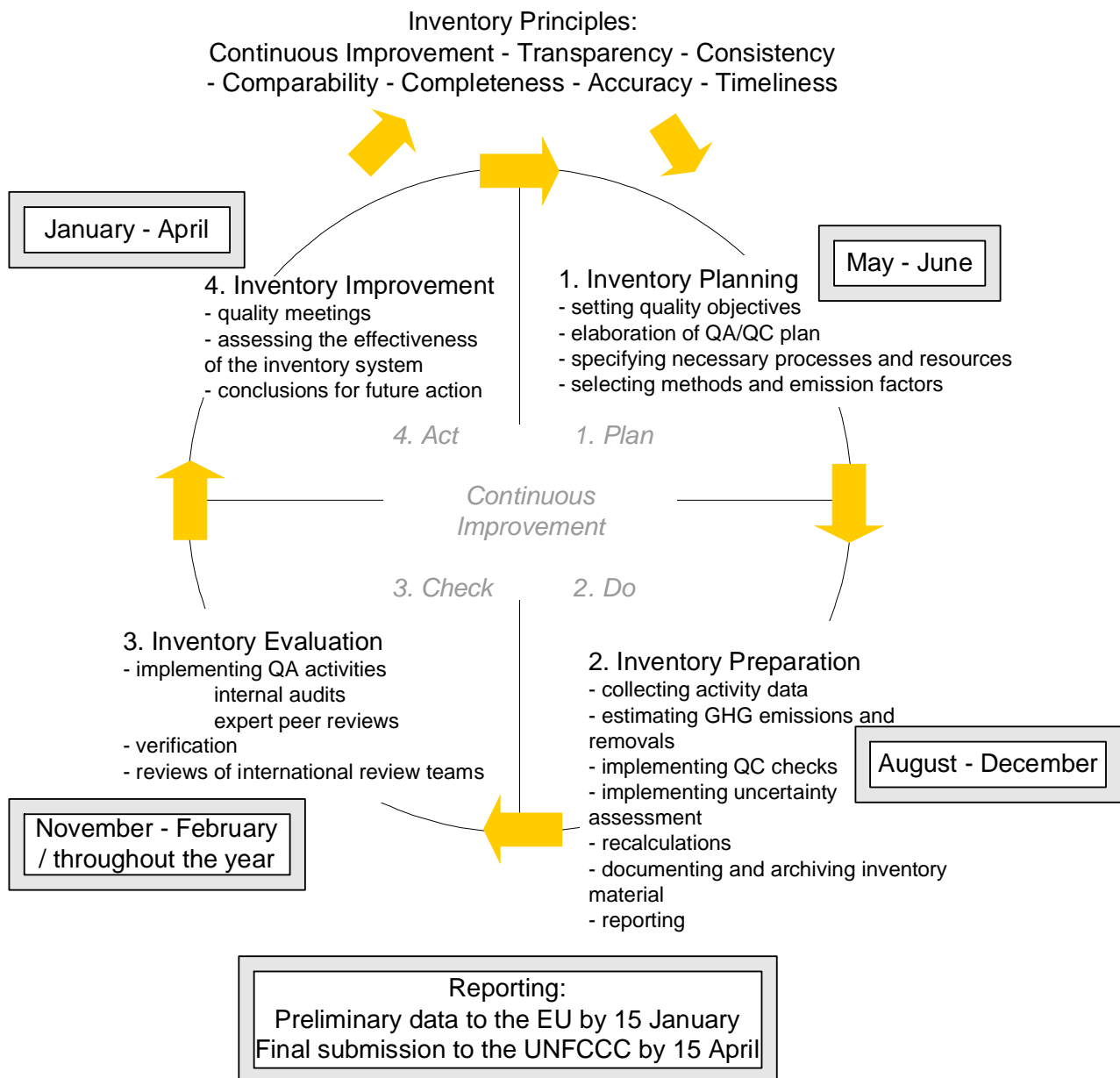


Figure 1.6-1 Inventory process.

1.6.3 QA/QC process

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

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

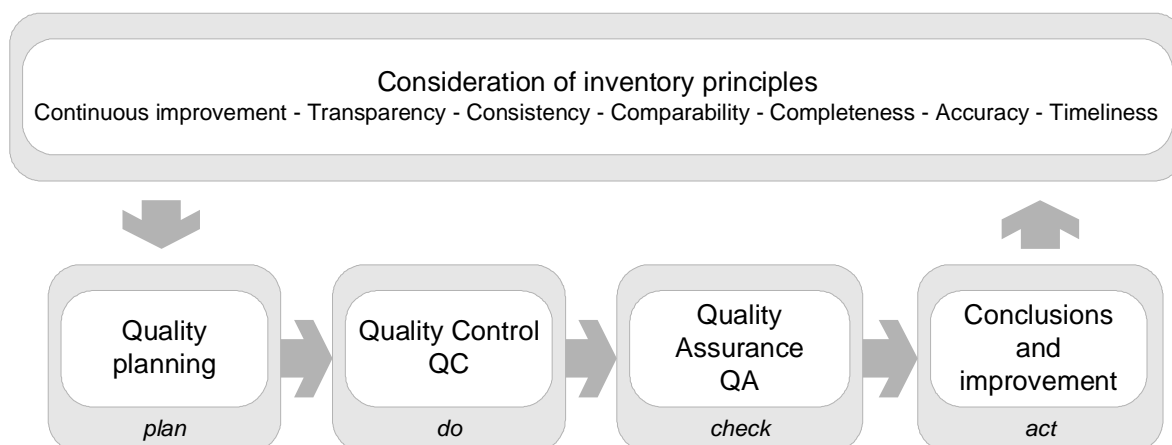


Figure 1.6-2 QA/QC process of the inventory.

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

The inventory planning stage includes the setting of quality objectives and elaboration of the QA/QC plan for the coming inventory preparation, compilation and reporting work.

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

The quality objectives regarding all calculation sectors for the 2008 inventory were the following:

1. Continuous improvement
 - 1.1. Treatment of review feedback is systematic
 - 1.2. Improvements promised in the National Inventory Report (NIR) are carried out
 - 1.3. Improvement of the inventory is systematic
 - 1.4. Inventory quality control (QC) procedures meet the requirements
 - 1.5. Inventory quality assurance (QA) is appropriate and sufficient.
2. Transparency
 - 2.1. Archiving of the inventory is systematic and complete
 - 2.2. Internal documentation of calculations supports emission and removal estimates
 - 2.3. CRF tables and the National Inventory Report (NIR) include transparent and appropriate descriptions of emission and removal estimates and of their preparation.
3. Consistency
 - 3.1. The time series are consistent
 - 3.2. Data have been used in a consistent manner in the inventory.
4. Comparability
 - 4.1. The methodologies and formats used in the inventory meet comparability requirements.
5. Completeness
 - 5.1. The inventory covers all the emission sources, sinks, gases and geographic areas.

6. Accuracy
 - 6.1. Estimates are systematically neither higher nor lower than the true emissions or removals
 - 6.2. Calculation is correct
 - 6.3. Inventory uncertainties are estimated.
7. Timeliness
 - 7.1. High-quality inventory reports reach their receivers (EU / UNFCCC) within the set time.

The quality objectives and the planned general QC and QA procedures regarding all sectors are set in the QA/QC plan. This is a checklist that specifies the actions, schedules and responsibilities in order to attain the quality objectives and to provide confidence in the Finnish national system's capability to deliver high-quality inventories. The QA/QC plan is written in Finnish and updated yearly. 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 use source-specific QC checklists and perform source-specific QA and verification. These lists are included in the internal documentation of the calculation.

1.6.4 Quality control procedures aim at attainment of the quality objectives

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

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

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

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

1.6.5 Quality assurance comprises a planned system of review procedures

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

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

A basic review of the draft GHG emission and removal estimates and the draft report (i.e. a basic expert review of an inventory, Tier 1 QA according to the IPCC good practice guidance, Chapter 8.8) takes place before the initial submission to the EU (in November to December) and again before the final submissions to the EU and UNFCCC (January to March) by the inventory working group, the inventory unit and the advisory board. The 2010 submission to the UNFCCC has been reviewed in December 2009 and in March 2010.

Bilateral quality meetings function as Tier 1 QA audits (as defined in the IPCC good practice guidance, Chapter 8.8). The bilateral quality meetings have been held between the inventory unit (the compiler) and the expert organisations (producing the inventory estimates and descriptions) in January to February 2010. The main objective of the quality meetings is to ensure that the experts have implemented the QC checks and procedures according to the QC plan and to evaluate the results and documentation of the procedures. Quality meetings follow a fixed agenda that include the following items: Implementation of the QC plan, Sector-specific QC including Tier 2 QC if relevant, Sector-specific QA and verification, Review feedback, Structure and transparency of the reporting (submission 2010, NIR and CRF tables), Improvement needs and projects, and Functioning of the national inventory system (e.g. resources for inventory preparation).

Internal audits are sector-specific Tier 2 QA audits that have a specific viewpoint and timing in the QA system. They are extensive QA assessments that are focused on topical or otherwise important factors in one specific sector (not a submission) at a time, e.g. implementation of general and source-specific QC checks, QA and verification procedures, internal documentation or recalculations. In internal audits representatives of the inventory unit visit the expert organisation to evaluate how effectively the actual activity and the results attained in the specific calculation sectors comply with the requirements. Internal audits provide an in-depth analysis of the respective procedures taken to develop the inventory, and of the documentation available. Above all, the basic task of internal audits is to contribute to the improvement of an inventory in a longer term. Internal audits also contribute to learning and sharing of knowledge and good practices among the actors in the national system. The timing of internal audits is not dependent on the annual submissions: they are carried out throughout the year within the available resources. The first internal audit took place in the agriculture sector in November 2009.

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

Peer reviews may also be bilateral collaboration. For example, the Finnish and Swedish GHG inventory teams have met twice annually to exchange information, experiences and views relating to the preparation on the national GHG inventories. This collaboration also provides opportunities for bilateral peer reviews. The first step in this collaboration relating to quality assurance was an independent comparison and review of the emission factors in the energy sector in Swedish and Finnish inventories that was carried out from September to October 2006. The objectives of the review were to check whether the reporting and choice of emission factors were in accordance with the UNFCCC and IPCC guidelines and, in addition, to compare the emission factors used in Finland and Sweden, and to assess whether the differences (if any) were explainable and reasonable taking the national circumstances into account.

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

The UNFCCC inventory review teams co-ordinated by the UNFCCC Secretariat carry out international reviews of the inventory according to the annual schedule after the submission of the annual inventory report. The expert review teams produce yearly an independent review report on Finland's GHG inventory.

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

In addition to consideration of the special requirements of the guidelines concerning greenhouse gas inventories, development of the inventory quality management system has followed the principles and requirements of the ISO 9001 standard. ISO 9001 certification is under consideration. The certified quality management system would be subject to system audits conducted by external auditing organisations. In

system audits the conformity of the inventory quality management system is evaluated objectively against the requirements of the ISO 9001 standard.

1.6.6 QA/QC process contributes to the improvement of the inventory

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

1.6.7 Documentation and archiving

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

The inventory documentation system consists of the following document types:

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

The main archives of the greenhouse gas inventory unit are at Statistics Finland. The main archive's purpose is to fill the specific function mandated in the guidelines for national systems (UNFCCC Decision 20/CP.7, paragraphs 16 and 17): it holds all the important data, models and documentation needed in inventory development. Being situated in a single location, 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 May each year, after completion and submission of the inventory. This is when paper copies and electronically archived data are handed to the Library of Statistics, a division of Statistics Finland responsible for the preservation of records. 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.

Some of the expert organisations have implemented their archival procedures according to their own plans of archive creation, with designated record identification numbers and systems for electronic storage and retrieval of records.

Energy and Industrial processes

In the Energy and Industrial processes sector (except F-gases and NMVOCs, which are calculated by the Finnish Environment Institute) documentation and annual inventory records are archived according to a plan for archive formation. The archives are located physically in the premises of Statistics Finland. The so-called passive archive holds copies of the submitted inventories. These copies are printed on paper and stored on CD-ROMs. In addition to this, there is an active archive on a backed-up network server. All data, models and documentation needed in inventory preparation are preserved in this archive. The above-mentioned plan for archive formation is stored in a database application, where it can be viewed, changed and searched for information needed in archives management.

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

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

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

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 Finnish Environment Institute's archives for confidential material. Responses of the two most recent inventory years are archived in the office of the sectoral expert.
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. 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 and quality assurance plans for each year.
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 safe 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 racing of original copies of survey responses
 - Spreadsheet applications used for data analysing and calculation
 - Used methods, emission factors and parameters used are displayed on worksheets
 - Estimates are presented for different gases in subcategory level as well as in aggregated category level
 - Simulation reports of data uncertainty analysis
 - Initial data and assumptions are provided in reports
 - Backup copy of CRF Reporter database and submitted CRF data
 - Final version of inventory report (NIR)
 - Annual QA/QC plans

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

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

Agriculture

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

LULUCF

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

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

Waste

All electronic data (mainly Excel, Word or Access files) on the yearly waste inventory 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. Only the most important files are collected in the last two places. Yearly information on paper is collected in one place.

1.7 Summary of the uncertainty analysis

This section provides an overview of the approach to uncertainty analysis adopted for the Finnish inventory. The mandatory, detailed reporting table of the analysis is provided in Annex 6.

The present approach consists of two levels: screening and detailed analysis. Screening is done with Tier 1 uncertainty analysis that supplies information to Tier 2 key category analysis (IPCC 2000, 2003). Screening completes with two outputs: (i) the uncertainty reporting table of Annex 6, and (ii) the short list of key categories presented in section 1.5 above (and the complete set of reporting tables for key categories found in Annex 1). Both outputs are mandatory and fulfil the UNFCCC reporting requirements for uncertainty and key categories. The screening and reporting of mandatory information is carried out on an annual basis, i.e. the analyses of Tier 1 uncertainty and Tier 2 key categories are updated for each submission.

The key categories are subject to further scrutiny. The key categories are discussed with the sectoral experts during the annual quality meetings. For instance, in the January 2010 meetings, 9 topics were selected as the subject of more detailed analyses. These categories will be analysed by Monte Carlo simulation for uncertainty (Tier 2 methodology described in IPCC 2000, 2003), and variance-based, global methods for sensitivity (Saltelli, Tarantola, Campolongo and Ratto 2005). The goal is to pinpoint within the key categories those assumptions and data that have the greatest bearing for uncertainty, and therefore potential for improvement. Over time, this approach develops a list of detailed recommendations for the sectoral experts providing estimates for the Finnish inventory.

The approach makes use of work documented in Monni & Syri (2003), Monni (2004), and Monni et al. (2004, 2007). It however avoids the laborious updating of a detailed Tier 2 simulation model. Experience shows that this is not necessary for each and every submission, as the conclusions do not change unless significant changes are made to the inventory. The resources are better placed, and provide more useful recommendations for the inventory improvement, when the annual work cycle consists of a screening phase (simple Tier 1 uncertainty analysis combined with Tier 2 key category analysis), and a detailed analysis of one or more key categories from the screening phase. An added benefit of the approach is that the data, assumptions and conclusions of both uncertainty and key category analyses are contained within one electronic file. This file can be easily sent to, understood and reviewed by both sectoral experts of the Finnish inventory and the international expert review teams.

The list of category-gas combinations that form the structure for the uncertainty and key category analyses underwent a significant update process for the present submission. The list was amended with two new categories in road transportation and several new conversion categories in land use, land-use change and forestry. The list of categories together with emission and uncertainty estimates were sent to the sectoral expert for comments. As a result of this work, the number of categories increased from 127 to 154. The emissions total of the analyses corresponds to the emissions total of the CRF tables (compare table 6.1 in Annex 6 to CRF table “Summary 2” for 1990 and 2008).

The uncertainty analysis suggests that the inventory level is accurate within $\pm 49\%$. Moreover, the analysis suggests that the emission trend between 1990 and 2008 is accurate within 16%-points; in other words the trend is $(-36 \pm 16)\%$. Both uncertainty estimates include the sinks of land use, land-use change and forestry. The inclusion of land-use conversion categories increased the level uncertainty considerably. It should be noted however, that the uncertainty estimates for these categories are preliminary and subject to change.

Quantitative estimates of uncertainty of the Finnish inventory have been published since 2001, starting from inventory year 1999. This is immediately after the IPCC good practice guidance with its methodologies for uncertainty analysis was published. Table 1.7 summarises the estimates over time.

Table 1.7-1 Uncertainties have been analysed since inventory year 1999.

Uncertainty estimates			Method and documentation		
year 1990	year t	trend	method	source	notes
–	7 %	10 %-points	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	Excluding LULUCF. Including LULUCF.
–6 ... +13 % ±50 %	–5 ... +6 % ±30 %	2 ... 25 % –20 ... +130 %	tier 2	NIR 2006	Excluding LULUCF. Including LULUCF.
–7 ... +13 % ±50 %	–4 ... +7 % ±50 %	–14 ... +6 % –65 ... +45 %	tier 2	NIR 2007	Excluding LULUCF. Including LULUCF.
–	±50 %	±17 %-points	tier 1	NIR 2008	Including LULUCF
–	±23 %	±15 %-points	tier 1	NIR 2009	Including LULUCF
–	±49 %	±16 %-points	tier 1	NIR 2010	Including LULUCF

1.8 General assessment of completeness

1.8.1 Completeness by source and sink categories and gases

Finland has provided estimates for all significant IPCC source and sink categories according to the detailed CRF classification. Estimates are provided for the following gases: CO₂, N₂O, CH₄, F-gases (HFC, PFC and SF₆), NMVOC, NO_x, CO and SO₂.

In accordance with the IPCC Guidelines, international aviation and marine bunker fuel emissions are not included in national totals. However, CO₂, CH₄ and N₂O emissions from lubricants from International bunkers are included in emissions from feedstock and non-energy use of the fuels. Lubricants are not split between domestic and international, as only information on total sales of lubricants is available in fuel statistics. The impact on the total emissions is estimated to be very small.

Assessment of completeness is included in Annex 5.

1.8.2 Completeness by geographical coverage

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

1.8.3 Completeness by timely coverage

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

2 TRENDS IN GREENHOUSE GAS EMISSIONS

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

In 2008 Finland's greenhouse gas emissions totalled 70.1 Tg CO₂ (million tonnes of CO₂ equivalent). The emissions decreased by 1% (0.9 Tg CO₂ eq.) compared with the base year – the level to which Finland should limit its emissions during the Kyoto Protocol's first commitment period between 2008 and 2012. Emissions in 2008 were 10% lower in comparison with the emissions of the previous year.

Figure 2.1-1 shows a time series of CO₂ equivalent emissions in Finland during 1990–2008 and the emission target of the Kyoto Protocol. The total greenhouse gas emissions as CO₂ equivalence and indexed emissions in relation to the base year level are presented in Table 2.1-1.

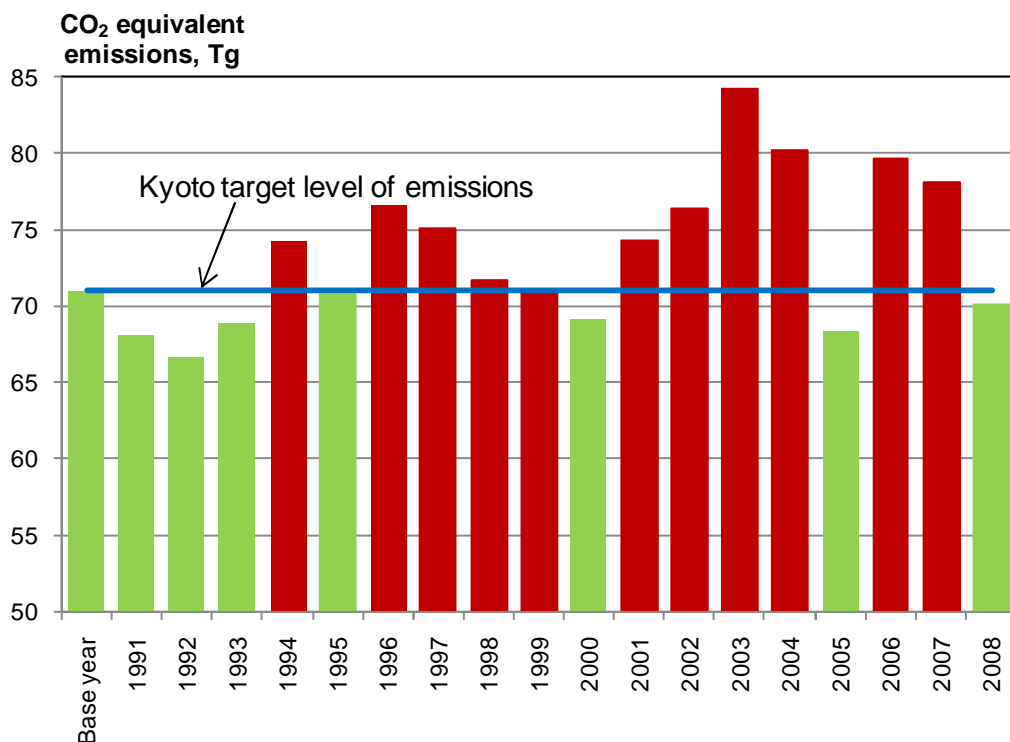


Figure 2.1-1 CO₂ equivalent emissions and the emission target of the Kyoto Protocol (Tg CO₂ eq.).

Table 2.1-1 Total greenhouse gas emissions in Tg CO₂ eq. and indexed 1990-2008 (index 1990=100).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
CO ₂ with LULUCF	40.5	25.4	31.4	35.8	48.5	43.7	39.6	41.9	40.6	37.2	34.0	35.6	37.4	44.4	39.1	23.4	29.7	35.3	22.6
CO ₂ without LULUCF	56.6	55.0	54.2	56.1	61.4	57.9	63.6	62.3	59.1	58.6	56.7	62.0	64.4	72.0	68.1	56.4	67.7	66.1	58.1
CH ₄ with LULUCF	6.3	6.3	6.3	6.3	6.3	6.1	6.0	6.0	5.7	5.6	5.4	5.3	5.1	4.9	4.7	4.5	4.6	4.5	4.3
CH ₄ without LULUCF	6.3	6.3	6.2	6.3	6.2	6.1	6.0	5.9	5.7	5.6	5.4	5.2	5.1	4.9	4.7	4.5	4.5	4.4	4.2
N ₂ O with LULUCF	7.4	6.9	6.4	6.5	6.7	6.8	6.9	6.8	6.6	6.5	6.5	6.5	6.6	6.7	6.7	6.8	6.7	6.7	6.8
N ₂ O without LULUCF	7.4	6.8	6.3	6.5	6.6	6.8	6.8	6.7	6.5	6.4	6.4	6.4	6.5	6.6	6.6	6.7	6.6	6.6	6.7
HFCs	0.000	0.000	0.000	0.000	0.007	0.029	0.077	0.17	0.25	0.32	0.49	0.65	0.46	0.65	0.70	0.86	0.75	0.90	0.99
PFCs	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.028	0.022	0.020	0.013	0.015	0.012	0.010	0.015	0.008	0.011
SF ₆	0.09	0.07	0.04	0.03	0.03	0.07	0.07	0.08	0.05	0.05	0.05	0.06	0.05	0.05	0.03	0.03	0.04	0.04	0.04
Total emissions with LULUCF	54.4	38.6	44.1	48.6	61.5	56.7	52.6	54.9	53.2	49.7	46.5	48.1	49.6	56.8	51.3	35.6	41.8	47.4	34.7
Total emissions	70.4	68.2	66.7	68.8	74.2	70.8	76.6	75.2	71.7	71.0	69.1	74.4	76.5	84.2	80.2	68.4	79.6	78.1	70.1
	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Index (1990=100)																			
CO ₂ without LULUCF	100	97.2	95.7	99.1	108.4	102.2	112.4	110.0	104.5	103.6	100.2	109.4	113.7	127.2	120.3	99.5	119.6	116.7	102.7
CH ₄ without LULUCF	100	99.7	99.3	99.7	99.1	96.6	95.3	94.1	90.9	88.9	85.5	83.5	80.4	77.6	74.9	71.5	72.4	70.5	67.4
N ₂ O without LULUCF	100	92.4	85.5	87.9	89.5	91.9	92.3	91.3	88.7	87.1	87.7	87.3	88.3	90.1	90.2	90.6	89.1	89.4	91.2
Total (group of three)	100	96.9	94.9	97.9	105.6	100.6	108.8	106.6	101.6	100.5	97.5	104.8	108.1	118.9	113.1	96.1	112.2	109.7	98.3
F-gases	100	71.4	39.0	35.8	44.0	103.7	158.4	258.2	316.1	421.9	601.3	765.5	559.7	757.0	784.7	959.6	850.6	1004.0	1106.8
Total (without LULUCF)	100	96.9	94.9	97.9	105.5	100.6	108.8	106.8	101.9	101.0	98.2	105.7	108.7	119.7	114.0	97.2	113.2	110.9	99.7

2.2 Description and interpretation of emission trends by gas

The most important greenhouse gas in Finland is carbon dioxide. The share of CO₂ emissions from the total greenhouse gas emissions has varied from 80% to 85%. In absolute terms CO₂ emissions have decreased 0.9 Tg (i.e. 1%) since 1990. Around 92% of all CO₂ emissions originate from the Energy sector. The amount of energy-related CO₂ emissions has fluctuated much according to the economic trend, the energy supply structure (including electricity imports and exports) and climate conditions.

Methane emissions (CH₄) have decreased by 33% 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 (N₂O) have also decreased by 9%, which has been occasioned mostly by the reduced nitrogen fertilisation of agricultural fields, the biggest decline was in the beginning of time series.

The development of emissions of the three main greenhouse gases in 1990-2008 (CO₂, CH₄ and N₂O) relative to the 1990 level is presented in Figure 2.2-1.

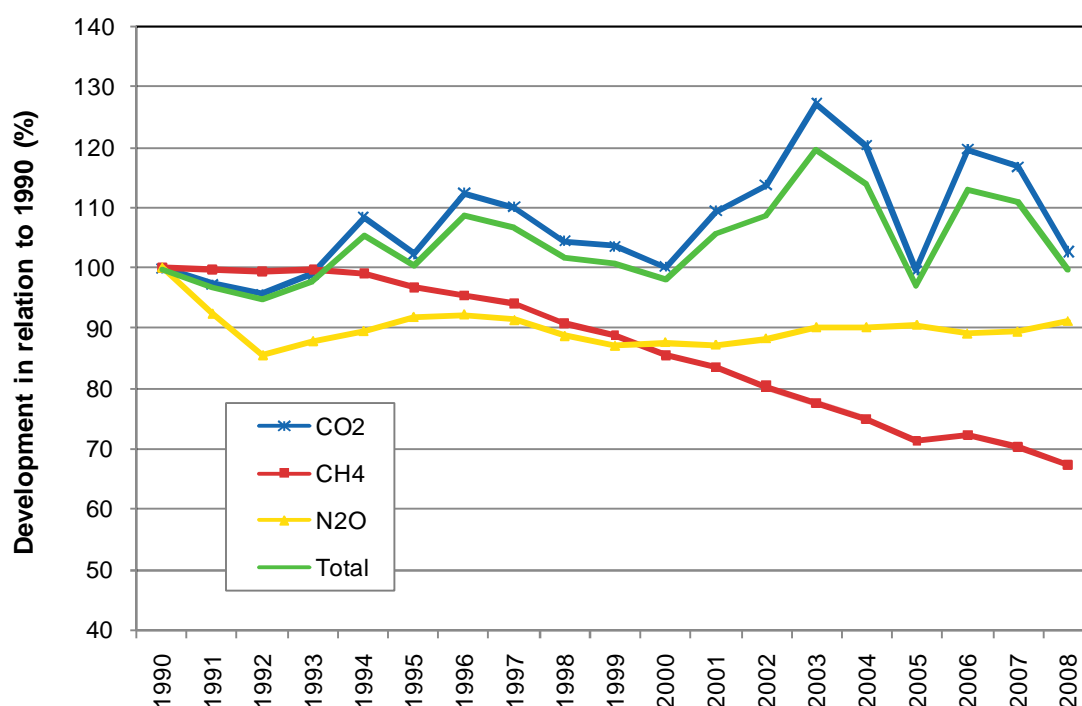


Figure 2.2-1 Relative development of CO₂, CH₄ and N₂O without the LULUCF sector in 1990-2008 relative to the 1990 level (%).

The emissions of F-gases have increased over tenfold during 1990-2008. A key driver behind the trend has been the substitution of ozone depleting substances (ODS) by F-gases in many applications. In Table 2.2-1 the development of emissions of F-gases during 1990-2008 is presented by gas category.

Table 2.2-1 Actual emissions of HFCs, PFCs and SF₆ in 1990-2008 (CO₂ equivalent Gg).

	HFCs	PFCs	SF ₆	Total F-gases
1990	0.02	0.07	94.4	94
1991	0.05	0.08	67.3	67
1992	0.10	0.09	36.6	37
1993	0.10	0.10	33.6	34
1994	6.5	0.12	34.9	42
1995	29.3	0.14	68.5	98
1996	77.3	0.16	72.2	150
1997	167.8	0.18	76.0	244
1998	245.2	0.21	53.2	299
1999	318.6	28.0	52.0	399
2000	494.1	22.5	51.5	568
2001	648.0	20.1	55.0	723
2002	464.1	13.4	51.3	529
2003	652.2	14.9	48.1	715
2004	695.3	12.2	33.8	741
2005	864.0	9.9	32.7	907
2006	747.8	15.4	40.2	804
2007	904.1	8.4	36.0	948
2008	994.0	11.2	40.4	1 046

2.3 Description and interpretation of emission trends by category

The development of the greenhouse gas emissions by sector is presented in Table 2.3-1. The energy sector is the most significant source of greenhouse gas emissions in Finland. This reflects the high energy intensity of the Finnish industry, extensive consumption during the long heating period, as well as energy consumption for transport in a large and sparsely inhabited country (Figure 2.3-1). In the middle of time series total energy consumption increased even if emissions decreased, reasons for that were in increased use of wood fuels, nuclear energy and net imports of electricity. In 2008 the energy sector's emissions were about 1% over the 1990 level. The total energy consumption decreased in 2008 approximately 4% compared with the previous year, totalling 33.8 Mtoe. Contraction of industrial output and mild weather brought the consumption of energy down from the previous year. The replacement of coal condensing power with hydro power in the production of electricity also reduced significantly the total consumption of primary energy and carbon dioxide emissions.

Energy industries (mainly electricity and district heating production) caused approximately 35% of the total emissions in the energy sector in 2008. Emissions from the energy industries were 27% higher in 2008 than in 1990.

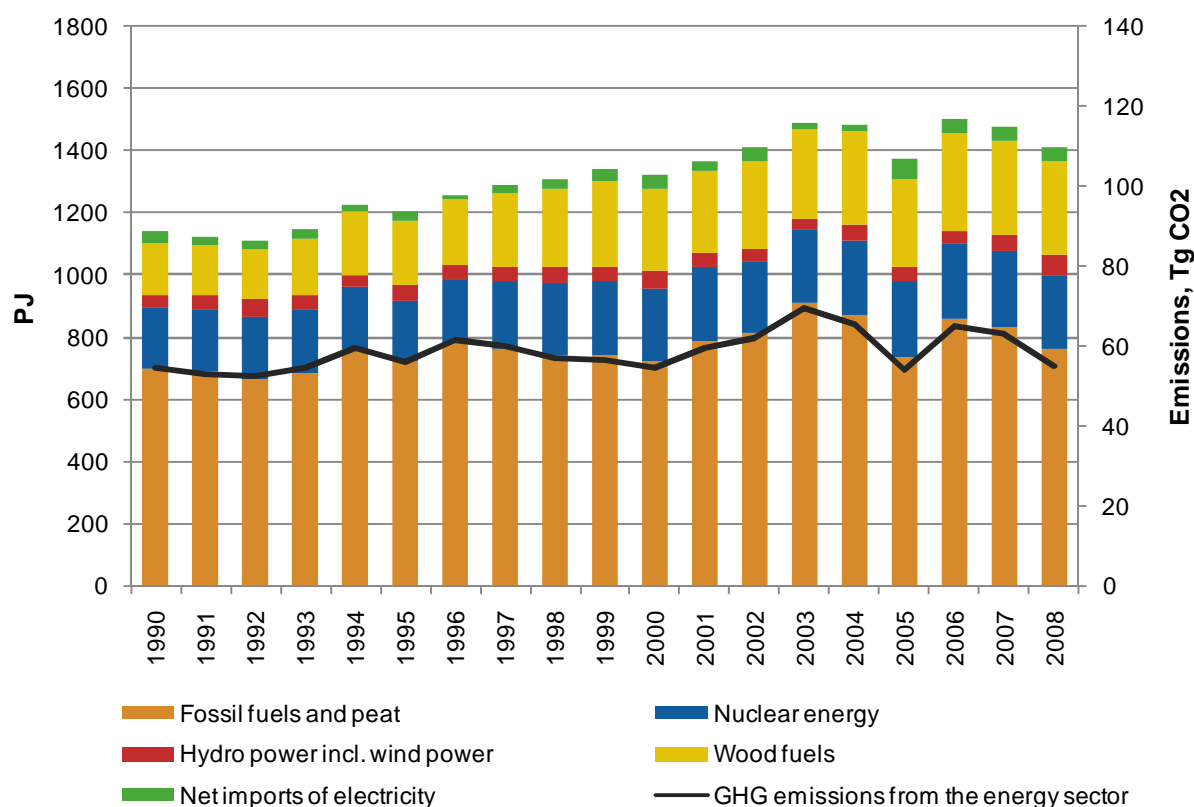


Figure 2.3-1 Development of total energy consumption by energy source (PJ) and the energy sector's greenhouse gas emissions (Tg CO₂ eq.) in Finland in 1990-2008 (GHG Inventory and Energy Statistics, Yearbook 2009).

Table 2.3-1 Summary of emission trend by source category and gas (unit Tg CO₂ eq.).

IPCC sector	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
1. Energy	54.5	53.1	52.4	54.3	59.5	56.1	61.8	60.2	57.0	56.4	54.4	59.7	62.2	69.7	65.6	54.0	65.2	63.2	55.0
A Fuel combustion total	54.3	52.8	52.1	54.0	59.3	55.8	61.5	59.9	56.8	56.2	54.2	59.5	62.1	69.5	65.4	53.8	65.0	63.0	54.8
CO ₂	53.0	51.6	50.8	52.7	58.0	54.5	60.2	58.6	55.5	54.9	53.0	58.2	60.7	68.1	64.0	52.5	63.7	61.7	53.5
1. Energy industries	19.1	18.8	18.6	21.3	26.2	23.9	29.6	27.2	23.9	23.4	21.9	27.2	29.9	36.8	32.6	21.7	32.5	30.5	24.0
2. Manufacturing industries and construction	13.2	12.7	12.1	12.2	12.5	12.0	11.8	12.1	11.7	11.7	11.7	11.3	11.0	11.3	11.4	11.2	11.4	11.3	10.6
3. Transport	12.5	12.2	12.1	11.6	12.0	11.8	11.7	12.3	12.5	12.7	12.6	12.7	12.9	13.1	13.4	13.5	13.7	14.0	13.4
4. Other sectors	7.0	6.9	7.0	6.5	6.2	5.7	5.8	5.8	5.9	5.8	5.5	5.7	5.6	5.5	5.3	5.1	4.9	4.8	4.5
5. Other	1.19	1.02	1.03	1.03	1.14	1.20	1.21	1.13	1.38	1.23	1.27	1.26	1.26	1.28	1.15	1.09	1.09	1.05	1.07
CH ₄	0.31	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.29	0.31	0.31	0.32	0.31	0.30	0.31	0.31	0.29
N ₂ O	1.00	0.97	0.95	0.99	1.02	0.98	1.03	1.03	1.01	1.00	0.98	1.03	1.05	1.10	1.07	0.95	1.05	1.02	0.96
B Fugitive fuel emissions	0.23	0.25	0.27	0.34	0.25	0.25	0.24	0.27	0.22	0.19	0.18	0.19	0.18	0.18	0.17	0.19	0.17	0.18	0.19
CO ₂	0.22	0.21	0.22	0.27	0.17	0.17	0.15	0.20	0.14	0.13	0.13	0.12	0.12	0.12	0.11	0.13	0.11	0.13	0.14
CH ₄	0.01	0.04	0.06	0.07	0.08	0.08	0.08	0.07	0.07	0.06	0.06	0.07	0.06	0.06	0.06	0.06	0.06	0.05	0.05
N ₂ O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2. Industrial processes	5.1	4.7	4.4	4.5	4.6	4.6	4.9	5.2	5.1	5.3	5.5	5.6	5.4	5.9	6.2	6.2	6.2	6.7	7.0
CO ₂	3.3	3.2	3.0	3.1	3.2	3.1	3.2	3.5	3.5	3.6	3.6	3.6	3.5	3.8	3.9	3.7	3.9	4.3	4.4
CH ₄	0.01	0.00	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	0.01
N ₂ O	1.66	1.44	1.30	1.36	1.43	1.46	1.46	1.44	1.38	1.35	1.36	1.29	1.33	1.41	1.50	1.63	1.44	1.48	1.56
HFCs	0.00	0.00	0.00	0.00	0.01	0.03	0.08	0.17	0.25	0.32	0.49	0.65	0.46	0.65	0.70	0.86	0.75	0.90	0.99
PFCs	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.02	0.02	0.01	0.01	0.01	0.01	0.02	0.01	0.01
SF ₆	0.09	0.07	0.04	0.03	0.03	0.07	0.07	0.08	0.05	0.05	0.05	0.06	0.05	0.05	0.03	0.03	0.04	0.04	0.04
3. Solvent and other product use	0.18	0.17	0.16	0.15	0.15	0.14	0.14	0.14	0.14	0.14	0.12	0.12	0.11	0.10	0.11	0.11	0.10	0.10	0.09
CO ₂	0.12	0.11	0.10	0.09	0.08	0.08	0.08	0.07	0.07	0.07	0.07	0.07	0.07	0.06	0.06	0.06	0.06	0.06	0.05
N ₂ O	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.05	0.05	0.04	0.04	0.04	0.05	0.04	0.04	0.03

IPCC sector	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
4. Agriculture	6.6	6.2	5.8	5.9	5.9	6.0	6.0	6.0	5.8	5.7	5.8	5.8	5.8	5.8	5.7	5.7	5.7	5.7	5.8
CH ₄	2.2	2.1	2.0	2.0	2.0	1.9	1.9	2.0	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.8
A. Enteric fermentation	1.9	1.8	1.8	1.8	1.8	1.7	1.7	1.7	1.7	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6	1.6
B. Manure management	0.23	0.22	0.23	0.23	0.24	0.25	0.25	0.27	0.27	0.26	0.27	0.26	0.27	0.28	0.28	0.28	0.28	0.28	0.29
E. Field burning of agricultural residues	0.002	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000	0.001	0.000	0.000	0.000	0.000	0.001	0.001
N ₂ O	4.5	4.2	3.8	3.9	3.9	4.1	4.1	4.0	3.9	3.8	3.9	3.9	3.9	3.9	3.9	3.9	3.9	3.9	4.0
B. Manure management	0.5	0.5	0.4	0.4	0.5	0.4	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
D. Agricultural soils	4.0	3.7	3.4	3.4	3.5	3.6	3.6	3.5	3.5	3.4	3.5	3.5	3.5	3.5	3.4	3.4	3.4	3.5	3.6
E. Field burning of agricultural residues	0.001	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	0.000	0.000
5. Land-use, land-use change and forestry	-16.0	-29.5	-22.7	-20.2	-12.7	-14.1	-24.0	-20.3	-18.4	-21.3	-22.6	-26.3	-26.9	-27.4	-28.9	-32.8	-37.9	-30.7	-35.4
CO ₂	-16.1	-29.7	-22.8	-20.3	-12.9	-14.2	-24.1	-20.4	-18.6	-21.5	-22.7	-26.4	-27.0	-27.6	-29.1	-33.0	-38.0	-30.8	-35.6
CH ₄	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
N ₂ O	0.09	0.08	0.07	0.07	0.08	0.08	0.08	0.09	0.09	0.09	0.09	0.09	0.09	0.09	0.10	0.10	0.10	0.10	0.12
6. Waste	4.0	4.0	4.0	4.0	4.0	3.9	3.8	3.7	3.6	3.5	3.3	3.1	2.9	2.8	2.6	2.4	2.5	2.4	2.2
CH ₄	3.8	3.9	3.9	3.9	3.8	3.7	3.7	3.6	3.4	3.3	3.1	3.0	2.8	2.6	2.5	2.2	2.3	2.2	2.0
N ₂ O	0.164	0.160	0.159	0.156	0.157	0.162	0.163	0.162	0.158	0.156	0.158	0.160	0.158	0.161	0.161	0.164	0.162	0.168	0.162
7. Other	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
National total emissions with LULUCF	54.4	38.6	44.1	48.6	61.5	56.7	52.6	54.9	53.2	49.7	46.5	48.1	49.6	56.8	51.3	35.6	41.8	47.4	34.7
NATIONAL TOTAL EMISSIONS	70.4	68.2	66.7	68.8	74.2	70.8	76.6	75.2	71.7	71.0	69.1	74.4	76.5	84.2	80.2	68.4	79.7	78.1	70.1

The most important drivers in the trend of the energy sector's greenhouse emissions have been the changes in the level of annually imported electricity and fossil fuel based condensing power in annual energy production (Figure 2.3-2). Total consumption of energy stood at 1.42 million terajoules (TJ) in 2008. The decrease from 2007 amounted to over four per cent. Examined by individual energy source, the consumption of coal (including hard coal, coke and blast furnace gas) decreased most, or by 26 per cent. The consumption of peat also decreased notably, or by over 20 per cent. Two successive summers with difficult production conditions resulted in a shortage of peat towards the end of the year. By contrast, the consumption of natural gas for energy grew by 2 per cent, mainly in combined heat and power production. The consumption of oil decreased by 2.5 per cent from the previous year. The consumption of wood-based fuels remained on level with the year before (Energy Statistics, Yearbook 2009).

The use of fuels in electricity and heat production decreased by 9 per cent in 2008. The use of coal and peat declined most, or by 33 and 20 per cent respectively. The use of oil and black liquor from forestry decreased as well. By contrast, the use of wood grew by 15 per cent. Electricity production with renewable energy sources grew by 15 per cent in 2008 from the previous year, as the use of wood fuels turned upwards and production of hydro power kept growing, reaching new records. Thirty-one per cent of the electricity needed by Finland was produced with renewable energy sources. In the production of renewable electricity hydro power accounts for 60 per cent, black liquor from the forest industry for 19 per cent and wood fuels for 16 per cent. The production of district heat stayed on level with the previous year, and industrial heat production was four per cent down on the year before. (Statistics on electricity and heat production, Statistics Finland).

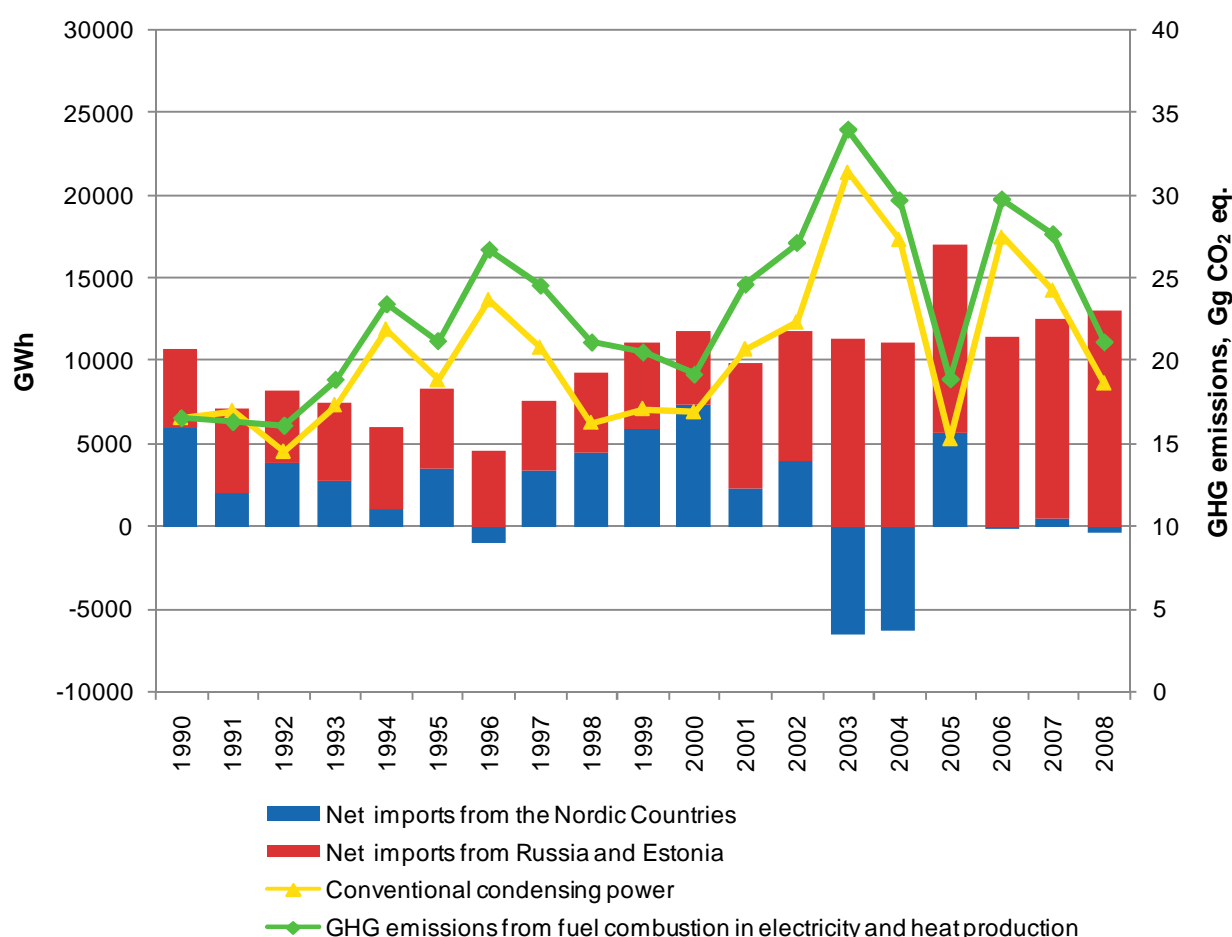


Figure 2.3-2 Greenhouse gas emissions from fuel combustion in electricity and heat production, net imports of electricity from the Nordic Countries and Russia and Estonia and production of conventional condensing power for 1990-2008 (Energy Statistics, Yearbook 2009).

Manufacturing industries and construction produce much energy themselves. Their share of the energy-related emissions was around 20% in 2008. Emissions from manufacturing industries and construction have declined by 20% since 1990. The main reason behind this trend is increased use of biofuels in the forest industry and other reason is outsourcing of power plants from industry to the energy sector.

Emissions in the transport sector have grown by around 7% compared with the 1990 level. The magnitude of the growth is smaller in Finland than in many other Annex I countries, mainly due to the effect that the economic recession in the early 1990's had on transport (see Section 3.3.2). The share of transportation of energy-related emissions was about one fourth in 2008.

Emissions from the residential sector have decreased by 35% and from commercial sectors by over 54% compared with the 1990 levels. The decrease is mainly due to substitution of direct oil heating with district heating and electricity.

Figure 2.3-3 provides an overview of the development of the CO₂ equivalent emissions in 1990-2008 by IPCC source sector.

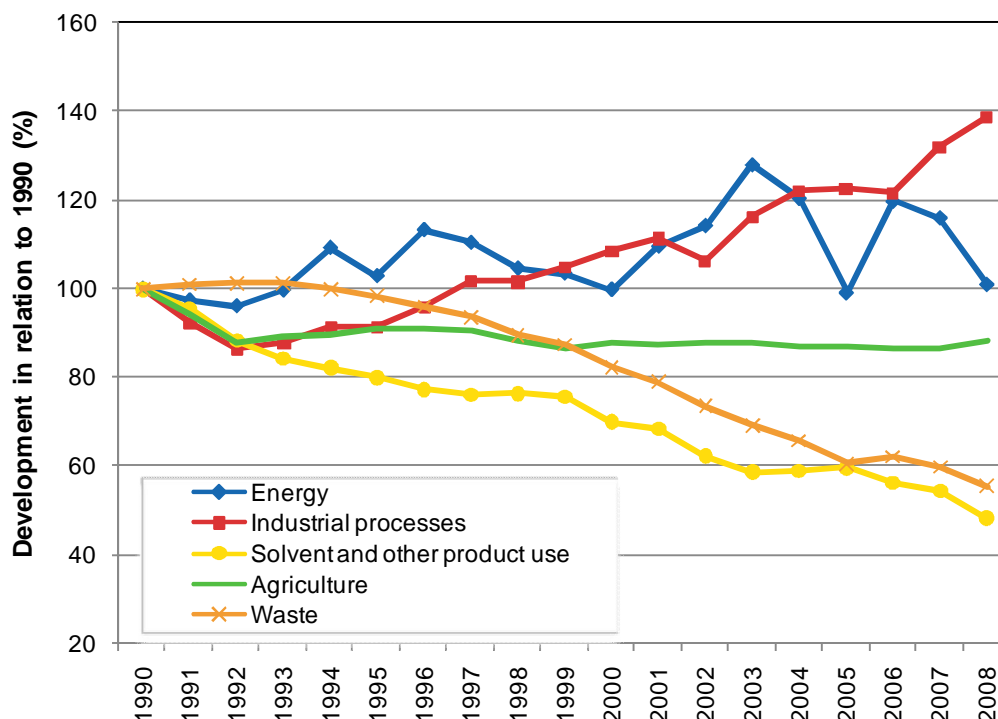


Figure 2.3-3 Relative development of greenhouse gas emissions by main source category relative to the 1990 level (1990=100%).

Emissions of industrial processes have increased by 39% from 1990 to 2008. 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. During the period 1990-2008 CO₂ emissions have increased 1.2 Tg and methane emissions 0.004 Tg CO₂ eq. Nitrous oxide emissions have decreased 0.1 Tg CO₂ eq. and emissions of all F-gases have increased 1.0 Tg CO₂ eq. A key driver behind the increasing trend in emissions of F-gases has been the substitution of ozone depleting substances (ODS) by F-gases in many applications.

Agricultural emissions have decreased by 12% (0.8 Tg CO₂ eq.) over the period 1990-2008. The main driver behind the decreasing trend has been the overall change in the economy of agriculture, which has resulted in a decrease in the number of animals and an average increase in farm size. Cattle produce the major part of the emissions from enteric fermentation in Finland, thus the 33% decrease in the number of cattle since has impacted on 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 also had an impact on the decreasing trend in N₂O emissions.

The most important sources of N₂O emissions in the agricultural sector are agricultural soils. Nitrous oxide emissions from agricultural soils have decreased by about 10% compared with the 1990 level. The decrease

has resulted mainly from lower use of synthetic fertilisers. The drop in agricultural emissions in 1992 is mostly due to decreased use of synthetic fertilisers. In 1992 almost 30% less synthetic fertilisers were sold than in 1990.

Emissions from the waste sector have declined quite constantly since 1990. The decrease of 1.8 Tg CO₂ eq. has mainly been due to the implementation of the new Waste Act in Finland in 1993. 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 waste tax and adoption of the National Waste Plan have also had an impact on the decreasing trend in emissions of the waste sector. In the early 1990's the economic recession reduced the amount of waste.

The LULUCF as a whole sector is a net sink in Finland. The sink has varied from approximately 17% to 50% of the annual emissions from other sectors during 1990-2008. Most of the removals in the LULUCF sector come from forest growth. The annual increment of trees has increased almost steadily for which reason the CO₂ uptake has also grown. The total drain of trees is very much affected by commercial fellings and the global market situation. In 2007 commercial roundwood fellings were at exceptional high level of nearly 58 million m³. The increase in fellings compared to the earlier year was 14% (Finnish Forest Research Institute, 2008). In 2008, the total drain decreased again and the CO₂ removals increased by 19%.

Figure 2.3-4 shows a plot of inventory estimates (in teragrams CO₂ eq.). The graph shows year-to-year variability, increasing somewhat over the years. Also, the level of emissions seems to increase: the graph shows an eye-fitted line to make the point. If such a partial description were to describe a possible trend behind the data, it would correspond to an addition of 0.4 Tg CO₂ eq. to the level each year, starting from 71 Tg in 1990.

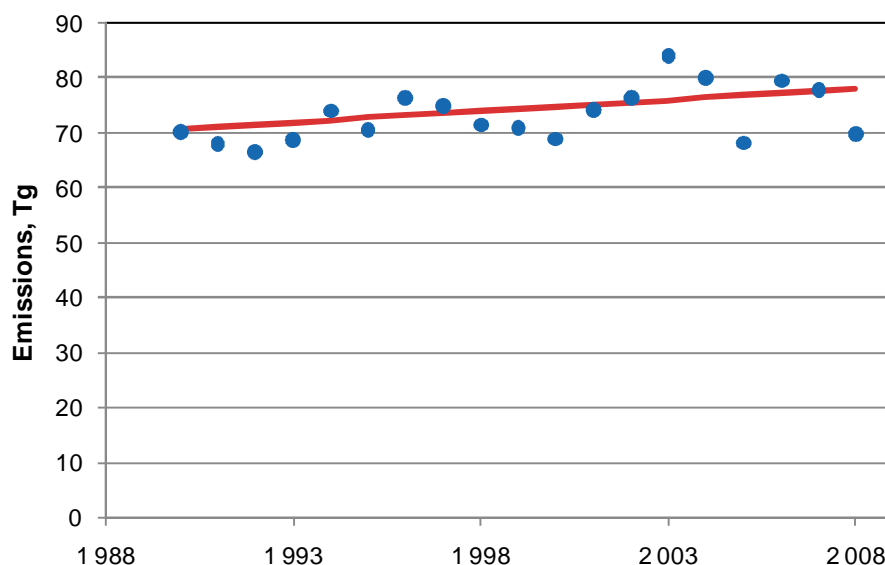


Figure 2.3-4 One possible description of a trend behind the data. The fitted line corresponds to an addition of 0.4 Tg CO₂ eq. to the level each year, starting from 1990.

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

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

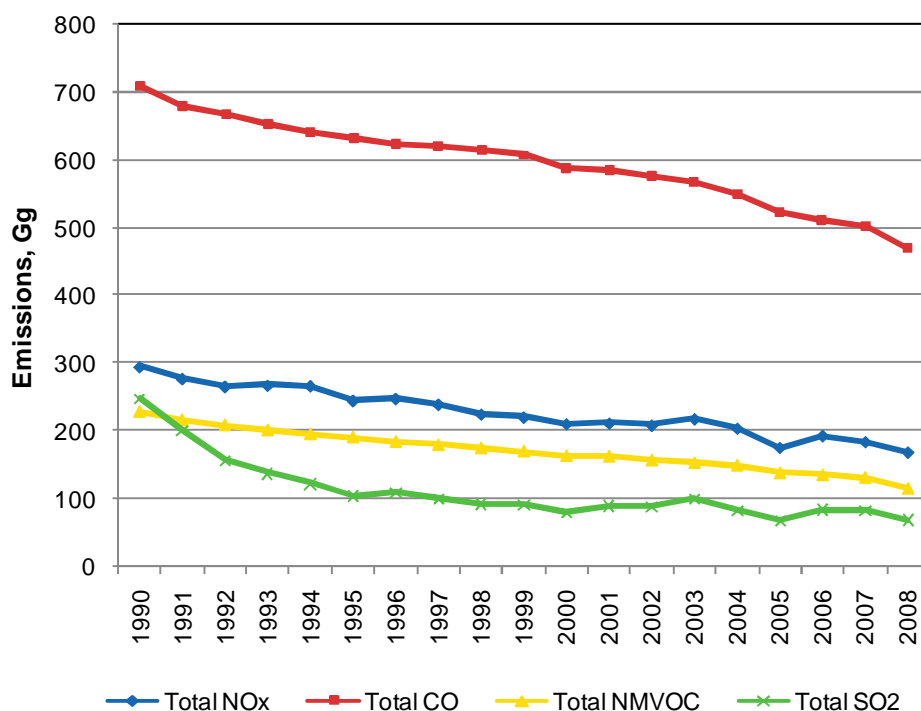


Figure 2.4-1 Indirect greenhouse gas and sulphur dioxide emissions in 1990-2008, Gg.

Nitrogen oxides (NO_x) were generated in the energy, industrial and LULUCF sectors. The energy sector is the most significant source, over 99% of emissions are energy related. Emissions have decreased by 43% and they were 168 Gg in 2008. The biggest decrease, 59%, has happened in the transport category due to the implementation of catalytic converters to cars and these emissions were 38% of the total emissions in 2008. Energy industries as well as manufacturing industries and construction generated 25% and 24% of the emissions, respectively.

Carbon monoxide (CO) emissions, total 469 Gg, originated almost exclusively in the energy sector, where transport generated 60% and other sectors (including small scale combustion in the residential energy sector as well as off-road machinery in forestry, agriculture and fishery) 28% of the total emissions. Total carbon monoxide emissions have decreased by 34% during this period and the biggest part of this reduction is resulted from increased amount of cars with catalytic converters.

The **non-methane volatile organic compounds (NMVOC)** totalled 117 Gg in 2008. In all, 71% of the total emissions were generated in the energy sector, 20% originated from solvent and other product use and 8% from industrial processes. Total NMVOC emissions have decreased by 49% from 1990 to 2008, the greatest decline has taken place in industrial sector, where emissions decreased by 57%.

The **sulphur dioxide (SO₂)** emissions totalled 69 Gg out of which 76% originated in the energy sector, where energy industries generated 42% of the total emissions and manufacturing industries and construction 22%. Sulphur dioxide emissions have totally decreased 72% from 1990, reasons for that are increased use of less sulphur containing fuels and sulphur abatement technology in energy production.

Table 2.4-1 Trends of NO_x, CO, NMVOC and SO₂ emissions in different sources in 1990–2008.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Total nitrogen oxides	295	278	266	268	267	245	248	240	225	221	211	212	209	218	204	176	193	184	168
- energy	294	277	265	267	266	244	247	239	224	219	210	211	208	216	203	174	191	182	166
- industry	1.01	1.01	1.00	0.78	0.91	1.16	1.04	0.99	1.10	1.06	1.10	0.99	1.02	1.50	1.48	1.55	1.73	1.71	2.00
- agriculture and LULUCF	0.11	0.03	0.04	0.03	0.03	0.04	0.04	0.04	0.02	0.03	0.04	0.04	0.05	0.04	0.02	0.03	0.04	0.03	0.03
Total carbon monoxides	710	679	668	654	642	634	623	621	616	607	587	586	577	567	550	521	511	503	469
- energy	706	678	666	653	641	632	622	620	615	606	586	585	576	566	549	520	510	502	468
- agriculture	1.9	0.2	0.1	0.4	0.1	0.3	0.6	0.3	0.2	0.1	0.8	0.4	0.5	0.5	0.4	0.2	0.3	0.6	0.5
- LULUCF	1.7	0.7	1.3	0.5	1.0	0.8	0.6	0.9	0.3	0.8	0.4	1.1	1.1	0.8	0.2	0.6	1.0	0.4	0.5
Total NMVOCs	229	217	209	202	197	192	185	180	176	171	165	164	158	154	150	139	137	133	117
- energy	153	146	146	142	139	137	134	131	129	125	119	119	116	114	109	102	99	94	83
- industry	23	21	20	19	18	17	16	15	13	12	12	12	11	11	11	10	10	11	10
- solvent and other product use	53	49	43	40	38	37	35	34	34	33	33	33	31	29	29	27	28	28	24
- waste	0.54	0.52	0.51	0.52	0.53	0.53	0.52	0.51	0.51	0.51	0.50	0.49	0.51	0.50	0.50	0.49	0.51	0.51	0.47
Total sulphur oxides	249	202	158	138	123	105	110	101	93	91	80	90	89	101	83	68	84	82	69
- energy	187	154	125	111	99	83	90	82	74	72	65	75	74	87	71	54	67	65	52
- industry	61.9	47.3	32.8	27.1	24.2	21.1	20.1	18.4	18.6	18.7	15.9	14.7	15.0	14.2	12.4	13.8	17.0	16.8	16.3

2.5 Emissions and removals from KP-LULUCF activities

The coverage of carbon pools and emission sources reported under afforestation (A), reforestation (R) and deforestation (D) (under Article 3.3), and forest management (FM) (under Article 3.4) are presented in Table 2.5-1. Below ground biomass is included in the above ground biomass for all reported activities. Similarly litter and dead wood are included to soil carbon pool. CH₄ and N₂O emissions from biomass burning on A and R lands are included under FM, because data for analysing burned areas under AR activities separately from those under FM were not available. N₂O emissions from drained Forest land are not reported.

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

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

¹ R (reported), NR (not reported), IE (included elsewhere), NO (not occurring), NA (not applicable)

Emissions and removals from KP-LULUCF activities are reported for the first time, thus trends are not available. Net emissions from ARD in 2008 were 1.82 million tonnes CO₂ eq., Since 1990 land areas afforested and reforested from cropland, grassland, settlements and wetlands were 48,100 ha, 60,500 ha, 20,300 ha and 20,300 ha, respectively. Land areas deforested from cropland, grassland, settlements and wetlands were 66,500 ha, 4,600 ha, 144,400 ha and 11,100 ha, respectively. Net removals from FM activity were 39.9 million tonnes CO₂ eq., in 2008 (Table 2.5-2).

Table 2.5-2 Emissions and removals resulting from activities under Article 3.3 and 3.4 of Kyoto Protocol in 2008.

GREENHOUSE GAS SOURCE AND SINK ACTIVITIES ^{1,2}	Net CO ₂	CH ₄	N ₂ O	Net CO ₂ eq.
	emissions/removals	(Gg)		emissions/removals
A. Article 3.3 activities				1 816
A.1. Afforestation and Reforestation	-1 077			-1 077
A.1.1. Units of land not harvested since the beginning of the commitment period	-1 077	IE	IE	-1 077
A.1.2. Units of land harvested since the beginning of the commitment period	NA	NA	NA	NA
A.2. Deforestation	2 886	NA	0.02	2 893
B. Article 3.4 activities				-39 891
B.1. Forest Management	-39 927	0.06	0.11	-39 891
B.2. Cropland Management	NA	NA	NA	NA
B.3. Grazing Land Management	NA	NA	NA	NA
B.4. Revegetation	NA	NA	NA	NA

¹ IE (included elsewhere), NA (not applicable)

² the signs for removals are negative (-) and for emissions positive (+)

3 ENERGY (CRF 1)

3.1 Overview of the sector (CRF 1)

The energy sector is the main source of greenhouse gas emissions in Finland. In 2008, the sector contributed 78% to total national emissions, totalling 55.0 Tg CO₂ 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.

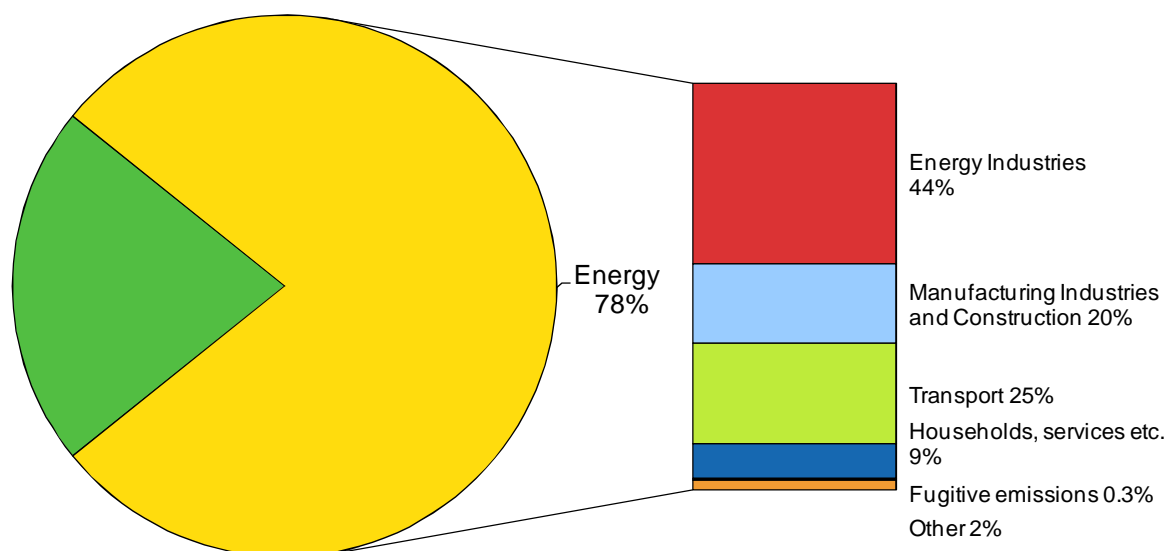


Figure 3.1-1 Emissions from the energy sector compared with the total emissions in 2008. Due to independent rounding the sums do not add up.

Emissions from the energy sector are divided into two main categories: emissions from fossil fuel combustion (CRF 1.A) and fugitive emissions from fuels (CRF 1.B). In the Finnish inventory, emissions from fuel combustion include direct (CO₂, CH₄, N₂O) and indirect (NO_x, CO, NMVOCs) greenhouse gas emissions, as well as emissions of SO₂ from fuel combustion. Point sources, transport and other fuel combustion are included. Fugitive emissions from fuels in Finland consist of CH₄ and NMVOCs emissions from oil refining and storage. CO₂, CH₄ and N₂O emissions from venting and flaring at oil refineries and the petrochemical industry are included as well, as are CH₄ emissions from natural gas transmission and distribution (Table 3.1-1). In addition, indirect CO₂ emissions due to atmospheric oxidation of fugitive CH₄ and NMVOCs have been taken into account (Section 3.6.2.1), as well as indirect N₂O emissions from nitrogen deposition caused by NO_x emissions. These indirect N₂O emissions are reported in category 1.A 5a Stationary. General assessment of completeness can be found in Section 1.8 and a more detailed assessment is included in Annex 5.

Energy-related CO₂ emissions vary much from year to year (Figure 3.1-2), mainly following the economic trend, the structure of the energy supply and climatic conditions. Compared with the base year 1990, the emissions in the energy sector in 2008 were about 1% higher. The main contributors to the excess are the energy industry with approximately 27% growth and transport with around 7% growth in emissions relative to 1990. Emissions from manufacturing industries and construction (-20%) and the rest of the energy sector (-32%) have decreased significantly compared to 1990. During the most recent years the emissions from these source categories have been fluctuating considerably. The trends are discussed in more detail in chapter 2 and the source-specific sections in this chapter.

Table 3.1-1 Emissions from the energy sector in 1990-2008 by subcategory and gas (Tg CO₂ eq.).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Total energy	54.5	53.1	52.4	54.3	59.5	56.1	61.7	60.2	57.0	56.4	54.4	59.7	62.2	69.7	65.6	53.9	65.2	63.2	55.0
Fuel combustion	54.3	52.8	52.1	54.0	59.3	55.8	61.5	59.9	56.8	56.2	54.2	59.5	62.1	69.5	65.4	53.8	65.0	63.0	54.8
CO ₂	53.0	51.6	50.8	52.7	58.0	54.5	60.2	58.6	55.5	54.9	52.9	58.2	60.7	68.1	64.0	52.5	63.7	61.7	53.5
CH ₄	0.307	0.301	0.299	0.297	0.299	0.297	0.304	0.302	0.302	0.295	0.285	0.307	0.315	0.318	0.312	0.303	0.312	0.307	0.295
N ₂ O	1.00	0.97	0.95	0.99	1.02	0.98	1.03	1.03	1.01	1.00	0.98	1.03	1.05	1.10	1.07	0.95	1.05	1.02	0.96
Fugitive fuel emissions	0.23	0.25	0.27	0.34	0.25	0.25	0.24	0.27	0.22	0.19	0.18	0.19	0.18	0.18	0.17	0.19	0.17	0.18	0.19
CO ₂	0.22	0.21	0.22	0.27	0.17	0.17	0.15	0.20	0.14	0.13	0.13	0.12	0.12	0.12	0.11	0.13	0.11	0.13	0.14
CH ₄	0.011	0.042	0.056	0.072	0.080	0.080	0.083	0.072	0.073	0.059	0.055	0.068	0.057	0.062	0.055	0.064	0.055	0.051	0.049
N ₂ O	0.0031	0.0031	0.0006	0.0008	0.0004	0.0004	0.0005	0.0008	0.0004	0.0003	0.0004	0.0004	0.0005	0.0004	0.0005	0.0005	0.0005	0.0007	0.0007

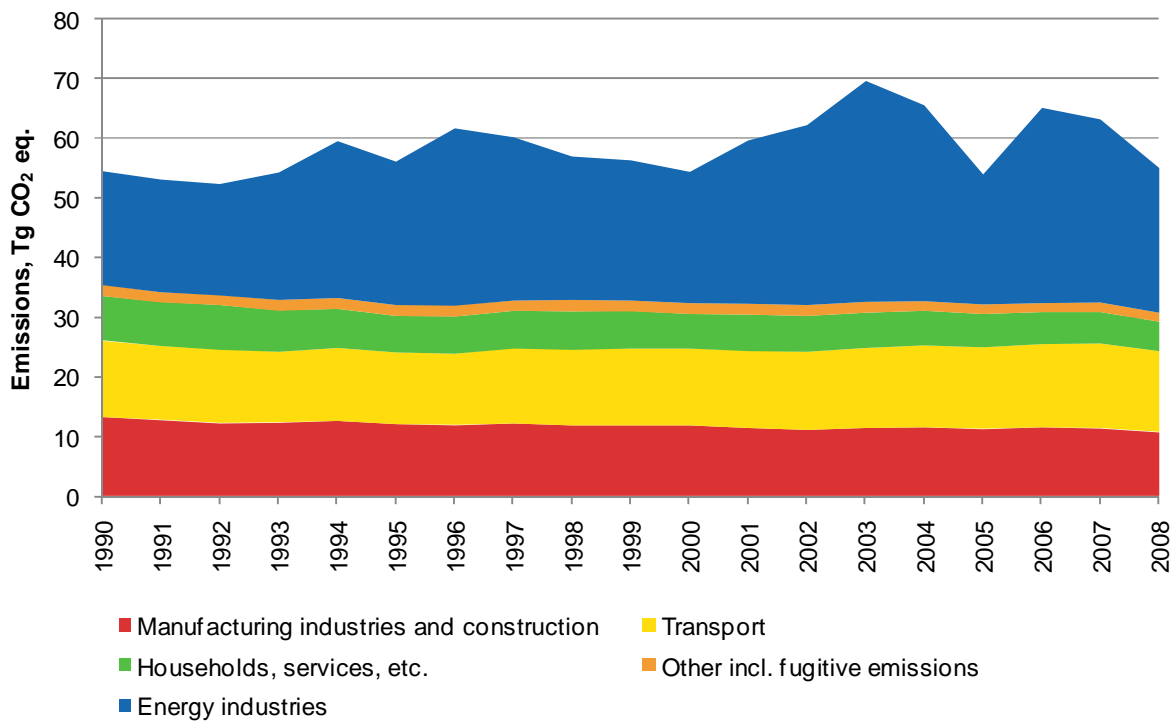


Figure 3.1-2 Emissions from the energy sector by subcategory in 1990-2008 (Tg CO₂ eq.).

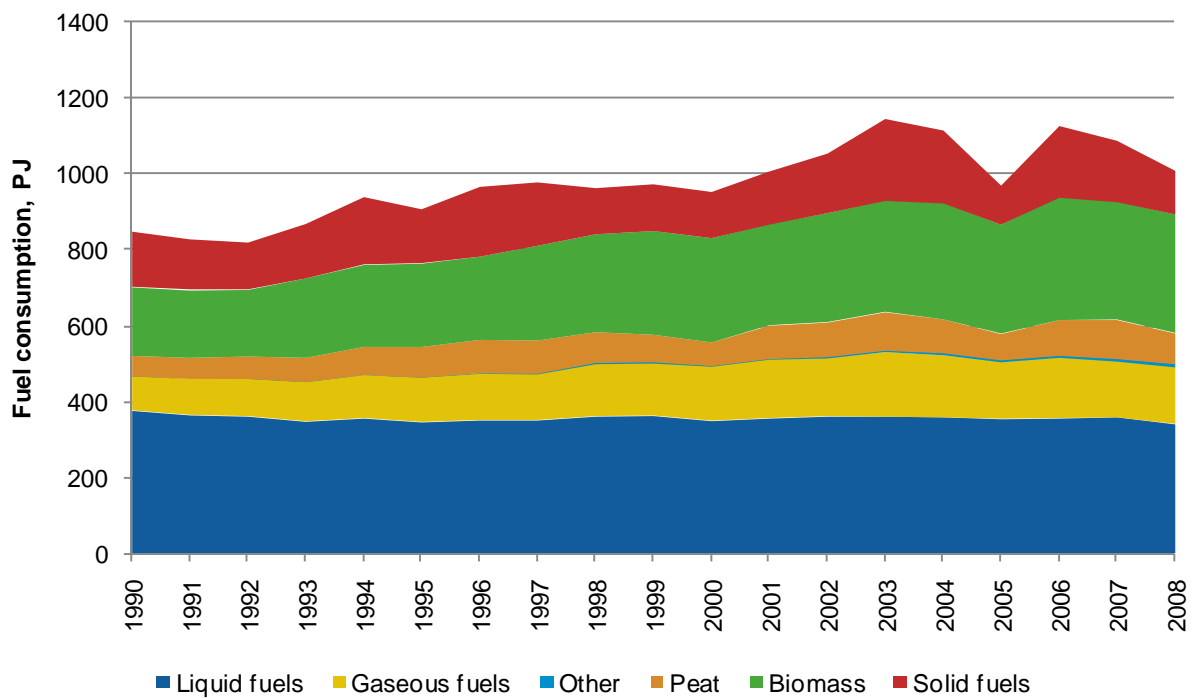


Figure 3.1-3 Consumption of fuels in 1990-2008 (PJ).

3.1.1 Emissions from fuel combustion (CRF 1.A)

3.1.1.1 Description

Emissions from fuel combustion comprise all fuel combustion, including point sources, transport and other fuel combustion. Direct and indirect greenhouse gases (CO₂, CH₄, N₂O, CO, NMVOC, and NO_x) as well as SO₂ are reported. As suggested in the UNFCCC guidelines, emissions from fuel combustion in the energy sector are divided into five subcategories as follows:

CRF 1.A 1 - Energy Industries

CRF 1.A 2 - Manufacturing industries and construction

CRF 1.A 3 - Transport

CRF 1.A 4 - Other sectors

CRF 1.A 5 - Other

Reported greenhouse gas emissions are listed in Table 3.1-2.

Table 3.1-2 Reported emissions under the subcategory fuel combustion in the Finnish inventory.

CRF	Source	Emissions reported
1.A 1	Energy Industries	
	a. Public Electricity and Heat Production	CO ₂ , CH ₄ , N ₂ O
	b. Petroleum Refining	CO ₂ , CH ₄ , N ₂ O
	c. Manufacture of Solid Fuels and Other Energy Industries	CO ₂ , CH ₄ , N ₂ O
1.A 2	Manufacturing industries and construction	
	a. Iron and Steel	CO ₂ , CH ₄ , N ₂ O
	b. Non-Ferrous Metals	CO ₂ , CH ₄ , N ₂ O
	c. Chemicals	CO ₂ , CH ₄ , N ₂ O
	d. Pulp, Paper and Print	CO ₂ , CH ₄ , N ₂ O
	e. Food Processing, Beverages and Tobacco	CO ₂ , CH ₄ , N ₂ O
	f. Other	
	Construction	CO ₂ , CH ₄ , N ₂ O
	Other non-specified	CO ₂ , CH ₄ , N ₂ O
	Transferred CO ₂	CO ₂
1.A 3	Transport	
	a. Civil Aviation	CO ₂ , CH ₄ , N ₂ O
	b. Road Transportation	CO ₂ , CH ₄ , N ₂ O
	c. Railways	CO ₂ , CH ₄ , N ₂ O
	d. Navigation	CO ₂ , CH ₄ , N ₂ O
	e. Other Transportation	
	Other off-road machinery	CO ₂ , CH ₄ , N ₂ O
1.A 4	Other Sectors	
	a. Commercial/Institutional	CO ₂ , CH ₄ , N ₂ O
	b. Residential	CO ₂ , CH ₄ , N ₂ O
	c. Agriculture/Forestry/ Fisheries	CO ₂ , CH ₄ , N ₂ O
1.A 5	Other	
	a. Stationary	
	Other non-specified	CO ₂ , CH ₄ , N ₂ O
	Non-specified burning of feedstocks	CO ₂ , CH ₄ , N ₂ O
	Indirect N ₂ O emissions from NO _x	N ₂ O
	b. Mobile	
	Other non-specified	CO ₂ , CH ₄ , N ₂ O

3.1.1.2 Quantitative overview

CO₂ emissions from fossil fuel combustion (53.5 Tg) accounted for 98% of the energy sector's total emissions and 78% of total greenhouse gas emissions in 2008.

The portion of N₂O emissions from fuel combustion in 2008 was about 2%. N₂O emissions come mainly from fluidised bed combustion and transport. CH₄ emissions from fuel combustion are relatively small and are mainly due to the incomplete combustion of wood fuels (small-scale combustion) (Table 3.1-3).

The availability of hydro power in the Nordic electricity market influences significantly the electricity supply structure and hence the emissions. Especially in 2001-2003 and again in 2006 the shortage of hydro power in the Nordic market increased coal and peat-fuelled condensing power generation in Finland. Due to this, there was a ~15.7 Tg CO₂ eq. increase in the energy sector's emissions from fuel combustion between the years 1990 and 2003. In 2004 and 2005 there was good availability of hydro power in Nordic electricity markets and domestic condensing power production in Finland was replaced by imports of electricity. Total emissions from fuel combustion decreased by 22% from the 2003 record level compared with the 2005 level and were 0.4% above the 1990 level. In 2008 the need for condensing power produced mainly with coal and peat decreased by 39 per cent from the year before and at the end of 2008 Finland was a net seller on the Nordic electricity market. However, electricity imports from Russia and Estonia increased, which kept the net imports of electricity growing slightly (Figure 3.1-4).

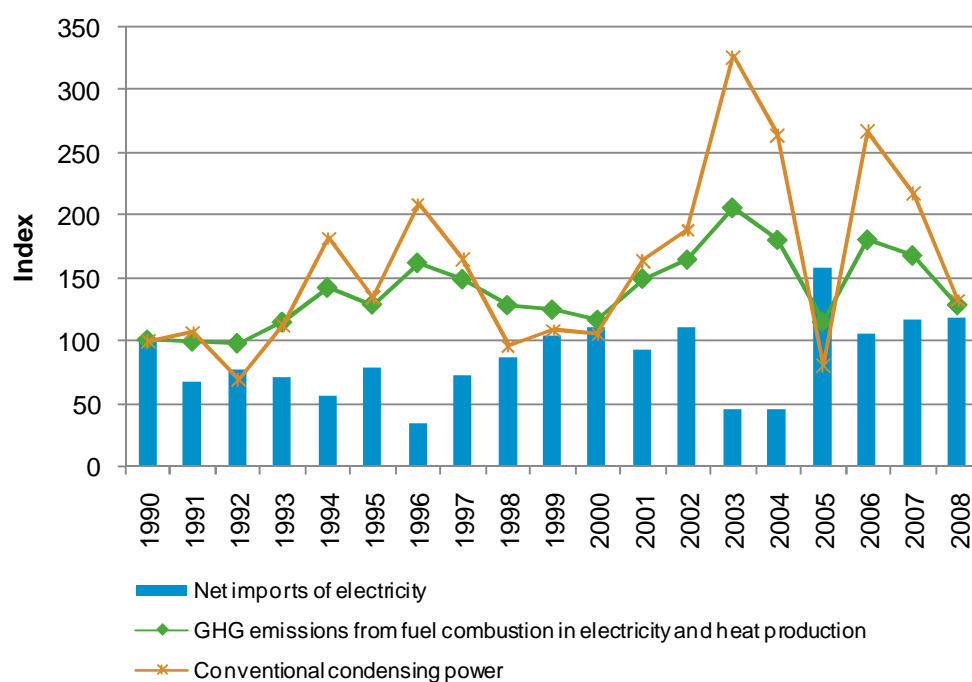


Figure 3.1-4 Greenhouse gas emissions from fuel combustion in electricity and heat production, net imports of electricity and conventional condensing power indexed (index 1990=100) for 1990-2008 (Energy Statistics, Yearbook 2009).

Table 3.1-3 Emissions from fuel combustion in Finland in 1990-2008 (Tg CO₂ eq.).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Total energy	54.5	53.1	52.4	54.3	59.5	56.1	61.7	60.2	57.0	56.4	54.4	59.7	62.2	69.7	65.6	53.9	65.2	63.2	55.0
Fuel combustion	54.3	52.8	52.1	54.0	59.3	55.8	61.5	59.9	56.8	56.2	54.2	59.5	62.1	69.5	65.4	53.8	65.0	63.0	54.8
CO ₂																			
Energy industries	19.2	19.0	18.7	21.5	26.4	24.1	29.8	27.4	24.2	23.7	22.1	27.5	30.3	37.2	33.0	21.9	32.9	30.8	24.3
Manufacturing industries and construction	13.2	12.7	12.1	12.2	12.5	12.0	11.8	12.1	11.7	11.7	11.7	11.3	11.0	11.3	11.4	11.1	11.4	11.3	10.6
Transport	12.8	12.4	12.3	11.9	12.2	12.0	12.0	12.6	12.7	12.9	12.8	13.0	13.1	13.4	13.7	13.7	13.9	14.3	13.6
Other sectors	7.31	7.15	7.26	6.78	6.42	5.96	6.09	6.10	6.19	6.10	5.71	5.95	5.89	5.80	5.64	5.42	5.24	5.12	4.76
Other	1.64	1.45	1.44	1.44	1.55	1.57	1.60	1.50	1.73	1.57	1.60	1.59	1.59	1.62	1.46	1.36	1.38	1.33	1.33
CH ₄	0.31	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.29	0.31	0.31	0.32	0.31	0.30	0.31	0.31	0.29
N ₂ O	1.00	0.97	0.95	0.99	1.02	0.98	1.03	1.03	1.01	1.00	0.98	1.03	1.05	1.10	1.07	0.95	1.05	1.02	0.96

Fuel combustion by fuel (PJ) and related CO₂, CH₄ and N₂O emissions for 1990-2008 are given in Appendix_3b at the end of the Energy section.

3.1.1.3 Methods

Emissions from fuel combustion (CRF 1.A 1 - 1.A 5) are calculated by multiplying fuel consumption with either a fuel type-specific emission factor or a technology-specific emission factor. When calculating CO₂ emissions, adjustment with the fraction of carbon (un)oxidised is included.

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

ILMARI combines three main types of activity source data:

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

The ILMARI calculation system has been used for national emission estimations of CO₂, SO₂, NO₂, CO, CH₄, N₂O, NMVOC and PM (particulate matter) emissions of fuel combustion from the year 1990, except for year 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 3.1-5.

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

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

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

Statistics Finland has decided the level of aggregation of data to be used in ILMARI, consistent with the IPCC 1996 GL and UNFCCC reporting guidelines, see Table 3.1-4. The breakdown (and coverage, as mentioned above) of data published in the VTT LIPASTO website (lipasto.vtt.fi/) are different from CRF categories, which must be noticed, when comparing the figures (Table 3.3-14).

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

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

A new version of the ILMARI calculation system was developed in 2002. Emissions from 2001 onwards have been calculated using this system. The calculation methods and formulas are the same as in the previous ILMARI, but the database system has been reconstructed. The activity data and time series consistency have been checked during 2005-2008. All results from the previous version of ILMARI have been converted to the present structure and stored in a specific time series database. Time series data by CRF category are produced using SAS Database queries and taken to the CRF Reporter via MS Excel sheets using the manual cut and paste operation. The functionality of the time series database is still being developed (for example, a more automatic export of results to the CRF reporter).

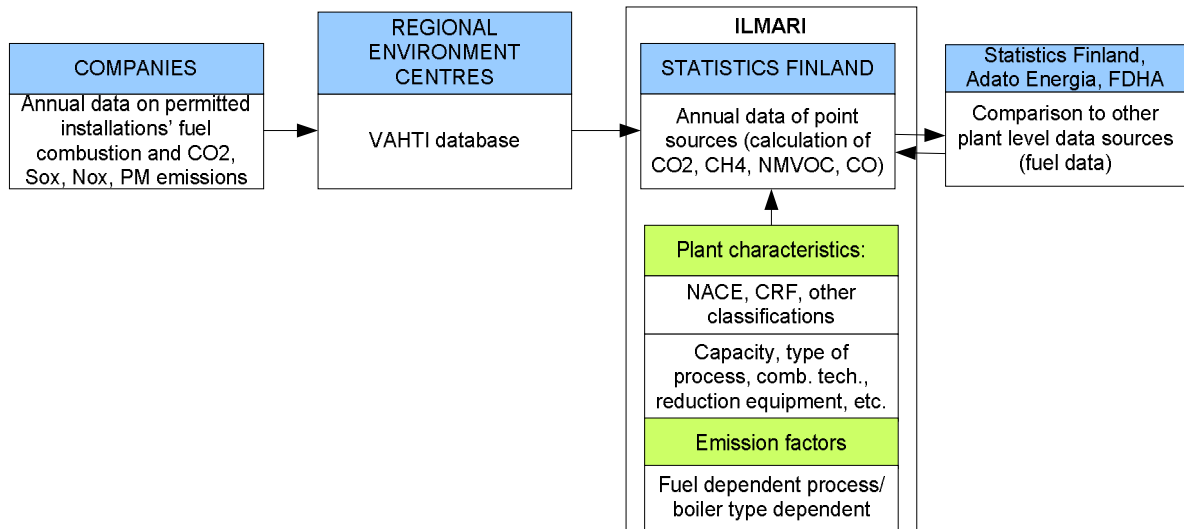
3.1.1.4 Sector-specific QA/QC

Fuel consumption data calculated within the submodels of LIPASTO system are taken to ILMARI system and crosschecked against national energy balance. In some cases minor corrections are needed to ensure full consistency to energy statistics. Statistics Finland is responsible for these corrections. If there are significant differences (more than 1-2 %) compared to the original data in LIPASTO, these are discussed with the VTT staff to check if updates are needed for example in model parameters or source data of the LIPASTO submodels.

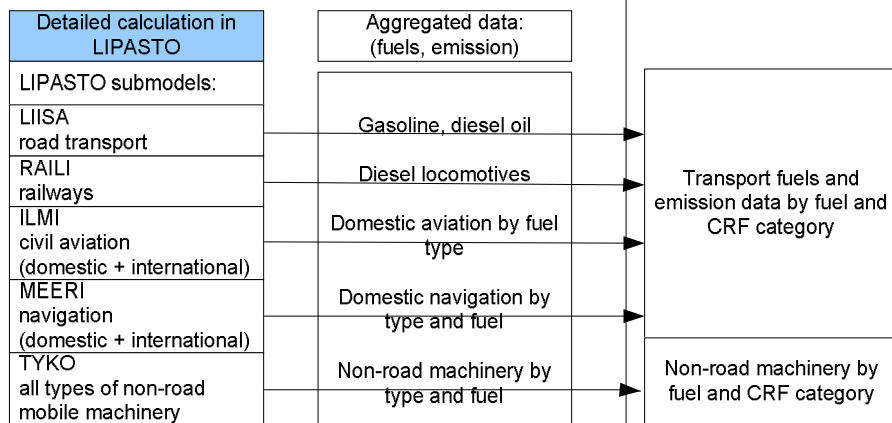
This crosschecking is a part of the general QA/QC of the Transport sector. QA/QC procedures of the subsectors of Transport are described in more details in the corresponding chapters.

Main data inputs of ILMARI

Point Sources



Transport and non-road machinery



Other emission sources

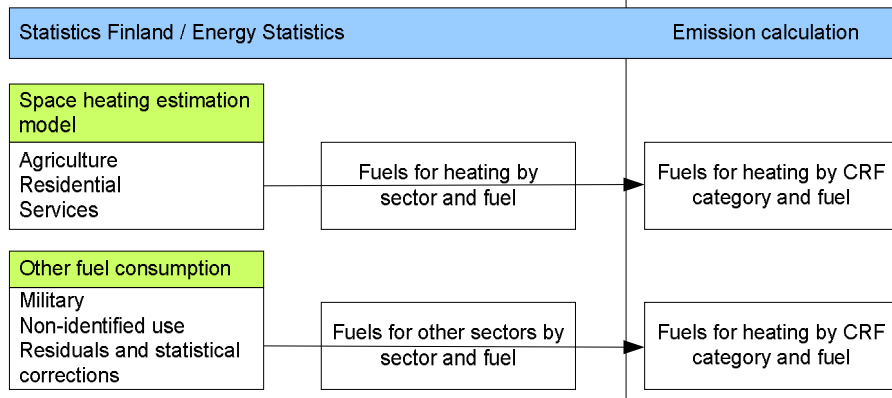


Figure 3.1-5 Data sources of the ILMARI calculation system.

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

Production of CRF data tables for sector 1.A Fuel combustion	
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 "Top 20" lists
2. Lipasto data input to ILMARI	Manual input of transport and non-road machinery data
3. Energy Statistics data input to ILMARI	Manual input of heating fuels data and other fuel consumption data
4. Comparison to Energy Statistics	Totals by fuel
5. 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.
6. CRF query from SAS database (output to excel sheets)	SAS database functions
7. CRF time series in excel sheets	Manual cut and paste to CRF Reporter

3.1.1.5 Key Categories

Several emission sources in the energy combustion sector are key categories. The key categories in 2008 by level and trend, without LULUCF are listed in Table 3.1-6.

Table 3.1-6 Key categories in Energy combustion (CRF 1.A) in 2008 (quantitative method used: Tier 2).

IPCC source category	Gas	Identification criteria
1.A. Fuel Combustion - gaseous fuels	CO ₂	T
1.A. Fuel Combustion - liquid fuels	CO ₂	L, T
1.A. Fuel Combustion - other fuels	CO ₂	L, T
1.A. Fuel Combustion - solid fuels	CO ₂	L, T
1.A.1 Energy Industries - biomass	CH ₄	T
1.A.1 Energy Industries - other fuels	CH ₄	T
1.A.3.b. Road Transportation - diesel	N ₂ O	L, T
1.A.3.b. Road Transportation - gasoline - cars with catalytic converters	N ₂ O	L
1.A.4. Other Sectors - biomass	CH ₄	L, T
1.A.5 Other - other fuels (mostly indirect N ₂ O from NO _x)	N ₂ O	L

3.1.2 Fugitive emissions from fuels (CRF 1.B)

3.1.2.1 Description

Under fugitive emissions from fuels, Finland reports CH₄ emissions from oil refining and from natural gas transmission and distribution, and CO₂, CH₄ and N₂O emissions from flaring at oil refineries and in the petrochemical industry. Indirect CO₂ emissions from fugitive emissions from fuels have also been calculated from NMVOC and CH₄ emissions for the whole time series. NMVOC emissions originate from oil refineries as well as storage of chemicals at the refineries, road traffic evaporative emissions from cars, the gasoline distribution network and refuelling of cars, ships and aircraft. Methane emissions result from evaporation during the refining and storage of oil. Reported emissions are listed in Table 3.1-7.

Table 3.1-7 Reported emissions under the subcategory fugitive emissions from fuels in the Finnish inventory.

CRF	Source	Emissions reported
1.B 1	Solid fuels	
	a. Coal Mining and Handling	NO
	b. Solid Fuel Transformation	NO
	c. Other	NO
1.B 2	Oil and Natural Gas	
	a. Oil	CO ₂ , CH ₄
	b. Natural Gas	CO ₂ , CH ₄
	c. Venting and Flaring	CO ₂ , CH ₄ , N ₂ O
	d. Other	CO ₂

3.1.2.2 Quantitative overview

Fugitive emissions from fuels comprise only about 0.2% of total greenhouse gas emissions in Finland. Emissions were totally 0.19 Tg in 2008 and 0.23 Tg in 1990. These emissions have decreased by 18% since the 1990 level (Table 3.1-8 and Figure 3.1-6) due to decreased emissions in oil refining, especially in flaring. Also indirect CO₂ emissions from NMVOC emissions have decreased strongly in the time-series due to capture of gasoline fumes in petrol distribution network and in refuelling of cars, less evaporative emissions from cars and better storage of chemicals at the refineries. There were some disturbances in oil refineries and petrochemical industry in 1993 and 1997 which caused higher flaring emissions.

Emissions from natural gas transmission have remained almost at the same level for the whole period, only more extensive maintenance breaks with emptying of pipelines have caused some peaks in the emissions. Natural gas distribution in town gas network started during 1991. The previously distributed town gas did not include CH₄, thus the fugitive CH₄ emissions were zero until 1990. Emissions of natural gas distribution were at its highest in 1994 and have halved since.

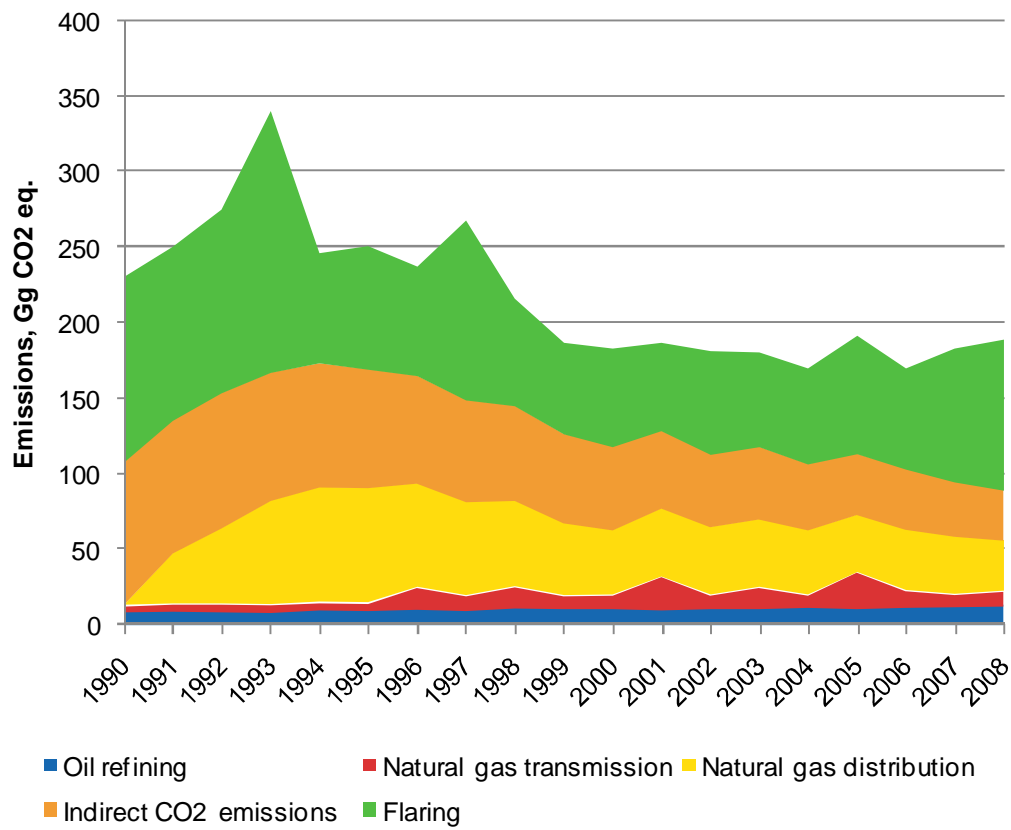


Figure 3.1-6 Fugitive emissions from fuels by subcategory in 1990-2008 (Gg CO₂ eq.)

3.1.2.3 Key Categories

There were no key sources in this subsector in 2008.

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

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
CO₂																			
1.B 2c Flaring	122	114	120	171	72	81	72	118	71	60	65	58	68	62	63	78	66	88	99
CH₄																			
1.B 2a Oil refining	0.36	0.38	0.37	0.35	0.42	0.4	0.44	0.4	0.47	0.46	0.45	0.42	0.46	0.46	0.48	0.448	0.49	0.51	0.53
1.B 2b Natural gas	0.17	1.60	2.30	3.10	3.40	3.40	3.49	3.01	3.00	2.35	2.17	2.81	2.26	2.47	2.14	2.60	2.15	1.93	1.80
1.B 2c Flaring	0.0019	0.0018	0.0018	0.0026	0.0011	0.0012	0.0011	0.0018	0.0011	0.0009	0.0010	0.0009	0.0010	0.0010	0.0010	0.0012	0.0010	0.0013	0.0015
N₂O																			
1.B 2c Flaring	0.0038	0.0035	0.0037	0.0053	0.0022	0.0025	0.0022	0.0036	0.0022	0.0018	0.0020	0.0018	0.0021	0.0019	0.0019	0.0024	0.0020	0.0027	0.0031
Indirect CO₂	97	94	98	95	93	90	83	78	72	68	63	61	56	57	52	49	48	44	40
Total CO₂ eq.	231	251	275	341	247	251	238	268	217	187	184	187	182	181	170	192	170	184	190

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

3.2.1 Source category description

Energy industries (CRF 1.A 1) and Manufacturing industries and construction (CRF 1.A 2) include emissions from fuel combustion in point sources in energy production and industrial sectors (power plants, boilers $P_{\text{fuel}} > 5\text{MW}$ and industrial plants with boilers and/or other combustion). The emissions from Energy industries by relevant subcategory and gas in 1990–2008 are presented in Table 3.2-1.

The emissions from Manufacturing industries and construction by relevant subcategory and gas in 1990–2008 are presented in Table 3.2-2.

In 2008, the greenhouse gas emissions from Energy industries amounted to 24.3 Tg and Manufacturing industries and construction amounted to 10.8 Tg CO_2 eq. The share of energy industries was 44% of energy sector's total emissions. The corresponding share was 20% for manufacturing industries and construction. These two subsectors accounted together for 50% of the total greenhouse gas emissions of Finland.

Regarding the annual variations of total greenhouse gas emissions in the Finnish GHG inventory, CO_2 emissions from Public power and heat production are dominant, as shown in Figure 3.2-1. (see also Section 2.3 and Figure 3.1-2).

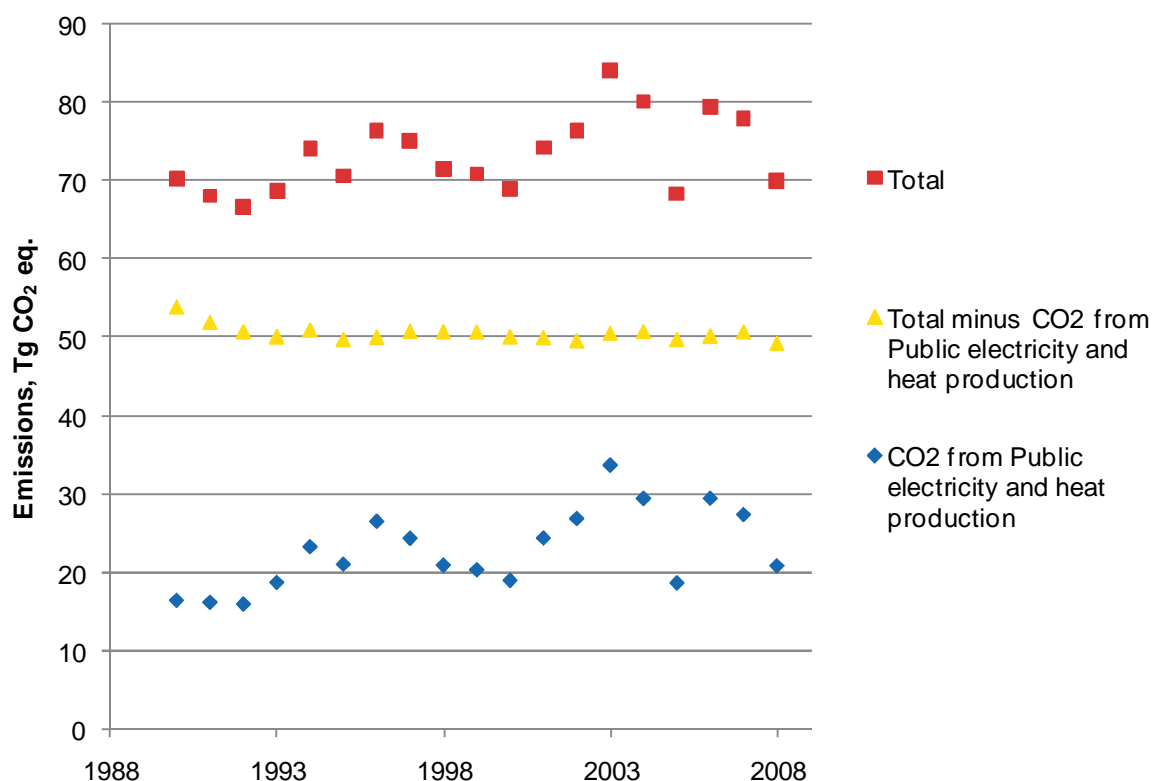


Figure 3.2-1 The effect of the CO_2 emissions of 1.A 1a Public Electricity and Heat Production to the total CO_2 equivalent emission trend.

Table 3.2-1 The emissions from Energy industries by relevant subcategory and gas in 1990-2008 (Tg CO₂).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Energy industries	19.2	19.0	18.7	21.5	26.4	24.1	29.8	27.4	24.2	23.7	22.1	27.5	30.3	37.2	33.0	21.9	32.9	30.8	24.3
CO ₂	19.1	18.8	18.6	21.3	26.2	23.9	29.6	27.2	23.9	23.4	21.9	27.2	29.9	36.8	32.6	21.7	32.5	30.5	24.0
Public electricity and heat production	16.5	16.2	16.0	18.7	23.3	21.0	26.5	24.4	20.9	20.3	19.0	24.4	26.9	33.7	29.4	18.7	29.4	27.4	20.9
Petroleum refining	2.26	2.25	2.25	2.20	2.59	2.56	2.77	2.51	2.64	2.68	2.55	2.53	2.73	2.80	2.79	2.59	2.68	2.76	2.76
Manufacture of solid fuels and other energy industries	0.35	0.35	0.36	0.37	0.33	0.32	0.30	0.34	0.38	0.42	0.35	0.32	0.36	0.39	0.42	0.39	0.40	0.35	0.33
CH ₄																			
Total	0.008	0.009	0.009	0.010	0.012	0.013	0.015	0.016	0.016	0.016	0.015	0.019	0.024	0.028	0.025	0.020	0.025	0.023	0.022
N ₂ O																			
Total	0.13	0.14	0.15	0.17	0.19	0.20	0.23	0.23	0.23	0.22	0.21	0.26	0.30	0.34	0.32	0.26	0.34	0.34	0.31

Table 3.2-2 The emissions from Manufacturing industries and construction by relevant subcategory and gas in 1990-2008 (CO₂ eq. Tg).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Manufacturing industries and construction	13.4	12.8	12.3	12.4	12.7	12.1	12.0	12.3	11.9	11.9	11.9	11.5	11.2	11.5	11.6	11.3	11.6	11.4	10.8
CO ₂	13.2	12.7	12.1	12.2	12.5	12.0	11.8	12.1	11.7	11.7	11.7	11.3	11.0	11.3	11.4	11.1	11.4	11.3	10.6
Iron and steel	2.49	2.55	2.60	2.82	2.88	2.66	2.77	3.20	3.35	3.42	3.69	3.31	3.36	3.59	3.56	3.67	3.79	3.41	3.26
Non-ferrous metals	0.34	0.23	0.14	0.17	0.14	0.11	0.11	0.13	0.13	0.14	0.14	0.15	0.13	0.12	0.11	0.10	0.10	0.10	0.10
Chemicals	1.29	1.26	1.24	1.26	1.34	1.37	1.34	1.27	1.16	1.15	1.18	1.25	1.17	1.30	1.29	1.33	0.92	0.94	0.94
Pulp, paper and print	5.34	5.16	4.98	4.95	5.17	4.83	4.63	4.57	4.25	4.18	4.06	3.92	3.68	3.81	3.94	3.58	4.09	4.32	3.85
Food processing, beverages and tobacco	0.82	0.79	0.76	0.72	0.72	0.70	0.66	0.61	0.56	0.49	0.32	0.32	0.32	0.26	0.25	0.21	0.20	0.18	0.15
Other	2.90	2.67	2.43	2.30	2.28	2.30	2.31	2.29	2.29	2.33	2.34	2.34	2.33	2.26	2.28	2.27	2.33	2.31	2.31
CH ₄																			
Total	0.013	0.012	0.012	0.014	0.014	0.015	0.014	0.015	0.014	0.015	0.015	0.014	0.014	0.014	0.014	0.014	0.015	0.014	0.013
N ₂ O																			
Total	0.172	0.160	0.147	0.165	0.170	0.167	0.170	0.187	0.183	0.189	0.189	0.183	0.173	0.174	0.182	0.170	0.163	0.156	0.149

Fuel combustion CO₂, CH₄ and N₂O emissions by fuels for 1990-2008 are given in Appendix_3b at the end of the Energy section.

3.2.2 Methodological issues

3.2.2.1 Methods

Emissions from fuel combustion in point sources are calculated with the ILMARI calculation system. All emissions within CRF 1.A 1 and 1.A 2 (except working machinery in the Construction sector, see section 3.3.5.) are based on actual bottom-up data. In the ILMARI system emissions are calculated using the annual fuel consumption data. Fuel combustion data are available by installation and by fuel type. For each point source, SO₂, PM, NO_x and CO₂ emissions are reported by plant. In the ILMARI system, SO₂, PM and NO_x emissions are split into each fuel. CO₂, N₂O, CH₄ and NMVOC are calculated based on fuel combustion data. The calculated CO₂ emissions from each fuel in a certain plant are summarised and compared with total CO₂ 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, SO₂ and NO_x).

Calculation of the CO₂ emissions is based on a country-specific (like Tier 2 or Tier 3³, Revised (1996) Guidelines) method using detailed activity (fuel consumption) data and fuel-specific emission factors. For working machinery see section 3.3.5.

The SO₂ and NO_x 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 CO₂ emissions in Iron and steel sector is described in section 4.4.

The emissions of CH₄, N₂O and CO are based on a country-specific method (Tier 2 or Tier 3, Revised (1996) Guidelines), using detailed activity data and technology-based emission factors for each boiler or process type (emission factors are available for approximately 250 categories of boilers and processes).

3.2.2.2 Emission factors and other parameters

Mainly country-specific or plant-specific emission factors are used in the calculations, although for some rare fuels IPCC default emission factors are used. CO₂ emission factors, oxidation factors and default net caloric values for different fuels are presented in Table 3.2-2.

³ Bottom-up installation level activity and technology data; technology dependent non-CO₂ emission factors.

Table 3.2-3 CO₂ emission factors, oxidation factors and net caloric values (NCV) by fuel.

Fuels	NCV	Unit	Emission factor g CO ₂ /MJ	Oxidation factor	Source of emission factor
Liquid fuels					
Town gas	16.9	GJ/1000 m ³	59.4	0.995	Neste 1993
Refinery gas (+ other gases)	49 (45-55)	GJ/t	53-71.4	0.995	Plant-specific
LPG (liquefied petroleum gas)	46.2	GJ/t	65	0.995	Neste/ET2004
Naphta	44.3	GJ/t	72.7	0.995	EE
Motor gasoline	43	GJ/t	72.9	1	VTT/Liisa Model/Neste
Aviation gasoline	43.7	GJ/t	71.3	1	EE/Neste
Jet fuel	43.3	GJ/t	73.2	1	EE /Fortum 2002
Other kerosenes (vaporising oil, lamp kerosene)	43.1	GJ/t	71.5	0.995	EE/IPCC1996
Diesel oil	42.8	GJ/t	73.6	1	VTT/Liisa Model/Neste
Gasoil (light fuel oil, heating fuel oil)	42.7	GJ/t	74.1	0.995	Neste/EE
Gasoil (for non-road use)	42.8	GJ/t	73.6	1	EE (same as diesel oil)
Residual fuel oil (RFO, heavy fuel oil), low sulphur	41.1	GJ/t	78.8	0.995	Neste/EE
Residual fuel oil (RFO, heavy fuel oil), normal	40.5	GJ/t	78.8	0.995	Neste/EE
Other residual fuel oil (heavy bottom oil)	40.2	GJ/t	79.2	0.995	Neste/EE
Petroleum coke	33.5 (20-36)	GJ/t	97 (90-102)	0.995	Plant-specific
Recycled waste oil	41	GJ/t	78.8	0.995	EE (=RFO)
Other petroleum products	35 (30-47)	GJ/t	78.8 (65-78.8)	0.995	EE (=RFO)
Solid fuels					
Anthracite	33.5	GJ/t	98.3	0.99	IPCC1996
Hard coal (bituminous)	25.5 (21-32)	GJ/t	94.6	0.99	StatFi 2005
Coal briquettes	30	GJ/t	94.6	0.99	EE
Coal tar	36.5	GJ/t	90.6	0.99	Plant-specific
Coke	29.3 (25-35)	GJ/t	108	0.99	IPCC1996
Coke oven gas	16.7	GJ/1000 m ³	41.5	0.99	Plant-specific
Blast furnace gas (BFG)	11.2-11.5	GJ/1000 m ³	155	0.99	Plant-specific
	3.6		263-265		
Gaseous fuels					
Natural gas	36	GJ/1000 m ³	55.04	0.995	Gasum 2005
Gasified solid waste*	13.3 (7-30)	GJ/1000 m ³	59	0.99	EE
Biomass fuels					
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	IPCC1996
Black and sulphite liquors	7.3-15	GJ/t	109.6	0.99	IPCC1996
Other by-products from wood processing industry (includes e.g. pine oil and tar, methanol, fibrous sludge, waste paper, stink gas, etc.)	3-37	GJ/t	109.6	0.99	IPCC1996,
	20	GJ/1000 m ³	59		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 ³	56.1	0.99	EE
Hydrogen	10.8	GJ/1000 m ³	0		
Other fuels, peat					
Peat (milled)	10.1	GJ/t	105.9	0.99	VTT 2003

Fuels	NCV	Unit	Emission factor g CO ₂ /MJ	Oxidation factor	Source of emission factor
Peat (sod peat)	12.3	GJ/t	102	0.99	VTT 2003
Peat (pellets and briquettes)	20.9	GJ/t	97	0.99	VTT 2003
Other fuels, wastes etc.					
Mixed fuels* (REF, RDF, PDF, MSW)	10–21	GJ/t	31.8	0.99	StatFi 2004
Demolition wood*	8-15	GJ/t	17.0	0.99	StatFi 2004
Impregnated wood*	12	GJ/t	11.4	0.99	StatFi 2004
De-inking sludge*	4	GJ/t	60	0.99	EE
Other residues and by-products	30	GJ/t	78.8	0.99	EE
Plastics waste	33 (25-40)	GJ/t	74.1	0.99	EE
Rubber waste	33	GJ/t	90	0.99	StatFi 2004
Hazardous waste	15 (10-15)	GJ/t	117	0.99	Ekokem 2004
Other non-specified waste (industrial waste, etc.)	15–30	GJ/t	75	0.99	EE

* Mixed fuels: contains fossil and non-fossil carbon; the CO₂ emission factor refers only to the fossil fraction of total energy content.

REF = recovered fuel

RDF = refuse-derived fuel

PDF = package derived fuel

MSW = municipal solid waste

Sources:

EE: expert estimation Kari Grönfors, Statistics Finland

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

Neste: product data sheets, personal communications

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 (Masters Thesis of Minna Jokinen)

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

Ekokem 2004: Environmental report 2004

Gasum 2005: personal communication

VTT2045: Properties of fuels used in Finland, VTT 2000

Fortum 2002: Composition of kerosenes

VTT 2003: Vesterinen 2003

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

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

In the Finnish greenhouse gas inventory peat is reported under the category of Other fuels. There are several reasons for reporting peat separately from the Solid fuels. In our inventory Solid fuels include hard coal, coke and other fuels derived from coal (BFG, coke oven gas). These coal based fuels are originally imported, whereas peat is domestic energy source. This categorisation follows the practise used in national energy statistics as well as in the IPCC 2006 Guidelines.

Peat is one of the main fuels in Finland. It is the fourth largest fuel (after wood, hard coal and natural gas), representing over 6% of Total primary energy supply (TPES) and over 8% of combustible fuels. Its share is higher than for example the share of any liquid fuel. The share of peat is generally around half of the share of hard coal, but varies considerable, like the share of hard coal, too. The CO₂ emission factor of peat is clearly higher than the emission factor of hard coal. If the figures of peat and hard coal were combined, this would cause significant variation in the implied emission factor of the Solid fuels. Also other properties of peat and hard coal are different, thus it is not reasonable to aggregate them under the same fuel category in Finland (see Table 3.2-4).

Appendix_3b presents the shares of each fuel in the fuel combustion subsector. In the inventory and CRF Reporter peat is reported separately as a category under Other fuels. In the printed CRF tables it becomes summarised with relatively small amounts of other fuels consisting mostly of wastes and waste derived fuels.

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

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

The CO₂ 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 CO₂ 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).

The CH₄, N₂O, 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 on the basis of expert judgment (when no data have been available from other sources).

The research study at VTT Technical Research Centre of Finland has evaluated the non-CO₂ (CH₄ and N₂O) emission factors used in the Finnish inventory. In 2005 VTT measured the non-CO₂ emissions at several power plants in Finland. The power plants were selected based on a literature survey on the emissions and advice from the project's management group with representatives from administration and industry. The emissions were measured at the plants during longer periods to cover start-ups, partial loads and other exceptional conditions as well. The results of the study were published in late 2005 and in 2006 and 2007 (Tsupari et al. 2005; Tsupari et al. 2006; Tsupari et al. 2007). The results of this study have been used in the calculation of time series. All emission factors used in the ILMARI system were checked and revised according to the VTT study. The CRF tables and Inventory Report were updated accordingly at that time.

Emission factors for small combustion are partly IPCC default factors and partly taken from the reference Boström et al. (1992). Emission factors for CH₄ and N₂O for small combustion of wood were revised taking into account the VTT study.

CH₄ and N₂O emission factors by main category/fuel are presented in Table 3.2-5 and Table 3.2-6.

Table 3.2-5 CH₄ 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
		Other (grate, burner, not specified) / > 50	2
		All / > 1	1
Oil fired boiler	30 (> 80% oil) and 83 (50% - 80% oil)	All / <1	5
		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
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
	101 (cupola oven)		1

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

Sources:

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

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

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

Table 3.2-6 N₂O 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>

3.2.2.3 Activity data

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

The VAHTI data contain, for example:

- basic data like identification of plants, location, etc.

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

The VAHTI system includes detailed (boiler/process level) data, which allows emissions calculation using technology-specific emission factors for non-CO₂ emissions. There are numerous emission components reported directly in the VAHTI system; CO₂, SO₂, NO_x, PM emission data are used as input for the ILMARI system. This input data from the VAHTI system are supplemented with plant level data taken from other sources like:

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

Individual plants and boilers from the VAHTI data are linked to statistical data collection units (local kind-of-activity unit) to allow comparisons with a fuel consumption census 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.

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

Fuel combustion totals by fuel (PJ) as well as greenhouse gas emissions by fuel for 1990-2008 are given in Appendix_3b at the end of the Energy section.

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

Table 3.2-7 Fuel consumption in Energy industries (CRF 1.A 1) in 1990-2008 (PJ).

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Liquid fuels	Heavy fuel oil	16.2	17.0	17.9	19.1	23.6	21.0	24.8	19.3	19.4	21.2	17.0	19.3	20.7	20.9	16.6	15.9	17.3	16.2	12.9
	Light fuel oil	0.5	0.5	0.5	1.0	0.6	1.2	1.3	1.1	1.3	1.1	0.9	1.4	1.3	1.5	1.7	1.4	0.6	0.6	0.6
	Refinery gases	18.0	17.2	16.4	15.4	17.0	16.6	17.7	17.2	17.6	17.0	14.8	15.6	18.2	16.9	15.3	16.3	17.7	19.0	17.4
	Other liquid fuels	3.9	4.2	4.4	4.2	4.6	4.3	5.1	4.5	4.6	4.4	4.5	4.3	4.6	4.5	4.6	4.4	4.9	5.6	5.5
Solid fuels	Hard coal	99	91	82	102	137	106	151	131	88	90	88	110	128	186	161	73	159	137	89
	Other solid fuels	2.1	2.1	2.1	3.1	3.2	3.2	3.2	3.3	3.5	3.6	3.2	3.1	3.3	3.4	3.4	3.4	3.5	3.9	3.6
Gaseous fuels	Natural gas and other gaseous fuels	47.8	50.2	52.5	57.2	64.5	68.8	75.0	74.0	92.7	92.7	95.5	105.4	104.7	119.6	113.8	104.4	111.9	97.0	103.9
Biomass	Woodfuels	3.1	4.0	4.8	9.8	14.0	16.1	18.4	24.3	28.3	31.9	34.5	38.7	50.0	58.4	59.3	59.1	63.5	55.6	65.4
	Biogas	0.00	0.00	0.00	0.01	0.01	0.08	0.08	0.06	0.08	0.10	0.14	0.15	0.22	0.24	0.30	0.97	0.81	0.98	4.61
	Other non-fossil fuels	0	0	0	0	0	0	0	0	0	0	0.03	0.06	0.75	0.92	0.70	0.75	1.05	1.35	1.40
Other fuels	Peat	37.7	41.3	44.9	49.8	57.6	63.6	70.1	70.5	66.1	58.4	50.2	74.2	80.0	86.7	75.2	55.8	77.5	85.1	65.2
	Other; mixed fuels and waste	0.01	0.01	0.01	0.08	0.76	0.82	0.10	0.23	1.33	1.68	0.61	0.83	1.9	2.5	3.5	4.3	3.1	4.6	5.0

Table 3.2-8 Fuel consumption in Manufacturing industries and construction (CRF 1.A 2)in 1990-2008 (PJ).

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Liquid fuels	Heavy fuel oil	34.1	31.2	28.3	26.6	28.3	27.7	25.8	25.4	24.0	24.0	22.7	22.5	21.7	20.0	20.9	18.4	18.4	16.9	12.7
	Light fuel oil	13.3	13.2	13.0	12.6	12.6	13.1	13.3	13.8	14.3	14.8	15.0	15.1	15.2	15.0	14.9	14.9	14.9	15.5	15.8
	LPG	4.2	3.8	3.4	4.0	4.3	4.4	4.7	5.8	7.0	7.7	8.2	8.0	8.0	8.8	9.4	9.7	10.3	9.6	9.4
	Refinery gases	5.0	5.7	6.4	4.8	5.9	5.7	5.7	4.9	6.7	7.0	6.6	6.8	5.9	7.3	7.4	7.9	6.9	7.2	8.6
	Recycled waste oil	0.5	0.4	0.3	0.5	0.4	0.5	0.7	1.0	0.9	0.9	0.9	0.8	0.9	1.3	1.4	1.3	1.1	0.8	0.9
	Other liquid fuels	2.7	2.4	2.1	2.4	1.5	2.2	2.1	2.1	2.0	2.1	1.6	1.1	1.8	1.5	2.1	2.1	2.1	2.1	2.0
Solid fuels	Hard coal	28.4	25.5	22.7	20.6	19.5	16.4	14.2	13.2	11.8	11.1	10.3	9.3	8.0	7.2	7.3	7.3	5.3	4.9	5.4
	Coke	5.9	5.4	5.0	5.1	5.3	4.9	4.3	5.5	5.4	5.5	5.4	4.7	4.7	5.1	5.6	5.6	5.2	4.9	4.7
	Other solid fuels	9.0	9.3	9.6	12.2	13.0	11.9	12.2	13.5	13.7	14.2	15.2	14.0	14.2	14.9	14.5	14.7	15.4	12.8	13.3
Gaseous fuels	Natural gas and other gaseous fuels	40.0	40.9	41.8	42.8	44.2	43.1	40.8	39.5	38.2	38.5	39.9	41.7	40.1	39.4	40.6	37.0	39.4	42.7	40.1
Biomass	Woodfuels	42.0	38.9	35.7	45.0	42.3	43.7	42.4	45.1	54.0	48.3	50.6	47.0	39.3	39.1	44.0	39.5	42.2	37.9	37.5
	Black/sulphite liquor	87.4	87.0	86.6	104.8	111.2	111.1	108.0	129.2	124.4	142.3	139.8	125.3	140.6	138.2	145.0	129.4	156.0	154.1	141.8
	Biogas	0.09	0.09	0.09	0.11	0.07	0.30	0.26	0.29	0.25	0.38	0.41	0.40	0.39	0.39	0.40	0.35	0.37	0.37	0.44
	Other non-fossil fuel	0.65	0.81	0.97	0.88	0.96	0.98	0.85	1.00	1.08	0.95	1.28	1.25	0.86	0.89	1.12	1.08	1.04	0.74	0.60
Other fuels	Peat	14.1	13.6	13.1	13.8	15.2	14.9	16.4	16.5	13.6	12.4	11.4	11.6	10.6	13.2	12.5	12.2	15.1	16.1	15.1
	Other; mixed fuels and waste	1.7	1.6	1.4	1.5	1.6	1.6	2.2	2.3	2.5	2.4	2.7	2.7	2.6	3.1	2.7	2.8	3.6	3.6	4.1

3.2.3 Uncertainties and time series' consistency

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

Uncertainty in CO₂ emissions from fuel combustion was estimated at an aggregated level (CRF 1.A). Uncertainty in CH₄ and N₂O emissions was estimated on CRF levels 1.A 1, 1.A 2 and by fuel type (solid, liquid, gaseous, biomass, other).

Uncertainty in fuel combustion (CRF 1.A) in total was $\pm 4\%$ in Finland in 2008. In Finland, all fossil fuels (oil, natural gas, coal) are imported, and import and export statistics are fairly accurate. Uncertainty in the activity data of oil, gas and coal on national level was estimated based on differences between top-down and bottom-up approaches, as described by Monni (2004). In addition, uncertainties in activity data were estimated as rather small ($\pm 1\text{--}2\%$) for solid, liquid and gaseous fuels in large installations (CRF 1.A 1 and 1.A 2).

The uncertainty in the total use of peat fuel and biomass cannot be estimated by using differences between different statistics. Peat is an entirely domestic fuel and therefore import figures cannot be used to justify total consumption. However, uncertainties can be estimated comparing differences in plant level data. Uncertainty in peat fuel and biomass use contains larger uncertainties than the use of fossil fuels at a national level. These uncertainties were estimated at a level of CRF categories 1.A 1, 1.A 2, 1.A 4 and 1.A 5. Estimates were based on expert judgement (see Monni & Syri, 2003; Monni, 2004). For peat, uncertainties are estimated at $\pm 5\%$. The uncertainties in biomass use are estimated larger ($\pm 15\text{--}20\%$). This is because the energy content of different biomass types varies quite much and because industrial plants, such as pulp and paper mills, burn their product residues – the amount of which is not known as exactly as the amount for commercially traded fuels.

In fuel combustion, the CO₂ emission factor mainly depends on the carbon content of the fuel instead of on combustion technology. Therefore, uncertainty in CO₂ emissions was calculated at a fairly aggregated level, i.e. by fuel type rather than by sector. Uncertainties in CO₂ emission factors of oil, gas and coal are small ($\pm 1\text{--}3\%$), because the carbon content of these fuels is relatively constant and carbon is nearly completely oxidised in combustion.

Uncertainty in the CO₂ emission factor for peat is larger than for fossil fuels, because the moisture and carbon content of peat fuel varies. This variability has been estimated using the results from a measurement project done at VTT Processes (Vesterinen, 2003). In the study, the CO₂ 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 $\pm 5\%$.

Emission factors for CH₄ and especially N₂O from combustion are highly uncertain. The nitrous oxide emission factor depends strongly on combustion technology. For example, fluidised bed combustion has higher N₂O 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_x reduction technologies).

The research and measurement project at VTT on non-CO₂ (CH₄ and N₂O) 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 CH₄ and N₂O emission factors in all stationary combustion categories.

Monte Carlo simulation has been used to combine the uncertainties of each calculation parameter in order to get the total uncertainty of the source category (see Section 1.7). A detailed description of the methodology of the uncertainty analysis has been presented in Monni & Syri (2003) and Monni (2004).

During 2005-2007 the whole time series was checked to remove possible inconsistencies in the earlier inventories caused by missing data of some plants, changing classifications, etc. Most of these corrections were already included in the previous submissions (2006 - 2008), but as the work has been continued, some additional minor corrections have been made in the present inventory. Overall, methodologies and data sources are now as consistent as possible with reasonable resource demands. The only exception is the year 1991; the point source data of 1991 are not included in the ILMARI system. Instead of the actual point source data, the inventory for 1991 is partly based on interpolation between the years 1990 and 1992 at CRF source category and fuel category level.

3.2.4 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6.

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 included in the data input process. For example, fuel data should be reported in physical quantities (t or 1,000 m³) 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. After the data input process there will be numerous manual checks, like comparison with previous years' data (totals and single values), comparison with other fuel data sets, "top 20" lists, etc.

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

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

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

Data for all major industrial plants and power plants are checked and corrected if needed. The top 20 method means that for most fuel types at least 20 most important users are checked by comparing with previous years and/or with other available datasets. In the case of Finland, this checking method usually covers some 80 to 90% of the most important fuels.

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

Table 3.2-9 The results of the point source QC procedures for 2008 data.

	Number	Quantity	PJ
Fuel records total (corrected values)	2 702	52 934	733
Fuel records original	2 301	57 113	913
Non-corrected original	1 968	33 982	474
Imputed fuel records	422	3 443	77
TJ corrected	203	0	-59
Quantity corrected	44	-4 127	0
Quantity and TJ corrected	88	-4 140	-197
Fuel code corrected	46	1 114	15
Total corrected records (net Quantity and PJ corrections)	734	-4 828	-179

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 m³ 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 either to 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 and GHG inventory data are used to complement each other to find out the total consumption of peat.

CO₂ emissions are also checked in the plant level data. The ILMARI system includes calculated CO₂ emissions from each fuel batch. It also includes plant level CO₂ 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 CO₂ from biomass is separated from fossil CO₂). The reported data are compared with the calculated data and out-of-range differences are checked.

Each year the latest inventory calculations (activity data and CO₂ emissions) are verified by cross-checking the results against the national energy balance (Annex 4). This reference calculation is based on energy balance and shows activity data (PJ) and CO₂ emissions. The idea of this cross-checking 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. (Note: for the inventory year 2008 calculation this checking has not yet been performed due to late finalisation of national energy balance.)

The cross-checking of installations' combustion technology and other technical properties (capacity, main fuel, emission reduction equipment, process type, etc.) for point sources in CRF 1.A 1 and 1.A 2 for the whole time series was mainly completed in 2005 and reported in the previous inventory submission although some minor corrections have been (and will be) done annually after 2005.

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

Finnish Environment Institute (FEI) calculates the final data for the UNECE Air Pollutant inventories. The calculation system is separate from the GHG calculation system, but uses the same basic data sources for calculation of emissions from fuel combustion. 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 GHG inventory. The list of corrections made to database of FEI is available only for the reporting on 15 March. This independent calculation system is used as a verification tool for GHG inventory, and moreover, as source of additional corrections.

A more comprehensive list on Tier 1 and 2 level QC activities in the Energy sector is included in the internal documentation (in Finnish and archived in the common disk (KHK-laskenta) at Statistics Finland.).

ETS data

CO₂ emission data taken from the EU ETS (Emission Trading System, see Section 1.4) were 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 CO₂ emissions taken from the ETS data were 36.2 Tg in 2008. The corresponding amount taken from the GHG inventory data was 36.2 Tg. In the ETS data 199 Gg of CO₂ and in the GHG data 200 Gg of CO₂ was transferred out of the ETS plants. The reduced amount is slightly different because the storage factor in the inventory is based on annual data and in the ETS a predetermined average storage factor is used (see section 3.2.7.1). The calculation method of amount of transferred emission in the GHG data is explained in section 3.2.7. The difference between the ETS and GHG data is 0.09 Tg, 0.2% of total ETS. There are more differences in the allocation of emissions to CRF categories, which can be seen in Figure 3.2-2.

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

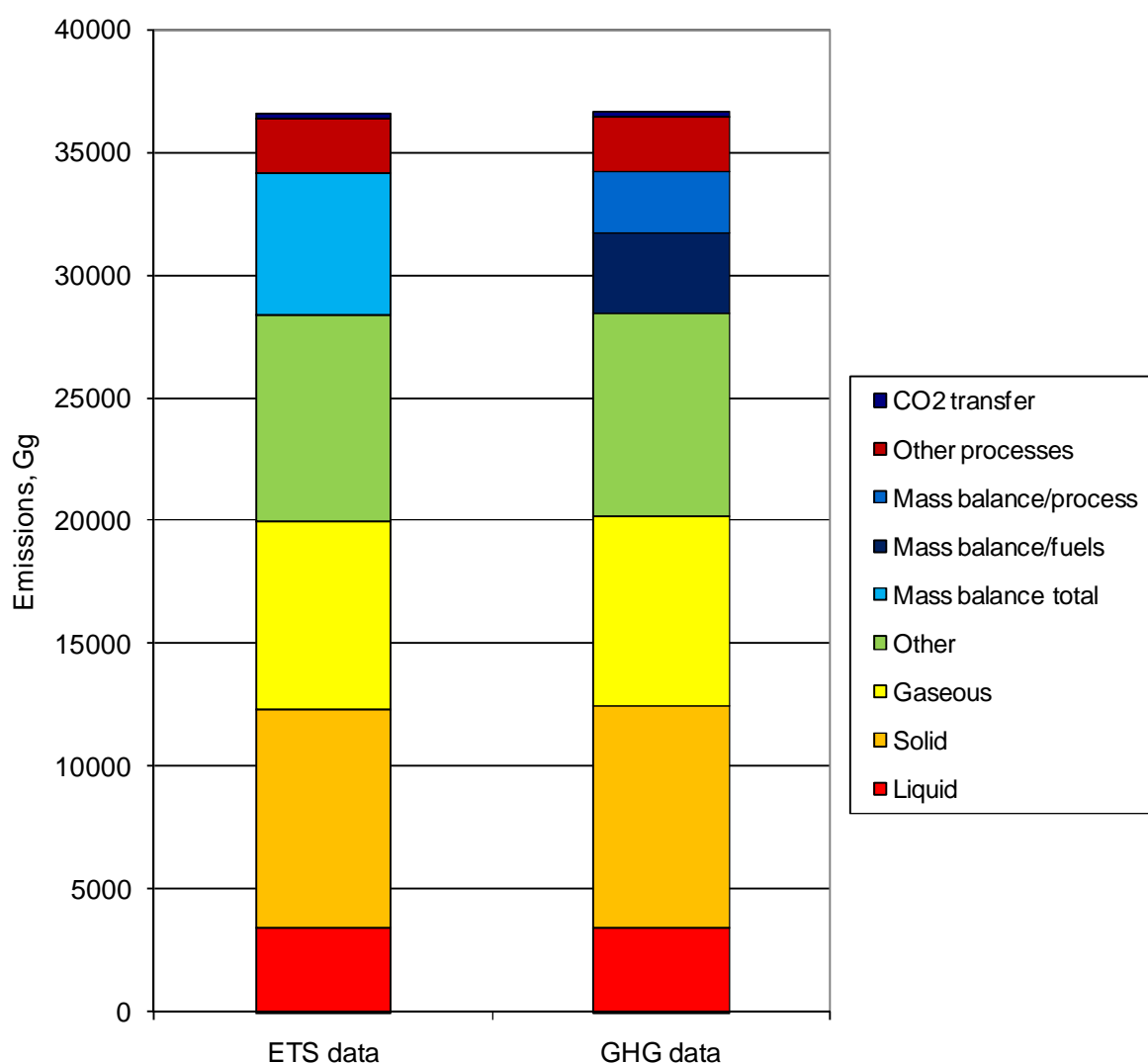


Figure 3.2-2 CO₂ emissions of ETS plants compared with the corresponding emissions reported in the greenhouse gas inventory in 2008.

From 2008 onwards ETS plants have been using mostly measured plant level calorific values and emission factors.

NCVs, CO₂ emission factors and fuel consumption data taken from the ETS system were aggregated to the most detailed fuel code level and compared with the corresponding data in the ILMARI system. If there were significant differences, correction 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 +1%. For wood fuels the differences in NCVs were clearly larger

(generally $\pm 5\%$). 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.

3.2.5 Source-specific recalculations

There were minor corrections in the point sources' data (activity, combustion technology or allocation) to remove inconsistencies in plant level time series data in categories 1.A 1 and 1.A 2. These corrections were in some cases reflected also in category 1.A 5, which includes residuals of certain fuels.

Some preliminary fuel consumption figures for 2007 were substituted with final data in subcategories of 1.A and amount of emissions were increased in subcategory 1.A 1 by 33.1 Gg and 1.A 2 by 48.9 Gg. Emissions of year 1990 of subcategory 1.A 2 were also recalculated and amount of emissions decreased 61.7 Gg. One of the reasons for recalculation was that the time series data of one iron and steel plant were checked and revised (more information in Section 4.4.2.6).

3.2.6 Source-specific planned improvements

Emissions from fuel combustion are by far the largest source of greenhouse gas emissions in Finland, and many point sources in this category are part of the EU Emission Trading Scheme. Monitored data for CO₂ emissions from these sources have become available from the emission trading system for the inventory years 2005 - 2008. In the Energy sector ETS data have been mainly used in:

- identifying missing point sources
- checking and verifying fuel consumption data
- verifying emission data

At the moment these checkings and comparisons have been done mostly by manual operations. In the future ETS plants and data will be linked to ILMARI to make automatic checking routines possible.

The process description and internal user manual of the Energy sector calculations have been under revision in 2008-2009 and this work will be continued. The user manual is written in Finnish.

3.2.7 CO₂ capture, transfer and storage in PCC

In Finland four pulp and paper and two paper plants are capturing and directing a part of their fuel combustion based CO₂ emissions to PCC (Precipitated Calcium Carbonate) plants nearby. The CO₂ capture in pulp production takes place in the lime kiln and in paper production in associated industrial power plants. PCC is widely used in different kinds of paper and paper board as filling or coating material. The first PCC plant using transferred CO₂ in Finland started its operation in 1993.

PCC in paper and paper board will form a long-term storage for the captured CO₂ (see Section 3.2.7.2) except in cases where the paper or sludge from recycled paper is combusted. The emissions from combustion are taken into account separately under relevant categories in the energy sector. Long-term storage is the main criteria used for inclusion of CO₂ capture and storage in the inventory.

3.2.7.1 Methodology

In the lime kilns of the pulp production process lime mud (basically CaCO₃) is burned back to lime (CaCO₃ -> CaO + CO₂) and after that lime is reused in causticising. The lime kiln has been chosen for the CO₂ source of PCC production because an excess amount of CO₂ 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 CO₂ comes from fuels used in the kilns.

The amount of CO₂ 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. Also 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 CO₂ emissions or the amount of CO₂ captured. Therefore they also estimate CO₂ transferred using amount of PCC produced.

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

The calculated amount of stored CO₂ is subtracted from subcategory 1.A 2f, or actually a negative emission figure is reported in this subcategory in the CRF Reporter (see Table 3.2-10). The way of reporting is chosen to show transparently the amount deducted from the inventory each year. The calculations are presented in more detail in Appendix_3c. This also in accordance with the guidance for reporting given in the 2006 IPCC Guidelines (IPCC 2006).

A small amount of carbonate (either PCC or other carbonates) based CO₂ is released in combustion of recycling sludge as well as part of MSW or REF (mostly in subsectors 1.A 1a, 1.A 2d and 1.A 2f). These emissions are taken into account in the corresponding emission factors.

Table 3.2-10 PCC production and transferred CO₂, 1993-2008.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
PCC production, 1000 t	2	46	123	167	241	290	356	413	403	401	430	473	425	482	532	485
CO ₂ transferred and subtracted from 1.A 2f, Gg	1	20	54	74	106	128	156	182	177	176	189	208	187	212	234	213

3.2.7.2 Source-specific QA/QC and verification

Statistics Finland clarified the characteristics of CO₂ storage in PCC in 2008 through literature and discussions with experts. According to the Finnish experts⁴, PCC in paper and recycled sludge disposed in landfills or used in landscaping constitute a long-term storage for CO₂. 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, CO₂ will be released, when PCC containing paper or sludge is burned.

In response to the review recommendation of submission 2009, the characteristics of the captured CO₂ were clarified from the calculation of the emissions of the plants capturing CO₂ for PCC production. About 85% of fuels used in the plants capturing the CO₂ from lime kilns of pulp production process have been fossil (natural gas, different type of oils) origin. Finland deducts all captured CO₂ 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 CO₂ has used exclusively fossil for the whole time series. The other power plant has used fossil fuels until 2001. Since 2001, this power plant has also combusted biomass fuels, but the total amount of captured and transferred CO₂ has not exceeded the CO₂ emissions from fossil fuels.

As a response to the review of Finland's inventory submission in 2009, Statistics Finland has calculated the share of fossil CO₂ used in PCC based on the above described plant-specific information for the last nine years (plant-level PCC production data were available only for years 2000-2008). For plants using fossil and biomass fuels, the share was calculated assuming that CO₂ captured would be proportional to the amount of fossil and biomass fuels used. Of the total transferred CO₂ amount, the average share of fossil CO₂ is 87 per cent. More details can be found in Appendix 3_c.

⁴ Prof. Eero Hanski, University of Oulu, prof. Olli Dahl, Helsinki University of Technology and Docent Kauko Kujala, University of Oulu (see Appendix_3d).

The PCC production data has been crosschecked with other data sources. Statistics Finland has collected plant specific data on the production amounts by PCC plant for the relevant years from the VAHTI database (national environmental permit registry) and the production statistics (plant specific data from Statistics Finland's manufacturing industry surveys). The data have also been crosschecked with the amount of captured and transferred CO₂ reported under the EU ETS. These data exist for the years 2005-2008 and include the captured and transferred amount of CO₂ 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 2005-2007. The difference is assumed to account for possible losses during transfer and production.

3.2.7.3 Source-specific recalculations

A minor double counting in the 2009 submission was discovered. The share of combusted recycling sludge was deducted from CO₂ capture and transfer (and thus seen as emitted CO₂.) These CO₂ emissions were also included in combustion of recycling sludge (these emissions may in addition contain CO₂ emissions from other carbonates than PCC). This double counting has now been removed.

3.3 Transport (CRF 1.A 3)

Source category description

In 2008, the greenhouse gas emissions from transportation amounted to 13.6 Tg CO₂ equivalent. The share of the transport sector of the total greenhouse gas emissions has remained fairly constant since 1990, and was approximately 18% in 1990 and 19% in 2008.

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

Table 3.3-1 Reporting categories in the transport category.

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

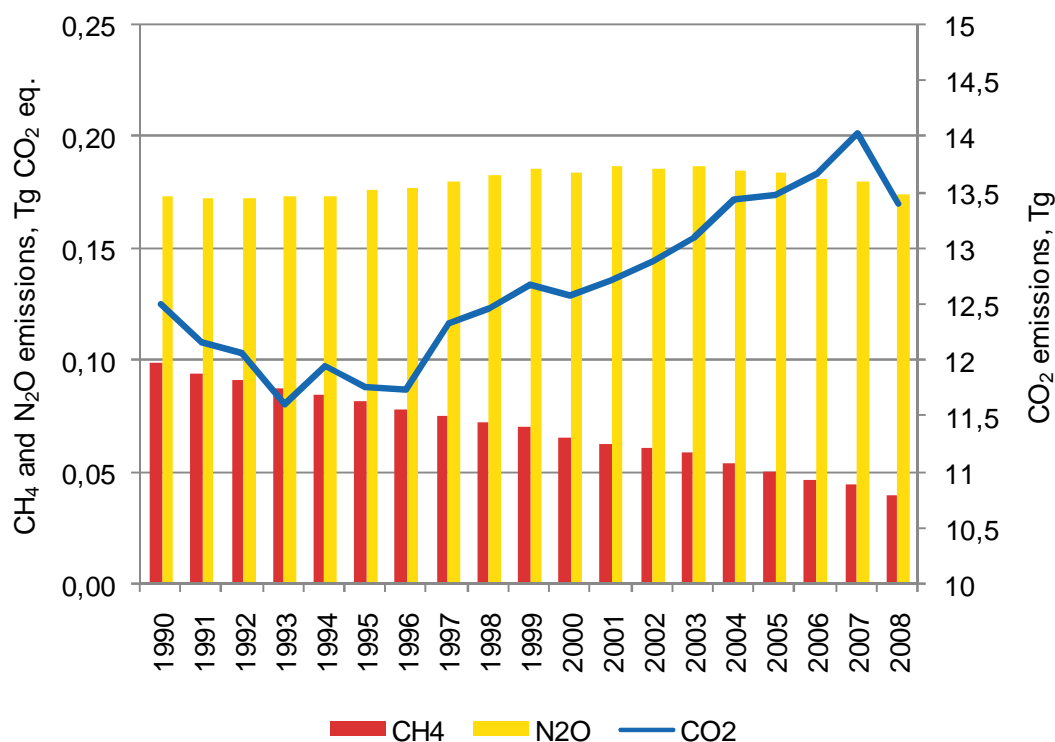


Figure 3.3-1 Emissions from transport sector by gas in 1990-2008 (Tg CO₂ eq.).

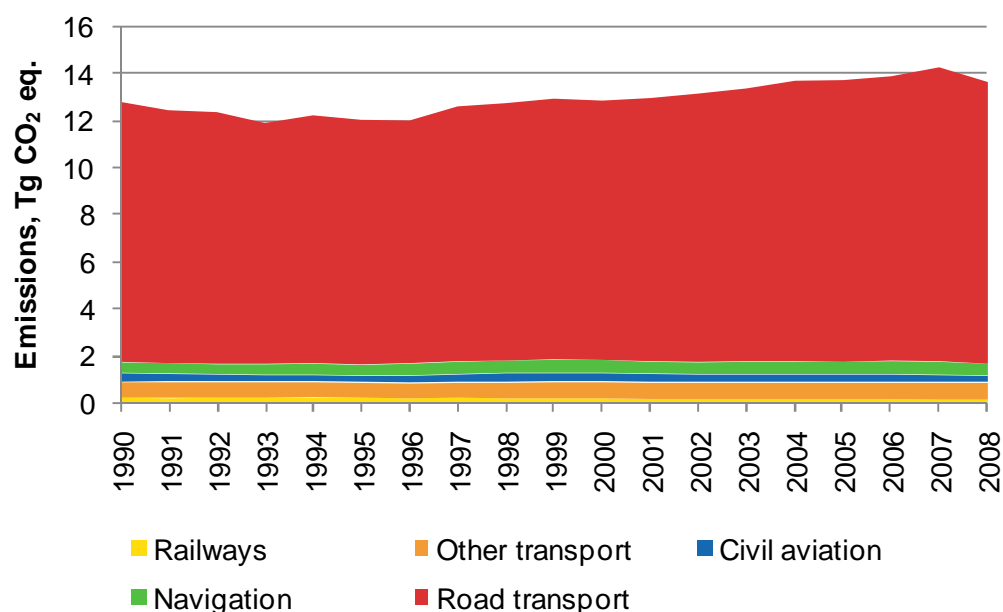


Figure 3.3-2 Emissions from transport by subcategory in 1990-2008 (Tg CO₂ eq.).

Road transportation is the most important emission source in transport, covering over 88% of sector's emissions in 2008. The emission trends for each sub-category are discussed in corresponding sections.

CO₂ emissions from transport decreased strongly after the year 1990. Reason for the decrease was the economic depression that was much deeper in Finland than in other European countries. The bottom was reached year 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.

Methodological issues

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

The LIPASTO system is comprised of four sectoral submodels:

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

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

VTT and Finavia are responsible for running the calculation models of emissions of mobile sources. Statistics Finland aggregates the results of these models to sub-categories of CRF sector 1.A Fuel combustion (see section 3.2) and to national energy balances as well. MEERI and ILMI include both domestic and international transport, but only domestic part of transport is taken to ILMARI as part of greenhouse gas inventory. The definition used for international transport in ILMI and MEERI is different from the IPCC definition, thus bunker emissions are calculated separately by Statistics Finland (see section 3.8)

The fuel consumption in the transport sector in 1990-2008 can be seen in Table 3.3-3.

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

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

Table 3.3-4 shows the changes in the allocation of diesel oil, non-road gasoil and heating gasoil used in different subsectors of the inventory. These allocations and their changes are based on expert judgment. The actual consumption figures are not available by user category, only total sales of each fuel. For the sake of completeness, the table includes also 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 yet separated in published statistics. The changes of emission factors due to the fuel shift have been included in the transport emission calculation submodels.

Table 3.3-2 Emissions from the Transport sector in 1990-2008 by subcategory (Tg CO₂ eq.).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Total	12.8	12.4	12.3	11.9	12.2	12.0	12.0	12.6	12.7	12.9	12.8	13.0	13.1	13.4	13.7	13.7	13.9	14.3	13.6
CO ₂																			
3. Transport	12.5	12.2	12.1	11.6	12.0	11.8	11.7	12.3	12.5	12.7	12.6	12.7	12.9	13.1	13.4	13.5	13.7	14.0	13.4
a. Civil aviation	0.39	0.34	0.31	0.28	0.26	0.26	0.31	0.34	0.39	0.38	0.38	0.37	0.32	0.33	0.33	0.33	0.32	0.31	0.30
b. Road transport	10.8	10.5	10.5	10.0	10.3	10.2	10.1	10.6	10.7	10.9	10.8	11.0	11.2	11.4	11.7	11.8	11.9	12.3	11.8
c. Railways	0.19	0.18	0.19	0.21	0.21	0.19	0.18	0.19	0.18	0.17	0.16	0.14	0.14	0.14	0.14	0.13	0.13	0.11	0.11
d. Navigation	0.44	0.44	0.42	0.45	0.50	0.47	0.50	0.53	0.52	0.54	0.54	0.50	0.52	0.54	0.52	0.53	0.57	0.58	0.49
e. Other transport	0.66	0.68	0.68	0.67	0.66	0.66	0.64	0.66	0.67	0.69	0.70	0.70	0.71	0.70	0.71	0.71	0.71	0.72	0.71
CH ₄																			
3. Transport	0.099	0.094	0.092	0.088	0.084	0.082	0.078	0.076	0.073	0.070	0.066	0.063	0.061	0.059	0.054	0.051	0.047	0.045	0.040
N ₂ O																			
3. Transport	0.174	0.172	0.172	0.173	0.174	0.177	0.177	0.181	0.183	0.186	0.184	0.187	0.186	0.187	0.185	0.184	0.182	0.180	0.175
a. Civil aviation	0.005	0.004	0.004	0.004	0.003	0.003	0.004	0.004	0.005	0.005	0.005	0.005	0.004	0.004	0.004	0.004	0.004	0.004	0.004
b. Road transport	0.160	0.159	0.160	0.160	0.161	0.164	0.164	0.167	0.169	0.171	0.169	0.173	0.173	0.173	0.172	0.170	0.168	0.166	0.161
c. Railways	0.0015	0.0014	0.0015	0.0016	0.0017	0.0016	0.0014	0.0015	0.0014	0.0014	0.0013	0.0011	0.0011	0.0011	0.0011	0.0010	0.0011	0.0009	0.0010
d. Navigation	0.0029	0.0029	0.0027	0.0029	0.0033	0.0030	0.0033	0.0035	0.0034	0.0037	0.0037	0.0033	0.0035	0.0036	0.0035	0.0036	0.0039	0.0040	0.0037
e. Other transport	0.0047	0.0048	0.0047	0.0047	0.0046	0.0045	0.0045	0.0046	0.0047	0.0047	0.0048	0.0048	0.0048	0.0048	0.0048	0.0048	0.0049	0.0050	0.0049

Table 3.3-3 Fuel consumption by fuel type in transport in 1990-2008 (PJ).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Civil aviation																			
Aviation gasoline	0.11	0.10	0.09	0.09	0.08	0.08	0.08	0.08	0.07	0.07	0.08	0.06	0.05	0.05	0.05	0.04	0.05	0.05	0.05
Jet kerosene	5.15	4.55	4.17	3.77	3.45	3.51	4.10	4.56	5.21	5.17	5.11	5.02	4.36	4.41	4.49	4.46	4.39	4.13	4.02
Road transport																			
Gasoline	80.7	80.6	80.8	75.8	77.6	76.6	73.9	75.8	74.6	73.9	71.1	72.1	73.2	73.7	74.9	74.7	73.9	73.7	67.0
Diesel oil	67.4	63.1	62.5	61.0	63.6	62.6	64.3	69.3	71.9	74.9	76.5	78.1	79.8	81.9	85.4	86.2	88.9	94.3	95.4
Natural gas	NO	NO	NO	NO	NO	NO	0.002	0.006	0.013	0.044	0.048	0.059	0.107	0.131	0.120	0.113	0.155	0.162	0.173
Liquid biofuels	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.033	0.176	0.186	NO	0.034	0.076	3.53
Railways																			
Gasoil	2.58	2.46	2.53	2.78	2.85	2.61	2.38	2.53	2.39	2.30	2.17	1.92	1.85	1.84	1.88	1.71	1.74	1.47	1.56
Navigation																			
Residual oil	1.56	1.55	1.35	1.69	2.27	1.86	2.12	2.46	2.27	2.16	2.39	1.84	2.12	2.29	2.00	1.91	2.08	2.24	1.91
Gasoil	2.52	2.52	2.40	2.42	2.46	2.39	2.52	2.54	2.51	2.87	2.71	2.66	2.68	2.68	2.79	2.98	3.20	3.20	2.75
Gasoline	1.80	1.86	1.89	1.89	1.89	1.96	1.97	2.01	2.10	2.17	2.12	2.13	2.17	2.15	2.17	2.20	2.30	2.33	1.94
Other transport																			
LPG	0.28	0.27	0.26	0.25	0.24	0.23	0.23	0.22	0.21	0.19	0.19	0.19	0.20	0.21	0.22	0.23	0.23	0.23	0.22
Motor gasoline	6.28	6.28	6.20	6.13	6.09	6.03	5.86	5.97	6.06	6.15	6.16	6.17	6.15	6.11	6.07	6.02	6.03	6.12	6.12
Gasoil	2.43	2.65	2.77	2.75	2.70	2.66	2.68	2.75	2.87	3.05	3.14	3.18	3.24	3.27	3.35	3.40	3.44	3.52	3.40

Table 3.3-4 The allocation of diesel oil, heating gasoil and non-road gasoil.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	
Road transport	67.4	63.1	62.5	61.0	63.6	62.6	64.3	69.3	71.9	74.9	76.5	78.1	79.8	81.9	85.4	86.2	88.9	94.3	95.4	Diesel oil
Leisure boats	0.45	0.46	0.47	0.47	0.47	0.48	0.49	0.50	0.52	0.54	0.52	0.53	0.54	0.53	0.54	0.54	0.56	0.56	0.48	
Domestic navigation	4.45	4.36	4.17	4.14	4.15	4.04	4.15	4.16	4.03	4.30	4.08	3.94	3.98	3.98	3.93	4.02	4.33	4.27	3.85	Non-road gasoil
Railway transport	2.58	2.46	2.53	2.78	2.85	2.61	2.38	2.53	2.39	2.30	2.17	1.92	1.85	1.84	1.88	1.71	1.74	1.47	1.56	
Non-road machinery	29.4	29.6	29.0	28.5	28.3	28.3	28.0	28.5	29.3	29.9	30.3	30.5	30.6	30.6	30.5	30.6	30.4	30.9	31.4	
Energy prod, heating, industry	68.8	67.6	66.7	66.0	64.0	63.2	64.9	64.1	68.0	66.2	60.4	61.8	60.7	58.1	56.8	53.6	49.5	48.2	43.8	Light fuel oil (=heating gasoil)

3.3.1 Civil aviation

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

The share of the civil aviation from transport category was over 2% and the amount of emissions was 0.30 Tg (CO₂ eq.) in 2008. It was 0.39 Tg in 1990. See Figure 3.3-3 and Table 3.3-5.

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 have been fairly constant during the last few years excluding the year 2007 with a 9% drop in number of flights. In 2008 number of flights increased 1% but the fuel consumption decreased about 3% compared to year before. This is a consequence of smaller jet aircrafts used in Finland. Flight hours of general aviation decreased 3% compared to year 2007.

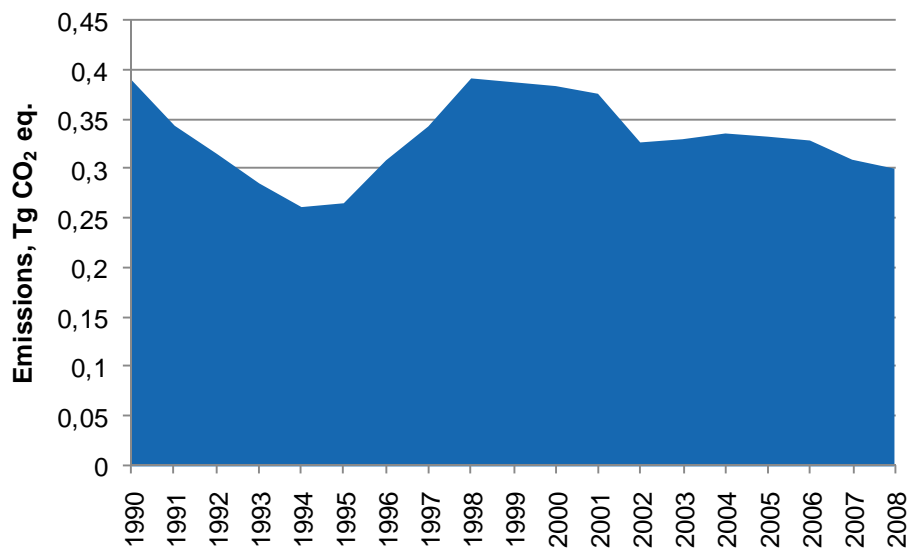


Figure 3.3-3 Emissions from domestic civil aviation in 1990-2008 (Tg CO₂ eq.)

Table 3.3-5 Emissions, fuel consumption and number of flights or flight hours by fuel type in the Civil Aviation (1.A 3a) sector in 1990-2008.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Civil aviation, emissions, Tg CO ₂ eq.	0.39	0.34	0.32	0.29	0.26	0.27	0.31	0.34	0.39	0.39	0.38	0.38	0.33	0.33	0.34	0.33	0.33	0.31	0.30
Aviation gasoline																			
Fuel consumption, PJ	0.11	0.10	0.09	0.09	0.08	0.08	0.08	0.08	0.07	0.07	0.08	0.06	0.05	0.05	0.05	0.04	0.05	0.05	0.05
Flight hours (general aviation)	97 770	85 140	79 680	76 569	66 065	61 365	60 769	58 840	57 663	55 400	60 991	50 644	41 774	36 000	35 359	30 160	38 834	37 362	36 202
Jet kerosene																			
Fuel consumption, PJ	5.15	4.55	4.17	3.77	3.45	3.51	4.10	4.56	5.21	5.17	5.11	5.02	4.36	4.41	4.49	4.46	4.39	4.13	4.02
Number of flights (air transport)	70 256	69 881	61 894	62 121	64 874	62 599	68 010	74 233	84 386	75 035	76 658	74 066	66 745	66 876	67 132	66 509	68 951	62 458	63 266

3.3.1.1 Methods

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

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

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

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

The calculation is based on traffic statistics, aircraft performance data and aircraft engine emission factors (unburned hydrocarbons EF HC, carbon monoxide EF CO, nitrogen oxides EF NO_x 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_x 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 CO₂, sulphur dioxide SO₂ and nitrous oxide N₂O 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_x, SO₂ and CO₂. For CH₄ and N₂O the methodology is comparable with the IPCC Tier 1 level method.

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

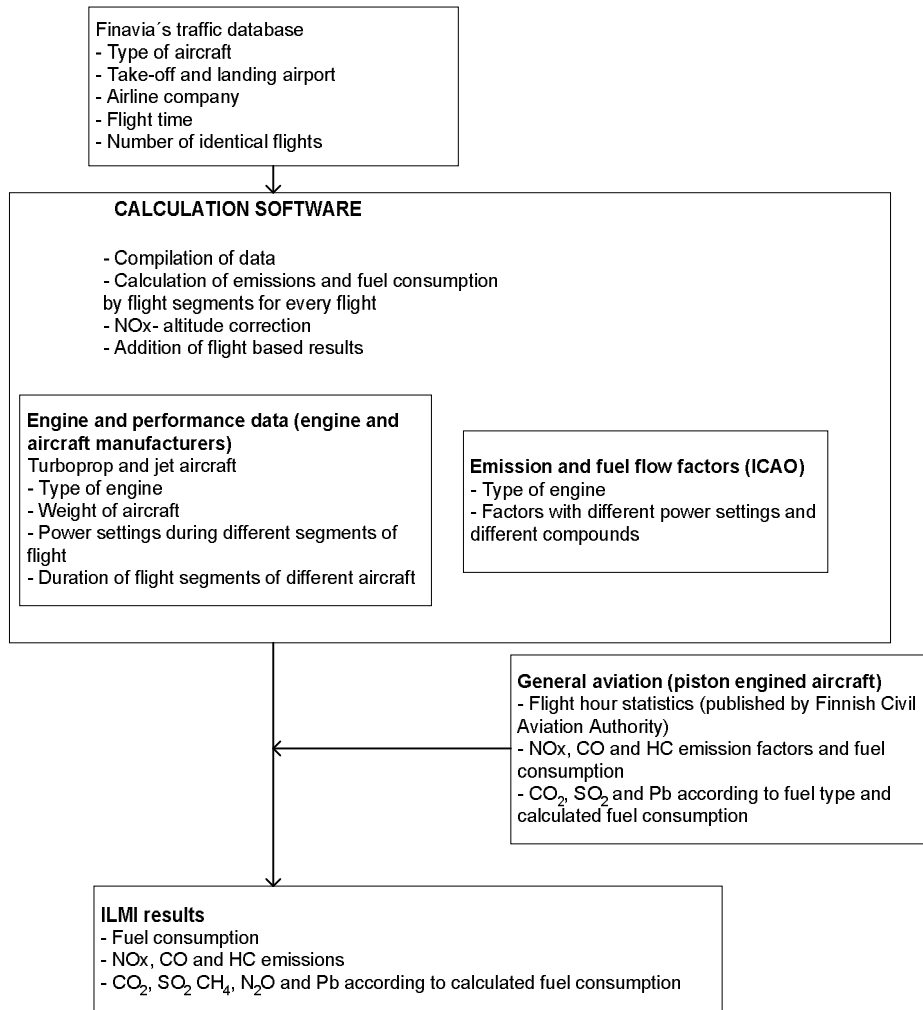


Figure 3.3-4 The ILMI calculation model.

3.3.1.2 Activity data

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

The data include fields for:

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

3.3.1.3 Emission factors and other parameters

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

The dependency on atmospheric pressure, so called altitude correction factor, is taken into consideration for the emission factors of NO_x per climb-out, cruise and descent. For HC and CO it is negligible.

Emission factor for N₂O (mean value 0.003 g/MJ) is derived from the Revised 1996 IPCC Guidelines (IPCC 1997, table 1-50, p. 1.96) and the emissions of methane CH₄ are assumed to be 10% of HC emissions according to the table mentioned.

CO₂ emission factors are country specific (see Table 3.2-3: jet fuel 73.2 g/MJ and aviation gasoline 71.3 g/MJ).

3.3.1.4 Uncertainties and time series' consistency

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

A summary of the uncertainty analysis methodology used in the inventory is given in Section 1.7. Monte Carlo simulation has been used to combine the uncertainties of each calculation parameter in order to get the total uncertainty of the source category. A detailed description of the uncertainty analysis method has been presented in Monni & Syri (2003) and Monni (2004).

3.3.1.5 Source-specific QA/QC and verification

Statistics Finland crosschecks the fuel consumption data calculated within the ILMI model. Jet fuel and aviation gasoline consumption data taken from ILMI 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 the year 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_x 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 Chapter 3.8). The results of Eurocontrol were close to those reported in the greenhouse gas inventory (Graichen, 2007). The difference in the total fuel consumption (domestic flights + bunkers) between Finnish greenhouse gas inventory data and Eurocontrol data was around 3% in 2005. Also the data on the share of domestic flights from total aviation were fairly close in both sources (Graichen, 2007).

3.3.1.6 Source-specific recalculations

No source-specific recalculations have been done.

3.3.1.7 Source-specific planned improvements

Eurocontrol has developed a comprehensive calculation system for aviation emissions. All the data necessary for the National Inventory Reports are included in the system output. However, it is unclear how soon Eurocontrol is able to provide national authorities with this information as the status of the ETS Support Facility and other services of the forthcoming regulatory "pillar" is unclear. Finland will start using aviation data from the Eurocontrol's source as soon as practicable.

If considerable discontinuity in the time series will be identified, necessary recalculation of Finland's data from 2004 onwards will be undertaken.

3.3.2 Road transportation

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

Road transportation is the most important emission source in the Transport sector. The emission of road transportation was 12 Tg (CO₂ eq.) in 2008, it was 88% of the sector's emissions and 17% of the total emissions. Emissions were 11.1 Tg (CO₂ 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 8% higher than the year 1990 (Figure 3.3-5).

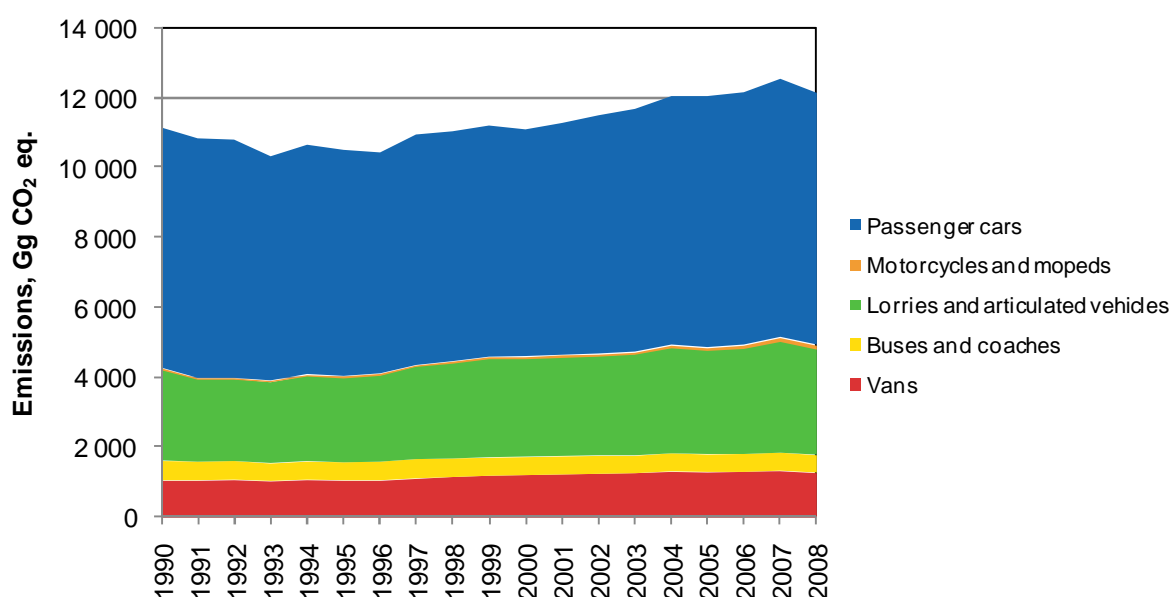


Figure 3.3-5 Emissions from road transportation by types of vehicle in 1990-2008 (Gg CO₂ eq.) (The detailed transport calculation models LIPASTO of VTT Technical Research Centre of Finland).

The main reason for emission growth is increased kilometrage. Fuel consumption per vehicle has stayed quite stable (see also Table 3.3-6). In 2008 the emissions deviated from the upward trend. The worldwide economic depression that began this year has decreased the mileage of all transport modes. At the same time, the change in Finland to CO₂ based taxation of cars has caused a transition from gasoline to diesel cars and lowered of the specific fuel consumption of gasoline cars as well.

3.3.2.1 Methods

Emission estimations from road transportation are made using the road traffic emission model LIISA, which is a part of the model for all transport modes, LIPASTO of VTT Technical Research Centre of Finland. The calculations comprise the emissions of CO₂, CH₄ and N₂O. The same model is also used for the calculation of SO₂, CO, NMVOC, NO₂ and PM emissions.

The methods for calculating emissions from road transportation correspond to the IPCC Tier 3 level method. Calculation of CO₂ emissions is based on fuel consumption of road vehicles and the emission factors. The calculation model is described in Appendix_3a at the end of Chapter 3. The definition of consumption of fuel on the country level is based on fuel sales. Road traffic in Finland uses basically two different fuels, reformulated gasoline and diesel oil. Besides road traffic use, the gasoline sold in Finland is also used in working machines and leisure boats and hence the amount of gasoline used for other purposes than road

traffic is deducted from the total sales of gasoline before the emission calculation (see under the paragraph Activity data). Diesel fuel sold in Finland is used almost exclusively by road traffic, but starting from year 2008 diesel has been used also as fuel in leisure boats. The amount of fuel imported in fuel tanks of vehicles from other countries is estimated to be small. The use of natural gas in road traffic in Finland is very small and is not included in the LIISA model. The emissions from natural gas in road traffic are calculated separately in the ILMARI model (see Chapter 3.1.1.3) based on activity data obtained from annual Energy Statistics.

N₂O and CH₄ 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 CH₄ and N₂O emission factors (g/km). Emission factors are a sum of hot driving, idle and cold start-ups. Finally all emissions are summed up. The calculation model is described in Appendix_3a at the end of Chapter 3.

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

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

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

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

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

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

3.3.2.2 Activity data

The activity data in CO₂ calculation are the amount of fuel consumed in road traffic. Total fuel sales are from statistics compiled by the Finnish Oil and Gas 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 2,172 million litres and in leisure boats and working machines 175 million litres (7.6% of total sales). Diesel fuel sales were 2,660 million litres, of which use in leisure boats were 13.3 million litres (almost 0.5% of total sales). Biodiesel and biogasoline are included in these figures (see Table 3.3-7).

Activity data of blended biofuels are based on separate survey made by Statistics Finland (Energy statistics unit). The data includes the amount of blended biogasoline (ethanol), starting from 2002, as well as blended biodiesel, starting from 2007. At the moment the data of other biogenic compounds, like ETBE (ETBE =

ethyl tert-butyl ether, is bio ethanol based gasoline component), is not available for years prior to 2008. Starting from 2008, the activity data of blended and pure biofuels is collected by Finnish Customs. This data includes the following biofuels and bio-components:

- bioethanol, NExBTL-gasoline, bioshares of ETBE and TAAE⁵
- biodiesel and synthetic biodiesel (mostly NExBTL⁶-diesel)

Biogenic CO₂ emissions are calculated directly from tonnes of used biogenic fuel, because conversion factors from tonnes to TJ and TJ to CO₂ are considered more uncertain. Although gasoline is consumed also in other subcategories, all biogenic emissions have been allocated to Road transport to increase the transparency. In all other subcategories the value of biogasoline (or biodiesel) is very small, and the biogenic emissions would be very close to zero.

The consumption figures are originally included in total use of gasoline and diesel oil. Biogenic CO₂ emissions have been subtracted from fossil emissions of gasoline and diesel oil. 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.

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

For modelling purposes, the data are broken down into different vehicle types and road types. However, this does not affect the country level CO₂ emission calculation because at the end these sub-results are summed up and the total fuel consumption remains unchanged.

For activity data for N₂O and CH₄ calculations, the Finnish Transport Agency has provided the kilometrage [km/a] on public roads as a database from the road register. Further division to subcategories is done at VTT. Data for total street kilometrage in Finland are obtained from the Finnish Transport Agency. Further division is made at VTT. Division of kilometrage to subcategories is based on vehicle fleet data from Statistics Finland, research done by the University of Oulu and VTT, street kilometrage systems of city of Helsinki and Espoo and population data of cities.

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

Road traffic kilometrage in Finland in 1990-2008 is presented in Table 3.3-6.

⁵ tertiary amyl ethyl ester

⁶ Production process for renewable diesel oil, commercialised by Neste Oil co. A small amount of bio gasoline is by-produced in the process

Table 3.3-6 Road traffic kilometrage in Finland [Million km/a] (LIISA).

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

Table 3.3-7 Consumption and biogenic CO₂ emissions of biogasoline and biodiesel 2002-2008, t.

	Biogasoline		Biodiesel	
	Consumption, t	CO ₂ , t	Consumption, t	CO ₂ , t
2002	1 143	2 183	NO	NO
2003	6 255	11 946	NO	NO
2004	6 752	12 897	NO	NO
2005	NO	NO	NO	NO
2006	1 184	2 261	NO	NO
2007	2 447	4 674	125	390
2008	100 435	191 832	11 405	35 583

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

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

Number of cars with catalytic converters is rather low (82% of all gasoline cars, 90% of the kilometrage of gasoline cars) compared to other European countries. This is due to the very high average age of cars and the economic depression that occurred at the beginning of 90's when the cars with catalytic converters emerged to the market (Table 3.3-8).

Table 3.3-8 Share of gasoline used in cars with catalytic converter (CAT) and without it (non-CAT), TJ and per cent.

	Gasoline, CAT (TJ)	Gasoline, non-CAT (TJ)	share of CAT, %
1990	4 464	76 735	5
1991	8 706	72 567	11
1992	11 924	69 528	15
1993	14 137	62 356	18
1994	17 724	60 641	23
1995	20 940	56 508	27
1996	23 666	51 086	32
1997	28 523	48 158	37
1998	31 821	43 500	42
1999	35 520	39 024	48
2000	37 767	33 911	53
2001	41 523	31 049	57
2002	45 855	28 122	62
2003	49 647	24 714	67
2004	55 109	20 729	73
2005	58 397	16 800	78
2006	60 795	13 141	82
2007	63 389	10 458	86
2008	61 893	8 467	88

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

3.3.2.3 Emission factors and other parameters

Emission factors are determined for all the activity categories mentioned above. CO₂ emission factors are based on national figures (Table 3.2-3). They differ slightly from those expressed in the IPCC guidelines. The emission factors are based on product analysis in Neste Oil laboratories. Neste Oil Corporation is the leading company in oil product manufacturing in Finland (market share over 90%). Reformulated gasoline and diesel oil have different CO₂ emission factors. The same emission factor is used for both gasoline types E95 and E98.

The following emission factors were used to calculate biogenic emissions: ethanol: 1.91 t CO₂/t and biodiesel: 3.12 t CO₂/t. Emission factor for ethanol is based on stoichiometric relation. For biodiesel the emission factor is based on 85% carbon content. These emission factors are first estimates, and they will be checked, when more data becomes available. Amounts of used biogasoline and biodiesel as well as biogenic CO₂ emissions are presented in Table 3.3-7.

Country-specific net calorific values and CO₂ emission factors are shown in Table 3.2-3.

Emissions factors for CH₄ and N₂O are a sum of hot driving, idle and cold start-ups. The inventory review from the year 2008 recommended Finland to check the N₂O emission factor for gasoline. The comparison of EFs stated that all European countries have different EFs for N₂O transport emissions. According to the recommendations in the review the N₂O emission factors have been thoroughly checked and updated in the LIISA model. Emission factors used in the COPERT 4⁷ program have been used as the reference values. The only vehicle categories that needed substantial modifications were gasoline cars and vans equipped with catalytic converters. Originally the LIISA model included only one N₂O factor for catalytic converters. Now all the Euro-classes (i.e. each catalytic converter generation) of vehicles have own emission factor. Trend in

⁷ [Copert 4](#) is an MS Windows software program aiming at the calculation of air pollutant emissions from road transport. The technical development of COPERT is financed by the European Environment Agency (EEA).

the emission factors for vehicles with catalytic converters have been declining. As a result N₂O emissions calculated with the LIISA model are substantially lower after the year 1990 than reported earlier.

CH₄ and N₂O emissions factors for natural gas in road transport are taken from IPCC 1997 (Table 1-8 and Table 1-43).

3.3.2.4 *Uncertainties and time series' consistency*

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

A summary of the uncertainty analysis methodology used in the inventory is given in Section 1.7. Monte Carlo simulation has been used to combine the uncertainties of each calculation parameter in order to get the total uncertainty of the source category. A detailed description of the uncertainty analysis method has been presented in Monni & Syri (2003) and Monni (2004).

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 N₂O emissions, gasoline driven cars are divided into cars with and without catalytic converters. As CO₂ emissions mainly depend on the carbon content of the fuel, uncertainty in these emissions was estimated at an upper level (CRF 1.A).

Emissions of CH₄ and N₂O 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 CO₂ emissions. CH₄ 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).

N₂O emissions vary more than CH₄ emissions and are highly dependent on the type and age of the catalytic converters used. The uncertainty in these emissions is estimated based on different studies and measurements (Pringent and de Soete, 1989; Potter, 1990; Becker et al., 1999; Perby, 1990; Egeback and Bertilsson, 1983; Odaka et al., 2000; Jimenez et al., 2000; Lipman and Delucchi, 2002; Oonk et al., 2003; Behrentz, 2003). For N₂O emission factors, uncertainties are estimated largest for cars with catalytic converters.

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

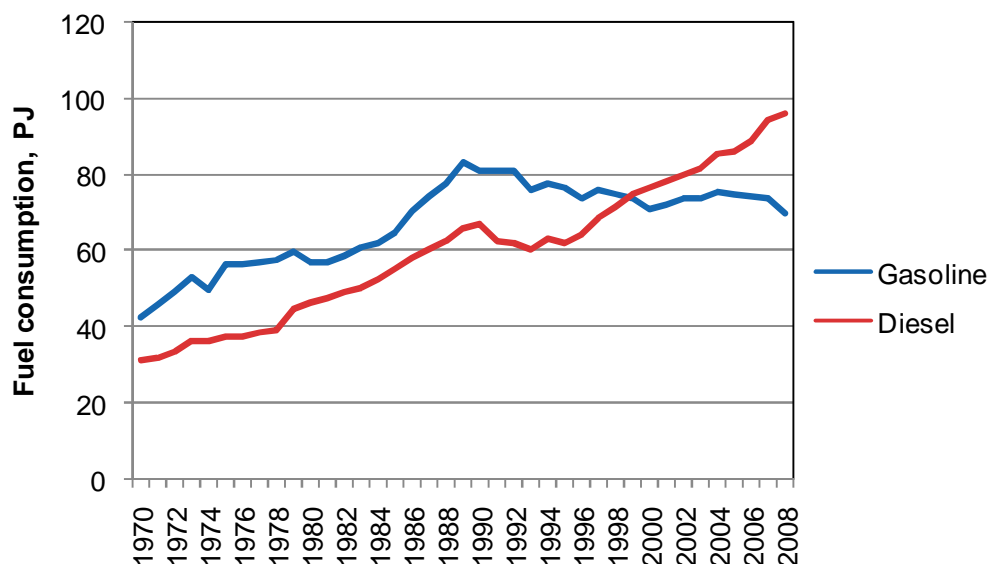


Figure 3.3-6 Consumption of diesel and gasoline in road transportation in 1970-2008 (Energy Statistics, Yearbook 2009).

The road traffic kilometrage in Finland has increased by about 20 per cent in the period of 1990-2004, but the corresponding CO₂ emissions have only increased by 9 per cent. The divergence is thus ca. 10%. According to the statistics the energy efficiency of new cars has increased by 4-5% during the period of 1990-2008. The remaining 5% could be explained by the overestimation of the kilometrage. The yearly kilometrage on highways in Finland is fairly accurate ($\pm 2\%$) because of the very sophisticated measuring system on the road network. On the contrary, the kilometrage driven on streets is rather poorly known, as is the case in all countries. The total kilometrage in a city is not a key issue in the transport planning. However, the street kilometrage forms ca. one third of the total kilometrage. Roughly estimating the margin of error of street kilometrage could be up to $\pm 20\%$. The problem has been identified earlier and research efforts have already been taken to solve it. A preliminary study was conducted in 2008. However, methods to measure the street kilometrage are all expensive and present efforts have not yet yielded proper results. The research will be continued.

3.3.2.5 Source-specific QA/QC and verification

The quality management process and the QA/QC plan for the whole inventory are presented in section 1.6. The QA/QC plan for the transport sector includes the QC measures based on the IPCC Good Practice Guidance. These measures are implemented every year during the transport sector inventory. Potential errors and inconsistencies are documented and corrections are made if necessary.

Small differences (for most years less than 1%) in total 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 gasoline consumption, to ensure full consistency between Energy Statistics and GHG inventory. The corresponding CO₂ emissions are corrected as well.

3.3.2.6 Source-specific recalculations

The inventory review of the 2008 submission recommended Finland to check the N₂O emission factor for gasoline. The comparison of EFs stated that all European countries have different EFs for N₂O transport emissions. According to the recommendations in the review the N₂O emission factors have been thoroughly checked and updated in the LIISA model. Emission factors used in the COPERT 4 program have been used as the reference values. The only vehicle categories that needed substantial modifications were gasoline cars and vans equipped with catalytic converters. Originally the LIISA model included only one N₂O factor for catalytic converters. Now all the Euro-classes (i.e. each catalytic converter generation) of vehicles have own

emission factor. Trend in the emission factors for vehicles with catalytic converters have been declining. As a result N₂O emissions calculated with the LIISA model are substantially lower after the year 1990 than reported earlier.

3.3.2.7 Source-specific planned improvements

As already stated in Section 3.3.2.4 there exists some inconsistency in kilometrage and fuel consumption data. A preliminary study of the total kilometrage was conducted during the year 2008 and will be further extended to kilometrage per vehicle. This will be done by analysing the massive amount of vehicle inspection data available.

3.3.3 Railway transportation

Emissions of railway transportation in Finland comprise railway transport operated by diesel locomotives. In 2008 83% of railway kilometres were electrified, the number was not changed since previous year. Emissions from electricity used in electric trains are not included this category, but in category 1.A 1.

Railway transportation is a minor emission source in the transport sector. The emissions of railway transportation were 0.12 Tg (CO₂ eq.) in 2008, it was only 1% of the sector's emissions. The emissions were 0.19 Tg (CO₂ eq.) in 1990 (Figure 3.3-7). CO₂ emissions from diesel trains have decreased since 1994. There are two main reasons for this. One is the electrification of the railway lines. The other reason is that transportation in minor railway lines has ceased.

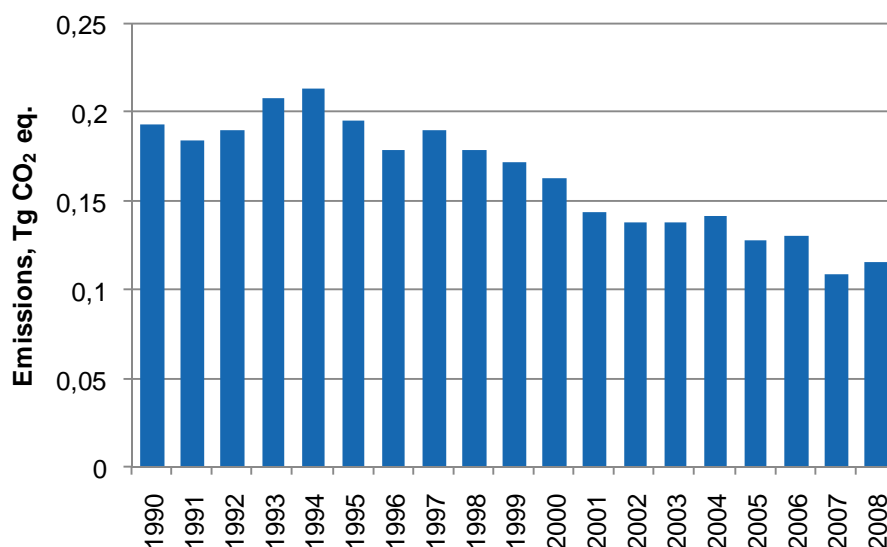


Figure 3.3-7 Emissions from railway transportation in 1990-2008 (Tg CO₂ eq.).

3.3.3.1 Methods

Calculations of emissions from railway transportation are made using the railway traffic emission model RAILI, which is a part of the model for all transport modes LIPASTO of VTT Technical Research Centre of Finland. Calculation comprises the emissions of CO₂, CH₄ and N₂O. The same model is also used for the calculation of SO₂, CO, NMVOC, NO₂ 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 Ltd, the Finnish railway operator) where the total energy use of these activities was calculated and then divided with the total amount of tonne kilometres resulting in a factor for the extra fuel consumption per tonne kilometre.

3.3.3.2 Activity data

Activity data consist of gross tonne kilometres for ten train weight classes on all rail sections (229 sections). Shunting locomotive use is expressed as time (h/a) in all rail yards. There are four separate diesel locomotive types in the model and ten train weight classes for both passenger and freight transport. For every locomotive type, specific energy consumption (litre/gross tonne km) has been determined. Shunting locomotive consumption is determined as litres per hour. Emission factors are expressed as grams per kg fuel used for each gas. Density for the diesel oil is 845 kg/m³. Emissions from wagon heating and the use of aggregates (for electricity production) are calculated by multiplying gross tonne kilometres with emission factors for wagon heating and aggregates.

Fuel oil consumption in railway transportation in Finland is presented in Table 3.3-9.

The gross tonne kilometre database and shunting locomotive statistics originate from VR Ltd, the only railway operator in Finland. The calculated amount of diesel fuel is crosschecked with the information of VR Ltd on the total fuel usage. All fuel used in railway transportation is nowadays gasoil for non-road use, which is technically the same product as sulphur free diesel oil.

Table 3.3-9 Fuel oil consumption in railway transportation in Finland (tonnes/a, VR Ltd).

Year	tonnes/a
1990	60 397
1991	57 710
1992	59 268
1993	65 084
1994	66 656
1995	61 117
1996	55 767
1997	59 249
1998	55 942
1999	53 842
2000	50 822
2001	44 890
2002	43 236
2003	43 101
2004	44 132
2005	40 154
2006	40 853
2007	34 413
2008	36 508

3.3.3.3 Emission factors and other parameters

The emission factors used in the calculation of emissions from Railway transportation are presented in Table 3.3-10. The emission factors of CH₄ and N₂O are based on international measurements and the IPCC guidelines. The N₂O emission factor for wagon heating (0.0071 g/kg fuel) is derived from U.S. EPA (2002) (residential furnace). The CO₂ factor is presented in Table 3.2-3.

Table 3.3-10 Emission factors used in the calculation of emissions from Railway transportation (Neste Oil Ltd, IPCC guidelines).

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

The N₂O emission factor for non-road diesel engines is taken from the IPCC Guidelines (IPCC, 1997), but the factor given for US Non-Road Mobile Sources (0.08 g/kg_{fuel}, Table 1-47) is used instead of the one given for Europe (1.3 g/kg_{fuel}, Table 1-49). The factor for Europe is 16 times higher than that for the US. According to the international measurement data obtained so far, the US value seems to be more accurate and in line with automobile engines.

3.3.3.4 Uncertainties and time series' consistency

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

A summary of the uncertainty analysis methodology used in the inventory is given in Section 1.7. Monte Carlo simulation has been used to combine the uncertainties of each calculation parameter in order to get the total uncertainty of the source category. A detailed description of the uncertainty analysis method has been presented in Monni & Syri (2003) and Monni (2004).

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 CO₂ emissions is estimated to be low. This was also shown in a measurement project of Kymenlaakso Polytechnic (Korhonen & Määttänen, 1999). In the current inventory, CO₂ uncertainties are estimated at CRF category level 1.A.

Uncertainties in CH₄ and N₂O emission factors are larger than those in CO₂. 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 CH₄ was estimated based on variation in hydrocarbon emissions in a measurement project (Korhonen & Määttänen, 1999). Uncertainty in the N₂O 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 CH₄ and N₂O emission estimates would require more measurement data and more information on the use of the engines of locomotives (frequency of start-ups, shut-downs, etc). However, the importance of these emissions in the Finnish greenhouse gas inventory is very small.

3.3.3.5 Source-specific QA/QC and verification

The quality management process and the QA/QC plan for the whole inventory are presented in section 1.6. The QA/QC plan for the transport sector includes the QC measures based on the IPCC Good Practice Guidance. These measures are implemented every year during the transport sector inventory. Potential errors and inconsistencies are documented and corrections are made if necessary.

The amount of gasoil calculated by VTT is crosschecked with the information of VR Ltd on the total fuel usage. Statistics Finland crosschecks the fuel consumption data calculated within the RAILI model. Gasoil consumption data taken from MEERI is summed up in the ILMARI system with other user's estimated consumption and the calculated total is compared to total sales of gasoil.

3.3.3.6 Source-specific recalculations

No source-specific recalculations have been done.

3.3.3.7 Source-specific planned improvements

No source-specific improvements are planned.

3.3.4 Domestic navigation

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

Domestic navigation is a minor emission source in this category. The emissions of domestic navigation were 0.50 Tg (CO₂ eq.) in 2008, it was less than % of the sector's emissions. The emissions were 0.45 Tg (CO₂ eq.) in 1990. Emissions from domestic navigation by ship types are presented in Figure 3.3-8.

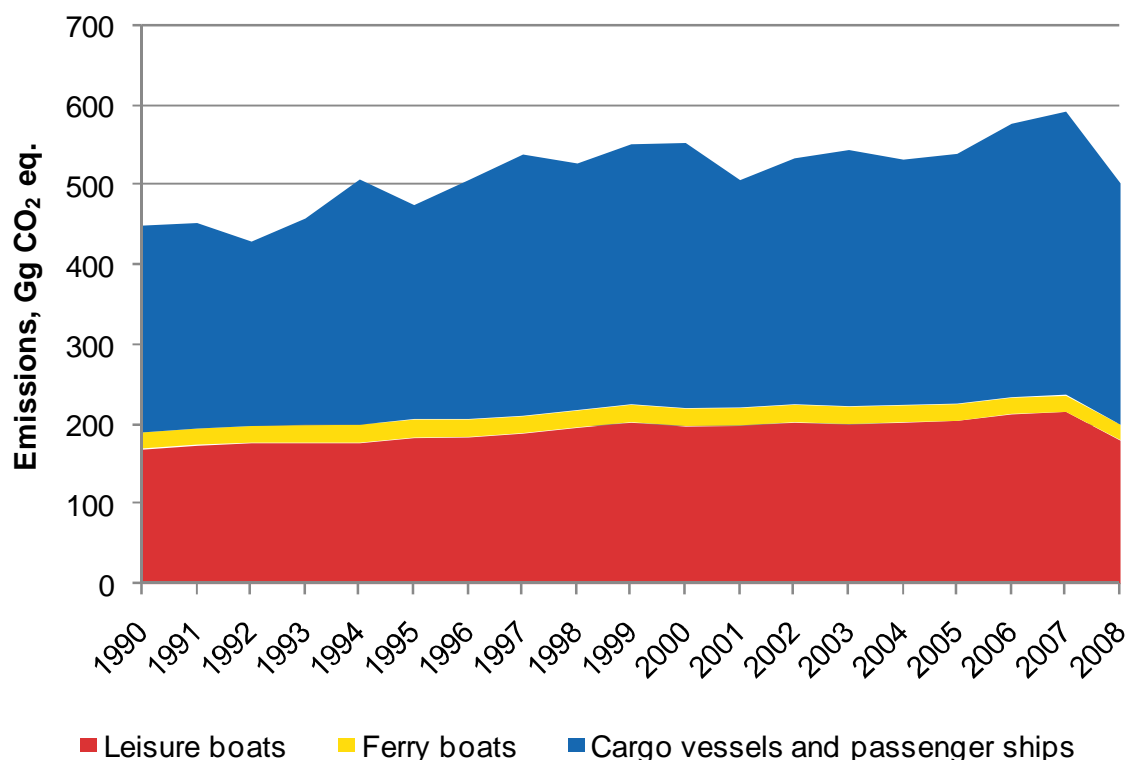


Figure 3.3-8 Emissions from domestic navigation by ship types in 1990-2008 (Gg CO₂ eq.)

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 last decade. 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. Main reason for the sharp decrease in cargo vessels and passenger ships is the change in icebreaker fuel use. Depending on the ice conditions at the Baltic Sea the fuel consumption of icebreakers can vary substantially as can be seen in Table 3.3-12.

3.3.4.1 Methods

Calculations of emissions from civil navigation are made with the waterway traffic emission model MEERI, which is a part of the model for all transport modes LIPASTO. Calculation comprises emissions of CO₂, CH₄ and N₂O. The same model is also used for the calculation of SO₂, CO, NMVOC, NO₂ and PM emissions.

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

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

For calculating emissions in ports, the time (h) of manoeuvring and berthing is determined. Using engine power (kW), engine load (%) and time (h) taken for manoeuvring and berthing, the total energy use in the ports (kWh) is calculated for every ship type. The total emissions are obtained by multiplying the total energy use (kWh) of ships by the emission factors (g/kWh) of different engine types (2-stroke and 4-stroke and auxiliary engines) (g/kWh). Emission factors are at the year 1996 level but correction factors are used to update the factors to date.

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

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

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

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

Calculation models are described in Appendix_3a at the end of Chapter 3.

3.3.4.2 Activity data

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

Data on total fuel consumption of icebreakers are obtained from the Finnish Transport Agency.

Data on total fuel consumption of ferryboats are acquired from road authorities (Ferryboats are used to transport road vehicles across narrow water straits on the public road network). Amount of used fuels by ship type are described in Table 3.3-11.

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

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

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

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

There was another change in legislation for leisure boats, too. From 2008 on leisure boats equipped with diesel engine are no more allowed to use lower taxed gasoil. Instead they are obliged to use diesel oil, which has higher tax. This can be seen as a minor change in the allocation of fuels starting from 2008.

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

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

Table 3.3-11 Amount of used fuels in domestic navigation by ship type, PJ (MEERI).

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

3.3.4.3 Emission factors and other parameters

The CH₄ and N₂O emission factors for ships are the IPCC values for Ocean-going ships (IPCC 1997, Table 1-48). CO₂ emission factors are based on national figures (Table 3.2-3). They differ slightly from those expressed in the IPCC Guidelines. The difference is small. The emission factors are based on product analysis in Neste Oil laboratories. Neste Oil Corporation is the leading company of oil product manufacturing in Finland (market share over 90%).

The CH₄ and N₂O emission factors for working boats, cruisers, ferryboats and leisure boats are based on international and national sources.

The emission factors, net caloric values and densities used in the calculation of emissions from domestic navigation for CH₄ and N₂O are presented in Table 3.3-12.

Table 3.3-12 Emission factors, net caloric values and densities used in the calculation of emissions from domestic navigation (Neste Oil, IPCC 1997).

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

3.3.4.4 Uncertainties and time series' consistency

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

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

In Finland, fuels used in waterborne navigation include residual oil, gasoil and gasoline and starting from 2008, diesel oil. Diesel oil and gasoline are used mainly by leisure boats. The share of fuels sold for leisure boats is rather poorly known due to lack of consumer surveys. Uncertainty in this activity data is estimated at $\pm 20\%$ based on expert judgement. Uncertainty in the use of residual oil and gasoil is estimated smaller, $\pm 10\%$.

As CO₂ emissions mainly depend on the carbon content of the fuel, uncertainty in these emissions was estimated at an upper level (CRF 1.A).

Uncertainties in CH₄ and N₂O emission factors are larger than those in CO₂. 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 N₂O emissions is larger than in CH₄ emissions. Reduction of uncertainty in CH₄ and N₂O emission estimates would require more measurement data and more information on the use of engines in ships (frequency of start-ups, shutdowns, etc).

3.3.4.5 Source-specific QA/QC and verification

The quality management process and the QA/QC plan for the whole inventory are presented in section 1.6. The QA/QC plan for the transport sector includes the QC measures based on the IPCC Good Practice Guidance. These measures are implemented every year during the transport sector inventory. Potential errors and inconsistencies are documented and corrections are made if necessary.

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

3.3.4.6 Source-specific recalculations

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

3.3.4.7 Source-specific planned improvements

The thorough renovation of the national boat register during the next three years will necessitate some modifications in the leisure boat model.

3.3.5 Other transportation

Emission sources of other transportation are non-road vehicles and machinery, excluding those machinery, that are allocated to CRF categories 1.A 2f Other / Construction and 1.A 4c Agriculture/Forestry/Fisheries. In this category there are several types of non-road machinery, like fork lifts, snowmobiles, etc. Complete list of machine types included in each CRF category in Table 3.3-15.

Other transportation is the second largest source of emissions in the transport sector. The emissions were 0.72 Tg (CO₂ eq.) in 2008, it was over 5% of the sector's emissions and over one per cent of total greenhouse gas emissions. Emissions were 0.67 Tg (CO₂ eq.) in 1990. Emission trend of other transport followed the overall trend of emissions; economic depression at the beginning of 90's decreased emissions. After that especially emissions from leisure time activities has increased (gasoline; ATV (all-terrain vehicle), snowmobiles) while emissions from business activities have decreased (diesel). Economic depression that started in the year 2008 has lowered the leisure time activity and hence the emissions in 2008. Emissions by fuel in 1990-2008 are presented in Figure 3.3-9.

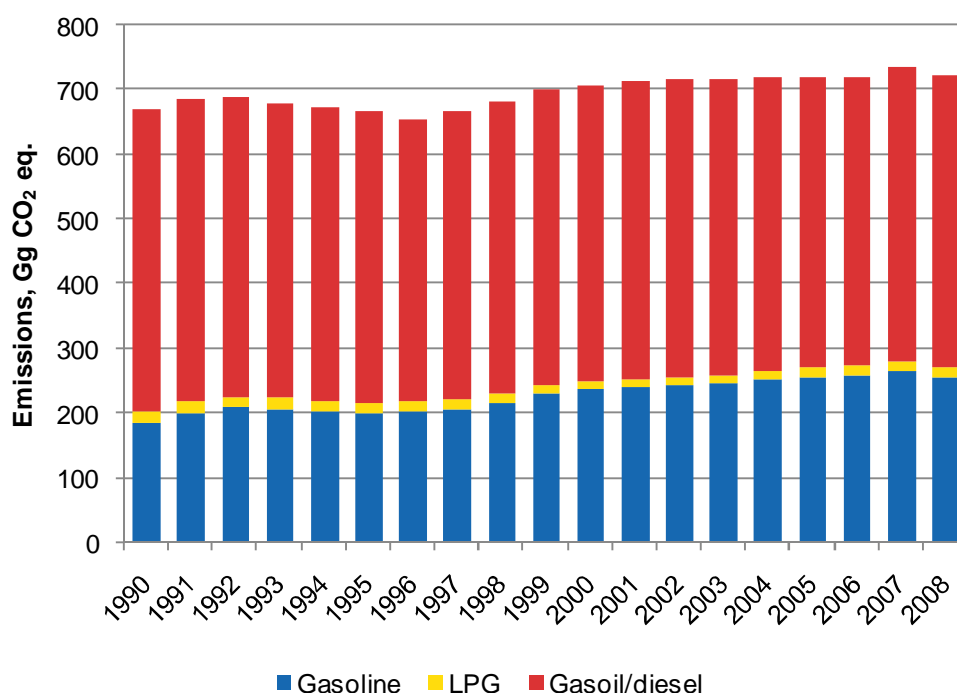


Figure 3.3-9 Emissions from other transportation by fuel in 1990-2008 (Gg CO₂ eq.)

3.3.5.1 Methods

The TYKO model from VTT Technical Research Centre of Finland estimates emissions and energy consumption of non-road machinery, which are reported in the Finnish inventory under sectors 1.A 2f Other / Construction, 1.A 3e Other transportation and 1.A 4c Agriculture/Forestry/Fisheries. The machinery included in the TYKO model is divided into five main categories: Drivable diesel, drivable gasoline, moveable diesel, moveable gasoline and handheld gasoline, totalling 51 different machine types. The model calculates the machinery in the categories mentioned above. The division to different CRF source categories (construction, agriculture, forestry, other) is made afterwards for the ILMARI system (see Section 3.3.5.2) by Statistics Finland. As the TYKO model calculates emissions of all non-road machinery in Finland, this model description is valid for all source categories that deal with machinery. The main results of the TYKO model can be seen on the website: <http://lipasto.vtt.fi/tyko/results.htm>. Emissions by CRF subcategories are presented in Table 3.3-13.

Table 3.3-13 Greenhouse gas emissions from TYKO model by CRF subcategories (Gg CO₂ eq.).

	1.A 2f Other / Construction	1.A 3e Other transportation	1.A 4c Agriculture	Forestry
1990	841	671	700	237
1991	846	687	710	213
1992	833	689	710	191
1993	819	680	710	173
1994	813	674	719	162
1995	828	666	716	164
1996	832	654	675	186
1997	842	667	665	218
1998	869	682	650	259
1999	903	701	616	293
2000	935	708	593	310
2001	955	713	585	313
2002	961	716	591	310
2003	960	715	602	302
2004	960	719	608	296
2005	966	719	614	286
2006	983	720	602	262
2007	1 020	734	596	259
2008	1 054	723	589	238

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

The calculation formula, which applies to all non-road machinery in the TYKO model, is presented in Appendix_3a at the end of Chapter 3.

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

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

3.3.5.2 Activity data

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

Table 3.3-14 Breakdown of different machine types in TYKO model to CRF subcategories.

CRF subcategory	Type of machine
1.A 2f Other / Construction	Cranes Bulldozers Rollers Wheel loaders Backhoe loaders Mini excavators, skid steer Excavators, skid steer Excavators, rubber tire Dumpers Telehandlers Generator sets, diesel Compressors

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

3.3.5.3 Emission factors and other parameters

Emission factors are originally based on the CORINAIR study by Andrias et al. (1994): The Estimation of the Emissions of 'Other Mobile Sources and Machinery'. Subparts 'Off-Road Vehicles and Machines', 'Railways', and 'Inland Waterways' in the European Union. Some emission factors are based on the publication: National Nonroad Emission Model. U.S. EPA (1998). Especially the emission factors of small engines are based on national measurements (Ahokas, J. & Elonen E., (1997). In updating (see Section 3.2.2.6) all emission factors were checked, especially emission stages II-IV.

3.3.5.4 Uncertainties and time series' consistency

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

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

3.3.5.5 Source-specific QA/QC and verification

The quality management process and the QA/QC plan for the whole inventory are presented in section 1.6. The QA/QC plan for the transport sector includes the QC measures based on the IPCC Good Practice Guidance. These measures are implemented every year during the transport sector inventory. Potential errors and inconsistencies are documented and corrections are made if necessary.

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

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

3.3.5.6 Source-specific recalculations

No source-specific recalculations have been done.

3.3.5.7 Source-specific planned improvements

No improvements have been planned.

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

3.4.1 Source category description

Subcategory CRF 1.A 4 includes emissions from combustion in commercial, institutional and residential sectors. These cover mainly fuels used in heating of buildings. Also emissions from heating of agricultural buildings, non-road machinery in agriculture and forestry as well as fishing boats are included in this source category.

Subcategory CRF 1.A 5 includes emissions from non-specified consumption of fuels, military use and statistical corrections of fuel consumption.

The emissions of these subcategories were 6.1 Tg (CO₂ eq.) in 2008; it was over 11% of the energy sector's emissions and almost 9% of total greenhouse gas emissions of Finland. Emissions were 8.9 Tg (CO₂ eq.) in 1990. Amount of emissions have decreased mainly due to increased use of district and electric heating in residential, commercial and public buildings (Figure 3.4-1).

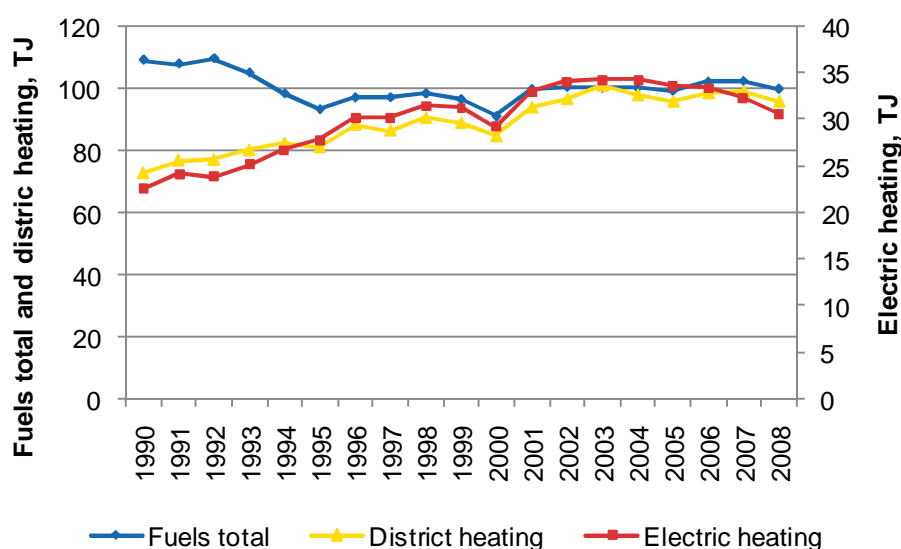


Figure 3.4-1 Energy consumption of heating in residential, commercial and public buildings, 1990-2008 (Energy Statistics, Yearbook 2009).

The sector Other also includes indirect N₂O emissions caused from N deposition by total NO_x emissions in Finland. The main source for the NO_x emissions is fuel combustion in the Energy sector, with transportation being the most significant source category. The IPCC GPG 2000 (IPCC, 2000) states that indirect N₂O from other sources of N deposited on soils, in addition to those coming from the Agriculture sectors can be accounted for and that the estimated emissions should be reported under the sector in which the originating activity is reported. The 2006 IPCC Guidelines for National Greenhouse Gas Inventories include a methodology and guidance on estimating and reporting of indirect N₂O emissions from the atmospheric deposition of nitrogen in NO_x and NH₃.

The indirect N₂O emissions from agricultural sources (mainly from NH₃ emissions) are included in the Agriculture sectors as was done in previous submissions and in accordance with the guidance in the IPCC Guidelines. Possibilities to complement the estimates on indirect N₂O emissions with emissions from nitrogen deposition due to industrial NH₃ emissions and other possible sources will be explored in future inventories. These sources are estimated to be of small, if not negligible, significance.

Emissions from these sectors in 1990-2008 by subcategory are presented in Table 3.4-1.

Table 3.4-1 Emissions from sectors 1.A 4 Other sectors and 1.A 5 Other in 1990-2008 by subcategory (Tg CO₂).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
CO ₂																			
4. Other sectors	7.0	6.9	7.0	6.5	6.2	5.7	5.8	5.8	5.9	5.8	5.5	5.7	5.6	5.5	5.3	5.1	4.9	4.8	4.5
a. Commercial and institutional	1.95	1.88	2.01	1.60	1.47	1.20	1.27	1.28	1.29	1.27	1.17	1.23	1.22	1.21	1.17	1.12	1.11	1.06	0.88
b. Residential	3.07	2.96	2.97	2.92	2.69	2.53	2.57	2.57	2.60	2.54	2.34	2.49	2.42	2.34	2.25	2.15	2.12	2.02	1.88
c. Agriculture, forestry and fisheries	2.02	2.04	2.01	1.99	2.00	1.97	1.97	1.98	2.03	2.02	1.95	1.95	1.96	1.96	1.93	1.87	1.71	1.75	1.71
5. Other	1.19	1.02	1.03	1.03	1.14	1.20	1.21	1.13	1.38	1.23	1.27	1.26	1.26	1.28	1.15	1.09	1.09	1.05	1.07
Stationary, non-specified	0.92	0.75	0.75	0.73	0.80	0.89	0.94	0.87	1.14	0.96	0.98	0.99	0.97	1.01	0.93	0.84	0.82	0.75	0.78
Stationary, non-specified burning of feedstocks	0.21	0.17	0.17	0.17	0.18	0.18	0.16	0.14	0.14	0.13	0.13	0.13	0.13	0.10	0.09	0.09	0.09	0.11	0.10
Mobile	0.06	0.11	0.11	0.13	0.16	0.13	0.11	0.11	0.10	0.13	0.16	0.14	0.16	0.17	0.12	0.17	0.17	0.19	0.20
CH ₄																			
4. Other sectors	0.183	0.183	0.184	0.183	0.185	0.185	0.194	0.194	0.196	0.191	0.186	0.208	0.213	0.215	0.216	0.217	0.223	0.224	0.219
5. Other	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002
N ₂ O																			
4. Other sectors	0.087	0.085	0.086	0.082	0.080	0.075	0.078	0.078	0.079	0.078	0.074	0.079	0.079	0.079	0.078	0.076	0.076	0.075	0.071
5. Other	0.45	0.42	0.40	0.41	0.41	0.37	0.38	0.37	0.35	0.34	0.32	0.32	0.32	0.33	0.31	0.27	0.30	0.28	0.26
Indirect N ₂ O emissions from NOx	0.44	0.41	0.40	0.40	0.40	0.36	0.37	0.36	0.33	0.33	0.31	0.31	0.31	0.32	0.30	0.26	0.29	0.27	0.25

3.4.2 Methodological issues

3.4.2.1 Methods

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

To calculate the emissions in ILMARI from the non-specified burning of feedstocks there is a separate module. The ILMARI system includes point source (bottom-up) data on feedstock combustion in the petrochemical industry as well as recycled waste oil combustion in different branches of industry, and they are reported in corresponding subcategories of 1.A 2. These specified energy uses of feedstock and lubricants are subtracted from the corresponding total amounts. For the rest of the feedstock 100% of carbon is estimated to be stored in products (mainly plastics). For the rest of lubricants, 33% of carbon is estimated to be stored in products (recycled lubricants) and 67% of carbon released as CO₂ either in burning of lubricants in motors or illegal combustion of waste oil in small boilers. These non-specified emissions from burning of feedstocks (which are not included in 1.A 2) are included in category 1.A 5.

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

Nitrous oxide (N₂O) is produced in soils and surface waters through nitrification and denitrification. Increased nitrogen input to these systems enhances the production of N₂O and all anthropogenic sources of NH₃ and NO_x emissions are potential indirect sources of N₂O. The emissions are estimated based on the amount of nitrogen emitted in the country multiplied with an emission factor, assuming 1% of the nitrogen in the emissions to be converted to N₂O. The calculation method is the IPCC default method. The emissions are estimated at Statistics Finland based on total NO_x emissions in Finland. The methodology is the same independent of the source of the nitrogen, but agricultural indirect N₂O emissions are reported in the Agriculture sector, indirect N₂O emissions from other sources are included in this sector, although there are some other minor sources of NO_x emissions as well.

3.4.2.2 Activity data

The activity data for category CRF 1.A 4 are taken from annual energy statistics. The fuel consumption data for CRF 1.A 4 are presented in Table 3.4-2. It covers fuels used for the heating of commercial, institutional and residential buildings, which are estimated by the space heating estimation model (Raklam) maintained by Statistics Finland. Fuel consumption is estimated using building stock statistics, average specific consumption (MJ/m³/a) and annual heating degree days.

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

Activity data for fishing derive from the MEERI model of VTT (See descriptions in Section 3.3.4).

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

The indirect N₂O emissions are estimated at Statistics Finland based on total NO_x emissions in Finland.

Table 3.4-2 Fuel consumption in CRF categories 1.A 4 and 1.A 5 (PJ) (includes also fuels from non-energy use).

		1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Liquid fuels	Heavy fuel oil	19.2	18.6	18.1	13.7	10.7	7.3	7.3	7.1	7.4	7.4	6.8	7.9	7.6	7.7	7.3	6.7	6.9	6.8	6.7
	Light fuel oil	80.5	79.4	78.2	76.9	75.1	73.3	74.6	73.9	77.7	76.0	70.5	71.4	70.6	67.9	66.4	63.4	60.1	58.4	54.3
	LPG	2.1	2.1	2.1	1.5	2.4	2.5	2.4	2.3	2.9	1.1	2.6	2.6	2.7	2.9	2.8	3.0	3.3	2.8	3.6
	Other liquid fuels	4.1	4.0	4.0	4.2	4.8	4.3	3.7	3.5	3.3	3.5	3.8	3.6	3.9	3.6	2.9	3.3	3.5	3.9	3.8
Solid fuels	Hard coal	0.52	0.54	0.55	0.41	0.85	0.29	0.26	0.21	0.23	0.21	0.21	0.16	0.19	0.19	0.19	0.13	0.12	0.12	0.11
Gaseous fuels	Natural gas and other gaseous fuels	2.9	4.0	5.1	4.7	4.6	5.8	7.2	7.6	7.9	7.6	7.6	8.8	8.6	10.8	9.3	8.4	8.6	8.1	6.9
Biomass	Woodfuels	45.2	45.2	45.2	45.2	45.2	44.8	47.0	47.0	47.7	46.6	45.4	51.1	52.6	53.3	53.6	53.9	55.7	56.1	54.9
Other fuels	Peat	1.44	1.08	0.73	0.91	0.87	0.95	1.02	1.04	1.06	1.03	0.96	1.04	1.08	1.13	1.13	1.09	1.16	1.17	1.09
	Other; mixed fuels and waste	0.003	0.009	0.016	0.012	0.002	5E-04	0.002	0.003	8E-04	6E-04	0.001	6E-04	0.001	0.001	0.001	3E-04	NO	NO	NO

3.4.2.3 Emission factors

The emission factors used are partly IPCC default and partly based on national sources (Table 3.4-3).

Table 3.4-3 Emission factors of small combustion in the ILMARI calculation system.

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

3.4.3 Uncertainties and time series' consistency

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

Uncertainty in CO₂ emissions was estimated at an upper level (CRF 1.A). Uncertainty in CH₄ and N₂O emissions was estimated on CRF levels 1.A 4, 1.A 5 and by fuel type (solid, liquid, gaseous, biomass, other).

Uncertainties in activity data were based on energy statistics expert estimates for biomass, peat and coal (the significance of which is minor in these categories). The largest uncertainties were estimated for biomass ($\pm 25\%$), because biomass used in households and summer cottages is only very rarely commercially traded, and because consumption of biomass is partly estimated based on a model rather than on statistics or surveys.

In the case of oil and natural gas, fuel use in CRF categories 1.A 4 and 1.A 5 can be fairly accurately estimated using information on total fuel balance on national level and information on fuel use in large installations (CRF 1.A 1 and 1.A 2), which is also fairly accurate. The use of these data and their uncertainty also gives an upper bound to the uncertainty in activity data used in CRF categories 1.A 4 and 1.A 5. The calculation method used for the estimation of activity data uncertainty is described in detail by Monni (2004).

Uncertainties in emission factors for CH₄ and N₂O are high, because these emissions vary largely between different boilers, furnaces, etc. Especially in biomass combustion in small-scale applications, CH₄ 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 CH₄ and N₂O emission factors as well as uncertainties of these emission factors.

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

The consistency of time series of subcategory 1.A 4 is fairly good. The space heating model of Statistics Finland includes years starting from 1995. Prior to that year, fuels for different subsectors of space heating are based on estimated disaggregation.

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 to prevent systematic over or under estimations.

3.4.4 Source-specific QA/QC and verification

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

Each year, the latest inventory calculations (activity data and CO₂ emissions) are cross-checked against the national energy balance (Annex 4). This reference calculation is based on energy balance, showing activity data (PJ) and CO₂ emissions (Reference calculation can not be provided for this submission, because the finalised energy balance for the inventory year 2008 are not available).

3.4.5 Source-specific recalculations

Some updates were done to the space heating model. They can be seen as recalculations in 1.A 4 (1995-2007).

There were minor corrections in the NO_x emission time series, which caused recalculation of indirect N₂O emissions.

The oxidation factor for gasoil for one subcategory was corrected (1990-1992).

Correction in other categories' fuel data is reflected as a recalculation in this category.

3.4.6 Source-specific planned improvements

There are no source-specific planned improvements.

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

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

There are no coal mines in Finland.

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

3.6.1 Source category description

This source category includes CO₂, CH₄ and N₂O emissions from flaring at oil refineries and in the petrochemical industry, fugitive methane emissions from oil refining and methane emissions from gas transmission and distribution.

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

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

In 2008 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 0.19 Tg CO₂ eq. This is about 0.2% of Finland's total emissions.

The NMVOC emissions originate from oil refineries as well as storage of chemicals at the refineries, road traffic evaporative emissions from cars, the gasoline distribution network and refuelling of cars, ships and aircraft. There is no exploration or production of oil or natural gas in Finland.

3.6.2 Methodological issues

3.6.2.1 Methods

The fugitive methane emissions from the refining and storage of oil have been calculated on the basis of the Revised 1996 IPCC Guidelines using the default emission factors for oil refining and data from Energy Statistics (Energy Statistics, Yearbook 2009) on oil refining activities.

Estimates of carbon dioxide emissions from flaring are calculated using data from VAHTI system and emission factors of used fuels in ILMARI calculation system. Fugitive emissions from gas transmission are calculated by Gasum Oy (Riikonen A. 2008). Calculations are based on measurements for the years 1996-2008. 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.

Emissions from gas distribution are also partly based on measurements (1996-2008) made by Helsingin Kaasut Oy (Riikonen A. 2009) and partly on rough estimates (1991-1994) based on the volume of distributed gas. There were no emissions from gas distribution in 1990. The reason for this is that natural gas has been distributed in the old parts of the distribution network beginning from 1991. So called "town gas", which was earlier distributed in those parts, did not contain substantial amounts of methane.

The NMVOC emissions from oil refineries and storage are based on emission data from the VAHTI system. Evaporative emissions from cars are based on expert estimation at VTT Technical Research Centre of Finland (Mäkelä K. 2009) and emissions from the gasoline distribution chain and refuelling of vehicles on expert estimation of the Finnish Oil and Gas Federation for the years 1990-2008 (Pohjolainen, 2008). Indirect CO₂ emissions were calculated using the equation below. It was assumed for years 1990-2008 that the average carbon content is 80% by mass also under the sector fugitive emissions from oil and natural gas based on 2006 IPCC Guidelines. Used fossil carbon content fraction of NMVOC for years 1990-2008 is

based on the NMVOC speciation profile provided in the EMEP/CORINAIR Emission Inventory Guidebook under the sector asphalt roofing.

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

Method to calculate indirect CO₂ emissions from methane emissions is from 2006 IPCC Guidelines. Carbon dioxide emissions have been calculated from methane emissions from oil refineries, natural gas transmission and distribution. Indirect CO₂ emissions from methane emissions were calculated using the equation below.

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

3.6.2.2 Emission factors and other parameters

Emission factors for calculating emissions from the refining and storage of oil are based on the default factor given in the Revised 1996 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 (EF = 880 kg methane / PJ oil refined).

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

3.6.2.3 Activity data

Activity data for oil refining are taken from Energy Statistics (Energy Statistics, Yearbook 2009), indicating the quantity of oil refined.

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

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

3.6.3 Uncertainty and time series' consistency

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

Sources of uncertainty for estimates concerning the year 2008 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%.

Gas transmission and distribution:

- accuracy of measurements which introduces only a small uncertainty.

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

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

Transmission of gas: the figures concerning the years 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 $\pm 26\%$.

3.6.4 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6.

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 IPCC GPG, table 8.1. Some of the checks are performed annually, like comparing with previous emissions of subcategory of the calculated emissions and ensuring that there are no transcription errors in calculations and some when the calculation method has been developed.

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

In the calculation of NMVOCs and indirect CO₂ emissions general inventory QC procedures mentioned in IPCC GPG Table 8.1 have been performed. For example, emissions, activity data and plant-level information are compared to previous years.

3.6.5 Source-specific recalculations

The consistency between subcategories 1.A and 1.B has been improved. Now emissions from flaring (1.B 2c) and emissions from combustion of refinery gases (in 1.A 2c) are calculated with the same methodology, using energy quantities (TJ) of refinery gas as activity data instead of emission data received directly from companies. Emissions decreased 0.9 Gg in 1990 and 3.5 Gg in 2007.

3.6.6 Source-specific planned improvements

No source-specific improvements have been planned.

3.7 Reference approach

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

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

Main findings of the study were:

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

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

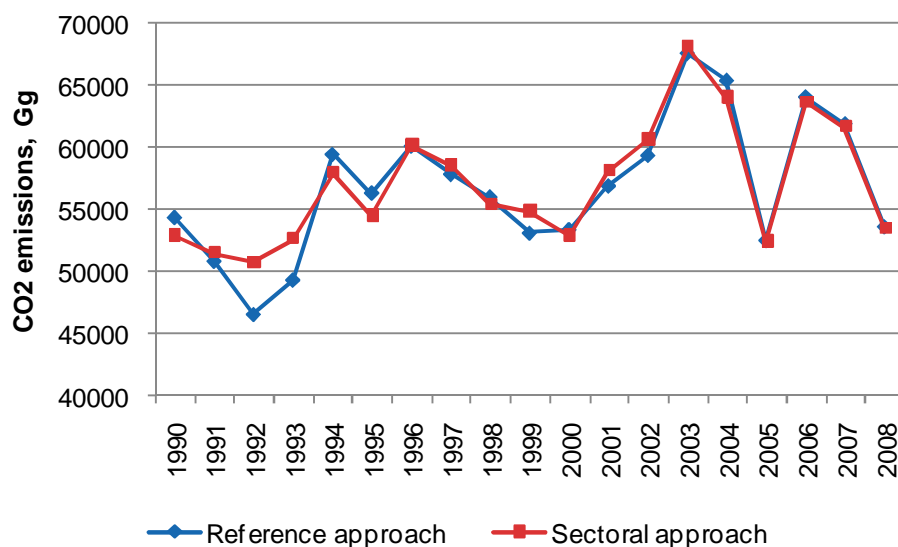


Figure 3.7-1 Carbon dioxide emissions of Reference and Sectoral Approach in 1990-2008 in Finland.

The Reference Approach fuel mapping is different from that used in the Sectoral Approach (SA). In the SA peat is included in Other fuels, whereas in the RA it is contained in Solid fuels. In the previous inventories this summary operation was manually corrected in the CRF excel sheets, but this correction is not possible in the CRF Reporter. This problem does not have any effect on total CO₂ amounts, but it makes it more difficult to compare consumption figures and emissions by CRF fuel category.

The difference between the RA and SA was 0.2% for 2008 and 2.6% for 1990. The differences are high especially in 1992 and 1993 (Figure 3.7-2). No obvious reasons for these differences have been found, although some possible explanations were identified in the background data of the study by Torniainen (2006). The final conclusions cannot be made without further, resource demanding, investigations.

Continuation of this work is under consideration, but not as the first priority. The main effort would be to check and revise the official Oil balance data of these years (mainly 1990 - 1997), which would require a lot of co-operation with several stakeholders (GHG inventory unit, Energy statistics, Oil industries, Foreign trade statistics etc.). The revision would also lead to updating of IEA (International Energy Agency) time series data, which would mean recalculation of the energy balances for these years. This would be extremely resource demanding. We are planning (in co-operation with Energy statistics unit) to check some parts of Oil balances, but the time schedule for this work has not been decided due to more urgent needs.

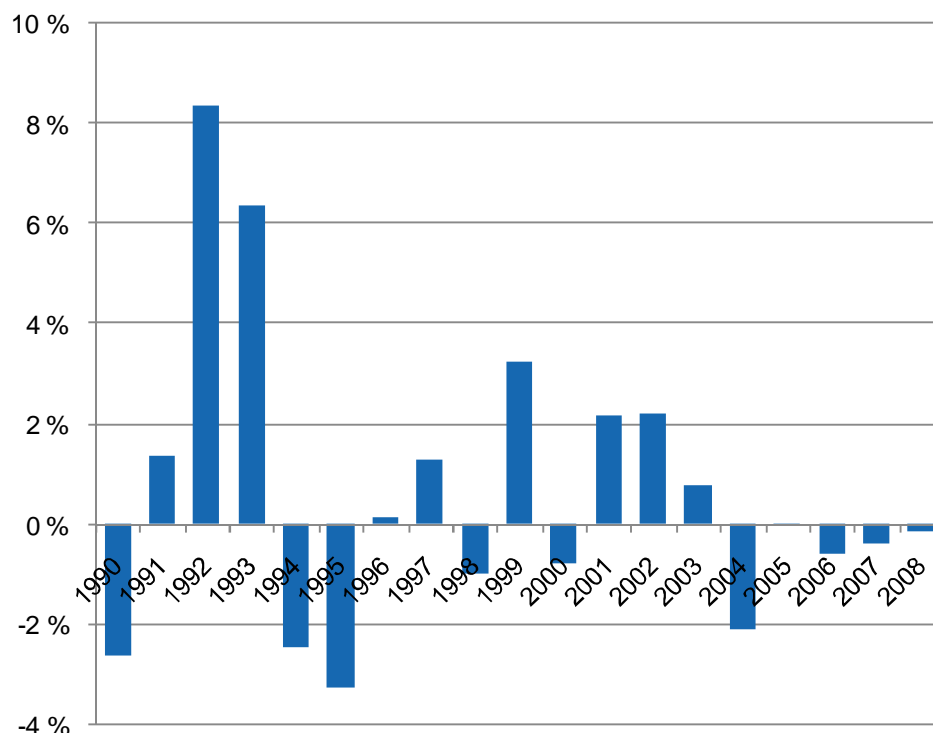


Figure 3.7-2 Difference between SA and RA, %.

A preliminary list of possibly erroneous data in the Oil balance time series has been produced, but due to excessive work load of energy statistics experts it has not been possible to check these and make necessary corrections in the data. Opening the energy balances might cause a lot of extra work for all the years concerned. The stakeholders are not interested in the corrections of the early 1990's data in energy statistics, in a situation where the energy statistics system face many future challenges (such as preparing for the monitoring of the EU Climate and Energy package).

Moreover it is not clear whether these corrections would solve the problems in the RA-SA comparison or not.

Another top-down reference calculation based on the energy balance for the 2008 inventory will be included in Annex 4.

3.8 International bunkers

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

Emissions from international bunkers were 1.8 Tg in aviation and 1.3 Tg CO₂ equivalents in navigation in 2008. Amount of emissions in international aviation has increased step by step for the whole time series except the beginning of the decade (Figure 3.8-1). The trend of emissions in international navigation has fluctuated during this period. The most important reason for these fluctuations is the variation in bunker fuel prices. Especially the ferries between Finland and Sweden can refuel in one or the other country depending on fuel prices. The Finnish Mark was devalued in the early 1990's, which affected strongly to fuel prices. This effect was disappeared due to Finland's EU membership and common currency.

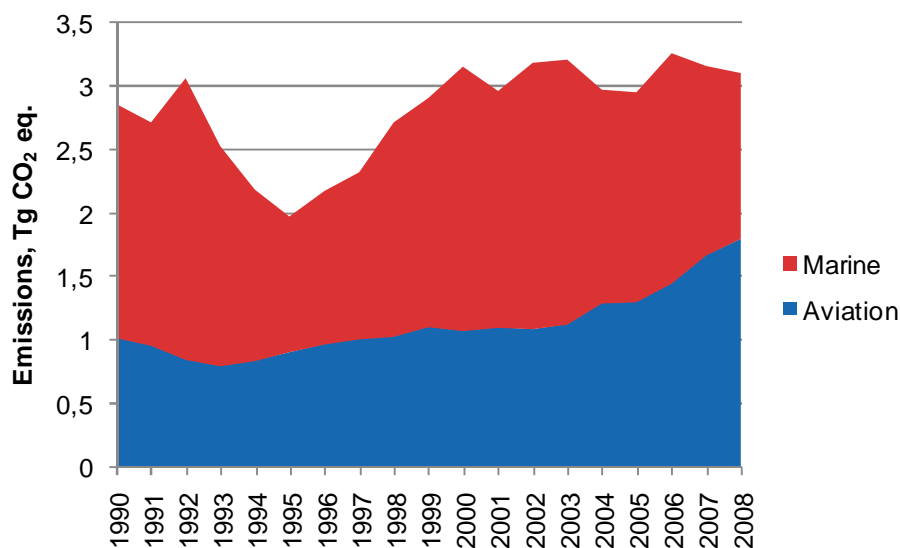


Figure 3.8-1 Emissions from international bunkers in 1990-2008, Tg CO₂ eq.

The emissions are calculated using the ILMARI calculation model of Statistics Finland (see closer CRF 1.A). Fuel consumption by transport mode is obtained from the energy statistics and it includes fuel sales to ships and aircrafts going abroad. The country-specific CO₂ emission factors are the same as for domestic aviation and navigation. The average non-CO₂ emission factors have been partly selected from the IPCC Guidelines and partly (non-GHGs) derived from the ILMI calculation system (see section 3.2.1), taking into account estimated fuel consumption and emissions from international landings, take-offs and overflights within the Finnish region. The activity data for international transport in the ILMI system do not follow the IPCC definition of bunkers, thus ILMI data cannot be used as such.

The case of Åland could be seen as an exception to the IPCC definitions. In the present inventory, all trips going to Sweden via Åland are treated as international, because the number of passengers (or cargo) leaving or entering the ships in Åland is very low. In the present calculation there is a possibility of a minor double counting with domestic navigation, where a small share of Åland transport has been allocated to domestic (see Section 3.3.4.2). This domestic share has not been subtracted from bunker fuels. Actually it is not evident whether fuels used in the ferries between Sweden and Finland are included in Swedish bunker sales or in Finnish bunker sales, because it depends on the fuel price variations. Bunker fuel sales are only available as annual totals.

The in-country and centralised reviews of the Finnish greenhouse gas inventory have accepted the allocation of bunker fuels used in the inventory to be consistent with the Revised 1996 IPCC Guidelines and the Good Practice Guidance (2000).

No uncertainty estimation for international bunkers has been carried out.

European Topic Centre for Air and Climate Change has compared aviation emissions reported in inventories to the results of Eurocontrol's estimates. This comparison has been described in section 3.3.1.1 (Graichen, 2007).

As a response to the latest reviews bunker fuel activity data and net calorific values were checked. All quantities are taken directly from the Energy statistics background data. Energy quantities (TJ) are calculated using the same NCVs for the whole time series (jet fuel 43.3 GJ/t, gasoil 42.7 GJ/t and residual fuel oil 40.5 GJ/t). The data were checked against the data reported to the IEA Oil Questionnaire. There were small differences (< 0.5%) in physical quantities, caused probably by differing roundings during the time series. The NCVs used by the IEA may differ from those used in the inventory.

The bunker fuel figures reported in Sectoral background data for energy tables; Table 1.C International bunkers and multilateral operations and Table 1.A(b) CO₂ from fuel combustion activities - Reference approach are consistent.

Appendix_3a

The formulas used in calculating emissions from the transport sector (1.A 3).

Road transportation

CO₂ emissions

$$E_y = \sum_{U=1}^U (V_{u,y} - O_{u,y}) c_u$$

E_y is total CO₂ 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

N₂O and CH₄

This formula applies to all automobiles in the LIISA model.

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

E is total emissions
 S is kilometrage
 b^a is the emission factor for hot driving
 b^j is the emission factor for idle
 b^k is the emission factor for cold start-ups
 l is type of vehicle
 m is model year of vehicle
 p is road type
 r is speed class
 u is fuel type
 v is compound
 y is calculation year

Railway transportation

This formula applies to all diesel trains in the RAILI model:

$$E_{v,y} = \sum_{l=1}^4 \sum_{m=1}^{10} \sum_{x=1}^2 S_{l,m,y} b_{l,m}^t V e_{x,v}^f + S_{x,y} b^z e_x^b + S_{x,y} b^a e_x^j + \sum_{r=1}^{123} H_{l,r,x,y} b_{l,x}^h e_{x,v}^f$$

E is total emissions
 S is gross tonne kilometre
 V is a factor for extra fuel consumption of non-line (¹ driving)
 H is shunting time
 b^t is the specific fuel consumption per gross tonne kilometre

- b^h is the specific fuel consumption per hour
 b^z is the specific fuel consumption of heating per gross tonne kilometre
 b^a is the specific fuel consumption of aggregate per gross tonne kilometre
 e^f is the emission factor per fuel used
 e^b is the emission factor per fuel used for wagon heating
 e^j is the emission factor per fuel used for aggregates

- l is type of locomotive
 m is train weight class
 x is train type
 r is rail yard
 y is calculation year
 v is compound

(l mobilisation time of the fleet, preparation and finishing times and extra transfer of the fleet)

Civil navigation

The calculation formula applies to all ships in the MEERI model (icebreakers excluded):

$$E_{v,y} = \sum_{l=1}^9 \sum_{m=1}^7 \sum_{z=1}^3 \sum_{p=1}^7 \left(\frac{S_{l,m,x,f,y} d_{x,l,m,f,y} p_{l,z,m} g_o}{f_{l,m}} e_{l,m,v,g,z} + S_{l,m,x,y} p_{l,z,m} g_o t e_{l,m,v,g,z} \right) + u p_{l,z,m} g_o e_{l,m,v,g,z}$$

- E is total emissions
 S is number of ships
 d is distance travelled (from previous port visit)
 e is the emission factor

- l is type of ship
 m is gross register ton class
 x is port
 o is operation area
 z is engine type
 p is engine power class
 g is engine load
 f is speed class
 t is time used for manoeuvre and berthing
 y is calculation year
 v is compound

The calculation formula for emission estimation of icebreakers:

$$E_{v,y} = V_y e_v$$

- E is total emissions
 V is total fuel use of icebreakers
 e is emission factor
 v is compound
 y is calculation year

The calculation formula for working boats:

$$E_{v,y} = \sum_{x=1}^3 S_{x,y} V_{x,y} e_v$$

E is total emissions
 S is number of working boats
 V is total fuel use of a working boat
 e is emission factor
 x is type of working boat
 v is compound
 y is calculation year

The calculation formula for leisure boats:

$$E_{v,y} = \sum_{l=1}^6 \sum_{m=1}^{10} \sum_{z=1}^4 S_{l,m,z,y} m_{l,z} g_l t_l e_{v,z}$$

E is total emissions
 S is number of boats
 e is the emission factor

 l is type of leisure boat
 m is engine power class
 z is engine type
 t is average operating time
 g is engine load
 y is calculation year
 v is compound

*Other transportation***Formula (1) applies to all off-road machinery in the TYKO model.**

$$E_{v,t} = \sum_{l=1}^{44} \sum_{r=1}^4 e_{l,r} \cdot g_{l,r} \sum_{t=1}^{40} k_{l,r,y} \sum_{m=1}^{40} \sum_{p=1}^4 \sum_{u=1}^3 \sum_{d=1}^2 S_{l,m,p,r,u,d,t} \cdot a_{l,p,r,u,m,t,v,t} \quad (1)$$

where ,

$E_{v,y}$ is total emissions v in year y
 S is number of machines (population)
 e is rated power
 g is average load factor
 k is activity (hours per year)
 a is emission factor
 indexes
 l is type of machinery
 m is model year of machine
 p is type of engine
 r is power class (average rated power)
 u is fuel type
 h is average lifetime
 d is type of usage (professional/leisure)
 y is age of machinery
 v is compound
 t is calculation year

$$S_t = S_{t-1} (1 - w_t) + C_t$$

S_t is machinery population in year t

w_t is wastage of machinery in year t

C_t is sales of machinery in year t

Appendix_3b

Fuel combusted and greenhouse gas emissions from combustion by fuel

Table 1_3b. Fuel combustion by fuel, PJ.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Solid fuels	145.1	133.7	122.4	143.9	178.7	142.6	185.2	166.8	122.8	124.6	122.4	140.8	158.8	216.9	192.2	104.3	188.9	163.8	116.5
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
Coke	5.9	5.4	5.0	5.1	5.3	4.9	4.3	5.5	5.4	5.5	5.4	4.7	4.7	5.1	5.6	5.6	5.2	5.6	4.9
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
Coke oven gas	4.2	4.2	4.2	6.9	7.6	7.2	6.8	7.1	7.2	7.2	7.1	7.1	7.2	7.1	7.0	7.0	7.3	5.4	6.7
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
Liquid fuels	374.9	365.7	360.1	345.4	355.1	344.7	349.4	349.9	359.3	361.0	347.7	353.7	358.9	358.5	356.8	352.6	354.4	356.8	338.4
Heavy fuel oil	71.0	68.3	65.6	61.0	64.9	57.9	60.0	54.1	53.0	54.7	48.9	51.5	52.2	50.9	46.8	42.9	44.7	42.1	34.3
Light fuel oil	105.7	104.3	102.9	101.9	99.7	98.7	99.9	99.8	104.2	103.3	97.5	98.7	97.7	95.0	93.7	90.4	86.6	85.3	80.5
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	79.0	79.6	80.8	80.7	80.0	80.0	72.6
Diesel oil	67.4	63.1	62.5	61.0	63.6	62.6	64.3	69.3	71.9	74.9	76.5	78.1	79.8	81.9	85.4	86.2	89.0	94.3	95.9
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
Refinery gases	22.9	22.9	22.9	20.2	22.9	22.4	23.4	22.0	24.4	23.9	21.5	22.3	24.1	24.2	22.7	24.2	24.7	26.2	26.0
Town gas	0.16	0.12	0.12	0.04	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
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
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
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
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	0.32	0.44	0.42
Other oil	4.5	4.1	3.7	3.8	3.8	3.9	3.6	3.1	2.8	2.8	3.0	2.9	2.5	2.0	2.0	1.9	2.7	2.9	2.7
Gaseous fuels	90.8	95.0	99.3	104.6	113.3	117.6	123.1	121.1	138.7	138.9	143.0	155.9	153.6	169.9	163.9	149.8	160.0	147.9	151.2
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
Other gas	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	1.2	2.0	0.7	0.7	0.9	0.7	0.6	0.5	0.4
Other	55.0	57.6	60.2	66.1	76.0	81.8	89.8	90.5	84.6	75.8	65.8	90.4	96.1	106.6	95.1	76.1	100.5	110.5	90.6
Peat	53.3	56.0	58.7	64.5	73.7	79.4	87.5	88.0	80.7	71.8	62.5	86.9	91.6	101.0	88.8	69.1	93.8	102.4	81.5
Mixed fuels (MSW/REF/RDF/	0.8	0.8	0.8	0.8	1.4	1.4	0.9	1.2	1.3	1.3	1.6	1.9	2.6	3.7	4.6	5.8	5.6	7.1	8.4
Other fossil wastes etc.	0.9	0.8	0.7	0.8	0.9	1.0	1.4	1.4	2.5	2.7	1.7	1.6	1.9	1.9	1.6	1.3	1.1	1.0	0.8
Biomass	178.5	176.0	173.4	205.8	213.7	217.1	217.0	247.0	255.7	270.5	272.1	263.9	284.9	291.6	304.6	285.1	320.8	307.2	310.2
Black/sulphite liquor	87.4	87.0	86.6	104.8	111.2	111.1	108.0	129.2	124.4	142.4	139.9	125.3	140.6	138.2	145.0	129.4	156.0	154.1	141.8
Other woodfuels	90.3	88.0	85.7	100.0	101.4	104.6	107.7	116.4	129.9	126.7	130.4	136.8	142.0	150.7	156.9	152.5	161.4	149.6	157.8
Biogas	0.1	0.1	0.1	0.1	0.1	0.4	0.3	0.4	0.3	0.5	0.6	0.6	0.6	0.6	0.7	1.3	1.2	1.4	5.1
Hydrogen	0.6	0.8	0.9	0.9	0.9	1.0	0.8	0.9	1.0	0.9	1.1	1.1	1.3	1.2	1.3	1.1	1.4	1.4	1.1
Other non-fossil fuels	0.03	0.03	0.03	0.00	0.03	0.03	0.03	0.07	0.05	0.08	0.2	0.2	0.4	0.6	0.5	0.7	0.7	0.7	0.9
Liquid biofuels in transp	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.0	0.2	0.2	NO	0.0	0.1	3.5
Bunker fuels	37.5	35.6	40.0	33.2	28.9	26.3	28.9	30.8	35.8	38.3	41.4	38.9	41.7	42.0	39.0	38.8	42.9	41.8	41.2
Jet fuel	13.8	13.0	11.5	10.8	11.4	12.3	13.2	13.7	14.0	15.0	14.6	15.0	14.8	15.3	17.6	17.7	19.7	22.7	24.5
Light fuel oil	5.2	4.9	5.6	6.1	6.3	6.6	6.4	6.6	6.8	6.8	6.8	6.1	4.4	4.0	2.1	2.1	2.6	3.3	3.2
Heavy fuel oil	18.5	17.7	22.8	16.2	11.2	7.4	9.3	10.5	15.0	16.5	20.0	17.9	22.5	22.7	19.3	19.0	20.6	15.8	13.6

Table 2_3b. CO₂ emissions from combustion by fuel, Tg

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Solid fuels	14.5	13.5	12.5	14.5	17.7	14.2	18.3	16.8	12.8	13.0	12.9	14.4	16.1	21.7	19.4	11.2	19.1	16.8	12.2
Hard coal	12.0	10.9	9.9	11.6	14.7	11.5	15.5	13.5	9.4	9.5	9.2	11.1	12.8	18.1	15.8	7.5	15.4	13.3	8.9
Coke	0.6	0.6	0.5	0.5	0.6	0.5	0.5	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.6	0.6	0.6	0.6	0.5
Blast furnace gases	1.7	1.8	1.9	2.1	2.1	1.9	2.1	2.4	2.5	2.6	2.8	2.4	2.5	2.7	2.7	2.7	2.8	2.6	2.5
Coke oven gas	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.3
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
Liquid fuels	27.8	27.1	26.7	25.6	26.3	25.5	25.8	25.9	26.5	26.6	25.6	26.1	26.5	26.4	26.3	25.8	25.9	26.0	24.4
Heavy fuel oil	5.6	5.4	5.1	4.8	5.1	4.5	4.7	4.2	4.2	4.3	3.8	4.0	4.1	4.0	3.7	3.4	3.5	3.3	2.7
Light fuel oil	7.8	7.7	7.6	7.5	7.4	7.3	7.4	7.4	7.7	7.6	7.2	7.3	7.2	7.0	6.9	6.7	6.4	6.3	5.9
Motor gasoline	6.2	6.2	6.3	5.9	6.0	6.0	5.8	5.9	5.8	5.8	5.6	5.7	5.8	5.8	5.9	5.9	5.8	5.8	5.3
Diesel oil	5.0	4.6	4.6	4.5	4.7	4.6	4.7	5.1	5.3	5.5	5.6	5.7	5.9	6.0	6.3	6.3	6.5	6.9	6.9
LPG	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.7	0.6	0.7	0.7	0.7	0.8	0.8	0.8	0.9	0.8	0.9
Refinery gases	1.5	1.5	1.5	1.3	1.5	1.4	1.5	1.4	1.6	1.5	1.4	1.4	1.6	1.6	1.5	1.4	1.4	1.5	1.4
Town gas	0.010	0.007	0.007	0.002	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Recycled waste oil	0.04	0.03	0.03	0.04	0.03	0.04	0.05	0.07	0.07	0.07	0.07	0.06	0.07	0.10	0.11	0.11	0.09	0.06	0.07
Petroleum coke	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	0.6	0.5	0.5	0.6	0.6
Jet fuel	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.5	0.4	0.4	0.4
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	0.03	0.03
Other oil	0.4	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.1	0.2	0.2	0.2
Gaseous fuels	5.0	5.2	5.4	5.7	6.2	6.4	6.7	6.6	7.6	7.6	7.8	8.5	8.4	9.3	9.0	8.2	8.8	8.1	8.3
Natural gas	5.0	5.2	5.4	5.7	6.2	6.4	6.7	6.6	7.6	7.6	7.8	8.4	8.4	9.3	8.9	8.2	8.7	8.1	8.3
Other gas	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.07	0.12	0.04	0.04	0.05	0.04	0.03	0.03	0.02
Other	5.7	6.0	6.2	6.9	7.8	8.5	9.3	9.4	8.7	7.8	6.8	9.3	9.9	10.9	9.6	7.5	10.1	11.0	8.9
Peat	5.6	5.9	6.1	6.7	7.7	8.3	9.2	9.2	8.4	7.5	6.5	9.1	9.6	10.6	9.3	7.2	9.8	10.7	8.5
Mixed fuels (MSW/REF/ RDF/PDF etc.)	0.04	0.03	0.03	0.03	0.05	0.05	0.04	0.05	0.05	0.05	0.06	0.07	0.09	0.13	0.15	0.18	0.17	0.21	0.25
Other fossil wastes etc.	0.09	0.08	0.08	0.09	0.10	0.11	0.16	0.14	0.23	0.25	0.17	0.16	0.18	0.19	0.16	0.13	0.12	0.12	0.09
Biomass	19.3	19.0	18.7	22.2	23.1	23.4	26.7	27.6	27.6	29.2	29.4	28.5	30.7	31.5	32.9	30.7	34.5	33.1	33.1
Black/sulphite liquor	9.5	9.4	9.4	11.4	12.1	12.1	11.7	14.0	13.5	15.5	15.2	13.6	15.3	15.0	15.7	14.0	16.9	16.7	15.4
Other woodfuels	9.8	9.6	9.3	10.9	11.0	11.4	11.7	12.6	14.1	13.7	14.1	14.8	15.4	16.4	17.0	16.5	17.4	16.2	17.1
Biogas	0.005	0.005	0.005	0.006	0.004	0.021	0.018	0.020	0.018	0.026	0.031	0.031	0.03	0.03	0.04	0.1	0.1	0.1	0.3
Hydrogen	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other non-fossil fuels	0.003	0.003	0.003	0.000	0.003	0.003	0.003	0.008	0.006	0.008	0.021	0.024	0.04	0.06	0.06	0.08	0.08	0.07	0.09
Liquid biofuels in transport	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.00	0.01	0.01	NO	0.00	0.01	0.23
Bunker fuels	2.9	2.7	3.1	2.5	2.2	2.0	2.2	2.3	2.7	2.9	3.1	3.0	3.2	3.2	3.0	2.9	3.3	3.2	3.1
Jet fuel	1.0	1.0	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
Light fuel oil	0.4	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.4	0.3	0.3	0.2	0.2	0.2	0.2	0.2
Heavy fuel oil	1.5	1.4	1.8	1.3	0.9	0.6	0.7	0.8	1.2	1.3	1.6	1.4	1.8	1.8	1.5	1.5	1.6	1.2	1.1

Table 3_3b. CH₄ emissions from combustion by fuel, Mg

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Solid fuels	286	275	265	231	398	181	223	199	150	149	146	163	179	238	213	122	207	181	132
Hard coal	269	258	248	211	377	161	204	177	128	125	122	141	156	215	189	98	183	158	109
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
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
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
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
Liquid fuels	5 877	5 572	5 418	5 195	5 008	4 843	4 703	4 535	4 449	4 294	4 018	3 900	3 772	3 603	3 383	3 174	2 954	2 817	2 495
Heavy fuel oil	256	242	227	186	172	135	145	137	141	144	127	136	138	138	127	117	121	119	109
Light fuel oil	801	791	781	773	755	743	754	741	778	766	712	723	716	691	678	651	622	609	566
Motor gasoline	4 188	3 967	3 859	3 693	3 555	3 463	3 325	3 201	3 099	2 979	2 795	2 671	2 553	2 411	2 225	2 051	1 860	1 740	1 480
Diesel oil	546	491	471	467	446	422	396	374	344	324	300	286	278	275	268	265	261	258	250
LPG	29	28	27	24	27	26	27	27	29	23	28	28	29	31	32	33	35	34	35
Refinery gases	23	23	23	20	23	22	23	22	24	24	21	22	24	24	23	25	25	26	26
Town gas	0.49	0.37	0.37	0.12	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Recycled waste oil	0.5	0.4	0.3	0.5	0.4	0.5	0.7	1.0	0.9	1.0	0.9	0.8	0.9	1.3	1.4	1.4	1.1	0.8	0.9
Petroleum coke	4.9	5.0	5.1	5.0	4.8	4.9	5.5	5.3	5.4	5.3	4.7	4.3	5.6	5.3	5.9	5.5	5.4	6.2	6.0
Jet fuel	13.9	14.2	13.4	13.4	14.2	13.1	15.4	16.9	18.3	19.2	19.2	17.9	18.4	19.5	17.1	18.9	16.1	15.3	15.8
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	0.16	0.22	0.19
Other oil	14.1	10.4	11.4	11.4	11.9	12.5	11.0	9.7	9.3	9.2	9.4	9.6	8.6	6.5	6.5	6.3	7.3	8.1	7.4
Gaseous fuels	111	133	156	153	169	193	209	242	292	290	289	337	474	543	476	409	450	384	394
Natural gas	111	133	156	153	169	193	209	242	292	290	288	335	473	543	475	403	449	378	390
Other gas	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	1.2	2.0	0.7	0.8	1.0	5.2	0.6	5.7	3.7
Other	240	231	223	251	280	309	341	351	335	298	284	354	376	415	368	314	419	447	389
Peat	230	225	220	247	274	303	335	344	326	290	274	345	366	402	353	297	404	428	365
Mixed fuels (MSW/REI)	4.0	2.7	1.4	1.5	3.5	3.6	2.1	2.5	3.0	3.0	6.0	4.6	6.0	9.1	11.5	15.5	13.6	18.5	22.8
Other fossil wastes etc.	5.1	3.2	1.2	2.4	2.7	1.9	4.5	4.5	6.3	5.3	4.4	4.3	4.7	4.3	3.5	2.1	1.1	1.1	0.8
Biomass	8 085	8 130	8 176	8 309	8 358	8 624	8 989	9 075	9 169	9 031	8 842	9 862	10 183	10 345	10 414	10 426	10 804	10 785	10 581
Black/sulphite liquor	87	87	87	105	111	111	108	129	125	143	140	125	141	138	145	129	156	154	142
Other woodfuels	7 997	8 043	8 089	8 192	8 240	8 470	8 834	8 893	9 002	8 832	8 645	9 682	9 990	10 148	10 219	10 246	10 596	10 574	10 380
Biogas	0.4	0.3	0.2	12.1	6.3	42.9	47.2	52.3	42.4	55.7	56.9	54.8	51.2	55.7	49.3	49.2	50.0	55.5	56.0
Hydrogen	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
Other non-fossil fuels	0.1	0.1	0.1	0.0	0.1	0.1	0.1	0.3	0.2	0.3	0.5	0.6	1.3	3.3	1.1	1.5	1.5	1.6	3.2
Liquid biofuels in t	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.9	4.5	4.2	NO	0.6	1.2	47.7
Bunker fuels	163	154	185	147	118	96	117	127	156	177	200	179	184	185	155	156	166	146	130
Jet fuel	27	24	21	21	21	23	31	33	34	39	44	40	27	28	36	32	31	35	37
Light fuel oil	22	21	24	26	27	28	28	29	30	33	31	27	20	18	9	10	12	16	15
Heavy fuel oil	114	109	140	100	69	45	57	65	93	106	125	112	137	139	110	114	122	94	78

Table 4_3b. N₂O emissions from combustion by fuel, Mg

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Solid fuels	293	279	265	300	321	274	313	300	247	248	240	274	294	361	336	241	324	300	236
Hard coal	274	261	248	278	295	248	292	277	223	223	215	250	271	336	311	215	298	273	211
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
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
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
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
Liquid fuels	971	958	950	935	945	935	946	944	970	979	943	961	963	955	939	926	916	907	856
Heavy fuel oil	154	148	142	131	135	118	121	110	114	117	101	106	105	101	95	89	92	87	72
Light fuel oil	210	207	204	203	198	197	201	201	210	208	196	197	196	190	187	180	173	170	161
Motor gasoline	300	305	311	312	315	323	319	319	319	318	307	311	303	294	282	267	250	231	191
Diesel oil	220	211	208	209	208	210	214	223	230	238	244	251	260	270	277	287	296	311	326
LPG	10.0	9.3	8.6	8.7	10.0	10.0	10.7	12.2	14.0	13.2	15.6	15.3	15.7	17.2	17.9	18.3	19.6	18.5	18.9
Refinery gases	42.4	42.6	42.9	38.5	45.0	43.3	46.0	43.3	48.1	47.5	42.4	44.1	47.5	47.8	45.1	48.9	48.9	51.3	50.2
Town gas	0.160	0.120	0.120	0.040	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
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	10.8	12.3	12.1
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	18.9	18.1	17.7	17.7
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	0.65	0.89	0.75
Other oil	7.8	7.1	6.5	6.6	6.8	7.5	6.9	6.1	5.6	5.5	6.0	6.7	5.3	4.2	4.2	4.1	5.1	5.4	5.0
Gaseous fuels	103	108	113	118	127	130	139	136	154	156	164	175	171	187	183	167	177	167	171
Natural gas	103	108	113	118	127	130	139	136	154	156	163	173	170	187	182	166	177	166	171
Other gas	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	1.16	2.00	0.70	0.79	1.19	0.69	0.59	0.47	0.38
Other	172	186	200	225	258	296	348	352	332	284	265	375	419	461	410	333	422	462	378
Peat	169	183	197	222	253	290	341	345	323	277	257	365	406	441	387	306	398	431	342
Mixed fuels (MSW/REF/RDF/	1.2	1.3	1.4	1.5	3.5	3.6	3.2	3.4	3.4	3.0	4.0	5.5	7.7	15	18	25	22	30	34
Other fossil wastes etc.	1.95	1.65	1.35	1.63	2.13	2.18	3.14	3.22	5.46	4.78	4.01	4.43	5.25	4.98	4.60	2.58	2.18	2.04	1.54
Biomass	282	274	267	329	345	357	381	447	477	509	524	517	543	551	594	564	618	575	629
Black/sulphite liquor	88	87	87	105	111	111	108	129	125	143	140	125	141	138	145	129	156	154	142
Other woodfuels	193	186	179	223	232	244	272	316	350	364	381	389	399	409	444	429	456	415	473
Biogas	0.10	0.10	0.09	0.12	0.09	0.40	0.35	0.35	0.33	0.52	0.64	0.64	0.77	0.77	0.89	1.50	1.38	1.73	8.96
Hydrogen	0.63	0.83	1.02	0.95	1.06	1.07	0.95	1.06	1.25	0.98	1.22	1.34	1.46	1.43	1.50	1.33	1.66	1.54	1.25
Other non-fossil fuels	0.20	0.20	0.20	0.00	0.20	0.20	0.21	0.49	0.34	0.50	0.90	1.01	1.31	1.63	2.05	2.53	2.88	2.71	3.91
Liquid biofuels in transp	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	0.13	0.69	0.68	NO	0.11	0.23	9.96
Bunker fuels	90	85	93	78	69	65	71	76	86	94	99	94	98	100	93	95	106	107	107
Jet fuel	42	39	35	32	34	37	40	41	42	45	44	45	44	46	53	53	59	68	73
Light fuel oil	10	10	11	12	12	13	13	13	14	14	14	12	8.7	8.0	4.1	4.1	5.1	6.5	6.3
Heavy fuel oil	38	36	47	33	23	15	19	21	31	35	41	37	45	46	36	38	41	32	27

Appendix_3c

Data on CO₂ 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
Produced PCC using transferred CO ₂ , t	1 951	45 633	123 151	167 256	241 253	290 366	355 854	417 187	399 527	401 326	423 496	483 801	417 434	481 977	531 609	484 861

The Finnish Forest Industries collected the total produced amount of PCC for years 1993-2007. Statistics Finland have collected PCC data for year 2008 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 CO₂.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
The share of biological emission of total transferred CO ₂ (%)			No plant level data of PCC production until 2000					8	16	15	15	13	14	14	12	13
The share of fossil fuels and other emissions of total transferred CO ₂ (%)			No plant level data of PCC production until 2000					92	84	85	85	87	86	86	88	87

All fuels used in the lime kilns and industrial power plants for the whole time series have been collected at unit level and the percentage of emissions from fossil fuels have been calculated separately.

Table 3_3c Reported (negative emission figure in 1.A 2f Transferred CO₂) emissions in the inventory.

	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Reported transferred CO ₂ (tonnes CO ₂)	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

Statistics Finland has received kiln and plant level data of transferred CO₂ from 2005 to 2008 (emissions trading periods) from the Energy Market Authority. The ETS companies do not measure the amount of transferred CO₂ but calculate it based on the amount of produced PCC. The amount of transferred CO₂ 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 CO₂ amount of every single plant (years 2005 to 2008) summed up is the same as the amount calculated from the total amount of PCC production.

Appendix_3d

STATEMENT ON POTENTIAL CO₂ EMISSIONS FROM CALCIUM CARBONATE IN FIBRE SLUDGE

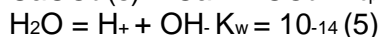
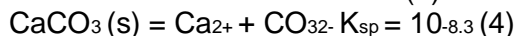
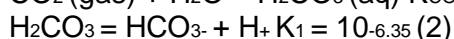
Concerning the potential emission of CO₂ from calcium carbonate-water interaction in fibre sludge-bearing earth structures, we state the following:

Precipitated Calcium Carbonate, also known as PCC, is a widely used artificial additive in paper making processes, particularly as a filler in fine paper production. Depending on the material efficiency in paper making, 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 paper making is the use of chemical pulp, certain amounts of wood-based fibres can also be found from this recovered fraction.

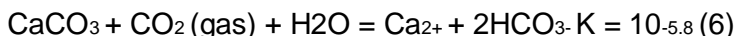
PCC-bearing fibre sludge is nowadays mainly utilized in many earth construction applications, e.g., as a hydraulic barrier in landfill cover structures, in impermeable reactive walls and in sub-base filter in roads and sport areas. Under these circumstances, it will be occasionally exposed to acid rain water. Infiltration of water into a fiber sludge layer depends on its hydraulic conductivity, which is typically lower than 10⁻⁹ 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/dm³. 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/dm³. 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 CO₂ 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 CO₂

2) for one Ca²⁺ ion dissolved one CO₂ molecule is consumed from the solution. In the open system, this CO₂ is replaced from the CO₂ in the atmosphere. In other words, dissolution of calcium carbonate contributes to the atmospheric CO₂ sink rather than causes emission of CO₂ 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 CO₂ is retained (open system) or
- 2) the system becomes closed to atmosphere before reaction with calcium carbonate is started.

Results are shown in the Table1. Rainwater which is in equilibrium with the present CO₂ 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 Ca²⁺ 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 Ca²⁺ 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 CO₂ in the open system promotes the solution reaction.

Table 1. Contents of carbon species (mol) and Ca²⁺ (mg/l), pH, and P_{CO₂} (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 ₂	-3.5	-3.5	-6.0
pH	5.7	8.3	9.9
logH ₂ CO ₃	-5.0	-5.0	-7.5
logHCO ₃ ⁻	-5.7	-3.0	-4.0
log CO ₃ ²⁻	-10.3	-5.0	-4.4
logCT	-4.9	-3.0	-3.9
Ca ²⁺	-	20	5.7

In conclusion, based on the above discussion, no CO₂ emission to the atmosphere can be expected from dissolution of PCC if fibre sludge is used as a material in earth construction.

References

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Garrels, R.M., Christ, C.L., 1965. Solutions, Minerals, and Equilibria. Harper and Row, New York, 450 p. September 14, 2007

September 14, 2007

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4 INDUSTRIAL PROCESSES (CRF 2)

4.1 Overview of the sector

4.1.1 Description and quantitative overview

Greenhouse gas emissions from Industrial processes contributed 10% to the total anthropogenic greenhouse gas emissions in Finland in 2008 (Figure 4.1-1), totalling 7.0 Tg CO₂ equivalent.

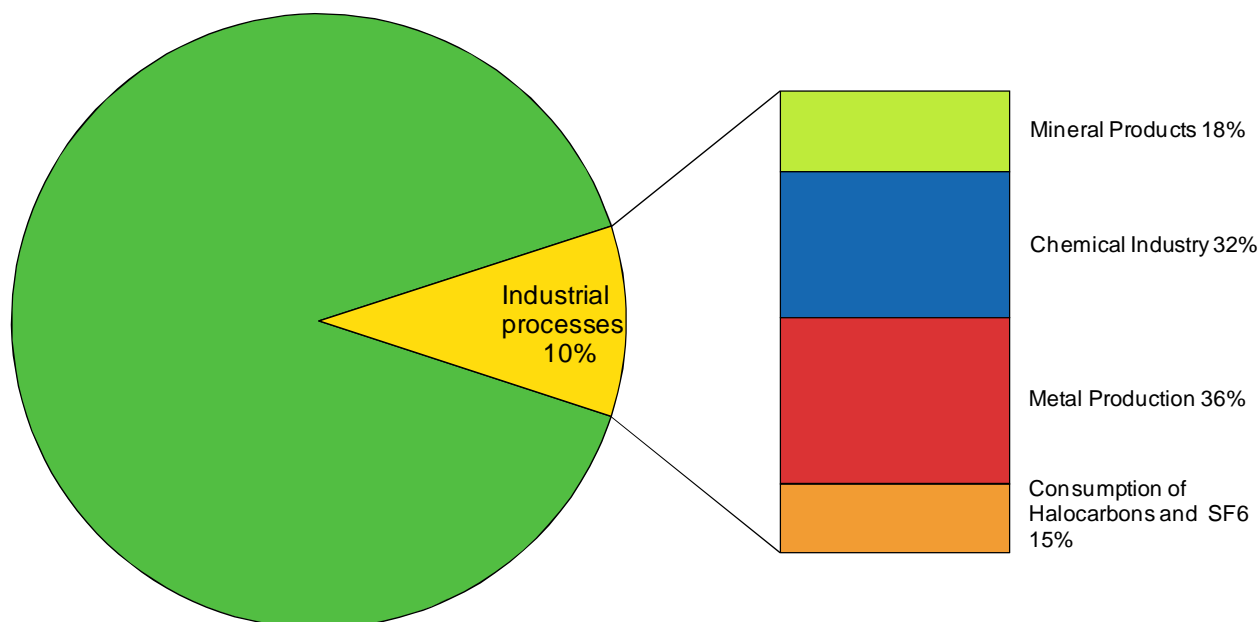


Figure 4.1-1 Emissions from industrial processes compared with total emissions in 2008

Finnish greenhouse gas emissions from Industrial processes are divided into following emission categories:

- Mineral products (CRF 2.A) include CO₂ emissions from cement, lime and glass production, limestone, dolomite and soda ash use.
- Chemical industry (CRF 2.B) include N₂O emissions from nitric acid and CO₂ emissions from hydrogen production.
- Metal production (CRF 2.C) include CH₄ emissions from coke production and CO₂ emissions from coke and heavy bottom oil used in blast furnaces.
- Consumption of halocarbons and SF₆ (CRF 2.F) covers emissions of F-gases from refrigeration and air conditioning, foam blowing, aerosols and electrical equipment, as well as some smaller sources, such as semiconductor manufacturing and fixed fire protection systems.

General assessment of completeness could be found in Section 1.8 and more detailed assessment is included in Annex 5.

Under Other production (CRF 2.D) Finland reports NMVOC emissions from the forest and food industries. In addition, NMVOC emissions from asphalt roofing and road paving with asphalt are reported under Mineral processes and NMVOC emissions from iron and steel production and non-ferrous metals are reported under Metal production. Other NMVOC emissions reported under Chemical industry include emissions from the chemical industry and storage of chemicals.

Indirect CO₂ emissions from Industrial processes have also been calculated from NMVOC and methane emissions.

The most important greenhouse gas emission sources of Industrial processes in the Finnish inventory in 2008 were CO₂ emissions from iron and steel production, N₂O emissions from nitric acid production and CO₂ emissions from cement production with 3.6%, 2% and 1% shares of the total greenhouse gas emissions,

respectively. F-gases emissions comprised together 1.5% of the total greenhouse gas emissions in Finland. The small amount of F-gases emissions in Finland is explained by the absence of certain large industrial point sources that account for most of the F-gases emissions globally.

The emissions from Industrial processes have fluctuated somewhat since 1990 (Figure 4.1-2). The decrease in the emissions during early 1990's was largely due to the economic recession in Finland (see chapter 2). Since these years the overall trend in the emissions has been increasing (Table 4.1-2). The most significant change is the increase in emissions of F-gases which are now ten-fold compared with the 1990 as well as the 1995 emissions, which is the base year for these emissions under the Kyoto Protocol. N₂O emissions have had annual fluctuations up to 15% during the period 1990 to 2008; first fast decrease due to closing of a plant and after that started a slow increase of emissions. CH₄ emissions have increased by 77% since 1990 but their contribution to the total industrial emissions is very small. Industrial CO₂ emissions decreased considerably at the beginning of the 1990's, but have increased since 1996 and were in 2008 approximately 33% higher than in 1990.

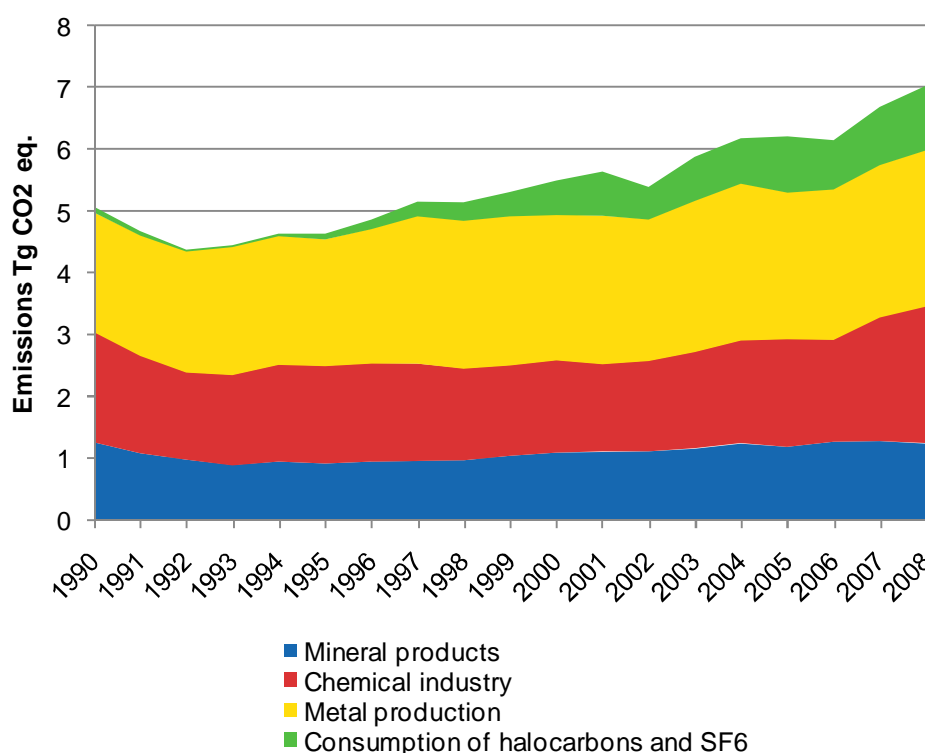


Figure 4.1-2 Total greenhouse gas emission from Industrial processes in Finland in 1990-2008 (Tg CO₂ eq.).

Industrial emissions are divided between three sectors:

- industrial process emissions are in sector 2: Industrial processes
- emissions from fuel combustion in industry are in sector 1: Energy
- waste and wastewater generated emissions in industry are in sector 6 (Figure 4.1-3).

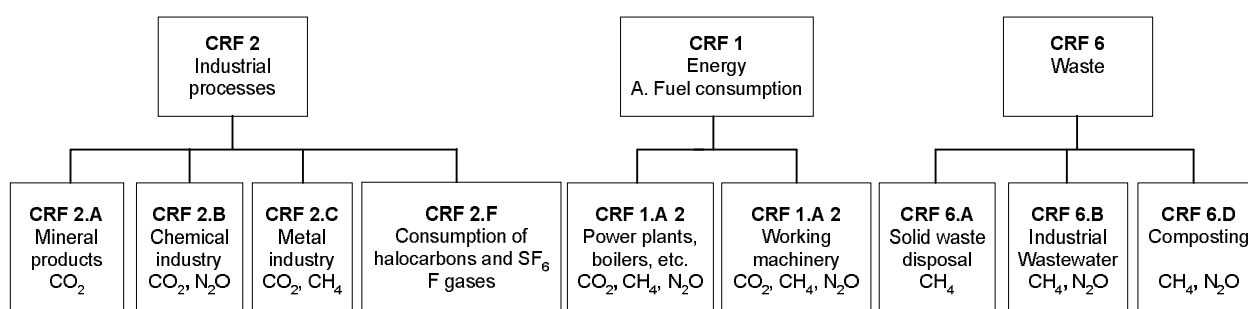


Figure 4.1-3 Emissions from industrial sources and their reporting categories in the national greenhouse gas inventory.

4.1.2 Key categories

The key categories in industrial processes in 2008 are summarised in Table 4.1-1.

Table 4.1-1 Key categories in Industrial processes (CRF 2) in 2008 (quantitative method used: Tier 2).

Source Category	Gas	Criteria
2.B 2 Nitric Acid Production	N ₂ O	L, T
2.B 5 Other: Hydrogen production	CO ₂	T
2.C 1 Iron and Steel production	CO ₂	L, T
2.F 1 Refrigeration and Air Conditioning Equipment	HFCs, PFCs	L, T
2.F 8 Electrical equipment	SF ₆	T

Table 4.1-2 Trend in greenhouse gas emissions from industrial processes (Tg CO₂ eq.).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
CO ₂																			
A Mineral Products	1.25	1.08	0.97	0.88	0.94	0.91	0.94	0.95	0.96	1.04	1.09	1.10	1.10	1.15	1.24	1.18	1.26	1.27	1.24
B Chemical Industry	0.13	0.14	0.10	0.09	0.13	0.11	0.13	0.13	0.12	0.11	0.12	0.12	0.13	0.15	0.16	0.12	0.20	0.52	0.66
C Metal Production	1.94	1.95	1.96	2.08	2.08	2.05	2.17	2.39	2.39	2.41	2.35	2.40	2.28	2.45	2.54	2.37	2.44	2.46	2.52
CH ₄																			
C Metal Production	0.005	0.005	0.005	0.009	0.010	0.010	0.010	0.009	0.010	0.009	0.010	0.010	0.010	0.009	0.009	0.009	0.009	0.009	0.009
N ₂ O																			
B Chemical Industry	1.66	1.44	1.30	1.36	1.43	1.46	1.46	1.44	1.38	1.35	1.36	1.29	1.33	1.41	1.50	1.63	1.44	1.48	1.56
HFCs	0.00002	0.0001	0.0001	0.0001	0.007	0.029	0.077	0.168	0.245	0.319	0.494	0.648	0.464	0.652	0.695	0.864	0.748	0.904	0.994
PFC	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0002	0.0002	0.0002	0.028	0.022	0.020	0.013	0.015	0.012	0.010	0.015	0.008	0.011
SF ₆	0.094	0.067	0.037	0.034	0.035	0.069	0.072	0.076	0.053	0.052	0.051	0.055	0.051	0.048	0.034	0.033	0.040	0.036	0.040
Total	5.07	4.68	4.38	4.46	4.64	4.64	4.86	5.16	5.15	5.31	5.50	5.65	5.39	5.89	6.19	6.21	6.16	6.69	7.03

4.2 Mineral Products (CRF 2.A)

4.2.1 Source category description

Non-fuel emissions from cement and lime production and from limestone and dolomite use as well as emissions from soda ash use are reported in this category (Table 4.2-1 and Table 4.2-2). There are no key sources in this source category. Soda ash is not produced in Finland. Lime production also includes lime production in the iron and steel industry. Limestone and dolomite use comprises the use in the production of tile, steel, calcium chloride, phosphates, mineral wool and in the energy industry for sulphur dioxide control. Soda ash use also includes the use in the production of pigments and sodium silicate. Emissions from glass and glass wool production are reported in their own source category.

Table 4.2-1 Reported emissions under the subcategory mineral products in the Finnish inventory.

CRF	Source	Emissions reported
2.A 1	Cement production	CO ₂
2.A 2	Lime production	CO ₂
2.A 3	Limestone and dolomite use	CO ₂
2.A 4	Soda ash use	CO ₂
2.A 6	Road paving with asphalt	CO ₂
2.A 7	Glass production	CO ₂

In the production of cement CO₂ is emitted when an intermediate product, clinker, is produced. In that process limestone is heated to a high temperature, which results in 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 (MgCO₃), which will calcinate in the process causing CO₂ emissions. CO₂ emissions from lime production and limestone and dolomite use are also due to calcination of calcium and magnesium carbonates at high temperatures (Slioor, 2004).

In addition, carbon dioxide is released when soda ash (Na₂CO₃), is heated to high temperatures.

Indirect CO₂ emissions from NMVOC emissions of asphalt roofing and road paving with asphalt are also reported (asphalt roofing is included in road paving) in this source category.

Emissions of the category Mineral products were over a quarter of the emissions of the Industrial processes sector in 1990 and less than one fifth in 2008 as well as almost 2% of Finland's total greenhouse gas emissions. Amount of emissions were 1.3 Tg (as CO₂ equivalents) in 1990 and 1.2 Tg in 2008 (Figure 4.2-1).

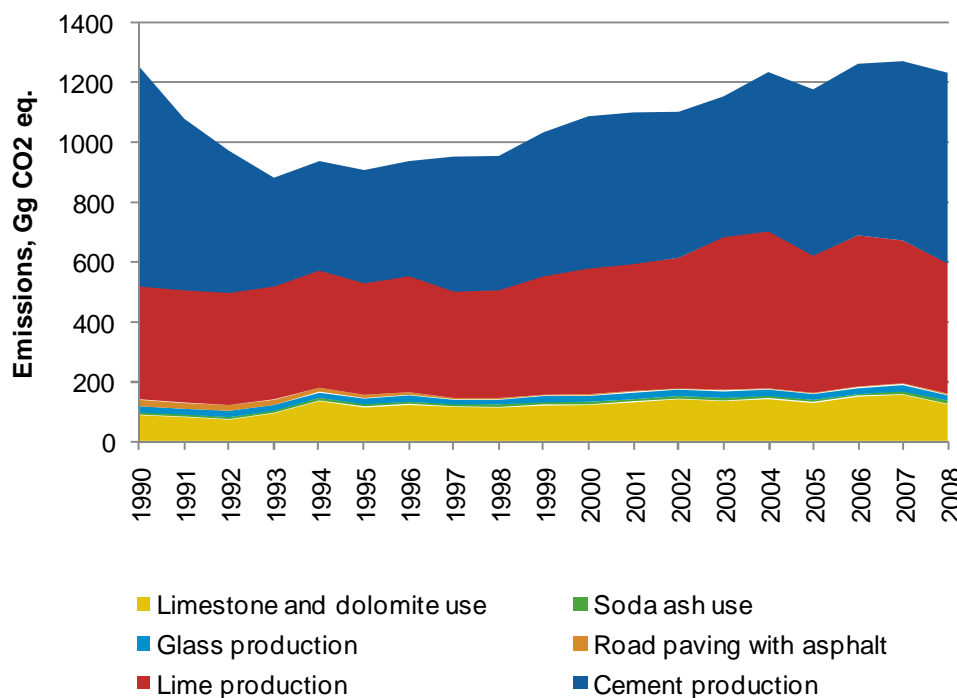


Figure 4.2-1 Greenhouse gas emission from Mineral products in 1990-2008 (Gg CO₂ eq.).

Cement production is the biggest source of greenhouse gas emissions in the Mineral products category, being 0.6 Tg in 2008. Emissions were almost 15% in 1990 and 9% in 2008 of the emissions in the Industrial processes sector and less than 1% of Finland's total emissions in 2008. There was a rapid decrease in the production volume at the beginning of the decade due to the closing down of a plant in 1993. The output has had a slight growing trend although it is not yet as high as it used to be at the beginning of the time series.

Lime production is the second largest source in the category Mineral products, emissions were 0.4 Tg in 2008. Emissions have been less than 9% of this sector's emissions for the whole period. Production output has been quite constant during this period, only the setting up of a new plant in 2003 increased it noticeably.

Limestone and dolomite and soda ash use are minor sources, their contribution to the sector's total emissions has been around 2% during this period. The usage has been increasing and it was 42% greater in 2008 than in 1990.

Glass production is also a minor source in the category Mineral products. Emissions have been less than 1% of this sector's emissions for the whole period. The amount of used carbonates has been quite constant during the time series, however a temporary closedown of a plant decreased the amount for a couple of years (1997-98).

Indirect CO₂ emissions were 1% of the emissions of Industrial processes in 1990, since the emissions have decreased to only one fourth of the figures recorded at the beginning of 1990's.

Summary of the uncertainty analysis has been described in Section 1.8.

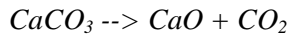
Table 4.2-2 CO₂ emissions from Mineral products (Gg).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
2.A 1 Cement production	734	572	476	363	365	380	384	451	450	481	507	506	488	469	532	556	574	600	638
2.A 2 Lime production	383	380	378	382	395	375	393	358	364	400	425	429	439	513	528	461	510	480	439
2.A 3 Limestone and dolomite use	88	83	74	95	137	116	124	117	115	122	124	133	143	137	145	131	152	159	125
2.A 4 Soda ash use	8.3	6.9	6.9	8.1	8.3	9.1	8.2	8.1	9.0	9.2	8.1	7.3	8.6	8.7	8.7	8.4	6.1	9.9	11
2.A 6 Road paving with asphalt	21	20	19	18	14	11	8.0	3.9	3.7	2.9	2.9	2.9	2.9	3.1	2.2	2.3	2.0	2.7	2.4
2.A 7 Glass production	21	18	20	18	19	19	21	15	16	21	21	24	22	23	21	20	21	22	19
Total of Mineral products	1 254	1 080	974	884	939	910	939	954	957	1 035	1 088	1 102	1 103	1 154	1 236	1 179	1 265	1 273	1 235

4.2.2 Cement production

Category 2.A 1 covers CO₂ emissions from cement production. CO₂ is released when carbonaceous materials are heated in rotary kiln ovens to produce clinker. Clinker is then mixed with gypsum and other materials that together make up the cement.

The mixture of raw material fed into the oven is called the raw mix. The main carbonaceous components of the raw mix are limestone (CaCO₃) and dolomite (CaCO₃ * MgCO₃). When heated to 1,400-1,500 degrees centigrade, CO₂ is released. For example, the reaction for limestone is:



There are currently two operating plants in Finland. At a third plant production ceased in 1993.

4.2.2.1 Methods

Emissions were calculated using Tier 2 methodology from the good practice guidance (equations 3.1 and 3.3, pp. 3.10 and 3.13, IPCC 2000). 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 sources 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.

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

4.2.2.2 Emission factors

The emission factor x_i was calculated as follows:

$$x_i = w_{\text{CaO},i} r_{\text{CaO}} + w_{\text{MgO},i} r_{\text{MgO}},$$

where $w(\cdot)$ are the weight fractions in clinker and $r(\cdot)$ are the molecular mass ratios of CO₂ to CaO and MgO. The weight fractions were obtained from the producer, and were as follows: plant 1 (0.650, 0.020), plant 2 (0.647, 0.031). For plant 3 data was not available, so means of the two other plants (0.649, 0.026) were used.

Implied emissions factors are presented in the next figure (Figure 4.2-2).

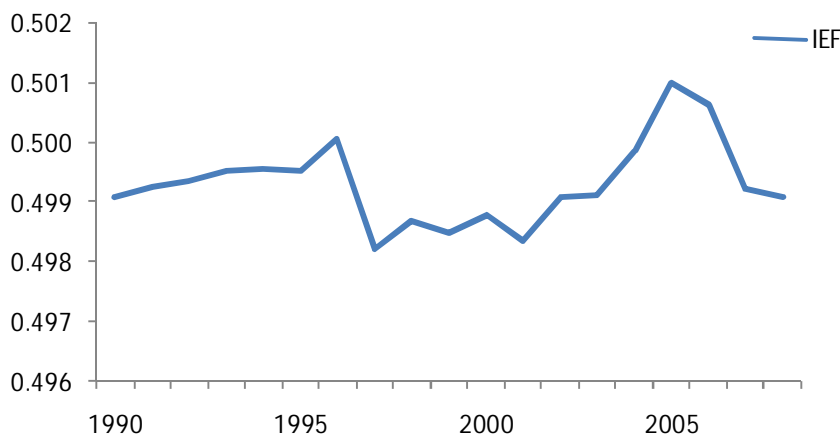


Figure 4.2-2 Time-series of implied emission factor.

4.2.2.3 Activity data

The cement kiln dust data was available 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 was complete and no imputation was necessary. Data for the years 1990-2008 for clinker production (Table 4.2-3) are received directly from the company.

4.2.2.4 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

4.2.2.5 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6.

The emissions of last four years have been compared with ETS data. Differences between those figures have been less than 3%.

4.2.2.6 Source-specific recalculations

No source-specific recalculations were done.

4.2.2.7 Source-specific planned improvements

No source-specific improvements have been planned.

4.2.3 Lime production

4.2.3.1 Method

Emissions from lime production are calculated by multiplying emission factors with lime output. 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, although the total amount of produced lime has been checked from industrial statistics.

There are no different Tier levels in the IPCC Good Practice Guidance for Lime production, but the calculation method corresponds to the Tier 2 level used in cement production.

4.2.3.2 Emission factors

There are two emission factors used in Finland to calculate emissions of lime production. The first emission factor is based on the actual CaO and MgO contents of lime derived from measurements by a company that has 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.

The second emission factor has been specified by a company founded in 2003 and it is also based on the actual CaO and MgO contents in lime.

The implied emission factors can be found in Table 4.2-3.

4.2.3.3 Activity data

In calculation of these emissions the amount of (quick)lime (CaO) produced annually is used as activity data. Hydrated lime, Ca(OH)_2 , is produced via (quick)lime by adding water to it. This process does not cause emissions and is not considered in the calculations. Activity data for the years 1990-1997 are partly collected from the industry and partly taken from industrial statistics and companies' reports. 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 were received from the Energy Market 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 were compared with the data from industrial statistics and the VAHTI system. The total activity data of the time series are presented in Table 4.2-3

4.2.3.4 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

For 2008 uncertainty in lime production is partly due to the small margin of error associated with the measurements of 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 was estimated to be $\pm 4\%$ (Slioor, 2004).

Due both to lack of knowledge concerning the years 1990-1997 and to better knowledge concerning the years 1998-2003 the time series for lime production is calculated using partly estimated data. The time series have been checked to be consistent. The differences from the inventory of 2008 in the source of data and the methods are described below.

The years 1990-1996: Activity data are partly collected from the industry and partly taken from industrial statistics and companies' reports.

The year 1997: All activity data are taken from industrial statistics and companies' reports.

The years: 1990-1997: The emission factor is the mean value of the emission factors of 1998-2002.

The years: 1998-2008: The emission factor for all lime production is based on the actual (measured) CaO and MgO contents of lime.

4.2.3.5 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6.

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

Some source category-specific quality control procedures have been carried out during calculation. One of them is that the used emission factors have been compared with the IPCC default emission factor and no large differences between the company-specific factors and the default factor have been found. Secondly that emission factor is based on accurate measurements of a company and therefore it represents the best possible knowledge of that production process and used rawmaterials. Activity data have been checked using as many independent sources as possible and only slight differences between figures have been noticed (1-3%). 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 all plants have been verified with ETS data (all plants are included in EU Emission Trading Scheme) and emissions have been found to be almost equal. Differences have been formed because in EU-ETS companies calculate emissions using default emission factors and in the inventory emission factors are based on actual CaO and MgO content of lime as mentioned in Section 4.2.3.2.

4.2.3.6 Source-specific recalculations

No source-specific recalculations have been done.

4.2.3.7 Source-specific planned improvements

No source-specific improvements have been planned.

4.2.4 Limestone and dolomite use

4.2.4.1 Method

Emissions from limestone and dolomite use are calculated by multiplying emission factors with activity data. Activity data are collected mainly directly from the industry but industrial statistics have also been used to calculate emissions at the beginning of the time series. Emission factors are based on the IPCC's default factors.

4.2.4.2 Emission factors

Emission factors for calculating emissions from limestone and dolomite use are based on the IPCC default factors. The default factors are believed to be fairly accurate in Finland. Due to the small amount of emissions in these categories the derivation of country-specific emission factors was not considered necessary. For a couple of plants different factors have been used because more detailed information on the composition of limestone is available. The time series of emission factors is given in Table 4.2-3.

4.2.4.3 Activity data

The consumption of limestone and dolomite has been used as activity data when calculating emissions from limestone and dolomite use. Activity data for 2008 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 and a small part has been estimated using industrial statistics. Also data on previously uncertain limestone and dolomite users have been checked using industrial statistics and web sites of companies and discovered that their use does not cause CO₂ emissions. The amounts of used limestone and dolomite are described in Table 4.2-3.

4.2.4.4 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

Uncertainty in limestone and dolomite use was estimated to be $\pm 10\%$ (Slioor, 2004). It is partly due to uncertain activity data: there is a margin of error in the measurements used to determine the amounts of carbonates that are used. 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.

4.2.4.5 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6.

In the calculation of emissions from limestone and dolomite use several general inventory quality control procedures have been performed as mentioned in IPCC GPG, table 8.1. Some of the checks are performed annually, like comparing with previous emissions of subcategory of the calculated emissions and ensuring that there are no transcription errors in calculations and some when the calculation method has been developed. Despite all previous checkings, emissions of one company were not been calculated for latest two years, the error has now been corrected.

Some source category-specific quality control procedures have been carried out during calculation. The default emission factor has 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, results are included in the calculation sheets. All activity data are site-specific and reported to industrial output statistics or reported due to monitoring of environmental permit of a company. During calculation it was noticed that emissions of one company using limestone for sulphur dioxide control was missing from the calculations (years 2006 and 2007) and that was corrected.

The calculated emission data of 19 plants (out of 25) have been verified with ETS data and emissions have been found to be almost equal. Reason for difference is that in the inventory calculation not all carbonate is assumed to calcinate in the production process.

4.2.4.6 Source-specific recalculations

During calculation of emissions some calculation errors and missing emissions of one plant of the years 2006 and 2007 was corrected. Emissions of the base year diminished 0.02 Gg and emissions of 2007 were increased 6.4 Gg.

4.2.4.7 Source-specific planned improvements

No source-specific improvements have been planned.

4.2.5 Soda ash use

4.2.5.1 Methods

Emissions from soda ash (= sodium carbonate) use are calculated by multiplying emission factors with the amount of used soda ash. Activity data are gathered mainly directly from the industry but industrial statistics have also been used.

The emission factors are based on the IPCC's default factors.

4.2.5.2 Emission factors

The IPCC's (1996 Revised Guidelines) emission factor for soda ash use is slightly corrected by a factor of 0.99, because it is not likely that sodium carbonate is calcinated completely in the various processes. The emission factor is $0.411 \text{ t CO}_2 / \text{t Na}_2\text{CO}_3$.

4.2.5.3 Activity data

Consumption of sodium carbonate is used as activity data calculating emissions from soda ash use. Activity data are collected directly from individual companies. Other data of soda ash uses have been checked using industrial statistics; production processes of companies which have been identified as potential soda ash users have been checked using their web sites. This has resulted in confirmation that their use does not cause CO₂ emissions. The amount of used soda ash which causes CO₂ emissions is given in Table 4.2-3.

4.2.5.4 *Uncertainty and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

Uncertainty in soda ash use was estimated to be -5%...+7% (Slioor, 2004). It is partly due to uncertain activity data: there is a margin of error in the measurements used to determine the amount of sodium carbonate that is used. Another 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 concerning the year 2008.) For some early years all activity data have not been received directly from companies. In these cases the data of industrial statistics or estimations based on other years' data have been used.

4.2.5.5 *Source-specific QA/QC and verification*

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6.

In the calculation of emissions from soda ash use there have been performed several general inventory quality control procedures as mentioned in IPCC GPG, table 8.1. Some of the checks are performed annually, like comparing with previous emissions of subcategory of the calculated emissions and ensuring that there are no transcription errors in calculations and some when the calculation method has been developed.

Some source category-specific quality control procedures have been carried out during calculation. The default emission factor has been defined to be adequate for Finnish circumstances and processes. Activity data have been checked using as many independent sources as possible and data have been found to be same. 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 a plant have been verified with ETS data and emissions have been found to be almost equal (+/-1%). Reason for this difference is that in the inventory calculation not all carbonate is assumed to be calcinated in the production process. Also calculated emissions of another company have been verified with data performed by soda ash using company, differences do exist but reason for that is the same as in the first case.

4.2.5.6 *Source-specific recalculations*

No source-specific recalculation has been done.

4.2.5.7 *Source-specific planned improvements*

No source-specific improvements have been planned.

4.2.6 *Indirect CO₂ emissions from NMVOC emissions of asphalt roofing and road paving with asphalt*

4.2.6.1 *Methods*

The NMVOC emissions (see Table 4.2-3) are calculated at the Finnish Environment Institute. The activity data and emission factors used in the calculations are from Fortum Oil and Gas Ltd. The part activity data has to be retrieved from Finland Custom Statistics (ULTIKA/ULJAS) since the inventory of 2006 because the share of Fortum Oil and Gas' bitumen from the total used bitumen in Finland was considerably smaller than before (Blomberg, 2007).

Indirect CO₂ emissions from the use of asphalt have been calculated from NMVOC emissions for the time series 1990-2008. Indirect CO₂ emissions were calculated using the equation below. The average carbon content used is 80% by mass and it is based on 2006 IPCC Guidelines. According to the Guidelines, the fraction is based on NMVOC speciation profile provided in the EMEP/CORINAIR Emission Inventory Guidebook.

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

4.2.6.2 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

The latest uncertainty analysis for NMVOC has been carried out for the 2007 emissions and reported to the UNECE CLRTAP Secretariat March 2009. Since, according to the reporting obligation under the CLRTAP, the uncertainty analysis is required only in every five years the analysis will be performed for the 2011 submission. The uncertainties for 2008 are estimated to be approximately at the same level as in 2007. The documentation of the 2007 uncertainty analysis is available in the Finnish Informative Inventory Report (IIR) under the CLRTAP. The Finnish IIRs are published on the website <http://www.environment.fi> > State of the environment > Air > Air pollutant emissions in Finland (In English). According to the analysis the uncertainty for the 2007 NMVOC emissions were estimated at -25% - +25%. Uncertainty in NMVOC emissions from asphalt roofing and road paving with asphalt is partly due to uncertain activity data: there is a margin of error in statistics. Larger source of uncertainty is the used calculation method: the used NMVOC shares are highly uncertain.

4.2.6.3 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6.

In the calculation of emissions from asphalt roofing and road paving with asphalt there have been performed several general inventory quality control procedures as mentioned in IPCC GPG, table 8.1. For example reported emissions are compared with previous emissions of subcategory annually.

4.2.6.4 Source-specific recalculations

No recalculations have been done.

4.2.6.5 Source-specific planned improvements

No source-specific improvements have been planned.

4.2.7 Glass production

4.2.7.1 Methods

Process emissions in glass production are generated from limestone, dolomite and soda ash (= sodium 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.

The emission factors are based on the IPCC's default factors.

4.2.7.2 Emission factors

Emission factors for calculating emissions from limestone and dolomite use are based on the IPCC default factors. The time series of emission factors is given in Table 4.2-3.

The IPCC's (1996 Revised Guidelines) emission factor for soda ash use is corrected by a factor of 0.99, because it is likely that sodium carbonate is not calcinated completely in the various processes. The emission factor is therefore $0.411 \text{ t CO}_2 / \text{t Na}_2\text{CO}_3$.

4.2.7.3 Activity data

The consumption of limestone and dolomite has been used as activity data when calculating emissions from limestone and dolomite use. Activity data for 2008 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 and a smallish part has been estimated using industrial statistics. The amounts of used limestone and dolomite are given in Table 4.2-3.

Consumption of sodium carbonate is used as activity data when calculating emissions from soda ash use. Activity data are collected directly from individual companies. For some early years all activity data have not 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.

4.2.7.4 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

Uncertainty in limestone and dolomite use was estimated to be $\pm 10\%$ (Slioor, 2004). It is partly due to uncertain activity data: there is a margin of error in the measurements used to determine the amounts of carbonates that are used. 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.

Uncertainty in soda ash use was estimated to be $-5\% \dots +7\%$ (Slioor, 2004). It is partly due to uncertain activity data: there is a margin of error in the measurements used to determine the amount of sodium carbonate that is used. Another 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 concerning the year 2008.) For some early years all activity data have not been gained directly from companies. In these cases the data of industrial statistics or estimations based on other years' data have been used.

4.2.7.5 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6.

In the calculation of emissions from glass production several general inventory quality control procedures have been performed as mentioned in IPCC GPG, table 8.1. Some of the checks are performed annually, like comparing with previous emissions of subcategory of the calculated emissions and ensuring that there are no transcription errors in calculations and some when the calculation method has been developed.

Some source category-specific quality control procedures have been carried out during calculation. The default emission factors have been defined to be adequate for Finnish circumstances and processes. 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. During checking it was noticed that emissions of a small glass production plant were missing for years 2005-2007. They are now attached to the calculations.

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 ($\pm 2\%$). Reason for difference is that in the inventory calculation not all

carbonate is assumed to be calcinated in the production process. In the verification it was also noticed that one company using dolomite reports their emissions miscalculated to Energy Market Authority for year 2007, there seems to be some error in dolomite use data and emission factor differs from the factor used earlier years.

4.2.7.6 Source-specific recalculations

The limestone use of a company was added to the calculation for years 2005, 2006 and 2007. Emissions increased by 0.03 Gg for all those years.

4.2.7.7 Source-specific planned improvements

No source-specific improvements have been planned.

Table 4.2-3 Activity data and emission factors for mineral products.

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
2.A 1																			
Clinker production, 1 000 t	1 470	1 146	953	727	731	760	767	906	902	964	1 017	1 015	977	940	1 064	1 110	1 147	1 201	1 279
EF t/t	0.499	0.499	0.499	0.500	0.500	0.500	0.500	0.498	0.499	0.499	0.499	0.498	0.499	0.499	0.500	0.501	0.501	0.499	0.499
CKD correction factor	1.009	1.009	1.008	1.008	1.008	1.008	1.009	1.006	1.008	1.007	1.008	1.007	1.009	1.009	1.009	1.012	1.011	1.009	1.009
2.A 2																			
Lime production, 1 000 t	519	516	513	519	536	509	533	486	498	545	575	578	594	682	710	619	686	658	590
EF t/t	0.737	0.736	0.737	0.737	0.737	0.737	0.737	0.737	0.731	0.734	0.739	0.741	0.739	0.753	0.744	0.745	0.743	0.730	0.745
2.A 3																			
Limestone consumption, 1 000 t	183	174	156	205	304	255	275	256	246	254	253	274	301	285	299	263	312	320	255
EF t/t	0.427	0.427	0.426	0.426	0.426	0.426	0.426	0.426	0.426	0.427	0.427	0.427	0.423	0.424	0.425	0.432	0.431	0.431	0.432
Dolomite consumption, 1 000 t	23	20	17	16	17	16	17	18	23	31	35	36	34	35	39	39	40	46	34
EF t/t	0.435	0.434	0.431	0.431	0.431	0.431	0.431	0.431	0.449	0.449	0.451	0.451	0.450	0.451	0.452	0.450	0.449	0.449	0.447
2.A 4																			
Soda ash consumption, 1 000 t	20	17	17	20	20	22	20	20	22	22	20	18	21	21	21	20	15	24	28
2.A 6																			
Amount of NMVOCs, 1 000 t	7.2	6.8	6.4	6.1	4.9	3.7	2.7	1.3	1.3	1.0	1.0	1.0	1.0	1.1	0.8	0.8	0.7	0.9	0.8
2.A 7																			
Limestone and dolomite consumption, 1 000 t	24	22	25	21	22	23	25	18	18	23	24	27	25	26	22	20	21	23	20
EF t/t	0.459	0.457	0.453	0.456	0.455	0.454	0.453	0.445	0.444	0.454	0.454	0.452	0.452	0.451	0.456	0.457	0.456	0.456	0.459
Soda ash consumption, 1 000 t	24	20	22	20	22	22	25	18	19	25	25	28	27	28	25	26	27	28	23

4.3 Chemical Industry (CRF 2.B)

4.3.1 Source category description

In the Finnish inventory this category includes non-fuel emissions of nitrous oxide from nitric acid production and carbon dioxide emissions from hydrogen production. Earlier methane emissions from ethylene production were included in these emissions, but due to new information received from the producer the emissions were removed from the total time series.

Table 4.3-1 Reported emissions under the subcategory chemical industry in the Finnish inventory.

CRF	Source	Emissions reported
2.B 1	Ammonia production	CO ₂
2.B 2	Nitric acid production	N ₂ O
2.B 5	Hydrogen production	CO ₂
	Chemicals production	CO ₂

Nitric acid and hydrogen production are key sources of this source category in the Finnish inventory. All emissions of this category are presented in Table 4.3-2 by gas and subcategory. Ammonia, adipic acid, carbides, carbon black, dichloroethylene, styrene and methanol are not produced in Finland. Indirect CO₂ emissions from the chemical industry have been calculated from NMVOC emissions for the whole time series.

Emissions of chemical industry in 2008 were 2.2 Tg CO₂ eq. and it was almost 32% of this sector's emissions and over 3% of Finland's total emissions. Emissions of hydrogen production increased 25% from year 2007 to 2008 and they are now six-fold compared to time before launching of a new hydrogen plant in autumn 2006 (Figure 4.3-1).

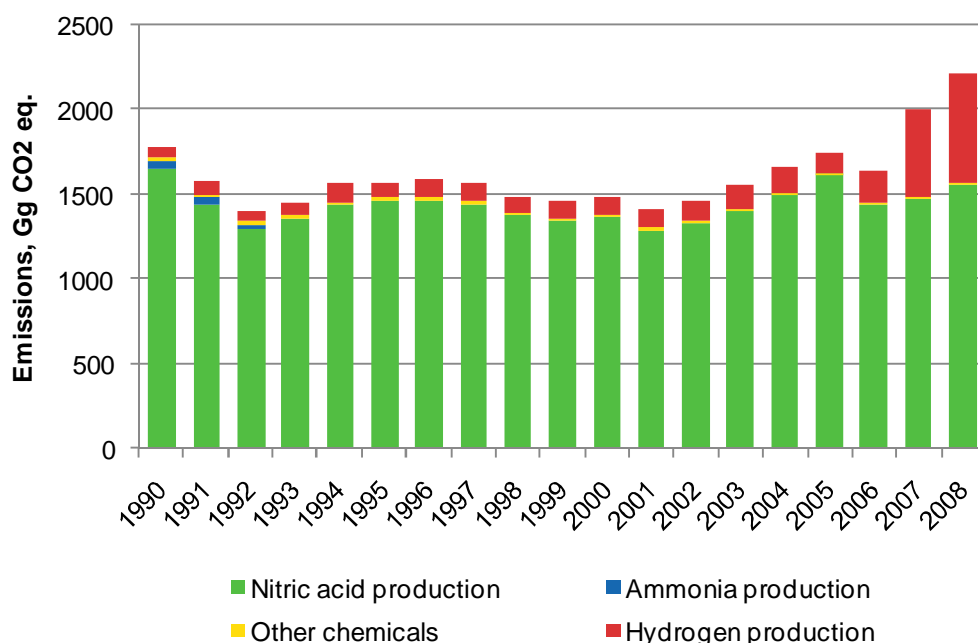


Figure 4.3-1 Greenhouse gas emission from Chemical industry in 1990-2008 (Gg CO₂ eq.).

Nitric acid is nowadays produced in Finland in three single-stage medium pressure plants (4.8, 6.2 and 7.6 bar). Emissions of N₂O from nitric acid production were approximately 5.0 Gg in 2008, which was over 2% of Finland's total greenhouse gas emissions and 22% of emissions of the sector Industrial Processes. This quantity includes also a small amount of N₂O emitted from a fertiliser production plant.

In 1990 there were four nitric acid plants in Finland. One was closed down in 1992 which could be also seen in a rapid decrease of emissions. In October 2004 a new plant was commissioned at an existing site and therefore the amount of produced acid has increased. The new plant replaced an older plant which was closed in April 2005. The production of nitric acid has varied from about 430 to 630 Gg nitric acid per year.

Emissions of CO₂ from hydrogen production were approximately 648 Gg in 2008, which was almost 1% of Finland's total emissions. All hydrogen production does not cause CO₂ 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 CO₂ in the processes but in practice, a small amount of feedstock does not react. One company has a system to capture formed carbon dioxide for recovery and use which occur in another company, but this amount of emission has not been reduced from the total emissions.

All ammonia currently used in Finland is imported. In 1990-1992 small amounts (4-30 Gg per year) were produced using mainly peat and heavy oil as feedstock for the needed hydrogen. From 1993 on there has been no ammonia production in Finland (Table 4.3-2). The CO₂ emissions from these processes have been estimated and included in the inventory.

The NMVOC and indirect CO₂ emissions from the chemical industry and storage of chemicals at the sites are also reported under subcategory Other (CRF 2.B 5).

Table 4.3-2 Emissions by gas and subcategory (Gg).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
CO ₂																			
2.B 1 Ammonia production	44	44.5	18.9	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO	NO
2.B 5 Hydrogen production	57	74	63	75	110	91	106	105	101	99	112	107	122	141	152	112	195	517	648
2.B 5 Indirect	24	21	21	19	20	20	21	20	15	14	13	13	11	10	12	7.8	8.9	6.9	8.5
N ₂ O																			
2.B 2 Nitric acid production	5.3	4.6	4.2	4.4	4.6	4.7	4.7	4.7	4.4	4.3	4.4	4.2	4.3	4.5	4.8	5.2	4.6	4.8	5.0
Total of subcategory, Gg CO ₂ eq	1 781	1 577	1 406	1 454	1 564	1 574	1 590	1 569	1 491	1 460	1 488	1 411	1 468	1 558	1 661	1 745	1 577	2 003	2 217

4.3.2 Nitric acid production

4.3.2.1 Methods

Statistics Finland co-operates with the nitric acid manufacturers to produce the annual emission estimates. For emissions in 1990–2004 the procedure was as follows: the manufacturers provided the activity data and emission factors (see below), and Statistics Finland carried out the calculations using an agreed methodology that corresponds to the IPCC Good Practice Guidance equation 3.9 (IPCC 2000, p. 3.31). The equation simplifies to

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

since no abatement or destruction takes place at the Finnish plants. Emissions were calculated for each plant separately and then summed up to give the reported figure (which includes, as mentioned earlier, also a small quantity of N₂O from fertiliser production).

Starting from the inventory year 2005 both emissions and activity data have been received from the Vahti system. Currently it is the specific emission factors rather than emissions that are calculated by the inventory unit.

4.3.2.2 Emission factors

One of the three plants is equipped with a continuous emissions measurement unit and has been in operation since 2004. In 2005 the company also purchased a portable measurement device that is used at the other two plants. An outside consultant hired by the company made measurement at the plants in 1999–2004. No measurements are available prior to 1999.

Based on the measurements the following emission factors were defined (mass of N₂O emitted per mass of nitric acid produced):

- plant A, 7.6 kg/t for 1990–2005 (closed down in beginning of 2005);
- plant B, 9.5 kg/t for the years 1990–2004 and 3.3–7.4 kg/t for the later years⁸;
- plant C, 9.3 kg/t for 1990–2008;
- plant D that was in operation until 1992, 9.2 kg/t for 1990–1992 (the process of a plant D was similar to plant B (Pipatti, 2001))
- plant E, 7.9–10.7 kg/t for 2004–2008⁹

More specific data of plant level emission factors cannot be disclosed due to confidentiality reasons. All relevant data have been available for the review team during the in-country review in May 2007.

4.3.2.3 Activity data

The annual nitric acid production figures have been obtained from the production plants or from the Vahti system (see description in Annex 2). Production amounts of nitric acid are presented in Table 4.3-3.

4.3.2.4 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

The uncertainty estimate for nitric acid production was changed a couple of years ago. Uncertainties of the estimate for 1990 were kept unchanged and are still based on the work by Monni (2003, 2004). The estimate

⁸ 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.

⁹ Plant E started operation in 2004 and during the first years of operation the plant was not performing optimally and the emission factor was higher than presently.

for 2004 was revised after a visit to the producer and the following discussions. The current estimate reflects the improved measurements done by the producer, as discussed above. Specifically, an estimate of $\pm 15\%$ was obtained (Gåpås 2005). This gives a 95% confidence interval for N_2O emissions from nitric acid production. The estimates now reflect better the history of no emission measurements, and therefore a large uncertainty for 1990, as well as the current circumstances with extensive measurements, and thus a lower uncertainty deduced from that information.

4.3.2.5 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6.

In the calculation of emissions from nitric acid production several general inventory quality control procedures have been performed as mentioned in IPCC GPG, table 8.1. Some of the checks are performed annually, like comparing with previous emissions of subcategory of the calculated emissions and ensuring that there are no transcription errors in calculations and some when the calculation method has been developed.

Some source category-specific quality control procedures have been carried out during calculation. One of them is that the used emission factors have been compared with the IPCC default emission factor and reasons for differences have been clarified and explained in Section 4.3.2.2. Secondly emission factors are based on accurate measurements of a company and therefore it represent the best possible knowledge of that production process and equipment.

Production amount have been checked using as many independent sources as possible and only small differences ($\pm 1\%$) between figures have been noticed. All activity data are site-specific and reported to industrial output statistics or reported due to monitoring of environmental permit of a company.

4.3.2.6 Source-specific recalculations

Emission calculation of one nitric acid plant was corrected for year 2007, emission decreased 0.01 Gg N_2O .

4.3.2.7 Source-specific planned improvements

No planned improvements.

4.3.3 Hydrogen production

4.3.3.1 Methods

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 IPCC Guidelines, for which reason the stoichiometric ratio of chemical reactions is used. One company has a system to capture formed carbon dioxide for recovery and use.

4.3.3.2 Emission factors

No default factor for hydrogen production is available in the IPCC's 1996 Revised Guidelines or Good Practice Guidance 2000. The emission factor for calculating emissions from hydrogen production is based on the stoichiometric ratios of chemical reactions.

Reforming: $\text{C}_n\text{H}_m + n\text{H}_2\text{O} \rightarrow (n + m/2)\text{H}_2 + n\text{CO}$

CO inverting: $\text{CO} + \text{H}_2\text{O} \rightarrow \text{CO}_2 + \text{H}_2$

Natural gas as activity data: $\text{CH}_4 + 2\text{H}_2\text{O} \rightarrow \text{CO}_2 + 4\text{H}_2$

Reactions are corrected by a factor of 0.94 to take into account the fact that the reactants do not react completely in the processes. The correction factor is based on the information about the percentage of feedstock that is actually converted to hydrogen and carbon dioxide reported by one producer of hydrogen (Slioor, 2004).

When hydrogen has been produced from natural gas the emission factor is 5.5 t CO₂/ t produced hydrogen and 2.75 t CO₂/ t used natural gas. If heavier hydrocarbons are been used the emission factor is bigger.

4.3.3.3 Activity data

The consumption of hydrocarbons is used as activity data in calculating emissions from hydrogen production. The feedstocks used are natural gas, naphtha and propane. 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 4.3-3.

4.3.3.4 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

The uncertainty in hydrogen production was estimated at -10%...+13% (Slioor, 2004). The uncertainty is partly due to uncertain activity data. Another factor that causes uncertainty is the lack of knowledge concerning the exact number of reagents that actually react in the various processes.

The data on the emissions have improved in recent years, mainly due to increased availability of measured data. Therefore uncertainties in recent years are smaller than at the beginning of the 1990's.

4.3.3.5 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6.

In the calculation of emissions from hydrogen production several general inventory quality control procedures have been performed as mentioned in IPCC GPG, table 8.1. Some of the checks are performed annually, like comparing with previous emissions of subcategory of the calculated emissions and ensuring that there are no transcription errors in calculations and some when the calculation method has been developed.

Few source category-specific quality control procedures have been carried out during calculation. The stoichiometric emission factors with correction factor 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 two plants (out of 6) have been verified with ETS data and emissions have been found to be equal. These two plants are biggest emitters in this category, amount of their emissions represents more than 90% of category's emissions.

4.3.3.6 Source-specific recalculations

Activity data of a new plant was corrected; emissions of 2006 were increased by 65 Gg.

4.3.3.7 Source-specific planned improvements

No source-specific improvements have been planned.

4.3.4 Ammonia production

4.3.4.1 Methods

CO₂ emissions from ammonia production are calculated by multiplying the amount of produced ammonia with the emission factor. Activity data have been received directly from the company and the emission factor is the default factor from the IPCC.

4.3.4.2 Emission factors

Emissions have been calculated with the mean value of two IPCC default emission factors (1.55 tonne CO₂/tonne ammonia produced).

4.3.4.3 Activity data

The amount of produced ammonia has been received from a company which was producing it at the beginning of the time series. The amount of produced ammonia is shown in Table 4.3-3.

4.3.5 Indirect CO₂ emissions from NMVOC emissions from chemical industry

4.3.5.1 Methods

The NMVOC emissions are based on emission data from the VAHTI system and collected by the Finnish Environment Institute. Indirect CO₂ emission was calculated using the equation below. It was assumed that the average carbon content is 80% by mass for years 1990-2008 for all categories under the sector Industrial Processes based on 2006 IPCC Guidelines. Used fossil carbon content fraction of NMVOC is based on the NMVOC speciation profile provided in the EMEP/CORINAIR Emission Inventory Guidebook under the sector asphalt roofing.

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

The amount of NMVOCs emitted in the chemical industry in 1990-2008 is presented in Table 4.3-3.

4.3.5.2 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

The latest uncertainty analysis for NMVOC has been carried out for the 2007 emissions and reported to the UNECE CLRTAP Secretariat March 2009. Since, according to the reporting obligation under the CLRTAP, the uncertainty analysis is required only in every five years the analysis will be performed for the 2011 submission. The uncertainties for 2008 are estimated to be approximately at the same level as in 2007. The documentation of the 2007 uncertainty analysis is available in the Finnish Informative Inventory Report (IIR) under the CLRTAP. The Finnish IIRs are published on the website <http://www.environment.fi> > State of the environment > Air > Air pollutant emissions in Finland. According to the analysis the uncertainty for the 2007 NMVOC emissions was estimated at -25% - +25%. Uncertainty is due to the uncertain activity data: it is assumed that the uncertainty of data from VAHTI system is ±100%. Monitoring of NMVOC emissions is not very often included in the emissions monitoring programmes of the plants and therefore the methods used by the plant operators to estimate their NMVOC emissions are not always known.

4.3.5.3 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6.

In the calculation of indirect CO₂ emissions from the chemical industry and storage of chemicals at the sites several general inventory quality control procedures have been performed as mentioned in IPCC GPG, table 8.1. For example reported emissions are compared with previous emissions of subcategory annually.

4.3.5.4 Source-specific recalculations

No recalculations have been done.

4.3.5.5 Source-specific planned improvements

No source specific improvements have been planned.

Table 4.3-3 Production of ammonia and nitric acid, amount of used hydrocarbons and NMVOC emissions as activity data (Gg).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Ammonia	28.4	28.7	12.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Nitric acid	549	480	428	445	461	476	477	480	452	453	451	430	448	477	503	582	599	615	629
Used hydrocarbons	18.5	24.2	20.6	24.3	36.9	30.0	35.3	32.6	31.9	31.2	35.5	34.3	39.4	46.1	50.1	36.4	64	183	227
NMVOC emissions	8.3	7.1	7.1	6.4	6.7	6.8	7.1	6.9	5.0	4.9	4.4	4.4	3.8	3.4	4.0	2.6	3.0	2.3	2.9

4.4 Metal Production (CRF 2.C)

4.4.1 Source category description

This source category in the Finnish inventory includes CO₂ emissions mostly from coke and heavy bottom oil used in blast furnaces and CH₄ emissions from coke production (reported in CRF tables under Iron and steel production). CO₂ emissions from ferroalloys production in Finland are reported in Iron and steel production, because ferrochromium production is part of integrated stainless steel plant (Table 4.4-1 and Table 4.4-2). In addition, NMVOC emissions from iron and steel production and from secondary aluminium production are reported. There is no primary aluminium production in Finland. Iron and steel production (CO₂ emissions) is one of the key source in the Finnish inventory.

Table 4.4-1 Reported emissions under the subcategory metal production in the Finnish inventory.

CRF	Source	Emissions reported
2.C 1	Iron and steel production	
	Steel	CO ₂
	Pig iron	IE (Steel)
	Sinter	IE (Steel)
	Coke	CH ₄ , CO ₂
2.C 2	Ferroalloys production	IE (Iron and steel production)
2.C 5	Non-ferrous metals	CO ₂

SF₆ 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 SF₆ data, and reported under CRF category 2.F Consumption of halocarbons and sulphur hexafluoride.

Degreasing in metal industry is included in CRF 3.B. and painting in CRF 3.A.

In the earlier inventories CH₄ emissions from pig iron and sinter production were also reported. Based on the Revised 1996 Guidelines and measurements carried out at the Finnish plants, these emissions are now considered to be negligible and omitted from the inventory.

Emissions of metal production were 2.5 Tg CO₂ eq. in 2008 and this was over 36% of sector's and about 3.6% of Finland's total greenhouse gas emissions. Iron and steel production contributes over 99% of emissions of metal production.

Amount of produced steel has increased by 54% since 1990 while total emissions of iron and steel industry have increased only 36% at the same time. There was a sudden growth in production amount in the beginning of the 2000's because one steel plant increased production and improved its energy efficiency. In 2007 and 2008 the production of steel was lower due to market situation (Figure 4.4-1). This caused higher CO₂ IEF, because the energy efficiency of the processes becomes lower, when full capacity cannot be used (Hemminki, 2008). Methane emissions from coke production almost doubled in 1993 due to opening of a new line of production in a steel factory.

Indirect CO₂ emissions from metal production have been calculated from NMVOC and methane emissions for the time series 1990-2008.

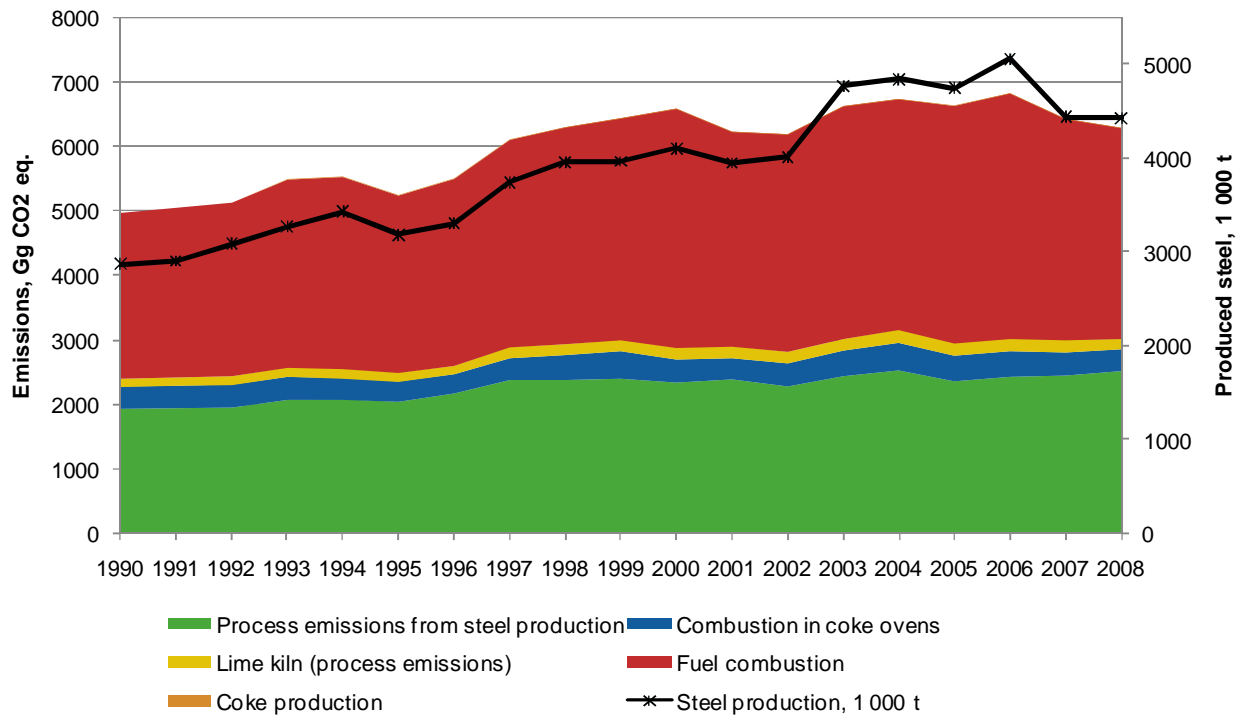


Figure 4.4-1 Total emissions of steel production and amount of produced steel.

Table 4.4-2 Emissions by gas and subcategory (Gg).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
CO ₂																			
2.C 1 Production of steel	1931	1945	1958	2071	2079	2042	2170	2381	2386	2406	2345	2397	2279	2443	2536	2367	2433	2456	2520
2.C Indirect	4.13	3.96	4.07	4.79	5.16	4.59	4.32	4.99	5.22	4.94	5.39	5.12	4.72	4.89	4.55	4.90	4.74	4.28	4.03
CH ₄																			
2.C 1Coke production	0.24	0.24	0.25	0.44	0.46	0.46	0.46	0.44	0.46	0.45	0.46	0.45	0.46	0.45	0.45	0.45	0.43	0.43	0.43
Total of subcategory, Gg CO ₂ eq.	1 941	1 953	1 967	2 085	2 094	2 056	2 184	2 396	2 401	2 420	2 360	2 411	2 293	2 458	2 550	2 381	2 447	2 469	2 533

4.4.2 Steel production

4.4.2.1 Methods

The calculation method of CO₂ emissions from the iron and steel industry is a country-specific bottom-up methodology. Both fuel-based emissions and process emissions are calculated in connection with the ILMARI calculation system (see Section 3.2 Emissions from fuel combustion) using plant/process level data. The methodology is slightly plant-specific, because all plants differ from each other.

The plants included are:

- One iron and steel plant including coke oven, blast furnace, lime production plant and steel converter
 - One iron and steel plant including blast furnace and steel converter
 - One integrated ferrochromium and stainless steel plant
 - One steel plant with 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).

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 CO₂ emissions (described below). Fuel-based emissions are allocated to CRF 1.A 2a and CRF 1.A 1c (coke ovens). The rest of emissions are allocated to process emissions in CRF 2.C 1 (and CRF 2.A 1 in the case of lime kilns).

Total CO₂ emissions for each installation (coke oven, sinter plant, blast furnace, lime kiln, steel converter, rolling mills and power plants/boilers) in each plant are mostly taken from the VAHTI system (see also section 1.4 and Annex 2). These emissions are basically calculated by plant operators using carbon inputs (fuel inputs and reducing materials) and they are reported by installations separately.

The time series of CO₂ emission data are not fully complete in the VAHTI system. Emissions for the years 1990-1995 have not been reported to VAHTI. Therefore total CO₂ 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. 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 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 CO₂ emissions.

Emissions are reported in the CRF categories using the allocations as mentioned in Table 4.4-3

Table 4.4-3 Allocation of emissions from iron and steel production in Finland.

CRF category	Emission source
CRF 1.A 1c	Emissions from fuels used in coking plants (coke oven gas and BF gases)
CRF 1.A 2a	Emissions from fuels used in iron and steel plants' processes and power plants: (LPG, residual fuel oil, gasoil, coke oven gas and BF gas, excluding BF gas used for blast furnaces' air pre-heaters)
CRF 2.A 2	Process emissions from lime production in iron and steel plant
CRF 2.C 1	Process emissions from iron and steel production (includes ferroalloys production in integrated stainless steel plants)

From 2005 on, all four iron and steel plants in Finland report to the EU ETS. Starting from 2007 submission (2005 data), the total CO₂ 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.

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 more accurate data were to become available for historical time series, a recalculation could be considered, but at the moment this option seems very unlikely.

4.4.2.2 Emission factors

The CO₂ emission factors used in the calculation are presented in Table 3.2-3. Plant-specific CO₂ emission factors have been used as far as possible. Implied emission factors for CO₂ emissions can be seen in Figure 4.4-2.

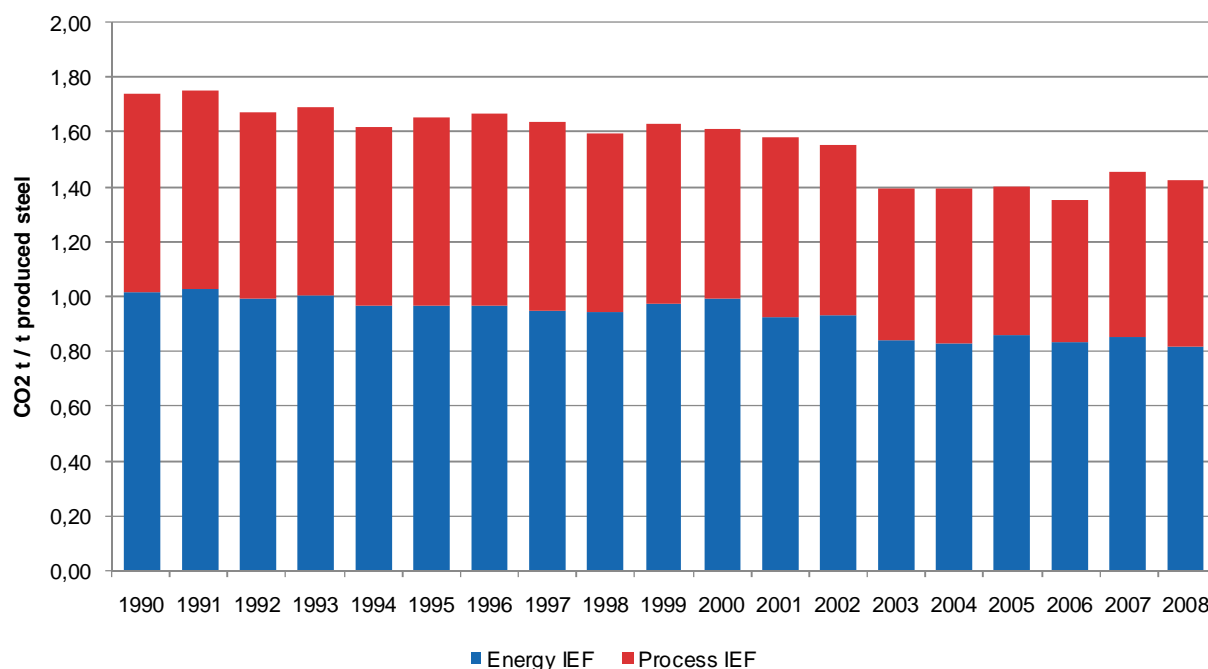


Figure 4.4-2 Implied emission factors for CO₂ in energy production and industrial processes in steel industry for years 1990-2008.

4.4.2.3 Activity data

Activity data for the calculation and comparison of CO₂ emissions are taken from the VAHTI system, energy statistics (Energy Statistics, Yearbook 2009), 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. CO₂ 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 CO₂ 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). Also 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 ₂ 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 ₂ 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 CO₂ emissions for these years have been calculated using fuel data, reducing agents and CaCO₃ 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 ₂ 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 CO₂ emissions for these years have been calculated using fuel data, reducing agents and CaCO₃ input data. Process emissions have been partly estimated using later years' data. Recalculation in 2010 submission: coke consumption time series data were updated (see chapter 4.4.2.6).

4.4.2.4 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

The uncertainty in CO₂ process emissions from Iron and steel production was estimated at $\pm 10\%$ (Grönfors, 2007) in 1990 and 2008. However, the overall uncertainty in Iron and steel production including energy and process emissions was estimated to be $\pm 5\%$. This subject and its effect on total GHG uncertainty will be studied further. Summary of the uncertainty analysis has been described in Section 1.8.

4.4.2.5 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6.

The main quality checks are:

- Comparison of different methodologies (reported and calculated emissions)
- Comparison to the mass/balance approach for certain years
- Checking of activity data from several independent sources.

A new quality check was performed for this inventory. CO₂ emissions were calculated using IPCC tier 1 default methodology. This comparison is shown in Figure 4.4-3.

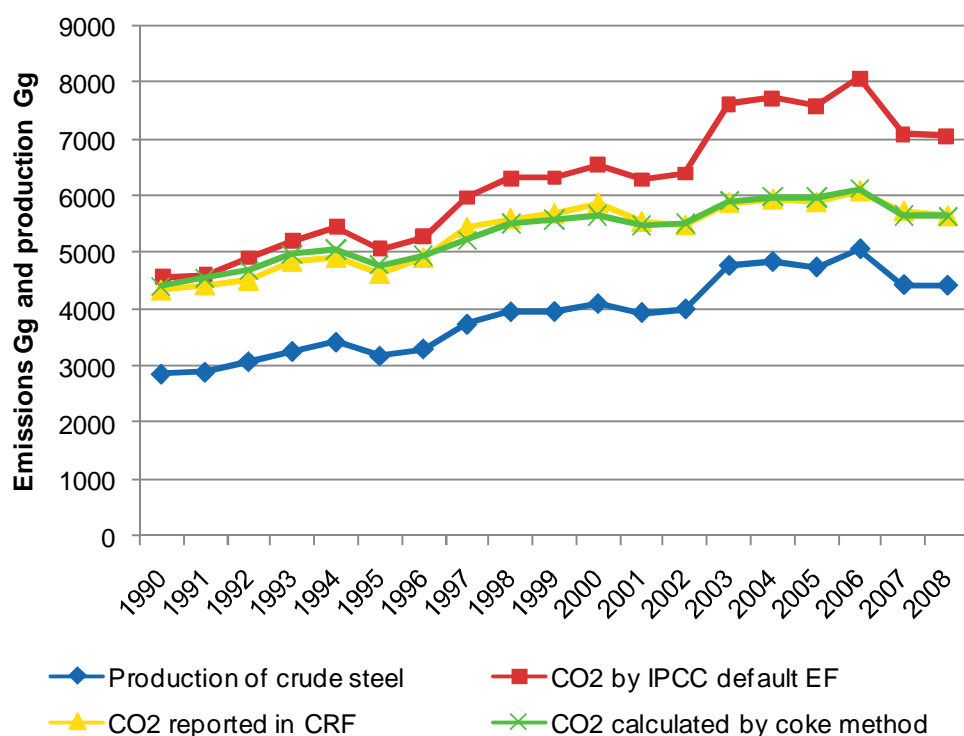


Figure 4.4-3 Comparison of CO₂ emissions from Iron and steel, includes both energy based emissions and process emissions.

4.4.2.6 Source-specific recalculations

Time series data of one plant were checked and revised. There were several corrections, described below.

The consumption of coke had been reported inconsistently in different source data sets. The data were revised taking all years from the same source, manufacturing industry statistics. This data set seems to have the best consistency over time and also very good consistency with special questionnaire by Statistics Finland (which includes years starting from 1994). The annual data in these two data sets differs clearly from VAHTI data which has been the primary data source in previous inventories.

In addition, the allocation of fuels to different processes during 1990 - 1994 was revised, to get more consistent time series. The original data was more aggregated than the data for 1995 - 2008.

One more correction was that 1996 fuel data had been partly estimated, and now the data was replaced with actual values.

The recalculation increased 1990 CO₂ emissions in this subcategory by 74 Gg. The effect of the recalculation was from -82 to +117 Gg. Since 2003 difference was less than 1 Gg/a.

These changes vary from 0% to 6% of the subcategory's total CO₂ emissions. However, it must be noted, that in most years the recalculation had an opposite effect on the CO₂ emissions of the Energy sector (1.A 2a). Thus the overall effect of the recalculation on total CO₂ emissions of 1.A 2a and 2. C 1 was clearly lower, varying between - 9 Gg and + 40 Gg (1990 total change was 13 Gg). The only exception is 1996. There the total change was clearly higher (-191 Gg) than in any other year, due to the fact that all estimated activity data of the plant were replaced with actual data.

4.4.2.7 Source-specific planned improvements

No source-specific improvements are planned for now.

4.4.3 Coke production

4.4.3.1 Methods

The calculation method for CH₄ emissions from coke production is consistent with the IPCC Guidelines.

4.4.3.2 Emission factors

Production of coke: The emission factor 0.5 kg/t used in the calculation of CH₄ emissions from coke production is the IPCC default value (IPCC 1996).

4.4.3.3 Activity data

Activity data for the calculation of CH₄ emissions from coke production are obtained from Energy Statistics. Coke production data are presented in Table 4.4-4.

4.4.3.4 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

The uncertainty for activity data in coke production was estimated to be around $\pm 3\%$ and for emission factors around $\pm 20\%$ in 2008 (Slioor, 2004).

4.4.3.5 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6.

The calculated emissions have been compared with previous emissions of the subcategory.

All activity data are site-specific and reported to industrial output statistics or due to monitoring of environmental permit of a company. Activity data have been checked using as many independent sources as possible.

4.4.3.6 Source-specific recalculations

No recalculations have been done.

4.4.3.7 Source-specific planned improvements

No source-specific improvements have been planned.

4.4.4 Indirect CO₂ emissions from NMVOC and methane emissions from iron and steel and secondary aluminium production

4.4.4.1 Methods

NMVOC emissions from iron and steel production and secondary aluminium production are calculated at the Finnish Environment Institute based on emission data from the VAHTI system and the Federation of Finnish Technology Industries. The emission factors are taken from the Joint EMEP/Corinair Atmospheric Inventory Guidebook.

Indirect CO₂ emissions from NMVOC emissions were calculated using the same equation mentioned in Section 4.3.5. In addition, indirect CO₂ emissions from methane emissions were calculated using equation mentioned in Section 3.6.2.1. Amount of emitted NMVOC and methane are included in Table 4.4-4.

Table 4.4-4 Production of coke and steel, and NMVOC and methane emissions as activity data, Gg.

	Production of coke	Production of crude steel	NMVOC emissions	Methane emissions
1990	487	2 861	1.18	0.24
1991	471	2 890	1.13	0.24
1992	498	3 077	1.15	0.25
1993	874	3 256	1.22	0.44
1994	922	3 420	1.33	0.46
1995	920	3 176	1.13	0.46
1996	910	3 301	1.05	0.46
1997	879	3 734	1.29	0.44
1998	912	3 952	1.35	0.46
1999	900	3 956	1.26	0.45
2000	910	4 096	1.41	0.46
2001	909	3 938	1.32	0.45
2002	912	4 003	1.18	0.46
2003	895	4 766	1.25	0.45
2004	904	4 830	1.13	0.45
2005	894	4 738	1.25	0.45
2006	870	5 054	1.21	0.43
2007	865	4 431	1.05	0.43
2008	860	4 417	0.97	0.43

4.4.4.2 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

The latest uncertainty analysis for NMVOC has been carried out for the 2007 emissions and reported to the UNECE CLRTAP Secretariat March 2009. Since, according to the reporting obligation under the CLRTAP, the uncertainty analysis is required only in every five years the analysis will be performed for the 2011 submission. The uncertainties for 2008 are estimated to be approximately at the same level as in 2007. The documentation of the 2007 uncertainty analysis is available in the Finnish Informative Inventory Report (IIR) under the CLRTAP. The Finnish IIRs are published on the website www.environment.fi > State of the environment > Air > Air pollutant emissions in Finland. According to the analysis the uncertainty for the 2007 NMVOC emissions was estimated at -25% - +25%.

Uncertainty is due to the uncertain activity data: it is assumed that the uncertainty of data from VAHTI system is $\pm 100\%$. Monitoring of NMVOC emissions is not very often included in the emissions monitoring programmes of the plants and therefore the methods used by the plant operators to estimate their NMVOC emissions are not always known. The uncertainty of the emissions factors is estimated to be $\pm 80\%$.

4.4.4.3 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6.

In the calculation of indirect CO₂ emissions from iron and steel and secondary aluminium production there have been performed several general inventory quality control procedures as mentioned in IPCC GPG, table 8.1. The calculated emissions have been compared with previous emissions of the subcategory. Part of the activity data is site-specific and reported due to monitoring of environmental permit of a company or

reported for statistics and part of activity data are totals from statistics. All activity data have been checked using as many independent sources as possible.

4.4.4.4 Source-specific recalculations

No recalculations have been done.

4.4.4.5 Source-specific planned improvements

No source-specific improvements have been planned.

4.5 Other Production (CRF 2.D)

4.5.1 Source category description

This source category includes NMVOC emissions from the forest and food industries. In 2008 they amounted to 5.1 Gg. Non-fuel based CO₂ emissions from the pulp and paper and food industries are estimated to be negligible in Finland. All N₂O and CH₄ emissions from the pulp and paper industry are reported as fuel-based emissions under CRF 1.

NMVOC emissions from the forest industry, including pulp and paper as well as mechanical wood industry, and from food industry are calculated at the Finnish Environment Institute (Table 4.5-1)

Indirect CO₂ emissions from forest industry as well as from food and drink processing are considered to be biological.

NMVOC emissions from pulp and paper industry mainly originate from storage and handling of wood, major point sources are production of mechanical pulp and storage of woodchips, and are therefore considered to be 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. Rough expert estimation (Lindh, 2007) at Finnish Environment Institute, based on the environmental permits available through the VAHTI system, is that approximately 95% of the NMVOC emissions from the mechanical wood industry originate from biogenic sources, thus 98% of the entire NMVOC emission under the sector 2.D 1. Since the separation of biogenic and fossil based NMVOC emissions is difficult and the inclusion of indirect CO₂ emissions to the total CO₂ emissions would create a larger error, the indirect CO₂ emissions from this sector have not been calculated.

Table 4.5-1 NMVOC emissions from categories Pulp and paper and Food and Drink, Gg.

	Pulp and paper	Food and drink
1990	4.5	1.4
1991	4.2	1.4
1992	3.7	1.4
1993	4.0	1.3
1994	4.1	1.4
1995	4.2	1.4
1996	4.1	1.4
1997	4.0	1.4
1998	3.6	1.4
1999	3.4	1.4
2000	3.8	1.4
2001	3.6	1.4
2002	3.7	1.4
2003	3.8	1.4
2004	4.1	1.4
2005	3.4	1.5
2006	3.6	1.4
2007	4.9	1.4
2008	3.8	1.3

4.6 Consumption of Halocarbons and SF₆ (CRF 2.F)

4.6.1 Source category description

In 2008, greenhouse gas emissions under the source category CRF 2.F Emissions of consumption of halocarbons and SF₆ amounted to 1.0 Tg CO₂ eq., which is 1.5% of the total greenhouse gas emissions in Finland. Emissions from different subcategories reported under this sector are listed in Table 4.6-1.

Table 4.6-1 Reported emissions under the subcategory consumption of halocarbons and SF₆ in the Finnish inventory.

CRF	Source	Emissions reported
2. F 1	Refrigeration and air conditioning equipment	HFC, PFC
2. F 2	Foam blowing and use of foam products	HFC
2. F 4	Technical aerosols, one-component polyurethane foam, tear gas and metered dose inhalers	HFC
2. F 8	Manufacturing, use and disposal of electrical equipment	SF ₆
2. F 9	Emissions reported aggregated in a separate subcategory due to data confidentiality:	
	refrigeration and air conditioning	HFC-23
	fixed fire fighting systems	HFC-125, HFC-134a
	semiconductor manufacturing	HFC-23, CF ₄ , C-C ₄ F ₈ and SF ₆
	magnesium die casting	SF ₆
	shoes	SF ₆
	research	SF ₆

Note that the subcategory of Aerosols includes one-component polyurethane foam cans (OCF), an aerosol-like product. These products have been treated as aerosols in the Finnish inventory. This practice predates the Good Practice Guidance. In the Good Practice Guidance, OCF is discussed together with other foam types, and the methodology is slightly different from that applied to aerosols. Finland has decided not to change the practice of including OCF in the aerosols subcategory, because this would require recalculation of both the aerosol and foam time series, and because the recalculation would not improve the emission estimates.

There are no fugitive emissions from manufacturing, because F-gases are not produced in Finland. There is neither any manufacturing of other fluorinated gases, such as HCFCs or HFCs, which could lead to by-product emissions (e.g. HFC-23 from HCFC-22 manufacturing). Other point sources which make a considerable contribution to emissions elsewhere, but are absent from Finland, include the primary aluminium and magnesium industry.

The total emissions of F-gases have increased significantly since 1990. During the period 1990–1995, the emissions declined slightly due to downward trend in quantities of installed SF₆ in electrical equipment which was, by that time, the main emission source of F-gases. From mid-1990's emissions have increased strongly resultant to introduction of HFC and PFC substances as ODS substitutes. In 2008, the emissions were over ten-fold compared with the emissions of 1995, which was chosen as the base year for F-gas emissions under the Kyoto Protocol in Finland (Table 4.6-2, Figure 4.6-1 and Figure 4.6-2).

A key driver behind the growing emission trend has been substitution of ozone depleting substances (ODS) by F-gases, especially with HFCs, in many applications. Restrictions of ODS in mid-1990's led to rapid growth of the use of HFCs as refrigerant agents and simultaneously to increase of emissions towards the end of the decade. There are two deflections in the upward trend. Those are a temporary drop in the year 2002 and a fall from 2005 to the inventory year 2006.

There are no known changes on the market that would cause such fluctuation. In the quantities of imported chemicals, a similar drop cannot be seen in 2002. Therefore, it can be assumed that the consumed quantities have most likely been growing rather steadily until the latest years. The inter-annual variation in the

beginning of the 2000's is expected to be a result of variation in activity data. This is elaborated more in section 4.6.3. Closer analytical examination of each emission estimate in relation to the trend level and in the light of uncertainties shows, however, that it is hard to assess to what extent the estimate of 2002 is too low and how large part of the fluctuation is due to high estimates in adjacent years and to what extent the changes in the emission and data are real.

As a result of low response rate in the 2006 inventory, the quantities of bulk refrigerants exported and imported had to be imputed for some large companies. In the 2007 inventory answers were also received from these companies and a closer study proved that the exported HFC quantity could have been overestimated and the imported HFC quantity underestimated to some extent in the 2006 inventory. However, the study also showed that new evaluation of activity data based on 2007 responses would lead to a bit higher emission estimation but the emissions would, anyhow, be on a lower level than in 2005 or 2007. This indicates real fluctuations in the emission trend. It will be seen in coming years if the EC legislation, which came into force in 2007, as well as development of alternative technologies and low GWP substrates will diminish the emissions of F-gases.

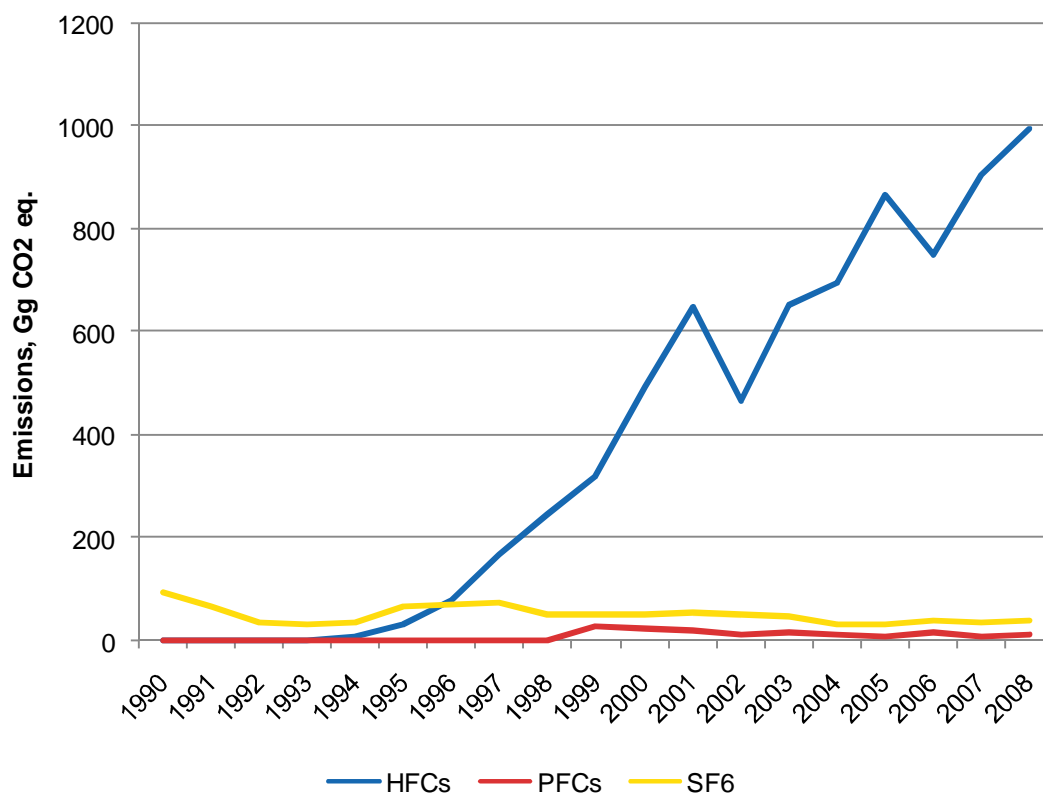
As opposed to the global growing trend, PFC emissions in Finland have declined since the peak level in the late 1990's. In Finland the two most important sources of PFC emissions are usage of PFCs in refrigerants and in semiconductor manufacturing processes. Both, the usage of PFC-218 (C_3F_8) for servicing refrigeration devices and the amount of PFC substances used in semiconductor manufacturing processes have decreased since the beginning of the 2000's. The decrease in the emissions from semiconductor manufacturing is due to recent transfers of production from Finland into other countries. It was assessed earlier that the decreasing trend in semiconductor manufacture might be temporary and that the emissions from this industry may start to increase again. The peak in 2006 is presumably caused by the low response rate of the 2007 survey. According to the 2008 and 2009 survey responses the quantity of PFCs imported to Finland is roughly on the level of 2005 whereas in 2006 the imputed amount was considerably larger resulting in the increased emission estimate.

SF_6 emissions from electrical equipment are an exception amongst the F-gases emission sources in Finland since emissions from this source have decreased compared to 1990. The amount of SF_6 gas used in annual activities in Finland is quite small. Therefore, changes in market activity do have a significant impact on the emission level and can cause inter-annual fluctuation. The peak in 1990 coincides with the high level of economic activity in the country in general, and the fall of 2–4 years after coincides with the darkest years of the early 1990's recession. After the recession a rather large amount of electrical equipment was installed again in 1995 and the amount of gas used for maintenance also increased. After some high years in the mid-1990s, the trend declines again towards the end of the decade as the environmental influences of SF_6 became known and led to lower emissions. In the recent years, the imported quantity of SF_6 has been used mainly in semiconductor manufacturing or in electrical equipment and the slight inter-annual fluctuation is caused by varying activity in these sectors.

Based on the level and trend analyses, refrigeration and air conditioning equipment is a key category. SF_6 from electrical equipment is a key category due to its trend.

Table 4.6-2 Actual emissions of HFCs, PFCs and SF₆, 1990-2008 (CO₂ equivalent Gg).

	HFCs	PFCs	SF ₆	Total F-gases
1990	0.02	0.07	94.4	94
1991	0.05	0.08	67.3	67
1992	0.10	0.09	36.6	37
1993	0.10	0.10	33.6	34
1994	6.5	0.12	34.9	42
1995	29.3	0.14	68.5	98
1996	77.3	0.16	72.2	150
1997	167.8	0.18	76.0	244
1998	245.2	0.21	53.2	299
1999	318.6	28.0	52.0	399
2000	494.1	22.5	51.5	568
2001	648.0	20.1	55.0	723
2002	464.1	13.4	51.3	529
2003	652.2	14.9	48.1	715
2004	695.3	12.2	33.8	741
2005	864.0	9.9	32.7	907
2006	747.8	15.4	40.2	804
2007	904.1	8.4	36.0	948
2008	994.0	11.2	40.4	1 046

**Figure 4.6-1** Actual emissions of HFCs, PFCs and SF₆, 1990-2008 (CO₂ equivalent Gg).

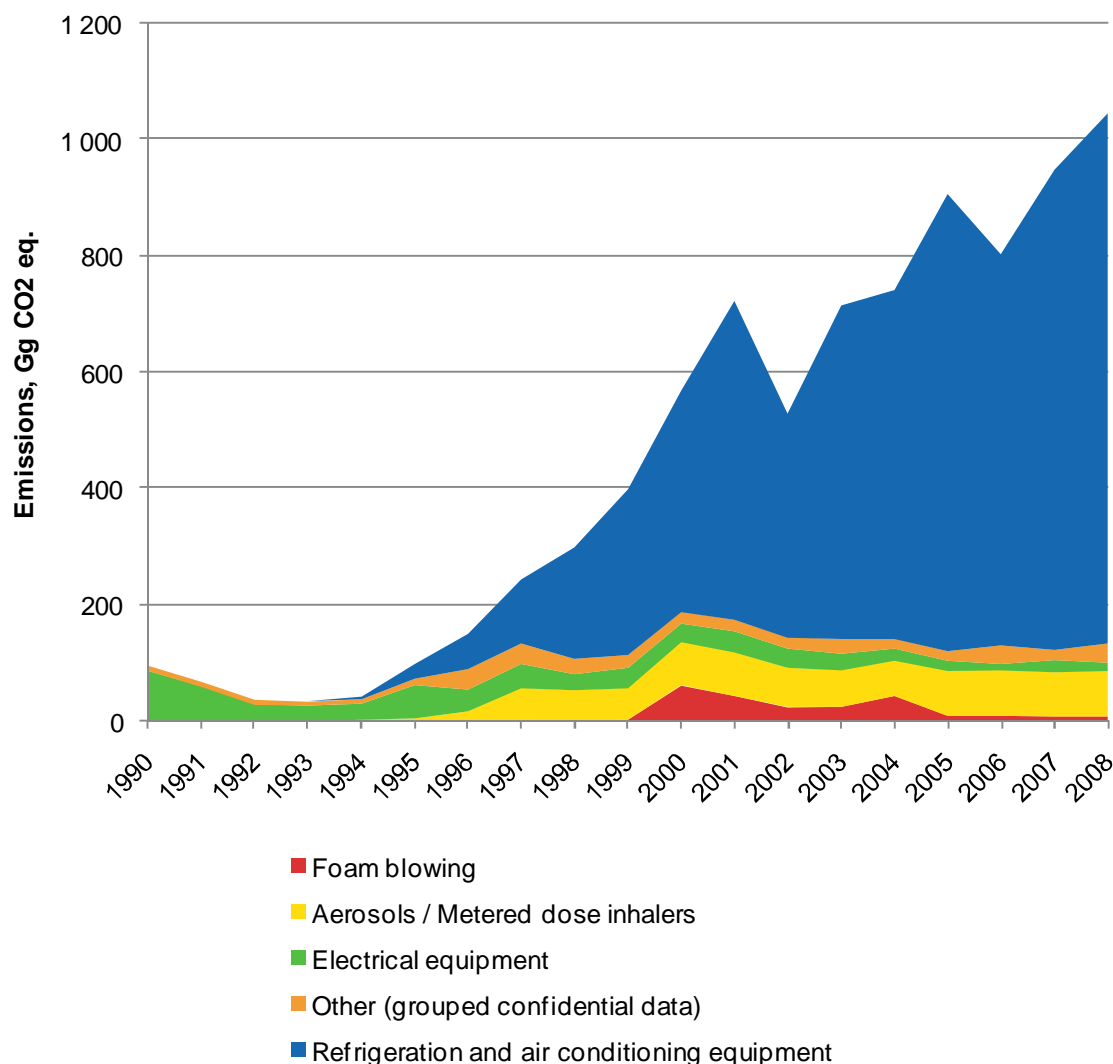


Figure 4.6-2 Actual emissions of F gases by subcategory, 1990-2008 (CO₂ equivalent Gg).

4.6.2 Methodological issues

4.6.2.1 Methods

An overview of the methods used to quantify emissions of F-gases is presented in Table 4.6-3. Emissions from each category are quantified using two or three different methods given in the IPCC GPG (2000). First of all, there are two tiers for estimation of potential emissions that describe gas consumption within a country (Tier 1a and 1b). The difference between the two is whether gases imported and exported in products are accounted for. Since in many cases there is a delay between consumption and emissions, the COP has decided that actual emissions – as opposite to simply quantifying consumption – should be quantified (Decision 2/CP.3). The COP has also decided that the Annex I Parties reporting actual emissions should also report potential emissions for reasons of transparency and comparability (Reporting guidelines, FCCC/SBSTA/2004/8).

Table 4.6-3 Summary of the methods used in the F-gases inventory.

Source category	Methods used and gases reported	Notes
Magnesium die-casting (CRF 2.C)	Direct reporting method, Tier 1a	Tier 1b is not applicable to this category because all SF ₆ used is imported in bulk. Emissions from this source are not reported separately due to confidentiality.
Refrigeration and air conditioning equipment (CRF 2.F 1)	Top-down Tier 2, Tier 1a, Tier 1b HFC-32, HFC-125, HFC-134a, HFC-143a, HFC-152a, PFC-218 (HFC-23 is reported in grouped data due to confidentiality)	The Tier 2 top-down method is used for all sources in this category, both stationary and mobile. Data are not collected for separate subcategories because such statistics are either not available or the preparation of such statistics would entail a very high reporting burden on companies. There is also some evidence that simpler questionnaires lead to better response activity. HFC-23 emissions from this source are not reported separately due to confidentiality.
Foam blowing (CRF 2.F 2)	Tier 2, Tier 1a, Tier 1b HFC-134a, HFC-245fa and HFC-365mfc	Emissions of HFC-245fa and HFC-365mfc are reported as additional greenhouse gases.
Fire extinguishers (CRF 2.F 3)	Tier 2, Tier 1a, Tier 1b HFC-125 and HFC-134a	Emissions from this source are not reported separately due to confidentiality.
Aerosols and one-component foam (CRF 2.F 4)	Tier 2, Tier 1a, Tier 1b HFC-134a and HFC-152a	One-component foam cans are treated as aerosols in this inventory, cf. Section 2.3.6 of Oinonen (2003). MDIs are not reported separately from other aerosols due to confidentiality.
Semiconductor manufacturing (CRF 2.F 7)	Tier 1, Tier 1a CHF ₃ , CF ₄ , SF ₆ and c-C ₄ F ₈	Tier 1b is not applicable to this category because all gases used are imported in bulk. Emissions from this source are not reported separately due to confidentiality.
Electrical equipment (CRF 2.F 8)	Tier 3c (country-level mass-balance), Tier 1b SF ₆	Tier 1a estimates cannot be calculated for this source because of lack of historical data. Tier 1b estimates have been calculated, however, based on survey and emissions data cf. Section 3.1 of Oinonen (2003).
Running shoes (CRF 2.F 9)	Method for adiabatic property applications, Tier 1b SF ₆	Tier 1a is not applicable to this category because all SF ₆ used is imported not in bulk, but in products (i.e. shoes). Emissions from this source have not been reported separately due to confidentiality. The emissions from running shoes ended in 2007.

HFCs and PFC-218 from refrigeration and air conditioning (CRF 2.F 1)

The source category covers HFCs and PFC-218 emissions from refrigeration and air conditioning equipment based on the vapour compression cycle. Included are *inter alia* domestic, commercial and industrial refrigeration systems, stationary and mobile air conditioning, as well as heat pumps. Emissions from refrigeration and air conditioning are reported as a single figure for all refrigeration and air conditioning subcategories (domestic, commercial, industrial, mobile, etc.).

Emissions are calculated by the IPCC Tier 2 and Tier 1a and 1b methods. In essence this means a material balance. The system under consideration is the geographic area of Finland. From the principle of conservation of mass, it follows that

$$\text{emissions} = \text{production} + \text{imports} - \text{exports} - \text{destruction} \pm \text{storage}.$$

HFC- or PFC-containing refrigerant gases are not manufactured in Finland, thus production = 0. Currently, the storage term is not equal to zero. Some of the gas imported is stored in equipment. At the same time, a proportion of the stored quantity is retired as the equipment reaches the end of its service life and is disposed of. The retiring capacity, however, is currently much smaller than the new capacity. It follows that the net change given by the storage term must be deduced from the imported quantity, thus

$$\text{emissions} = \text{imports} - \text{exports} - \text{destruction} - \text{storage}.$$

This model gives the Tier 2 actual emissions. Implementation of the top-down Tier 2 approach is recommended in the Good Practice Guidance. Emissions are not calculated for each equipment subcategory because this does not improve the inventory, but increases the companies' reporting burden. Also, respondents do not generally have data to support reporting at the level of subcategories. Current data gathering produces higher response activity and less uncertain activity data.

Potential emissions are given by the same formula, but assuming that storage is equal to zero. There are two variants of potential emissions. Tier 1a is defined to include only bulk quantities of imported and exported gases, whereas Tier 1b includes both bulk quantities and quantities imported in products. It is clear from above that actual emissions are currently smaller than potential ones.

More detailed descriptions of calculating emissions with the IPCC Tier 1a and b and Tier 2 methods (potential and actual emissions) are presented in Appendix_4 at the end of Chapter 4.

HFCs from foam blowing (CRF 2.F 2)

The source category covers HFC emissions from foam blowing and use of HFC-containing foam products. Blowing agent HFC emissions in Finland result from the manufacturing and use of extruded polystyrene (XPS), polyurethane (PU) integral skin foam, PU appliance foam, injected PU foam and PU panels. Most of the production has been based on hydrocarbons since the phasing out of CFCs and HCFCs. Some smaller producers decided to use HCFCs as long as possible and switched to HFCs when HCFCs were prohibited by an EC regulation in the year 2000.

Since the majority of the producers have changed to the use of hydrocarbons or CO₂ 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 2008 only about 24% 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. 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 have been 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. In 2008 the amounts of HFC-245fa and HFC-365mfc used in foam blowing increased further and it seems that there is an ongoing transition from the use of HFC-134a to the use of HFC-245fa and HFC-365mfc. Therefore the emissions of HFC-245fa and HFC-365mfc are now included in the inventory and reported as additional greenhouse gases. 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.

A small proportion of HFC-365mfc is used in the production of open-celled PU flexible moulded foam. The blowing agent used in open-cell foam blowing is released immediately. The emissions from open-celled foams can not be reported separately due to confidentiality. These emissions are reported together with the HFC-365mfc emissions from hard foams.

Actual emissions are calculated by IPCC Tier 2 method described in more detail in Appendix_4. Potential emissions are calculated according to the Tier 1a and 1b models described in the IPCC Revised 1996 Guidelines (Reference Manual pp. 2.47-2.50) and briefly outlined above.

HFCs from aerosols and metered dose inhalers (CRF 2.F 4)

The source category covers HFC emissions from technical and novelty aerosols, one-component polyurethane foam, tear gas and metered dose inhalers.

The emissions model used is from the Good Practice Guidance (p. 3.85).

$$x = (1 - f)a + fb,$$

where $f = 0.5$,

a = Tier 1b emission in 2007, and

b = Tier 1b emission in 2008.

Tier 1 methodology describes potential emissions which are equal to the amount of chemical consumed in the country minus the amount of chemical recovered for destruction or export in the year of consideration. A more detailed description of the model is given in Appendix_4.

SF₆ from electrical equipment (CRF 2.F 8)

The source category covers SF₆ emissions from manufacturing, use and disposal of electrical equipment. IPCC Tier 3c, Tier 1a and 1b are used in the calculation.

The 2008 inventory is based on the country-level mass-balance of the Good Practice Guidance (Equation 3.15, p. 3.56). In the 2003 inventory this basic model was developed further into a detailed mass-balance model which gave reasonable results as a three-year running mean for the years 2003 and 2004. For 2005, 2006 and 2007, the model suggested a negative value for the emission estimate when data from three latest years were used and the reported estimates were based on one year of activity data. For 2008 the detailed mass-balance model gave negative values based on both one year of activity data and several years of data. The large storage term in the equation draws the emission estimate down to negative values which, obviously, is not realistic. Therefore it was concluded that the activity data are not precise enough for such a detailed model.

In the 2008 inventory the country-level mass-balance model was simplified by leaving out the terms involving amounts of gas banked in manufacturers' and importers' stocks. A detailed account of the approach is given in Appendix_4.

The new model still gives negative emission estimates for isolated years, but the estimates calculated over several successive years of data are positive. The negative estimates are presumed to be caused by the stock changes taking place in reality but not taken into account in the equation. The unrealistic year-to-year fluctuation is compensated by using the data of several successive years. Calculations as both three-year running means and four-year running means gave unrealistically low emission estimates for one year. Therefore the results of the 2008 inventory and the recalculation of the inventory years 2003-2007 are reported with the Tier 3c method over five successive years of data.

Data grouped due to confidentiality (CRF 2.F 9)

This category includes the following sources and emissions that have been grouped due to confidentiality:

- HFC-23 from refrigeration and air conditioning equipment and semiconductor manufacturing
- HFC-125 and HFC-134a from fixed fire prevention systems
- CF₄ and c-C₄F₈ from semiconductor manufacturing
- SF₆ from magnesium die casting, semiconductor manufacturing, shoes and research.

The emissions from semiconductor manufacturing are reported with the IPCC Tier 1 method (Equations 3.31 and 3.32 in the Good Practice Guidance). The emissions of HFC-23 from refrigeration and air conditioning equipment are calculated with the Tier 2 model of the refrigeration and air conditioning sector described above.

HFC-125 and HFC-134a emissions from fixed fire fighting systems are reported with the "direct" method, i.e. the companies that sell, install and service the systems keep statistics on the quantities released in fires and the quantities released due to system malfunction. SF₆ from magnesium die casting is also reported with the "direct" method (Equation 3.12 Good Practice Guidance p. 3.48). For the reporting of SF₆ from shoes "adiabatic property applications" have been used (Equation 3.23 in the Good Practice Guidance p. 3.65), but these emissions are estimated to have ended in 2007.

4.6.2.2 Emission factors

Emission factors are described below for the models that incorporate such assumptions.

HFCs from foam blowing (CRF 2.F 2)

The model is dependent on the use of emissions factors for each foam type. Since such national factors are not available, IPCC default factors are used (Good Practice Guidance, p. 3.96 and 2006 Guidelines p. 7.37). The factors (probability density functions) used are shown in Table 4.6-4 below (Note that only the means of the distributions shown are from the Good Practice Guidance. The standard deviations were chosen based on expert judgement).

Table 4.6-4 Emission factors for foam blowing.

<i>i</i>	Foam type	HFC-134a		HFC-245fa/HFC-365mfc	
		$f_{M,i}$	$f_{B,i}$	$f_{M,i}$	$f_{B,i}$
1	XPS	N(0.40,0.08)	N(0.030,0.006)		
2	PU integral skin	N(0.95,0.20)	N(0.025,0.01)	N(0.95,0.20)	N(0.025,0.01)
3	PU injected	N(0.125,0.020)	N(0.005,0.01)	N(0.10,0.020)	N(0.005,0.01)
4	PU appliance	N(0.075,0.020)	N(0.005,0.01)	N(0.04,0.020)	N(0.003,0.01)
5	PU discontinuous panel	N(0.125,0.020)	N(0.005,0.01)	N(0.10,0.020)	N(0.005,0.01)

N = normal distribution, with mean (*m*) and standard deviation (*s*) given in parenthesis N(*m,s*).

If foam blowing was a key source in the Finnish inventory, 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 CO₂ as blowing agent, a detailed study does not seem necessary.

HFCs from aerosols and metered dose inhalers (CRF 2.F 4)

Emission factors were taken from the IPCC GPG (2000) referring to Gamlen et al. (1986). Both the value for the emission factor (50%) and the model itself, according to Gamlen et al. (1986), are from McCarthy et al. (1977).

Data grouped due to confidentiality

The method for semiconductor manufacturing is the only one using emission factors. These were taken from Table 3.15 of the Good Practice Guidance (p. 3.74) and are presented in Table 4.6-5.

Table 4.6-5 Emission factors for semiconductor manufacturing.

	CF ₄	C ₂ F ₆	CHF ₃	C ₃ F ₈	c-C ₄ F ₈	NF ₃	SF ₆
Use rate of gas (fraction destroyed or transformed in process)	0.2	0.3	0.7	0.6	0.7	0.8	0.5
Fraction of gas remaining in shipping container after use	0.1	0.1	0.1	0.1	0.1	0.1	0.1
kg CF ₄ created per kg of gas i	NA	0.1	NA	0.2	NA	NA	NA

4.6.2.3 Activity data

HFCs and PFC-218 from refrigeration and air conditioning (CRF 2.F 1)

The activity data for the refrigeration and air conditioning sector were compiled by a survey conducted in April to October 2009. The survey to collect activity data for the inventory has been carried out annually since 2002. The response activity to the survey in 2009 was higher than in 2008 and 2007 but still lower than it has been in previous years. This is partly due to an attempt to collect the data in an electrical form instead of postal mail. The internet-based electronic data collection system was established in 2008 and the questionnaire and its instructions were improved in 2009 based on the first year's feedback from the respondents. However, in order to receive more responses the possibility of answering by other means has also been maintained.

The survey gave a response activity of about 67% in the refrigeration and air conditioning sector. Approximately 45% of the answers were received through the electronic data collection system and the rest by postal mail, phone, e-mail or fax. There are difficulties in reaching some of the servicing companies via modern communication systems, as most of their work is done out of office. 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 2009 survey two general reminders were sent, from which the second was not as effective as the first. Further reminders were targeted to the main actors of the sector and some were contacted by phone as well.

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. Despite the uncertainty of the assumptions associated with data imputation, it has been estimated that the inaccuracy of the inventory would be higher if the missing data were not imputed. If no response is received from the largest manufacturers, importers or exporters, the activity data is estimated based on their previous responses.

In the 2009 survey nine companies reported bulk import of refrigerants for 2008. All of the major importers from the two previous years responded and no data imputation was required. The total quantity of bulk refrigerants imported in 2008 was 714,088 kg. The imported quantity has increased approximately 2% from 2007 and 17% from the estimated imported quantity of the 2006 inventory. A closer study of the 2006 activity data indicates that the data imputed due to non-response could have been slightly underestimated.

Even though all of the companies reporting bulk exports in the latest inventories responded, only two companies reported such activity in 2008. Therefore the total quantity of refrigerant bulk exports is confidential. The exported quantity increased substantially compared to the refrigerant exports of 2007, but is still considerably smaller than the estimated quantity of 2006. The increase from 2007 to 2008 is caused by the increased activity of a single company. Most of the previous bulk exporters had already given up the activity by 2007 and the trend in bulk refrigerant exports had been decreasing since 2001. The response rate in the 2007 survey for the year 2006 was poor and most of the data was imputed, which resulted in a highly uncertain estimate of the exported amount, presumably an overestimation. All in all the bulk export from Finland is rather small; most of the imported refrigerants are used in Finland.

Mobile air conditioning systems (MACs) is the largest HFC-containing product group – in terms of refrigerant quantity – imported to Finland annually. This quantity (x) is estimated using annual numbers of registered vehicles (passenger cars, vans, trucks and buses) (r), the proportion of vehicles equipped with MACs (p) and a typical refrigerant charge (c) for each type of vehicle (i , 1 = passenger cars, 2 = vans, 3 = truck and 4 = buses)

The number of registrations r is obtained from the Transport Safety Agency (TraFi). The proportion p is based on a survey of vehicle importers. Average charges were obtained from a 1999 survey of Finnish vehicle importers (Oinonen 2000 pp. 26-27). The import of used vehicles has been taken into account in the emission estimates starting from 2007. The number of imported used cars is obtained from TraFi and the proportion of vehicles equipped with MACs is assumed to be the same as in the newly registered vehicles. The total quantity of HFC-134a imported in MACs increased approximately 10% from 2007 to 2008.

Previously, in the case of MACs, the inventory was based on the assumption that the quantity exported was much smaller than the quantity imported and export was treated as negligible. The assumption and its effect to the total emissions were re-evaluated parallel with the 2007 inventory. Passenger car manufacture takes place at one plant in Finland. According to the company 100% of the cars are equipped with air conditioners and 99.9% of the cars are exported. Therefore, the manufacture of cars and their export is now included in the inventory, even though the export is much smaller than the import. The quantity of HFC-134a exported in MACs decreased somewhat from 2007 to 2008.

The effect of car manufacturing and export of MACs as well as import of used vehicles to the calculations of previous years were studied in the 2007 inventory. It was concluded that the total F-gas emissions as CO₂ equivalents would be only slightly (~2%) smaller than the reported figures. The correction would not affect

the base year. These amounts are well included in the uncertainty analysis and therefore the correction of time series was not considered to be essential. In addition, the old data of manufactured and exported MACs contains uncertainties and the correction of time series would not for certain lead to improved emissions estimates.

Refrigerants are also imported and exported in domestic refrigeration and air conditioning equipment, heat pumps, commercial refrigeration equipment and air conditioning units, for example. These quantities are included in the survey and obtained directly from the exporters and importers. In 2008 the quantity of refrigerants imported in equipment other than MACs increased considerably and is over two-fold compared to 2007. The activity of four small importers was imputed due to non response. From the total quantity of 83,479 kg, 1,039 kg is imputed based on the information from previous years. The quantity of refrigerants exported in equipment other than MACs increased 13% compared to 2007, but only about 3% compared to 2006. All of the companies previously exporting relevant amounts of refrigerants in equipment responded in the 2009 survey and no imputation was required.

The data of refrigerants charged into equipment in manufacturing, initial installation or conversion to a new refrigerant are also compiled through the survey. All of the main manufacturers responded and no data imputation was required. In 2008 the total refrigerant quantity consumed in the manufacturing of equipment including MACs was 58,356 kg which is 8% more than in 2007. The installed refrigerant quantities were imputed based on the assumption that non-respondents are a random sample of the respondents. The estimated total installed quantity in 2008 was 163,931 kg. The estimated installed quantity has increased 34% from 2007 and 10% from 2006.

The final piece of information needed to quantify the emissions model is the destructed refrigerant quantities which are also based on the survey. The destructed quantity was imputed, inferred from original reported quantities, based on the assumption that non-respondents are a random sample of all respondents. In addition the total imputed quantity was compared to the information on destructed fluorinated compounds of the only waste treatment company in Finland that treats F-gases. The estimated total quantity of refrigerants destructed in 2008 was 45,958 kg which is 9% more than in 2007.

Table 4.6-6 summarises the refrigerant activity data. Note that all of the used refrigerants are included in the reported quantities, not just those consisting of or containing HFCs or PFCs. Respondents provide actual quantities identified by the refrigerant number or trade name. The known composition of each refrigerant is then used to calculate activity in terms of individual HFC and PFC species. These levels are lower than those tabulated below because some of the consumption consists of HCFC-containing refrigerants and natural refrigerants.

Table 4.6-6 Summary of refrigerant activity data for inventory year 2008.

	Number of reporting companies	Quantity (kg)
Bulk refrigerants imported	9	714 088
Bulk refrigerants exported	2	C
Refrigerants in equipment imported	38	245 014
Refrigerants in equipment exported	24	40 638
Refrigerants used in manufacturing equipment	36	58 356
Refrigerants used in installation and conversion of equipment	205	163 931
Destructed refrigerant	131	45 958

¹Note that the number of reporting companies does not include the companies whose data were imputed or the companies importing, exporting or manufacturing MACs even though the refrigerant quantities include the corresponding estimated amounts.

HFCs from foam blowing (CRF 2.F 2)

The activity data for calculating emissions from foam blowing are presented in Table 4.6-7. The data are obtained from an annual survey of the Finnish companies manufacturing, importing and exporting relevant foam products and raw materials used in foam blowing. In 2009 the response activity was 92% and the missing data 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. This was due to the establishment of a new production plant by the biggest manufacturer in Finland at the beginning of 2004. In 2005 the same manufacturer replaced the HFC-134a blowing agent with CO₂ 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. In 2008 the quantity of HFC-134a used in foam blowing decreased further, but the consumed quantities of HFC-245fa and HFC-365mfc increased considerably. It seems that the manufacturers are switching from the use of HFC-134a to the use of HFC-245fa and HFC-365mfc. The total consumption of HFCs in foam blowing increased from 2007 to 2008 and the emissions from manufacturing increased as well when the additional greenhouse gases are taken into account. The emissions from product use have stayed approximately at the same level since 2004.

Table 4.6-7 Foam blowing activity data for 2008.

Activity	Blowing agents	Number of reporting companies	Quantity (kg)
Imported in bulk or in polyol	HFC-134a, HFC-245fa, HFC-365mfc	5	22 186
Imported in products	HFC-134a, HFC-245fa, HFC-365mfc	0	0
Used in manufacturing	HFC-134a, HFC-245fa, HFC-365mfc	9	22 495
Exported in products	HFC-134a, HFC-245fa, HFC-365mfc	5	1 030

CRF 2.F 4 HFCs from aerosols and metered dose inhalers

The data of 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). The response activity in the 2009 survey was 100%. The consumed, imported and exported quantities are mostly confidential due to the small number of companies active in the subsector.

CRF 2.F 8 SF₆ from electrical equipment

The activity data for the calculation of SF₆ emissions from electrical equipment are obtained from an annual survey of the Finnish companies manufacturing, importing and exporting electrical equipment. In the 2009 survey the response activity in this field of industry was 94%, and all the major companies responded. However, the activity of one non-respondent company still known to be active was imputed based on the information of previous years and one of the received responses was insufficient enough to also require imputation.

CRF 2.F 9 Data grouped due to confidentiality

The activity data for the calculation of emissions from semiconductor manufacturing, refrigeration and air conditioning, fixed fire fighting systems and magnesium die casting are obtained from annual surveys of companies, research institutes and importers of special gases. The response activity was 100% for both the survey of semiconductor manufacturers and the survey of special gas importers. Both of the two companies installing fixed fire fighting systems in Finland were also reached. The reliability of the data for grouped emission sources is therefore considered good.

SF₆ is no longer used in running shoes. The emissions from shoes are considered to have become negligible three years after the sale of SF₆-containing shoes ceased in 2004 and thus there were no emissions from running shoes in 2008. In 2008 a diminutive quantity of SF₆ was still imported and sold to be used in magnesium die casting but this use is expected to terminate as well.

4.6.3 *Uncertainty and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

CRF 2.F 1 HFCs and PFC-218 from refrigeration and air conditioning

The uncertainty of the emission estimates has been quantified using Monte Carlo simulation (the method described in Oinonen 2003, 2004). The same methodology was applied to the 2008 inventory. As a summary, the simulation suggests a 95% confidence interval for the level of emissions from refrigeration and air conditioning equipment in 2008 ranging from 377 to 508 tonnes. A Monte Carlo estimate for the mean of emissions was 443 tonnes and the median of output distribution equals to 442 tonnes.

The simulation results suggest that most of the uncertainty was due to uncertainty of the factor alpha (see Appendix_4). Also, uncertainty of the imported quantities both in products and in bulk have an effect on the output uncertainty.

Uncertainty has been quantified mainly for the most recent estimates and for 1990 when needed in trend analysis. For the years in between, the question regarding homogeneity (time series' consistency) must be addressed. The methodologies have not been the same for the entire time series of emissions from category 2.F 1. In the 1999 inventory (estimates for 1990-1998), a simple dynamical model in combination with the Tier 2 bottom-up emission factor based method was used. The bottom-up method was applied to mobile air conditioning systems (MACs) and domestic refrigeration. Other sources were quantified using the dynamic model (Oinonen 2000). In 2000, as the Good Practice Guidance was published, the recommended Tier 2 top-down sales based method was implemented for other sources of stationary refrigeration and air conditioning. Domestic refrigeration and MACs were still calculated using the bottom-up approach.

In 2001, the recommended top-down method was finally applied to all subcategories of 2.F 1. From then on, the use and refinement of the method has continued. Since the method has changed and evolved, a question of time series' homogeneity arises. This issue was tested and the results showed that although the methods do not give identical results for the two over-lapping years, the estimates are fairly close and probably within the error bounds of both approaches. The emission estimates and the error bounds are presented in Figure 4.6-3 below.

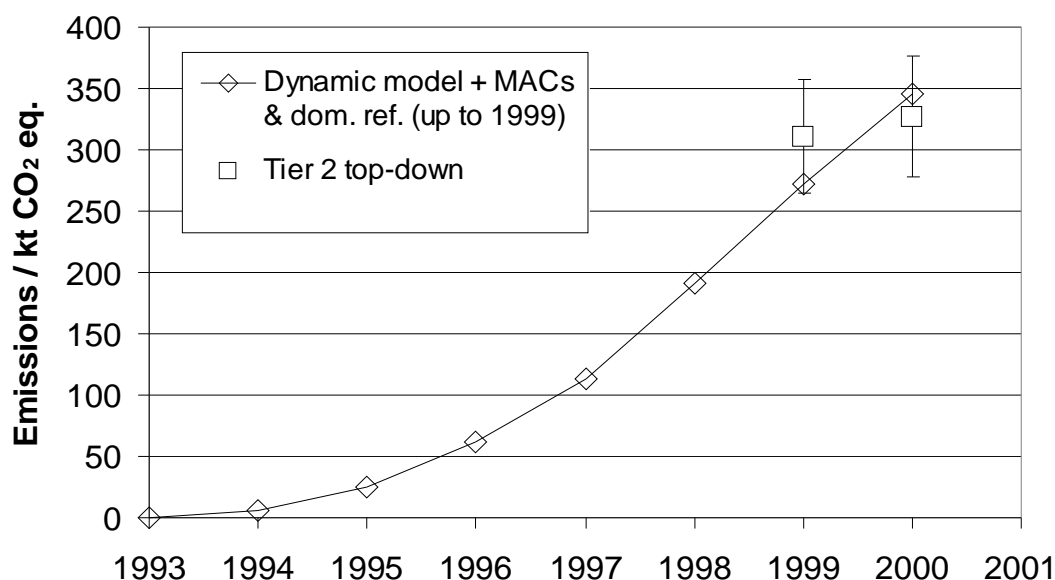


Figure 4.6-3 Emissions calculated with the dynamic model and the Tier 2 top-down method for two overlapping years (1999 and 2000).

The comparison thus suggests that little could be gained by recalculation and that non-homogeneity should not be an issue. The uncertainties of past inventories and historical data are significant. The current time series of emissions, however, should give a reliable overview of how the emissions evolved during the 1990's: a rapid growth during the latter part of the decade and subsequent stabilisation to the current level.

This trend is depicted in Figure 4.6-4 below. At first, the largest deviations of the emission estimates from the trend curve seem to occur in 2001, 2002 and perhaps in 2005, 2006. However, when these deviations are presented in relation to the emission level (Figure 4.6-5), it can be seen that the deviation of these inventory years is comparable with other fluctuations.

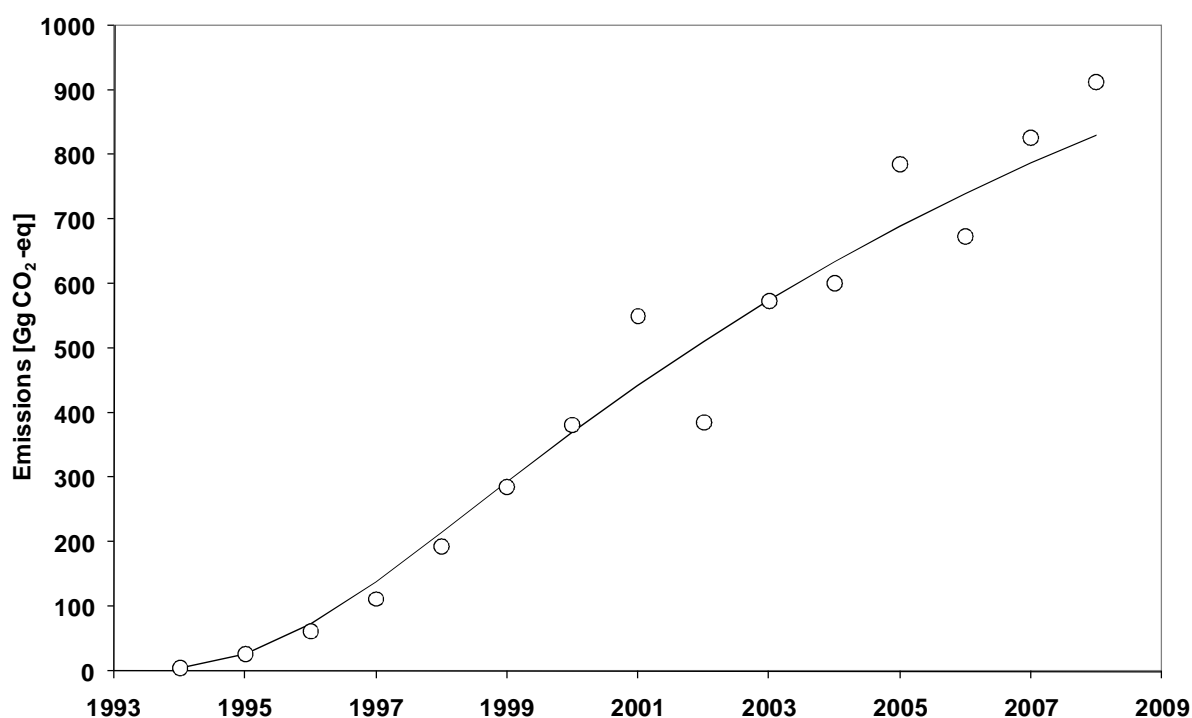


Figure 4.6-4 Emission estimates for category 2.F.1 reported in inventory reports (open circles) and the emission trend curve.

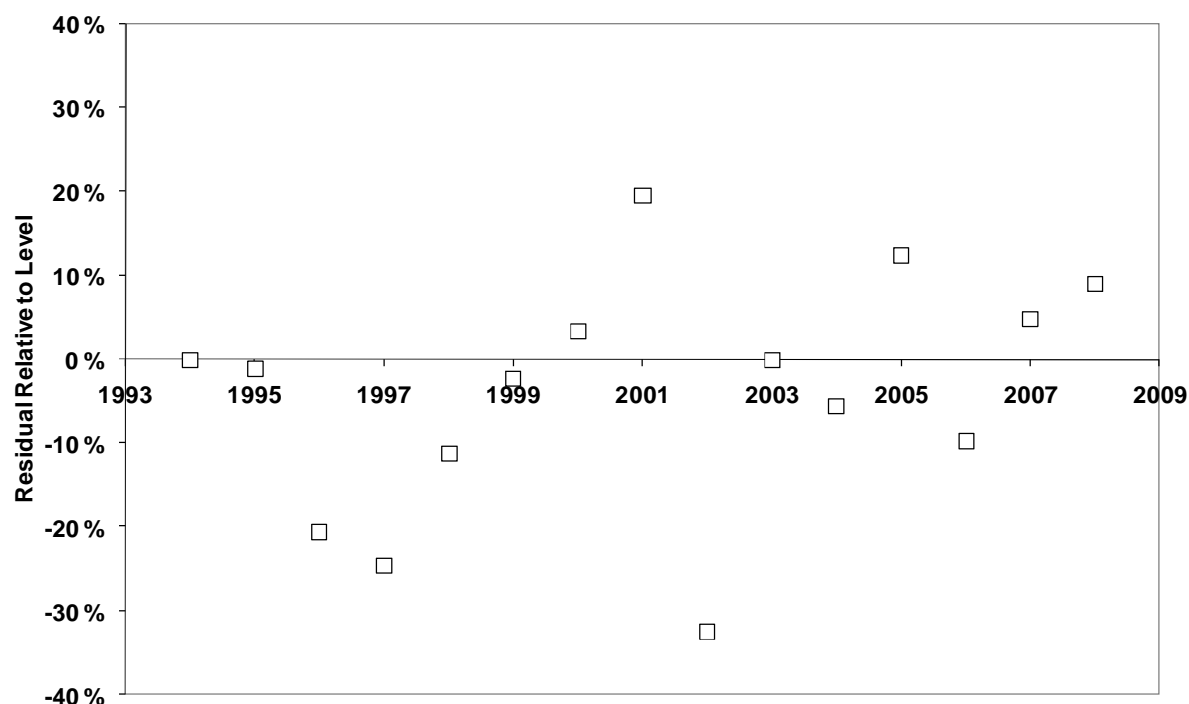


Figure 4.6-5 Deviations of reported emissions relative to the emission level.

Part of the inter-annual fluctuation is due to variation in activity data. In general, the survey response activity has been good (70%...80%) but there is some alternation in the reported data. As indicated in the inventory report submitted in 2004, the explanations for deviations in Tier 2 actual emissions should be sought from the terms *N* (installation of new equipment and conversion of existing equipment) and *M* (equipment manufacture). Moreover, most of the changes are allocated to be caused by the term *N* as it has previously been approximately five-fold to term *M*. The referred calculation method and the Tier 2 equation are described in detail in Appendix 4.

The changes in activity data are correlated to changes in the business activities of the reporting companies. The fluctuation between two following years has been rather high and therefore it has been estimated that not all of these changes are "real." This finding has led to a more detailed analysis of the survey respondents and non-respondents and to the conclusion that some of the inter-annual variation is due to missing data.

Nearly all importers, exporters and manufacturers have provided a survey response in previous years. On that account, the missing data concern mainly installation and service of equipment. This also supports the previous assumption where most of the changes in emission estimates were directed to the term *N*. To arrive at estimates for quantities affected by non-response missing data have to be imputed. Not imputing these quantities would lead to underestimation of installed and destructed refrigerants, which in turn, would lead to overestimated Tier 2 actual emissions.

The procedure used in the non-response analysis and data imputation has been described in detail in Oinonen 2004. Data imputation has also been documented and archived among other material for each inventory year.

CRF 2.F 2 HFCs from foam blowing

Monte Carlo simulation was used to quantify uncertainty of the level of HFC emissions from foam blowing. The results of the simulation of HFC-134a emissions in 2008 suggest an emission level of 6.6 tonnes with a give-or-take of about 5.9 tonnes (given as a 95% confidence interval). Correlation analysis of the simulation results suggests that most of the uncertainty is due to uncertainty of the emission factors for the use of foam in appliances and the use of XPS. The respective simulation results indicate an emission level of 1.1 tonnes with a give-or-take of about 0.5 tonnes for HFC-245fa emissions and 0.6 tonnes with a give-or-take of about

0.2 tonnes for HFC-365mfc emissions in 2008. Most of the uncertainty of HFC-245fa emissions is due to uncertainty of the emission factors for the manufacturing and use of appliance foams and most of the uncertainty of HFC-365mfc emissions due to uncertainty of the emission factors for the manufacturing and use of sandwich panels.

The previous inter-annual fluctuation of the foam blowing time series is caused by the changes in activity data. The changes are explained in Section 4.6.2.3 above. From 2005 onwards the emissions have stayed quite steady.

CRF 2.F 4 HFCs from aerosols and metered dose inhalers

For the year 2008 Tier 2 actual emissions from aerosols and MDIs totalled 80 tonnes. As this category is much simpler, in terms of the number of uncertain input parameters and the shape of their distributions, the uncertainty of emissions was quantified using Gaussian approximation. The uncertainty model can be expressed with the following equation:

$$\text{Var}[x] \approx (1 - f)^2 \text{Var}[a] + f^2 \text{Var}[b] + (b - a)^2 \text{Var}[f],$$

where $f = 0.5$, a = Tier 1b potential emission in 2007 in Mg and b = Tier 1b potential emission in 2008 in Mg, and $\text{Var}[x]$ denotes variance of x . Values used for the variances were $\text{Var}[f] = 0.02^2$, $\text{Var}[a] = \text{Var}[b] = 5^2 \text{ Mg}^2$.

Substituting values into the previous equation yield:

$$\begin{aligned} \text{Var}[x] &\approx (1 - 0.5)^2 \times 5^2 \text{ Mg}^2 + (0.5)^2 \times 5^2 \text{ Mg}^2 + (59.093 \text{ Mg} - 100.334 \text{ Mg})^2 \times 0.02^2 \\ \text{Var}[x] &\approx 13.18 \text{ Mg}^2 \end{aligned}$$

The Good Practice Guidance recommends that uncertainties be expressed as two times the standard deviation. The uncertainty is thus $2 \times (13.18 \text{ Mg}^2)^{1/2} \approx 7 \text{ Mg}$ and the emission estimate (80 ± 7) tonnes.

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 CO₂ equivalents, because of the great difference in their GWPs. For example in 2008 the total CO₂ equivalent emissions from aerosols and MDIs increased slightly from 2007, while the emissions in tonnes actually decreased somewhat.

CRF 2.F 8 SF₆ from electrical equipment

A new method Tier 3c was adopted in the 2003 inventory to calculate SF₆ emissions from electrical equipment. This method is based on a more detailed data survey and it has yielded results more similar to those of the Finnish electrical equipment industry than the previously used Tier 2 model. The industry's own annual estimate of SF₆ emissions had been approximately 0.2 Mg. The differences in previous inventories (prior to 2003) were analysed and discussed with the industry.

However, for the last three inventory years the previously developed detailed Tier 3c mass-balance model has unrealistically resulted in negative emission estimates over several successive years of data (see Section 4.6.2.1). In the 2008 inventory the country-level mass-balance model was simplified by leaving out the terms involving amounts of gas banked in manufacturers' and importers' stocks. In order to compensate for the stock changes in reality and to avoid unrealistic annual variation, the emission estimates are calculated over five successive years of data. A detailed account of the approach is given in Appendix_4. The time series was recalculated with the new method from 2003 to 2007, the years for which the Tier 3c method has been in use. The data of inventory years prior to 2003 is not detailed enough for the Tier 3c method and the recalculation would not result in improved emission estimates.

For the year 2008 the new Tier 3c model emission estimate was 0.58 tonnes. The uncertainty of the emission estimate was studied with a scenario tree analysis. The start values of 0.580 tonnes, 0.435 tonnes and 0.725 tonnes for the Tier 3c emission estimate were used to produce low, normal and high emission scenarios. Giving a median of 0.60 tonnes, the scenario tree analysis suggests that the value calculated with the Tier 3c model is a representative estimate.

In addition there is uncertainty especially in the quantity of disposed equipment and emission generated during decommissioning. In the scenario tree analysis low, normal and high rates for disposal emissions were also assumed. Using the upper limit for equipment use and a low rate for disposal the analysis suggests that the emissions from electrical equipment were not more than approximately ten tonnes in 2008.

The Tier 3c emission estimates are higher than the Finnish Electrical Equipment Industry's emission estimates (0.12 tonnes in 2008). The survey and emission estimate of the industry does not cover emissions from manufacturing or service work by subcontractors. However, the recalculated time series of the recent years does seem slightly overestimated compared to the industry's estimate and manufactured quantities.

The time series has been recalculated once before (the recalculation was applied to the 1990-2001 time series). The details are documented in Oinonen (2003). The recalculation was made because a new method was adopted. The new method incorporated the assumption that there are emissions from disposal, which led to an approximate doubling of the level of emissions.

CRF 2.F 9 data grouped due to confidentiality

Uncertainty for the category of grouped data was quantified using Monte Carlo simulation. The result is a give-or-take of about 0.2 Mg for the actual emissions mean value 5.99 Mg.

There is a discontinuity in the time series for grouped data. This is mainly due to phasing-out of halons in fixed fire suppression systems and their substitution with an extinguishant that is a mixture of HFC-125, HFC-134a and CO₂. First this led to the growth of HFC emissions and gas banks in this category. When the halons had been mostly replaced in the existing systems, the installing activity and imported quantities of HFCs for this purpose decreased leading to lower emission estimates. The actual emissions from fire suppression systems occur when the system is discharged in case of fire or accidentally and there is an element of chance affecting the annual emission level as well.

In addition to the substitution of ODS in fire fighting systems, there have been changes in the trends of shoe sales, semi-conductor manufacturing and magnesium die casting. Use of SF₆ in shoes and magnesium die casting was first growing at the beginning of the 2000's and later on the activities declined. Finally, SF₆ was phased out in shoes in 2004 and the emissions from this source are estimated to have ended in 2007. Some use in magnesium die casting was still reported in 2008 but this activity is also expected to cease.

Generally, there is a growing trend in the use of PFCs in semiconductor manufacturing processes but in Finland the gas consumption amount of used gases has remained fairly steady in the previous years. It was assessed earlier that the PFC emissions from semiconductor manufacture might start to increase in Finland, too. However, from 2003 to 2006 the PFC emissions stayed approximately at the same level and in 2007 the emissions declined due to one manufacturers phasing out of the market. In 2008 the PFC emissions decreased slightly more. The recent development of HFC-23 emissions from semiconductor manufacturing is similar to that of PFCs. The SF₆ emissions from semiconductor manufacturing, however, have been fluctuating annually for the last couple of years due to variation of the consumed quantities. After a peak in 2006 the emissions declined in 2007 almost to the level of 2004 and 2005, but increased again closer to the peak level of 2006 in 2008.

All in all the substantial increase in emissions of grouped emission sources in 2008 is induced by an increase in the total emissions from all the remaining emission sources included in the category, apart from HFC-23 from refrigeration and air conditioning equipment. There are several trends that simultaneously affect emissions from this category and it is difficult to estimate how the category level emission trend will develop in the future.

4.6.4 Source-specific QA/QC and verification

The quality objectives and general QA/QC procedures described in Section 1.6 are implemented in the F-gases sector. The 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 documentation and archiving of the F-gases category is detailed in Section 1.6.7.

In the 2008 inventory the planned improvements of the previous inventory year were carried out. The questionnaire and instructions of the web-based data collection system for the refrigeration and air conditioning sector were improved based on the feedback from the previous year's respondents. The improvements seem to be successful, since no relevant feedback considering the form or its use was received in the 2009 survey. Also, the Tier 3c model of electrical equipment was re-evaluated and modified for the 2008 inventory and the time series corrected accordingly, even though the methodology and activity data of the sub sector still needs further examination.

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 cross-checked simultaneously. In the 2008 inventory QC checks minor errors in the movement of inventory data among processing steps were detected and corrected.

The source category specific (Tier 2) QC procedures for F-gases include emission and activity data comparisons as well as uncertainty estimates. The results for each sub source category are compared with those obtained using a simpler model; i.e. actual emissions (T2 and T3) are compared with potential emissions (T1). The Tier 3c actual emissions from electrical equipment are also compared with the results given by the Tier 2 model used in 2001 and 2002.

The emission trends are graphed and explained for all sources and the emission estimates compared with corresponding estimates by industry when available. The emissions of SF₆ from electrical equipment seem slightly overestimated compared with the industry's estimates. The implementation of a hybrid approach (IPCC 2006 Guidelines) was considered as one solution, but the current activity data is not suitable for such models and the issue requires further examination.

The quality of activity data for each year is checked by comparing the data with the corresponding data of the three previous years. If unrealistic changes are noted the correctness of the data is checked with the survey respondent. Where secondary data sources are used it is checked that the data source is reliable. The data of electrical equipment are compared to the data collected via the industry's own survey. In the refrigeration and air conditioning sector the data of destructed refrigerant quantities are collected from two sources; via a direct survey for the servicing companies and from a hazardous waste treatment company. These data are compared together and both data are utilised in the emission calculation. Additional data on the quantities of refrigerants used in regular servicing is also compiled through the survey and compared with the data used in the calculations.

Uncertainty estimates are quantified for all of the source categories and the underlying assumptions documented. Importance analysis is used to elucidate the factors that have significant bearing on the uncertainty of each category. The results are described in Section 4.6.3 above.

4.6.5 Source-specific recalculations

CRF 2.F 2 HFCs from foam blowing

The time series of HFC-134a emissions from foam blowing was recalculated from 2000 to 2007. The recalculation is due to changes in the calculation model. The Tier 2 model was improved to better assess the changes of the amount of gas banked in foam products and its effect on the emission level. The model is detailed in Appendix 4. The recalculation affects the estimates of actual emissions from foam products and the estimated amount of gas stocked in products. The equation of actual emissions from manufacturing has not been changed, but the reported estimates were checked and the estimates of 2002 and 2005 slightly corrected. The improved model gives exactly the same result for the total HFC-134a emissions from foam blowing in 1999 as the reported estimate of 1999. The activity data does not support recalculation of the years prior to 1999.

The recalculation resulted in an increase of 0.4-2.6% for the total HFC-134a emissions from foam blowing in 2002-2007. The reported estimates of emissions from stock for 2000 and 2001 had been calculated incorrectly and the new estimates are respectively approximately 11% and 17% lower than the previously reported ones. Therefore the recalculation improves time series' consistency. The estimated amount of gas banked in foams decreased 2-3% in the earlier years of the recalculation. The decreasing effect of previous

gas releases gets stronger by the end of the time series and the change in the 2007 estimate is about 8%, while the total HFC-134a bank starts reducing.

The emissions of additional greenhouse gases HFC-245fa and HFC-365mfc from foam blowing are estimated to have started in 2007. The estimated emissions for 2007 were reported retrospectively in the 2008 inventory.

CRF 2.F 8 SF₆ from electrical equipment

The time series of SF₆ emissions from electrical equipment was recalculated from 2003 to 2007 due to modification of the Tier 3c model. The background and reasons for the modification are explained in the Sections above and a detailed account of the new approach is given in Appendix 4. The data of inventory years prior to 2003 is not detailed enough for the Tier 3c method and the recalculation would not have resulted in improved emission estimates.

The recalculation increased the emission estimates substantially apart from the 2006 estimate which is roughly at the previously reported level. The recalculated estimate of 2005 is over five-fold to the old estimate. However, the previously reported estimate of 0.16 tonnes for 2005 was lower than the industry's emission estimate, which does not include emissions from manufacturing, and therefore clearly an underestimation. The level of emissions from electrical equipment is small and even though the changes are of a great magnitude compared to the previously reported estimates, the quantified change at its highest is only 0.56 tonnes. The emission trend of the recent years is still slightly decreasing.

4.6.6 Source-specific planned improvements

The recalculated Tier 3c emission estimates for SF₆ from electrical equipment are higher than the Finnish Electrical Equipment Industry's emission estimates (0.12 tonnes in 2008). Even though the survey and emission estimate of the industry does not cover emissions from manufacturing or service work by subcontractors, the recalculated time series of the recent years does seem slightly overestimated compared to the industry's estimate and manufactured quantities. The implementation of a hybrid approach (IPCC 2006 Guidelines) has been considered as a potential solution, but the current activity data is not suitable for such models. The development of a hybrid model and the required changes in data compilation need further examination. In Finland the level of SF₆ emissions from electrical equipment is very low, but the potential of a hybrid approach should be evaluated in the future.

Appendix_4

The models used in calculating emissions from category CRF 2.F

HFCs and PFC-218 from refrigeration and air conditioning (CRF 2.F 1)

Potential emissions are equal to the amount of chemical consumed in the country minus the amount of chemical recovered for destruction or exported in the year of consideration. Potential emission calculations are regarded as the basic methodology for HFC and PFC emission estimates (Tier 1).

Tier 1a potential emissions are given by

$$X_{1a} = I_c - E_c - D,$$

where I_c = a vector of imported bulk quantities
 E_c = a vector of exported bulk quantities
 D = a vector of destructed quantities.

Tier 1b potential emissions are given by

$$X_{1b} = I_c + I_p - E_c - E_p - D,$$

where I_c = a vector of imported bulk quantities
 I_p = a vector of quantities imported in products
 E_c = a vector of exported bulk quantities
 E_p = a vector of quantities exported in products
 D = a vector of destructed quantities.

Estimates expressed in Gg CO₂-equivalent are obtained as a scalar product of X_{1a} and X_{1b} with G (a vector consisting of GWP values for each species).

Actual emissions are given by

$$X_2 = X_{1b} - (N + M + I_p - E_p) \alpha,$$

where T_{1b} = a vector of Tier 1b potential emissions
 N = a vector of quantities used in installing new equipment and converting existing equipment to a new refrigerant
 M = a vector of quantities used in manufacturing equipment
 I_p = a vector of quantities imported in products
 E_p = a vector of quantities exported in products
 α = a scalar to account for disposal emissions, given by

$$\alpha = 1 - \frac{1}{(1 + g)^L},$$

where g = annual growth of Tier 1a potential emissions, and
 L = average equipment lifetime.

For average lifetime, a value of 10 years is assumed, consistent with the previous inventories (Oinonen 2004). A value for g is calculated based on observed changes in Tier 1a potential emissions. A geometric mean of annual growth in Tier 1a emissions between 1994 and 2008 yields a value of 19.1%. Substituting these values in the above equation yields

$$\alpha = 1 - \frac{1}{(1 + 0.191)^{10}} \approx 0.826.$$

SF₆ from electrical equipment (CRF 2.F 8)

Because destruction of SF₆ does not take place in Finland, potential emissions of SF₆ from electrical equipment are calculated by

$$X_{1a} = I_c - E_c,$$

where I_c = import in bulk
 E_c = export in bulk

and

$$X_{1b} = I_c + I_p - E_c - E_p,$$

where I_c = import in bulk
 I_p = import in products
 E_c = export in bulk
 E_p = export in products.

The Tier 3c emissions model used for actual emissions is based on the Good Practice Guidance (2000) (eq. 3.15 p. 3.56).

$$\text{Emissions} = \text{Annual sales} - (\text{Net Increase in Nameplate Capacity}) - (\text{SF}_6 \text{ Destroyed})$$

To simplify the equation the changes of manufacturers' and importers' stocks are not taken into account and thus *Annual Sales* is assumed to be equal to X_{1b} , while *SF₆ Destroyed* is equal to zero. The *Net Increase in Nameplate Capacity* consists of the nameplate capacity of new equipment filled in factories and new equipment filled after installation subtracted by the nameplate capacity of retiring equipment. Therefore

$$X_{3c} = X_{1b} - (N + M + I_p - E_p - R)$$

where X_{1b} = annual sales assuming no stock changes
 N = nameplate capacity of equipment filled in installation
 M = nameplate capacity of equipment filled in manufacturing
 I_p = import in products
 E_p = export in products
 R = nameplate capacity of retiring equipment

To compensate for the stock changes taking place in reality, the annual estimates of actual emissions are calculated over five years of data.

HFCs from foam blowing (CRF 2.F 2)

Actual emissions of HFCs used as foam blowing agents for closed-cell foams are calculated using the Tier 2 model described in the Good Practice Guidance (2000) (pp. 3.93-3.97)

$$AE_{t,i} = f_{M,i} M_{t,i} + f_{B,i} C_{t,i} + R_{t,i} - D_{t,i}$$

where

$AE_{t,i}$ = HFC blowing agent (actual) emissions from foam type i in year t ,
 $M_{t,i}$ = amount of HFC used in manufacturing foam type i in year t ,
 $f_{M,i}$ = first-year loss emission factor for foam type i (note that the emission factor is assumed time-independent),
 $C_{t,i}$ = original HFC blowing agent charge of foam type i between year t and $t-n$,
 $f_{B,i}$ = annual loss emission factor for the foam type i ,
 $R_{t,i}$ = decommissioning losses of foam type i in year t , and
 $D_{t,i}$ = the amount of HFC blowing agent destroyed in year t (recovered from foams of type i).

In Finland retiring foam products are usually re-used as frost insulation or land filled without gas recovery. Therefore the emissions are assumed to continue at the same rate as in the original use-phase until all of the blowing agent has been emitted. Thus it is assumed that

$$R_{t,i} = 0$$

$$D_{t,i} = 0$$

n = the time in which the entire HFC charge of the given foam type has been released (note that this is not equal to the initial product lifetime).

$C_{t,i}$ is calculated by

$$C_{t,i} = \sum M_{t,i}(1 - f_{M,i}) - \sum Ep_{t,i} + \sum Ip_{t,i}$$

where $\sum M_{t,i}$ = sum of HFC used in manufacturing foam type i between years t and $t-n$
 $\sum Ep_{t,i}$ = sum of HFC exported in products of foam type i between years t and $t-n$,
 $\sum Ip_{t,i}$ = sum of HFC imported in products of foam type i between years t and $t-n$.

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 is estimated separately by

$$B_{t,i} = B_{t-1,i} + M_{t,i} + Ip_{t,i} - Ep_{t,i} - AE_{t,i}$$

where $B_{t-1,i}$ = amount of HFC blowing agent banked in foam type i in year $t-1$,
 $Ip_{t,i}$ = HFC import in products of foam type i in year t ,
 $Ep_{t,i}$ = HFC export in products of foam type i in year t

The total HFC blowing agent banked in foam products is a sum of the HFC banked in different foam types i .

HFC blowing agent emissions from open-celled foams are calculated using the Tier 2 Equation 3.37 described in the Good Practice Guidance (2000) (pp. 3.93). The annual emissions are equal to the annual amount of HFC blowing agent used in manufacturing.

HFCs from aerosols and metered dose inhalers (CRF 2.F 4)

The emissions model used is from the Good Practice Guidance (2000) (eq. 3.35 p. 3.85)

$$x = (1 - f)a + fb, \quad (1)$$

where $f = 0.5$,
 a = Tier 1b potential emission in 2007, and
 b = Tier 1b potential emission in 2008.

f is dimensionless, a and b have dimensions of mass. Note that the Good Practice Guidance talks about quantities of HFC and PFC contained in aerosol products sold each year.

The equation above thus assumes that consumption – as defined by Tier 1b potential emissions – equals sales of aerosol products to Finland.

Potential emissions were calculated by

$$X_{1a} = I_c, \text{ and} \quad (2)$$

$$X_{1b} = I_c + I_p - E_p. \quad (3)$$

where I denotes imports and E exports.

Both are vectors consisting of quantities of HFC-134a and HFC-152a. Subscripts *c* and *p* are used for bulk imports (imports in containers) and imports and exports in products (aerosols), respectively. Production of HFC propellants used in aerosols, bulk exports, as well as destruction, are all equal to zero ("not occurring" in the UNFCCC terminology), which is why they do not appear in (2) and (3).

Equation (3) defines a and b of Equation (1) as sums of the elements of X_{1b} calculated for 2007 and 2008, respectively.

Since all variables of (2) and (3) are vectors with two elements (quantities of HFC-134a and HFC-152a) expressed in mass units, CO₂-equivalent emissions are obtained by calculating the scalar product of X_{1a} and X_{1b} with vector G, which contains the GWP values:

$$X_{1a,eq} = X_{1a}G, \quad (4)$$

$$X_{1b,eq} = X_{1b}G, \quad (5)$$

where $G = [1300 \ 140]$.

5 SOLVENT AND OTHER PRODUCT USE (CRF 3)

5.1 Overview of the sector

5.1.1 Description

Solvent and other product use contribute a small amount to greenhouse gas emissions in Finland. Share of total emissions was 0.1% in 2008. The only direct greenhouse gas source in the solvent and other product use is the use of N₂O in industrial, medical and other applications reported under CRF category 3.D (Other). In Finland, N₂O is used in hospitals and by dentists to relieve pain and for detoxification.

Under CRF categories 3.A (Paint application), 3.B (Degreasing and dry cleaning), 3.C (Chemical products, manufacture and processing) and 3.D (Other) Finland reports indirect greenhouse gas emissions (NMVOCs) and also indirect CO₂ emissions from NMVOC emissions. CRF category 3.A includes NMVOC emissions arising from the use of paints in industry and households. CRF category 3.B includes emissions from degreasing in the metal and electronics industries and dry-cleaners. Under CRF category 3.C Finland reports NMVOC emissions from the pharmaceutical, leather, plastic, textile industries, rubber conversion and manufacture of paints. The activities reported under CRF category 3.D (Other) causing NMVOC emissions are the printing industry, preservation of wood, use of pesticides, glass and mineral wool enduction, domestic solvent use and fat and oil extraction in the Finnish inventory. General assessment of completeness could be found in Section 1.8 and more detailed assessment is included in Annex 5.

The compiling of NMVOC emission data from the solvent and other product use sector is performed at the Finnish Environment Institute (SYKE). The NMVOC inventory is carried out to meet the obligations of the United Nations Economic Commission for Europe's Convention on Long-Range Transboundary Air Pollution (UNECE CLRTAP).

5.1.2 Quantitative overview

Indirect CO₂ emissions were the most important greenhouse gas emissions from solvent and other product use in the Finnish inventory in 2008. Quantity of N₂O emissions as CO₂ equivalent from the use of N₂O was less than half of the indirect CO₂ emissions in this sector (Table 5.1-1).

NMVOC emissions from the solvent and other product use accounted for 21% of the total NMVOC emissions of Finland.

There is a decrease in the trend in CRF 3 Emissions from Solvent and other product use (Figure 5.1-1). N₂O emissions from CRF category 3 have been almost the same during the 1990's, but concurrently NMVOC emissions have decreased by 55%. Two major categories where decreasing of NMVOC emissions have occurred are paint application and printing industry. The decrease on NMVOC emissions is due the changes on use of low-NMVOC products during 1990's. In the beginning of 1990's the market-share of waterborne and low-NMVOC products in paint products rapidly were grown. Typical product types where changes occurred were indoor paints and road marking paints. It has been estimated that NMVOC emissions from these paints reduced 20-50%. At the same time the sale of thinners for paint products also decreased. Also in printing industry in the beginning of 1990's processes were improved and new abatement technologies as well as substitution and recovery of the NMVOC containing substances took place.

5.1.3 Key categories

There are no key categories in sector CRF 3 in the Finnish inventory.

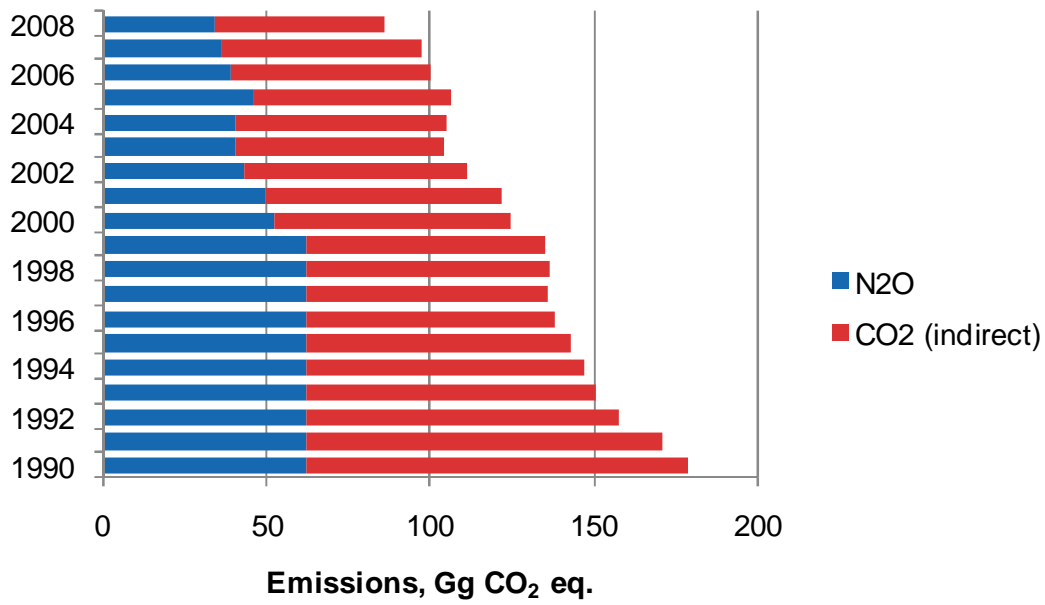


Figure 5.1-1 Trend in GHG emissions from solvents and other product use in 1990-2008 (Gg CO₂ eq.)

Table 5.1-1 N₂O, indirect CO₂ and NMVOC emissions in 1990-2008 reported under the category Solvent and other product use (Gg).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
N ₂ O																			
Use of N ₂ O in industrial, medical and other applications	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.17	0.16	0.14	0.13	0.13	0.15	0.13	0.12	0.11
CO ₂ (indirect)																			
From NMVOC emissions	116	109	96	88	85	81	76	74	74	73	72	72	68	64	65	60	61	61	52
NMVOC																			
Paint application	28	26	22	21	20	19	18	18	18	18	18	17	16	15	15	14	15	14	13
Degreasing and dry cleaning	2.6	2.3	2.1	1.8	1.7	1.5	1.3	1.3	1.3	1.2	1.2	0.7	1.0	1.0	0.8	0.9	0.8	0.6	0.6
Chemical products, manufacture and processing	4.3	4.2	3.6	3.9	3.9	4.4	3.4	3.3	3.4	3.2	2.9	3.8	4.2	3.2	3.9	3.3	3.5	3.7	2.8
Other	18.5	16.8	15.8	14.0	12.8	11.8	11.9	10.9	11.1	10.9	10.8	11.4	9.7	10.3	10.2	9.0	8.8	8.9	7.6
Total emissions* (Gg CO ₂ eq.)	178	171	158	150	147	143	138	136	136	135	125	122	111	104	105	106	100	97	86

5.2 Paint application (CRF 3.A), Degreasing and dry cleaning (CRF 3.B) and Chemical products, manufacture and processing (CRF 3.C)

5.2.1 Source category description

No N₂O emissions occur in these source categories, only indirect CO₂ emissions are calculated from NMVOC emissions (Table 5.2-1).

Table 5.2-1 Reported emissions under these subcategories in the Finnish inventory.

CRF	Source	Emissions reported
3.A	Paint application	NMVOC, CO ₂
3.B	Degreasing and dry cleaning	NMVOC, CO ₂
3.C	Chemical products, manufacture and processing	NMVOC, CO ₂

Paint application is the biggest source of NMVOC emissions of this sector. Emissions have been calculated from the use of paint and varnish in industry and households. Most Finnish paint producers or importers are members of the Association of Finnish Paint Industry and the use of paint is calculated in the Association using amount and solvent content of sold paint and varnish. The rest of emissions from use of paint and varnish have been estimated using a questionnaire sent to non-members of this association and emission data from the VAHTI system (detailed information in Annex 2). Detailed data of these calculations are included in the report to the UNECE: Air pollutant emissions in Finland 1990-2008, Informative Inventory Report (Finnish Environment Institute, 2010)

Degreasing and dry cleaning is a minor source of NMVOCs. Chlorinated organic solvents are used in the metal and electronics industries to clean surfaces of different components and in dry cleaners and emissions are based on import statistics of pure chlorinated solvents, amount of products containing chlorinated organic solvents and amounts of solvent waste processed in the hazardous waste treatment plant.

The NMVOC emissions are also emitted from the use of solvents in different industrial processes. In Finland there are these kinds of processes in the pharmaceutical industry, leather industry, plastic industry, textile industry, rubber conversion and manufacture of paints and inks. The emissions are foremost from the emission data of the VAHTI system. Questionnaires are also sent to companies in the textile, plastic and paint industry in which they report either the amount of used solvent or the emissions of their production processes.

5.2.2 Methodological issues

Indirect CO₂ emissions from solvents and other product use have been calculated from NMVOC emissions for the time series 1990-2008. Indirect CO₂ emissions were calculated using the equation below. It was assumed that the average carbon content is 60% by mass for all categories under the sector of solvents and other products use according to the 2006 IPCC Guidelines. As described in the Guidelines, the used fossil carbon content fraction of NMVOC is based on limited published national analyses of speciation profile.

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

5.2.3 *Uncertainty and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

The latest uncertainty analysis for NMVOC has been carried out for the 2007 emissions and reported to the UNECE CLRTAP Secretariat March 2009. Since, according to the reporting obligation under the CLRTAP, the uncertainty analysis is required only in every five years the analysis will be performed for the 2011 submission. The uncertainties for 2008 are estimated to be approximately at the same level as in 2007. The documentation of the 2007 uncertainty analysis is available in the Finnish Informative Inventory Report (IIR) under the CLRTAP. The Finnish IIRs are published on the website www.environment.fi > State of the environment > Air > Air pollutant emissions in Finland (in English). According to the analysis the uncertainty for the 2007 NMVOC emissions was estimated at -25% to +25%.

Due the diversity of the calculation the uncertainty in this subcategory is quit high. For example the uncertainty of data from VAHTI system is $\pm 100\%$. Monitoring of NMVOC emissions is not very often included in the emissions monitoring programmes of the plants and therefore the methods used by the plant operators to estimate their NMVOC emissions are not always known. The uncertainty of used emission factors is from -100% to +200%.

5.2.4 *Source-specific QA/QC and verification*

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6.

In the calculation of indirect CO₂ emissions from solvent and other product use there have been performed several general inventory quality control procedures as mentioned in IPCC GPG, table 8.1. The calculated emissions have been compared with previous emissions of the subcategory. Part of the activity data is site-specific and reported due to monitoring of environmental permit of a company or for statistics and part of activity data are totals from statistics or answers to questionnaires. All activity data have been checked using as many independent sources as possible.

5.2.5 *Source-specific recalculations*

No source-specific recalculations have been done.

5.2.6 *Source-specific planned improvements*

No source-specific improvement has been planned.

5.3 Other (CRF 3.D)

5.3.1 Source category description

The N₂O emissions in this category are from the medical use of N₂O. In 2008 these emissions totalled 34.1 Gg CO₂ eq. The activities causing NMVOC and therefore indirect CO₂ emissions under this category are the printing industry, preservation of wood, use of pesticides, glass and mineral wool enduction, domestic solvent use and fat and oil extraction (Table 5.3-1).

Table 5.3-1 Reported emissions under the subcategory Other in the Finnish inventory.

CRF	Source	Emissions reported
3.D 1	Use of N ₂ O in anaesthesia	N ₂ O
3.D 2	Fire extinguishers	IE (3.D 1)
3.D 3	N ₂ O from aerosol cans	IE (3.D 1)
3.D 4	Other use of N ₂ O	IE (3.D 1)
3.D 5	Other	NMVOC, CO ₂
	- Wood preservation	
	- Printing Industry	
	- Use of pesticides	
	- Glass wool induction	
	- Mineral wool induction	
	- Domestic solvent use	
	- Fat edible and non-edible oil extraction	

5.3.2 Use of N₂O

5.3.2.1 Methods

The N₂O emissions are calculated by Statistics Finland. The country-specific calculation method is consistent with a Tier 2 method. In the estimation of the N₂O emissions sales data are obtained from the companies delivering N₂O for medical use and other applications in Finland. For the years 1990 to 1999 the emissions have been assumed constant based on activity data obtained for the years 1990 and 1998. Since 2000 annual and more precise data have been received from the companies. The emission estimation is based on the assumption that all used N₂O is emitted to the atmosphere in the same year it is produced or imported to Finland. A very small part of emissions is estimated due to non-response.

5.3.2.2 Activity data

For the estimation of N₂O emissions production or importation data are obtained from companies for the years 1990, 1998 and all years starting from 2000. In 2008 one company reported that they have continued to export and that has been also taken into account in the calculations.

5.3.2.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

The uncertainty of emissions from N₂O use in 2008 was estimated at -34% to +39%.

5.3.2.4 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6.

5.3.2.5 Source-specific recalculations

No recalculations have been made since the last inventory submission.

5.3.2.6 Source-specific planned improvements

No source-specific improvements are under consideration at the moment.

5.3.3 Indirect CO₂ emissions from NMVOC emissions

5.3.3.1 Methods

NMVOC emissions are based on the emission data of the VAHTI system (detailed information in Annex 2), a questionnaire to presses and oil mills that do not report their emissions to the VAHTI system, activity data from the Finnish Environment Institute's Chemical Division database and the Finnish Food Safety Authority (EVIRA, 2008) and emission calculation of the Finnish Cosmetics, Toiletry and Detergents Association. Detailed data of these calculations are included in the report to the UNECE: Air pollutant emissions in Finland 1990-2007, Informative Inventory Report (Finnish Environment Institute, 2009).

Indirect CO₂ emissions from this category have been calculated from NMVOC emissions for the time series 1990-2008. Indirect CO₂ emissions were calculated using the equation below. It was assumed that the average carbon content is 60% by mass for all categories under the sector of solvents and other products use according to the 2006 IPCC Guidelines. As described in the Guidelines, the used fossil carbon content fraction of NMVOC is based on limited published national analyses of speciation profile.

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

5.3.3.2 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

The latest uncertainty analysis for NMVOC has been carried out for the 2007 emissions and reported to the UNECE CLRTAP Secretariat March 2009. Since, according to the reporting obligation under the CLRTAP, the uncertainty analysis is required only in every five years the analysis will be performed for the 2011 submission. The uncertainties for 2008 are estimated to be approximately at the same level as in 2007. The documentation of the 2007 uncertainty analysis is available in the Finnish Informative Inventory Report (IIR) under the CLRTAP. The Finnish IIRs are published on the website <http://www.environment.fi> > State of the environment > Air > Air pollutant emissions in Finland (In English). According to the analysis the uncertainty for the 2007 NMVOC emissions was estimated at -25% to +25%.

Due the diversity of the calculation the uncertainty in this subcategory is quit high. For example the uncertainty of data from VAHTI is ±100%. Monitoring of NMVOC emissions is not very often included in the emissions monitoring programmes of the plants and therefore the methods used by the plant operators to estimate their NMVOC emissions are not always known. The uncertainty of used emission factors is from -100% to +200%.

5.3.3.3 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6.

In the calculation of CO₂ emissions from solvent and other product use there have been performed several general inventory quality control procedures as mentioned in IPCC GPG, table 8.1. The calculated emissions have been compared with previous emissions of the subcategory. Part of the activity data is site-specific and reported due to monitoring of environmental permit of a company or for statistics and part of activity data are totals from statistics or answers to questionnaires. All activity data have been checked using as many independent sources as possible.

5.3.3.4 Source-specific recalculations

No recalculations have been made since the last inventory submission.

5.3.3.5 Source-specific planned improvements

No source-specific improvements are under consideration at the moment.

6 AGRICULTURE (CRF 4)

6.1 Overview of the sector

6.1.1 Description and quantitative overview

Finland's agricultural greenhouse gas emissions reported in the agriculture sector in 2008 were 5.8 Tg CO₂ equivalents in total. Agriculture is the third largest greenhouse gas emission source sector after the energy sector and industrial processes sector with an 8% share of the total greenhouse gas emissions in 2008 (Figure 6.1-1).

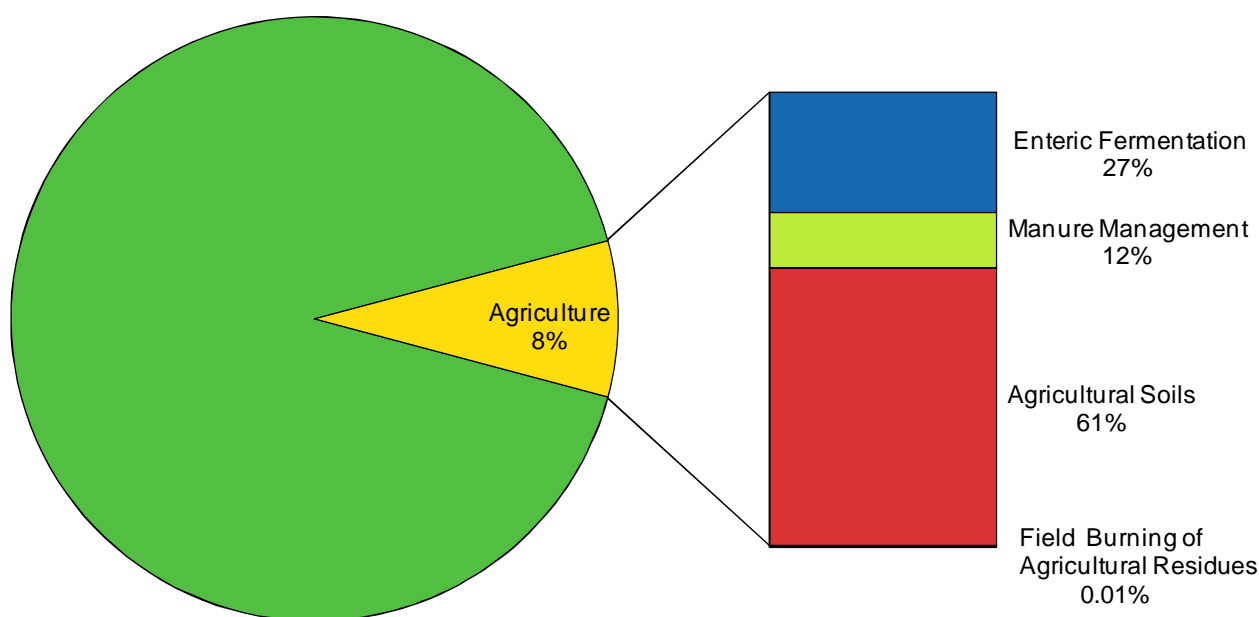


Figure 6.1-1 Agricultural emissions from the total greenhouse gas emissions in 2008.

Agricultural greenhouse gas emissions in Finland consist of methane emissions from enteric fermentation of domestic livestock and methane and nitrous oxide emissions from manure management as well as direct and indirect nitrous oxide emissions from agricultural soils and burning of agricultural residues. Direct nitrous oxide emissions from agricultural soils include emissions from synthetic fertilisers, manure applied to soils, biological nitrogen fixation of N-fixing crops, crop residues, sewage sludge application and cultivation of organic soils. Indirect nitrous oxide emission sources include emissions from atmospheric deposition and from nitrogen leaching and run-off to watercourses. Indirect emissions are estimated also for manure management. Nitrogen flow in agriculture is presented in Figure 6.1-4. The methane emissions from enteric fermentation were 27%, methane emissions from manure management 5%, nitrous oxide emissions from manure management 7.2% and nitrous oxide emissions from agricultural soils 61% of the total agricultural emissions. The emissions from burning of agricultural residues are less than 0.1% altogether. Rice is not cultivated in Finland and savannas do not exist in Finland. A general assessment of completeness can be found in Section 1.8 and more detailed assessment is included in Annex 5.

Emissions in the Agriculture sector have decreased by about 12% over the period 1990-2008 (Figure 6.1 2). One reason for this is Finland's membership in the EU that has resulted in changes in the economic structure followed by an increase in the average farm size (Farm Register 2008) and reduction in the livestock numbers except in the numbers of horses and swine that have increased in the recent years. The reduced use of nitrogen fertilisers and improved manure management resulting from the measures taken by the farmers as part of an agri-environmental programme aiming to minimise nutrient loading to water courses has also decreased the emissions in the Agriculture sector. For example, the use of mineral fertilisers has decreased 29% during the inventory period.

Some inter-annual variation between the years can be noticed from the time series (Table 6.1-1). This is mainly caused by fluctuation in activity data between the years due to changes in animal numbers. Changes in animal numbers are largely affected by agricultural policy and subsidies. Especially methane and nitrous oxide emissions from manure management are affected by the fluctuation in animal numbers as well as the proportion of manure managed in different manure management systems which vary depending on animal species. Nitrous oxide emissions from agricultural soils are affected by the amount of synthetic fertilisers sold annually, animal numbers and crop yields of cultivated crops, for example, which may have large variation between the years.

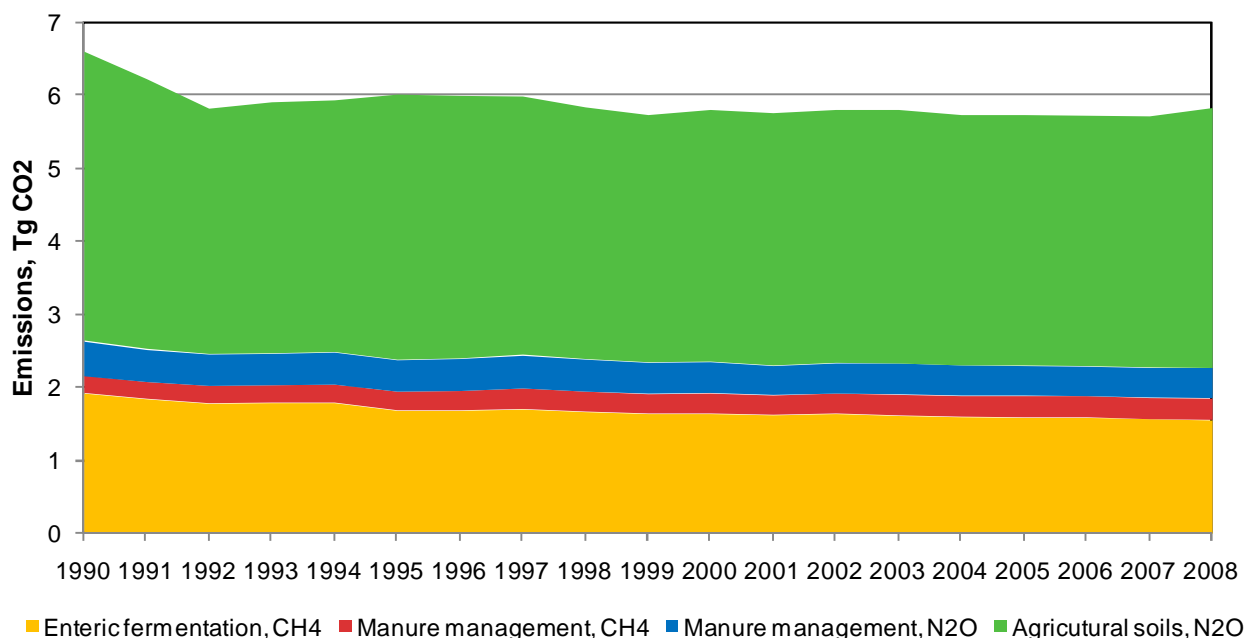


Figure 6.1-2 Trend in agricultural emissions by source category in 1990-2008 (Tg CO₂ eq.).

Carbon dioxide emissions from agricultural soils including CO₂ emissions from liming are reported in the Land use, Land-use change and Forestry (LULUCF) sector (Chapter 7) under Cropland and Grassland categories. Emissions from energy use of agriculture (e.g. fuel combustion, heating of buildings, etc.) are calculated and reported in the reporting sector Energy (Chapter 3) and are not included in the emissions reported in the Agriculture sector (Figure 6.1-3). Emissions from the energy use of agriculture were 1.3 Tg CO₂ eq. in 2008 and agricultural emissions reported in the Land Use, Land Use Change and Forestry sector 5.3 Tg CO₂ eq. in 2008 (reported in the LULUCF sector). When all agricultural emission sources from different reporting sectors (Energy, LULUCF and Agriculture) are taken into account, the share of agricultural emissions from the total emissions in 2008 was 18% (12.5 Tg CO₂).

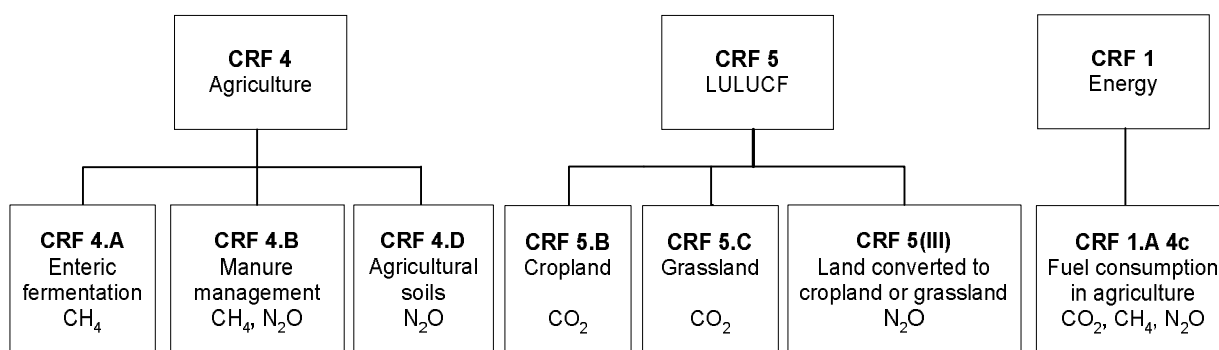


Figure 6.1-3 Emissions from agricultural sources and their reporting categories in the national greenhouse gas inventory. LULUCF=land use, land-use change and forestry.

Table 6.1-1 Finland's agricultural greenhouse gas emissions from sector Agriculture by source and gas in 1990-2008.

	Enteric fermentation	Manure management		Agricultural soils	Total CH ₄ emissions*	Total N ₂ O emissions*	Burning of agricultural residues	Total emissions
	Gg CH ₄	Gg CH ₄	Gg N ₂ O	Gg N ₂ O	Gg CH ₄	Gg N ₂ O	Gg CO ₂ eq. CH ₄ , N ₂ O	Gg CO ₂ eq. CH ₄ , N ₂ O
1990	91.4	11.0	1.6	12.8	102.4	14.4	2.4	6 616
1991	87.8	10.7	1.5	12.0	98.5	13.4	0.2	6 228
1992	84.9	10.8	1.4	10.9	95.7	12.3	0.2	5 823
1993	85.0	11.2	1.4	11.1	96.2	12.6	0.5	5 913
1994	85.0	11.6	1.5	11.1	96.7	12.6	0.2	5 941
1995	80.1	12.0	1.4	11.7	92.0	13.2	0.4	6 017
1996	80.3	12.1	1.5	11.7	92.4	13.1	0.7	6 007
1997	81.3	12.9	1.5	11.4	94.1	12.9	0.4	5 991
1998	79.3	12.6	1.5	11.2	92.0	12.6	0.3	5 848
1999	78.1	12.4	1.4	10.9	90.5	12.4	0.2	5 737
2000	78.3	12.7	1.4	11.2	91.0	12.6	1.0	5 809
2001	77.3	12.3	1.3	11.2	89.6	12.5	0.5	5 770
2002	78.0	12.8	1.4	11.2	90.8	12.6	0.7	5 814
2003	77.1	13.2	1.4	11.2	90.3	12.6	0.6	5 810
2004	76.2	13.1	1.4	11.1	89.4	12.5	0.5	5 741
2005	75.7	13.5	1.4	11.1	89.2	12.5	0.3	5 743
2006	75.7	13.5	1.3	11.1	89.1	12.5	0.4	5 733
2007	74.7	13.5	1.3	11.1	88.2	12.5	0.8	5 722
2008	74.1	13.7	1.4	11.5	87.8	12.9	0.7	5 834

* includes burning of residues

Key categories

The key categories in agriculture in 2008 are summarised in Table 6.1-2.

Table 6.1-2 Key categories in Agriculture (CRF 4) in 2008 (quantitative method used: Tier 2).

IPCC source category	Gas	Identification criteria
4.A. Enteric fermentation	CH ₄	L, T
4.B. Manure management	CH ₄	L, T
4.D. Agricultural soils: indirect emissions	N ₂ O	L, T
4.D. Agricultural soils: direct emissions, animal production and sludge spreading	N ₂ O	L, T

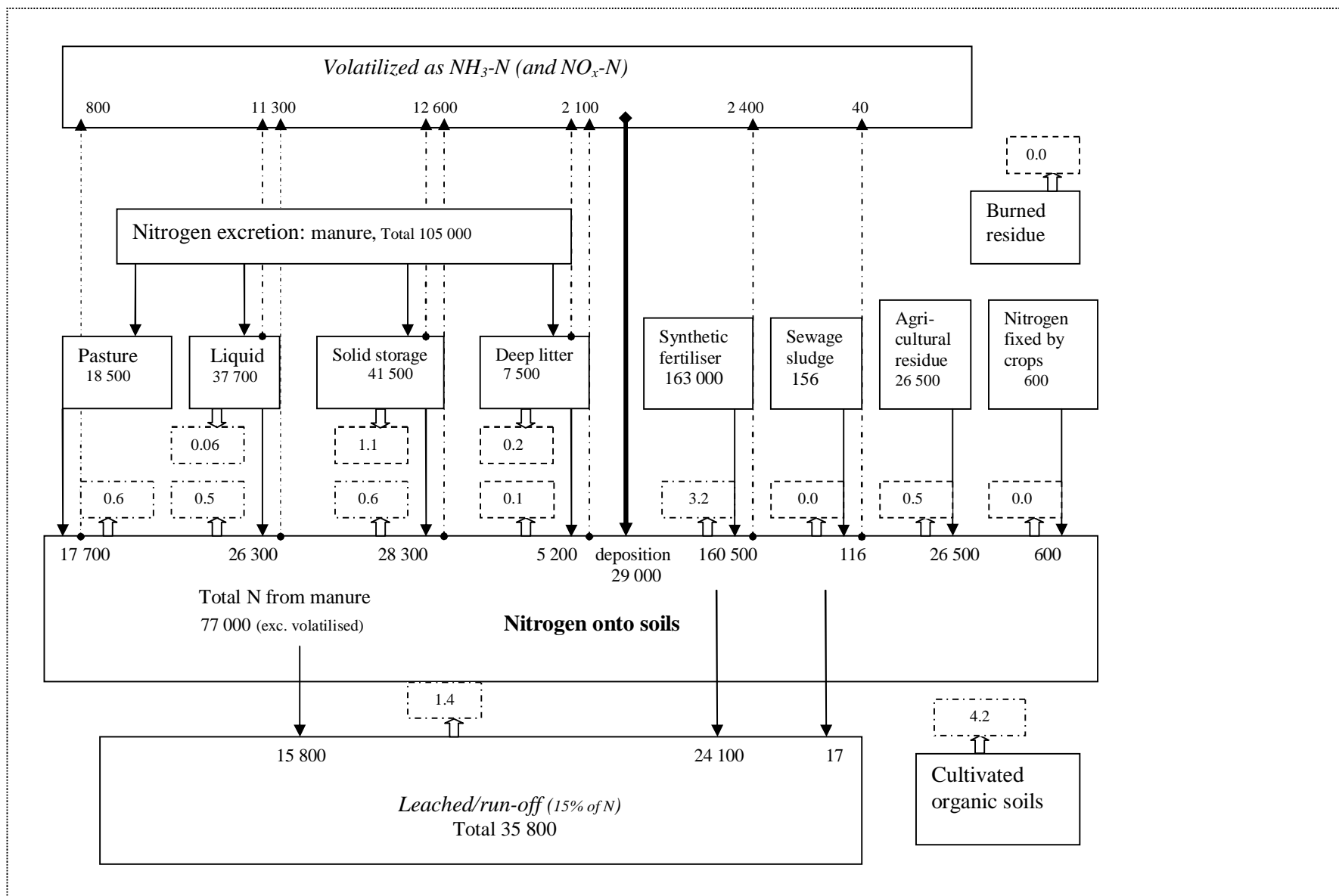


Figure 6.1-4 Nitrogen Flow in Agriculture 2008 (Bulk arrows stand for nitrous oxide emissions, thin arrows for nitrogen flow and broken arrows mean nitrogen volatilization during application on soil. Nitrogen amounts are in Mg/year and emissions (fragmental line) in Gg/year (rounded values)).

6.2 Enteric Fermentation (CRF 4.A)

6.2.1 Source category description

Methane emissions from enteric fermentation of domestic livestock comprised 27% of total agricultural emissions in Finland, being 1.6 Tg CO₂ equivalents in 2008.

This source category includes emissions from cattle (dairy cows, suckler cows, bulls, heifers and calves), horses, pigs, sheep, goats and reindeer and fur animals. Emissions from poultry are not estimated since a default method for the estimation of these emissions is lacking (see Table 6.2-1).

Table 6.2-1 Reported emissions under the subcategory Enteric Fermentation in the Finnish inventory.

CRF	Source	Emissions reported
4.A 1	Cattle	
	Dairy Cattle	CH ₄
	Non-Dairy Cattle	IE (4.A 10)
4.A 2	Buffalo	NO
4.A 3	Sheep	CH ₄
4.A 4	Goats	CH ₄
4.A 5	Camels and Llamas	NO
4.A 6	Horses	CH ₄
4.A 7	Mules and Asses	NO
4.A 8	Swine	CH ₄
4.A 9	Poultry	NE
4.A 10	Other	
	- Reindeers	CH ₄
	- Heifers	CH ₄
	- Bulls	CH ₄
	- Calves	CH ₄
	- Fur farming	CH ₄
	- Cows	CH ₄
	- Ponies	CH ₄

Methane emissions from enteric fermentation are produced as a by-product of the normal livestock digestive process. Feed consumed by the animal is fermented by the microbes in the animal's digestive system. This process is called enteric fermentation. Methane that is produced is exhaled by the animal (Gibbs et al. 2002). The most important animal group producing methane is ruminants (e.g. cattle and sheep) but other animals may also be significant emission sources if their number is large (Pipatti 1994).

Emissions have decreased by 19% since 1990 especially due to the decreasing number of cattle (Table 6.2-2). The number of dairy cattle, for example, declined from 490,000 in 1990 to 289,281 in 2008 (Table 6.2-2).

Table 6.2-2 Methane emissions (Gg) from enteric fermentation in 1990-2008 by animal type.

Year	Cattle					Other livestock							Total
	DC	SC	B	H	C	Sw	Sh	G	Ho	P	F	R	
1990	48.2	0.9	8.3	11.2	14.8	1.4	0.7	0.0	0.7	0.1	0.3	4.8	91.4
1991	44.1	1.3	8.2	11.0	14.8	1.4	0.7	0.0	0.8	0.1	0.3	5.2	87.8
1992	42.2	1.8	8.1	10.8	14.1	1.3	0.7	0.0	0.8	0.1	0.3	4.6	84.9
1993	42.7	2.1	7.8	11.3	13.5	1.3	0.8	0.0	0.8	0.1	0.3	4.3	85.0
1994	42.7	2.1	8.2	11.2	13.2	1.3	0.8	0.0	0.8	0.1	0.3	4.3	85.0
1995	41.2	1.9	6.2	9.9	13.1	1.4	1.1	0.0	0.8	0.1	0.4	4.1	80.1
1996	40.6	2.0	6.6	10.5	12.6	1.4	1.0	0.0	0.8	0.1	0.4	4.2	80.3
1997	41.4	2.1	6.8	10.3	12.6	1.5	1.0	0.0	0.9	0.1	0.4	4.0	81.3
1998	40.7	2.0	6.5	10.0	12.5	1.5	0.9	0.0	0.9	0.1	0.4	3.9	79.3
1999	40.3	1.9	6.7	9.9	11.9	1.4	0.7	0.0	0.9	0.1	0.4	3.9	78.1
2000	40.9	1.8	6.6	9.9	11.6	1.3	0.7	0.0	0.9	0.1	0.3	4.0	78.3
2001	40.6	1.8	6.5	9.8	11.6	1.3	0.7	0.0	0.9	0.1	0.3	3.7	77.3
2002	40.5	1.9	6.9	9.8	11.5	1.3	0.7	0.0	0.9	0.1	0.3	4.0	78.0
2003	39.6	1.9	7.0	9.8	11.3	1.4	0.7	0.0	1.0	0.1	0.4	3.9	77.1
2004	39.1	2.1	6.8	9.6	11.0	1.4	0.8	0.0	1.0	0.1	0.4	4.0	76.2
2005	38.6	2.3	6.6	9.4	10.9	1.4	0.7	0.0	1.0	0.1	0.4	4.1	75.7
2006	38.0	2.6	7.0	9.5	10.6	1.4	1.0	0.0	1.0	0.1	0.3	3.9	75.7
2007	37.0	2.9	6.9	9.4	10.5	1.5	1.0	0.0	1.1	0.2	0.3	3.8	74.7
2008	36.2	3.3	6.8	9.3	10.3	1.5	1.0	0.0	1.1	0.2	0.3	3.9	74.1
Share of total (%) in 2008	48.9	4.4	9.2	12.6	14.0	2.1	1.4	0.0	1.5	0.2	0.5	5.2	100.0

DC=Dairy cows, SC=Suckler cows, B=Bulls, H=Heifers, C=Calves, Sw=Swine, Sh=Sheep, G=Goats, Ho=Horses, P=Ponies, F=Fur animals, R=Reindeer, Poultry not estimated.

6.2.2 Methodological issues

Methods

Emissions from enteric fermentation of domestic livestock have been calculated by using the IPCC Tier 1 and Tier 2 methodologies presented in the Revised IPCC Guidelines (IPCC 1997) and the IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC 2000).

Methane emissions from enteric fermentation for horses, swine 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. The total emission is the sum of emissions from each category (IPCC 2000, Eq. 4.12 and Eq. 4.13, see Appendix_6 at the end of Chapter 6). The emissions from fur animals were calculated by multiplying the number of fur animals (minks, fitches, foxes, racoons) with an emission factor used in the inventory of Norway. The contribution of emissions from horses, swine, goats and fur animals to the total emissions from enteric fermentation is not significant.

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 IPCC (1997) and IPCC (2000). The Tier 2 method has been used for cattle, since emissions from cattle have been recognised as a key source in the Finnish inventory. Methane emissions from enteric fermentation of reindeer have been calculated by estimating the 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_6.

Activity data

Animal numbers are presented in Table 6.2-3.

The number of *cattle, sheep, swine, poultry and goats* was received from the Matilda database maintained by the Information Centre of the Ministry of Agriculture and Forestry (<http://www.agriculturalstatistics.fi/en/>) as well as from the Yearbook of Farm Statistics published annually by the Ministry of Agriculture and Forestry. The number of animals describes the number of animals on 1 May till year 2003. After that statistics have changed slightly and now the numbers describe animal numbers on 1 April (poultry, swine), 1 May (cattle) and 1 June (goats and sheep). The animal group of swine is divided into four subgroups and piglets are no more counted separately as they belong to a group “sows with piglets”.

The number of *horses* (number on 31 December) was received from the Finnish Trotting and Breeding Association (Suomen Hippos, <http://www.hippos.fi/hippos/englanti/>).

The number of *fur animals* was obtained from the Finnish Fur Breeders' Association and it describes the number of pelts produced annually. (<http://www.stkl-fpf.fi/>)

The number of *reindeer* was taken from the Yearbook of Farm Statistics and it describes the number of counted reindeer left alive during the reindeer herding year.

Emission factors and other parameters

IPCC default emission factors were used for calculating methane emissions from enteric fermentation of swine, goats and horses (Tier 1 method). Swine is divided into subgroups for manure management, but as there is only one (general) default EF for swine, subgroups were not used in calculating enteric fermentation emissions. For fur animals the Norwegian emission factor was used (0.1 kg/animal/a). The emission factor was derived by scaling the default emission factor of swine based on comparison between the average weights of swine and fur animals. Swine was assumed to be similar to fur animals with regard to digestive system and feeding. National emission factors for cattle were calculated with the Tier 2 method for cattle by using IPCC equations. The cattle category has been divided into the following subcategories: dairy cows, suckler cows, bulls, heifers and calves, for which separate emission factors have been calculated. 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 GE for dairy cows has changed from the value 250 in 1990 to 318 in 2008 resulting in a change in the emission factor being 98.3 in 1990 and 125.2 kg CH₄/animal/a in 2008 (Figure 6.2-1).

Table 6.2-3 Animal numbers in Finland in 1990-2008 (x 1 000).

Year	Cattle ¹	Dairy cows	Suckler cows	Bulls	Heifers	Calves	Horses ²	Ponies	Sheep
1990	1 360	490	14	149	219	488	39.4	6.0	103
1991	1 310	446	21	144	214	486	41.7	6.4	107
1992	1 273	428	28	143	211	463	42.7	6.4	108
1993	1 252	426	33	139	217	437	42.7	6.3	120
1994	1 233	417	33	144	215	425	42.1	6.2	121
1995	1 148	399	29	109	189	422	43.7	6.2	159
1996	1 146	392	31	115	201	407	45.6	6.4	150
1997	1 142	391	32	121	197	402	47.9	6.8	150
1998	1 117	383	31	115	190	398	49.2	6.9	128
1999	1 087	372	30	118	188	379	49.6	6.6	107
2000	1 057	364	28	115	185	365	50.7	6.7	100
2001	1 037	355	27	111	182	362	51.9	6.7	96
2002	1 025	348	28	115	180	354	52.1	7.0	96
2003	1 000	334	28	116	179	344	52.9	7.3	98
2004	969	324	31	111	173	330	53.8	7.3	109
2005	959	319	35	108	169	329	56.1	7.7	90
2006	949	309	39	113	171	318	58.1	8.0	117
2007	927	296	43	110	167	311	59.5	8.5	119
2008	915	289	48	109	165	305	60.6	8.8	122.2

Year	Goats	Swine ³	Sows with piglets	Fattening pigs (50- kg)	Boars	Veaned pigs (20-50 kg)	Poultry ⁴	Reindeer	Fur animals ⁵
1990	5.9	936	179	438	5.9	313	9 663	239	3 283
1991	5.4	911	174	426	5.8	305	8 929	260	2 597
1992	4.8	879	168	411	5.6	294	9 356	232	2 849
1993	4.8	862	165	403	5.5	289	9 639	215	2 880
1994	5.7	879	168	411	5.6	294	9 906	214	3 284
1995	6.0	925	161	451	6.5	306	10 358	208	3 749
1996	6.5	940	180	445	6.6	309	9 935	213	4 145
1997	8.0	1 029	185	470	7.1	367	10 827	203	4 322
1998	8.1	972	187	421	7.8	357	11 050	196	3 968
1999	7.9	914	180	431	5.8	297	11 034	195	3 705
2000	8.6	884	184	405	6.0	289	12 570	203	3 361
2001	7.4	852	164	391	5.4	292	10 554	186	2 943
2002	6.6	878	172	405	5.3	296	10 734	200	3 410
2003	6.8	924	178	444	5.0	297	10 997	197	3 583
2004	7.3	912	175	441	4.7	291	10 405	201	3 530
2005	6.9	950	177	460	4.4	309	10 538	207	3 786
2006	6.7	959	171	457	4.0	327	10 239	198	3 448
2007	6.2	1 020	175	497	4.1	345	9 791	193	3 481
2008	5.9	1 031	169	504	3.9	354	10 522	195	3 481**

¹ Includes dairy cows, suckler cows, bulls (>1 year), heifers and calves (<1 year). The number presented describes the numbers on 1 May (Source: Yearbook of Farm Statistics).

² Source: Finnish Trotting and Breeding Association (Suomen Hippos).

³ 1990-1994: Distribution of swine into classes is estimated according to average distribution in 1995-2005

⁴ 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.

⁵ Includes minks, fitches, foxes and racoons (number of pelts produced annually).

* The number of goats was not available for the year 1991, and the average of numbers for the years 1990 and 1992 was used.

** estimate

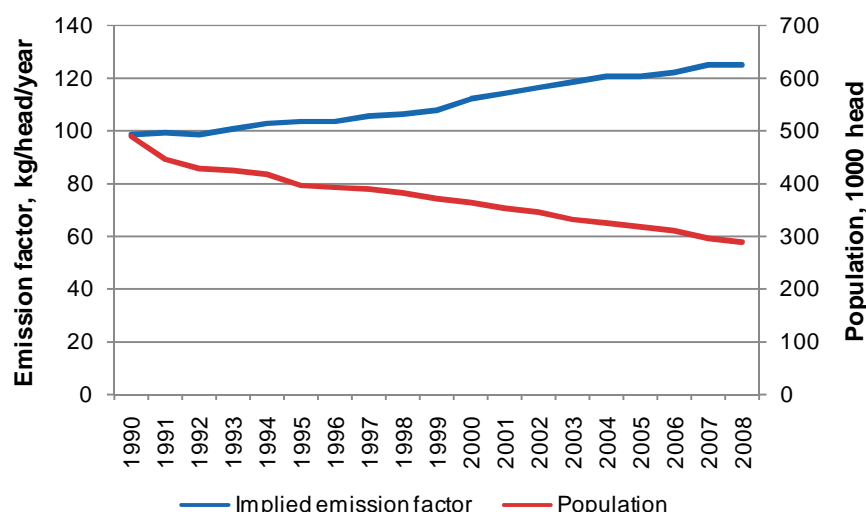


Figure 6.2-1 Development of emission factor and population of dairy cows, 1990-2008.

The IPCC gives no default emission factor for reindeer, thus it has been calculated by using the national methodology for estimating gross energy intake of reindeer on the basis of their forage. The same equation has been used for sheep, too.

The equations used for calculating emission factors are presented in the Appendix_6. (Source: Nousiainen, J. pers.comm. MTT Agrifood Research Finland; MTT 2004). Emission factors for methane emissions from enteric fermentation are presented in Table 6.2-4. Emission factors for cattle are updated annually. EFs for other animal groups will be updated if more national data become available.

Table 6.2-4 Emission factors for each animal category in 2008 used for calculating methane emissions from enteric fermentation.

Animal type	Emission factor (kg CH ₄ / animal/a)	EF type	Method for calculating EF
Dairy cow	125.24	National	IPCC, Tier 2
Suckler cow	68.23	National	IPCC, Tier 2
Bull	63.05	National	IPCC, Tier 2
Heifer	56.66	National	IPCC, Tier 2
Calf	33.96	National	IPCC, Tier 2
Reindeer	19.9	National	National
Swine	1.5	IPCC default	IPCC, Tier 1
Sheep	8.4	National	National
Goat	5.0	IPCC default	IPCC, Tier 1
Horse	18.0	IPCC default	IPCC, Tier 1
Fur animals	0.1	Modified IPCC default*	IPCC, Tier 1

*see 'Emission factors and other parameters'

Additional information needed for calculating emission factors for each cattle species includes animal weight, average daily weight gain, milk production per dairy cow and suckler cow, digestible energy of forage and length of pasture season (for this see chapter 6.3.2.1). This information has been received from the Association of Rural Advisory Centres (ProAgria) and experts of MTT Agrifood Research Finland (Huhtanen, P. & Nousiainen, J. pers.comm.).

Cattle weights and mature weights of dairy cow, suckler cow and bull are presented in Table 6.2-5 (Source: Nousiainen, J. pers.comm., MTT Agrifood Research Finland). The amount of milk produced per dairy cow and the fat content of milk are given in Table 6.2-6. Data on milk production (l/animal/a) have been obtained from the Yearbook of Farm Statistics (2006). 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 1990-2008, being 1,620 kg/a (Source: Nousiainen, J., MTT Agrifood Research Finland). Average daily weight gain for cattle was estimated to remain constant in 1990-2008, being 0 for dairy cow

and suckler cow, 1.1 for bull, 0.7 for heifer and 0.85 kg for calf. (Source: Huhtanen, P., MTT Agrifood Research Finland)).

Table 6.2-5 Cattle live weights and mature weights in 1990-2008 (Source: MTT Agrifood Research Finland).

Year	Dairy cow		Suckler cow		Bull (>1 a)		Heifer	Calf (<1 year)
	Live weight (kg)	Mature weight (kg)	Live weight (kg)	Mature weight (kg)	Live weight (kg)	Mature weight (kg)	Live weight (kg)	Live weight (kg)
1990	520	540	585	596	442	815	351	187
1991	520	542	591	602	454	819	354	189
1992	515	538	596	608	451	816	353	188
1993	531	556	601	613	454	842	363	194
1994	535	561	607	619	463	851	368	196
1995	533	559	612	624	460	848	366	195
1996	535	561	618	630	466	853	368	197
1997	545	571	623	636	463	867	373	200
1998	547	575	629	641	460	872	375	200
1999	552	580	634	647	464	880	378	202
2000	569	596	640	652	474	903	387	207
2001	577	605	645	658	487	916	394	211
2002	585	613	651	663	508	927	403	215
2003	594	623	652	664	525	941	410	219
2004	605	634	675	684	538	959	417	224
2005	607	636	668	680	537	962	418	224
2006	613	642	674	687	547	972	424	227
2007	624	654	674	687	560	988	431	231
2008	628	658	684	698	563	997	436	234

Table 6.2-6 Data of milk properties used for calculating methane emissions from enteric fermentation in 1990-2008.

Year	Fat content of milk ¹⁾ (%)	Milk production/ dairy cow ²⁾ (kg/a)
1990	4.35	5 713
1991	4.35	5 788
1992	4.34	5 781
1993	4.38	5 817
1994	4.35	6 045
1995	4.34	6 161
1996	4.33	6 173
1997	4.32	6 368
1998	4.31	6 412
1999	4.24	6 636
2000	4.23	6 990
2001	4.23	7 140
2002	4.22	7 331
2003	4.24	7 469
2004	4.23	7 626
2005	4.16	7 330
2006	4.16	7 875
2007	4.18	8 030
2008	4.21	8 000

¹ Source: Publication of the Ministry of Agriculture and Forestry (Tietokappi). Assumed to be the same for dairy cows and suckler cows.

² Source: Yearbook of Farm Statistics 2008 (Coefficient 1.03 used to express l/animal/a as kg/animal/a).

6.2.3 *Uncertainty and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

Uncertainty in methane emissions from enteric fermentation of domestic livestock were estimated at -20% to +30% in 2007. 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 $\pm 3\%$), 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 ($\pm 10\%$). In the calculation of uncertainty in emissions from enteric fermentation of other species than cattle, IPCC default uncertainties for emission factors were used excluding reindeer, for which the national emission factor has been used.

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 and milk production for each animal 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. The most important parameters affecting the uncertainty were percentage of digestible energy (DE) and net energy used for maintenance (NE_m).

For other species than cattle the IPCC default uncertainty of $\pm 50\%$ is used for the EF, except for reindeer, for which uncertainty was estimated larger.

Monte Carlo simulation has been used to combine the uncertainties of each calculation parameter in order to get the total uncertainty of the source category. A detailed description of the uncertainty analysis has been presented in Monni & Syri (2003), Monni (2004) and Monni et al. (2007).

As there are no changes in the calculation methods during 1990-2007, 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. This may cause some inconsistency in the time series. This uncertainty in animal numbers is included in the uncertainty analysis of the source category.

6.2.4 *Source-specific QA/QC and verification*

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6.

General (Tier 1) Quality Control (QC) procedures applied to the category Enteric fermentation (CRF 4.A):

The QA/QC plan for the agricultural sector includes the QC measures based on the IPCC GPG (IPCC 2000, Table 8.1, p. 8.8-8.9). These measures are implemented every year during the agricultural inventory. If errors or inconsistencies are found they are documented and corrected. The QC checklist is used during the inventory. While the calculation sheet was partly changed as Nitrogen flow model was integrated, an effort was made to make the whole sheet more well-defined and user friendly. This should reduce the possibility of calculation errors in the future. More graphs were added to the calculation sheet and EFs and most of other parameters were centralised to one worksheet so that they are easier to check (and update when necessary). In order to improve the accuracy of the report, one worksheet was made for the tables used in the National inventory report. These tables are linked to the calculations so that values automatically update when e.g. activity data changes. Tables are then copied to the annual report. A check sheet for CRF tables is in preparation.

Tier 2 QC for activity data:

A checklist is used for ensuring consistency of the activity data in different sections of the agricultural inventory.

Tier 2 QC for emission factors:

It is checked annually if new data for updating emission factors has been published. New national data is compared with the emission factors used in the inventory and the applicability of current emission factors in Finland's circumstances is evaluated. There was no new data available for this inventory for updating the emission factors.

The agricultural inventory has been reviewed several times by the UNFCCC Expert Review Teams, and improvements to the inventory have been made according to the suggestions. No specific verification process has been implemented for the agricultural inventory. However, a case-study between Finland and Germany was arranged in August 2004 where Finland's agricultural inventory was reviewed by the German experts. The purpose of the case-study was to find potential adjustments case and to test specific methods to calculate adjustments. The experiences of this exercise have been taken into account in the development of the inventory. The inventory was audited by Statistics Finland in autumn 2009 and it focused especially on recalculations. The results of the audit will help to further improve the inventory.

6.2.5 Source-specific recalculations

Animal numbers were harmonized with the Nitrogen mass flow model used by Finnish Environment Institute which caused some changes. For cattle, sheep, goats and horses more precise (less rounded) numbers were used than previously. Horses are now divided to horses and ponies (same EF). Number of swine declined as piglets are no longer in their own group, piglets now belong to a group "sows with piglets". Some poultry numbers were updated. Number of fur animals changed as the calculation of numbers changed, e.g. the year 1990/1991 animal number now relates to the year 1990 and not 1991. This is logical as the number of fur animals is based on pelts and culling is done in autumn. GE of cattle changed slightly because of changes in NEa as the length of pasture time was updated. Cattle weights and mature weights were updated. All these changes resulted in change in the emission time series (Table 6.2-7). Now the year 1990 value is slightly smaller than previously and the year 2007 value is slightly higher.

Table 6.2-7. Changes in calculation

Animal numbers	More precise values (less rounded): cattle, sheep, goats, horses, reindeer values updated: fur animals, swine, poultry
Animal groups	Swine: piglets excluded, new groups are: sows with piglets, boars, fattening pigs, weaned pigs horses divided to horses and ponies
Other parameters	GE; pasture time and weights of cattle updated
EF	Cattle EF's changed as activity data (GE's) changed

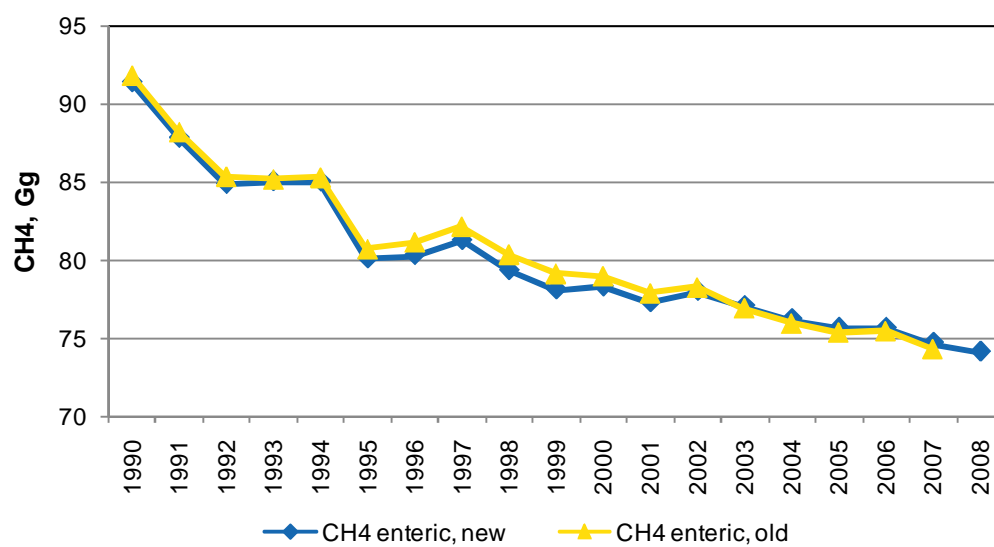


Figure 6.2-2 Previous submission values compared with new values, CH₄ enteric fermentation.

6.2.6 Source-specific planned improvements

There are no improvements planned.

6.3 Manure Management (CRF 4.B)

6.3.1 Source category description

Nitrous oxide and methane emissions from manure management were 1.4 Gg and 13.7 Gg in 2008, respectively, and their emissions as CO₂ equivalents were 0.7 Tg altogether. Nitrous oxide emissions from manure management were about 7% and methane emissions about 5% of total agricultural emissions in 2008.

This emission source covers manure management of domestic livestock. Finland reports both nitrous oxide (N₂O) and methane (CH₄) emissions from manure management of cattle (including dairy cows, suckler cows, heifers, bulls and calves), swine, horses, goats, sheep and poultry. Emissions from reindeer as well as emissions from fur animals are also included.

Table 6.3-1 Reported emissions under the subcategory Manure Management in the Finnish inventory.

CRF	Source	Emissions reported
4.B 1	Cattle	
	Dairy Cattle	CH ₄ , N ₂ O
	Non-Dairy Cattle	IE (4.A 10)
4.B 2	Buffalo	NO
4.B 3	Sheep	CH ₄ , N ₂ O
4.B 4	Goats	CH ₄ , N ₂ O
4.B 5	Camels and Llamas	NO
4.B 6	Horses	CH ₄ , N ₂ O
4.B 7	Mules and Asses	NO
4.B 8	Swine	IE
4.B 9	Poultry	CH ₄ , N ₂ O
4.B 10	Other	
	- Reindeers	CH ₄ , N ₂ O
	- Heifers	CH ₄ , N ₂ O
	- Bulls	CH ₄ , N ₂ O
	- Calves	CH ₄ , N ₂ O
	- Fur farming	CH ₄ , N ₂ O
	- Cows	CH ₄ , N ₂ O
	- Ponies	CH ₄ , N ₂ O
	-Sows with piglets	CH ₄ , N ₂ O
	-Boars	CH ₄ , N ₂ O
	-Fattening pigs	CH ₄ , N ₂ O
	-Weaned pigs	CH ₄ , N ₂ O
4.B 11	Anaerobic Lagoons	NO
4.B 12	Liquid Systems	N ₂ O
4.B 13	Daily spread	NO
4.B 14	Solid Storage and Dry Lot	N ₂ O
4.B 15	Other AWMS (Deep litter)	N ₂ O

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 and climatic conditions, for example.

Nitrous oxide emissions from manure management have decreased by 14% over the time period 1990-2008 (Table 6.3-2 and Figure 6.3-1). Methane emissions from manure management have been fluctuating during 1990-2008 but overall there is an increase of 25% in the emissions in 2008 compared with 1990 (Table 6.3-3). This is due to an increase in the number of animals kept in a slurry-based system. The fluctuation in the emissions is related to both changes in animal numbers, which is largely dependent on agricultural policy, as well as changes in the distribution of the manure management systems used. Slurry-based systems

increase methane emissions per animal tenfold compared with solid storage or pasture (IPCC 2000). On the other hand nitrous oxide emissions are bigger with solid storage than with slurry.

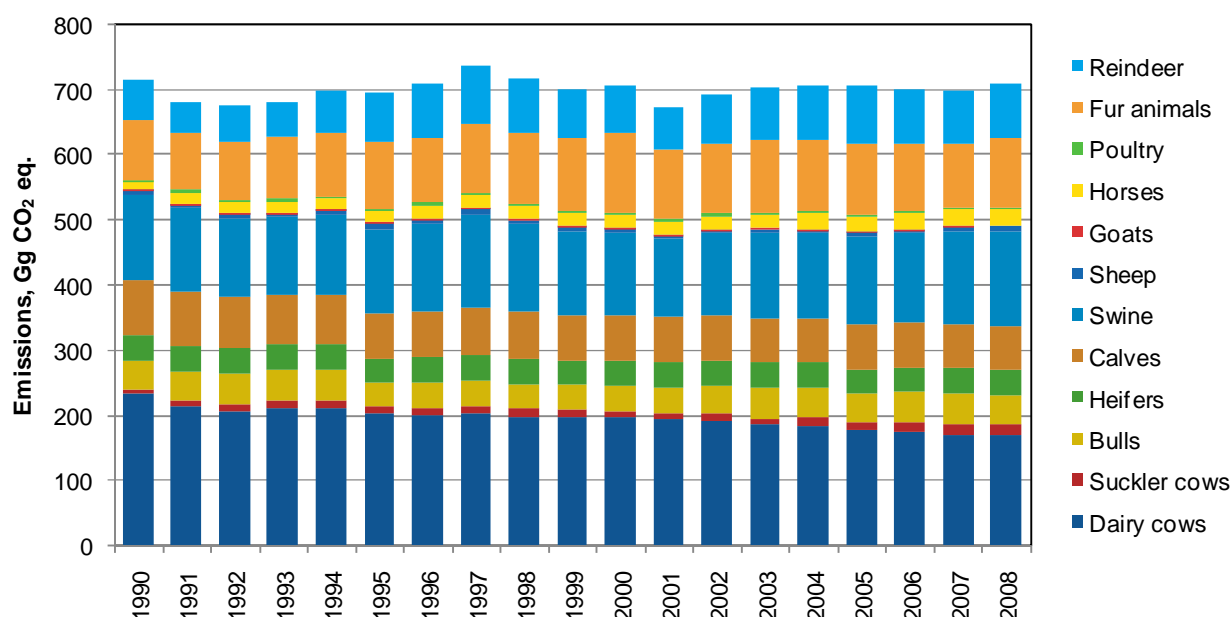


Figure 6.3-1 Emissions of manure management by animal type in 1990-2008, Gg CO₂ eq.

Table 6.3-2 Direct nitrous oxide emissions (Gg) from manure management in 1990-2008 by animal type (emissions from pasture not included, they are reported under 4.D Agricultural soils).

Year	Cattle					Other livestock								Total
	DC	SC	B	H	C	Sw	Sh	G	Ho	Po	P	F	R ^{**}	
1990	0.53	0.01	0.11	0.09	0.20	0.24	0.02	0.001	0.04	0.00	0.16	0.169	0	1.58
1991	0.48	0.02	0.11	0.09	0.20	0.22	0.02	0.001	0.05	0.01	0.15	0.133	0	1.46
1992	0.46	0.03	0.11	0.09	0.19	0.19	0.02	0.001	0.05	0.01	0.15	0.149	0	1.43
1993	0.47	0.03	0.11	0.09	0.18	0.18	0.02	0.001	0.05	0.01	0.16	0.150	0	1.44
1994	0.47	0.03	0.11	0.09	0.18	0.17	0.02	0.001	0.05	0.01	0.16	0.180	0	1.47
1995	0.45	0.03	0.08	0.08	0.17	0.16	0.03	0.001	0.05	0.01	0.17	0.205	0	1.43
1996	0.43	0.03	0.09	0.09	0.17	0.17	0.03	0.001	0.06	0.01	0.16	0.239	0	1.46
1997	0.43	0.03	0.09	0.09	0.17	0.18	0.03	0.002	0.06	0.01	0.17	0.252	0	1.50
1998	0.41	0.03	0.09	0.09	0.17	0.17	0.02	0.002	0.06	0.01	0.18	0.235	0	1.47
1999	0.40	0.03	0.09	0.08	0.17	0.17	0.02	0.002	0.06	0.01	0.18	0.214	0	1.42
2000	0.39	0.02	0.09	0.09	0.17	0.17	0.02	0.002	0.06	0.01	0.20	0.198	0	1.42
2001	0.37	0.02	0.09	0.09	0.17	0.15	0.02	0.002	0.06	0.01	0.18	0.175	0	1.38
2002	0.35	0.02	0.10	0.09	0.17	0.16	0.02	0.002	0.06	0.01	0.18	0.215	0	1.38
2003	0.32	0.02	0.11	0.09	0.17	0.16	0.02	0.002	0.06	0.01	0.19	0.236	0	1.38
2004	0.30	0.03	0.11	0.09	0.17	0.16	0.02	0.002	0.07	0.01	0.19	0.238	0	1.37
2005	0.27	0.03	0.10	0.09	0.17	0.16	0.02	0.002	0.07	0.01	0.19	0.261	0	1.35
2006	0.27	0.03	0.11	0.09	0.17	0.16	0.02	0.002	0.07	0.01	0.18	0.239	0	1.38
2007	0.26	0.04	0.11	0.09	0.17	0.16	0.03	0.001	0.07	0.01	0.17	0.230	0	1.35
2008	0.26	0.04	0.11	0.09	0.17	0.16	0.03	0.00	0.07	0.01	0.19	0.234	0	1.36
Share of total (%) in 2008 [*]	18.9	3.1	8.1	6.6	12.2	12.0	1.9	0.1	5.4	0.6	14.0	17.2	0.0	100.0

Table 6.3-3 Methane emissions from manure management in 1990-2008 by animal type (Gg).

Year	Cattle					Other livestock								Total
	DC	SC	B	H	C	Sw	Sh	G	Ho	Po	P	F	R"	
1990	3.40	0.05	0.56	0.51	1.01	2.79	0.02	0.00	0.05	0.01	2.11	0.44	0.03	10.97
1991	3.16	0.08	0.57	0.51	1.01	2.90	0.02	0.00	0.06	0.01	1.98	0.35	0.03	10.68
1992	3.06	0.10	0.59	0.52	0.97	2.99	0.02	0.00	0.06	0.01	2.10	0.38	0.03	10.83
1993	3.14	0.12	0.59	0.56	0.94	3.11	0.02	0.00	0.06	0.01	2.20	0.38	0.03	11.16
1994	3.18	0.12	0.64	0.57	0.92	3.35	0.02	0.00	0.06	0.01	2.29	0.44	0.03	11.63
1995	3.11	0.10	0.50	0.51	0.92	3.76	0.03	0.00	0.06	0.01	2.42	0.50	0.03	11.96
1996	3.19	0.12	0.53	0.55	0.89	3.78	0.03	0.00	0.06	0.01	2.33	0.55	0.03	12.06
1997	3.37	0.13	0.55	0.54	0.88	4.17	0.03	0.00	0.07	0.01	2.53	0.57	0.03	12.89
1998	3.44	0.13	0.52	0.52	0.88	3.91	0.02	0.00	0.07	0.01	2.59	0.53	0.03	12.64
1999	3.52	0.14	0.54	0.52	0.84	3.66	0.02	0.00	0.07	0.01	2.58	0.49	0.03	12.42
2000	3.70	0.13	0.53	0.51	0.81	3.52	0.02	0.00	0.07	0.01	2.94	0.45	0.03	12.73
2001	3.88	0.13	0.52	0.51	0.82	3.47	0.02	0.00	0.07	0.01	2.45	0.47	0.03	12.38
2002	4.09	0.14	0.56	0.51	0.81	3.61	0.02	0.00	0.07	0.01	2.46	0.46	0.03	12.77
2003	4.21	0.14	0.57	0.51	0.79	3.85	0.02	0.00	0.07	0.01	2.50	0.45	0.03	13.16
2004	4.37	0.16	0.55	0.50	0.77	3.85	0.02	0.00	0.07	0.01	2.34	0.48	0.03	13.15
2005	4.51	0.18	0.54	0.49	0.77	4.07	0.02	0.00	0.08	0.01	2.35	0.47	0.03	13.51
2006	4.44	0.21	0.57	0.50	0.75	4.13	0.02	0.00	0.08	0.01	2.28	0.50	0.03	13.51
2007	4.33	0.23	0.56	0.49	0.74	4.41	0.02	0.00	0.08	0.01	2.18	0.46	0.03	13.54
2008	4.24	0.26	0.56	0.49	0.73	4.48	0.02	0.00	0.08	0.01	2.34	0.46	0.03	13.70
Share of total (%) in 2008*	30.9	1.9	4.1	3.6	5.3	32.7	0.2	0.0	0.6	0.1	17.1	3.4	0.2	100

* The sum of the shares differs from 100 due to rounding. DC=Dairy cows, SC=Suckler cows, B=Bulls, H=Heifers, C=Calves, Sw=Swine, Sh=Sheep, G=Goats, Ho=Horses, Po=Ponies, P=Poultry, F=Fur animals, R=Reindeer

6.3.2 Methodological issues

6.3.2.1 Methods

Nitrous oxide – introduction of the Nitrogen mass flow model

Nitrous oxide emissions from manure management were calculated with a national calculation model for gaseous agricultural nitrogen emissions developed in a separate project which integrates the greenhouse gas and air pollutant inventories. The model is described in more detail in Grönroos et al. (2009). The new model includes both ammonia and nitrous oxide emissions from manure management in the same calculation model ensuring that the same activity data and parameters are used consistently in both inventories. Indirect nitrous oxide emissions from manure management are now also included in the model, they are reported in Agricultural soils/Atmospheric deposition.

The N model includes emissions from livestock by animal category and manure management stage, and emissions from mineral fertilizers. The manure management systems considered are slurry, deep litter, solid manure (farmyard manure: urine+dung+litter), urine (dung stored separately) and dung (urine stored separately). Emissions from grazing are calculated in a separate module. The distribution of manure management systems has changed from previous inventories. It was re-evaluated by sending a questionnaire to Regional Employment and Economic Development Centres and to Regional Environment Centres and by using statistical information and expert judgements. Information about manure application methods and time of application was also reserved. For greenhouse gas inventories, the manure management systems reported are slurry, solid storage, deep litter and pasture, 'solid' includes also urine and dung (Table 6.3-5).

In the model the fate of the excreted nitrogen is followed during the manure management chain and ammonia and nitrous oxide emissions into the atmosphere are calculated in each phase. Nitrogen amount declines in the chain. NO emissions are assessed for mineral fertilizers only (0.7% of fertilizer nitrogen). The model also considers different abatement measures (e.g. storage covers) and manure spreading techniques and their impact on emissions.

Direct nitrous oxide emissions from manure management are calculated in the model by using the IPCC methodology (IPCC 2000, Eq. 4.18). The equation is presented in the Appendix_6. The amount of nitrogen excreted annually per animal has been divided between different manure management systems and multiplied with the IPCC default emission factor for each manure management system. Nitrogen excretion during the year per animal (cattle, sheep, goats, swine, horses, poultry, fur animals and reindeer) and the distribution of manure management systems are national values (Table 6.3-4 and Table 6.3-5).

Note that the direct emissions from pasture are calculated under manure management, but are reported under *pasture, range and paddock manure* in CRF 4.D. Calculating direct nitrous oxide emissions from pasture manure in Finland differs from other manure management as the volatilisation is first subtracted from the nitrogen amount in order to avoid double counting. Volatilisation from dung and urine on pasture are assessed in the model separately, volatilisation has been estimated in total as c. 4.4% of nitrogen. Calculating manure excreted on pasture requires data of length of pasture season and time spent outside. For dairy cattle it has been estimated that 25% of cows spend nights inside (14 hours) during pasture season. The length of pasture season has been estimated as 140 days for suckler cows, heifers, horses and ponies 125 days for dairy cows, 100 for calves, 130-140 for sheep and goats, 365 for reindeer and 0 for bulls, swine (some exceptions), poultry and fur animals.

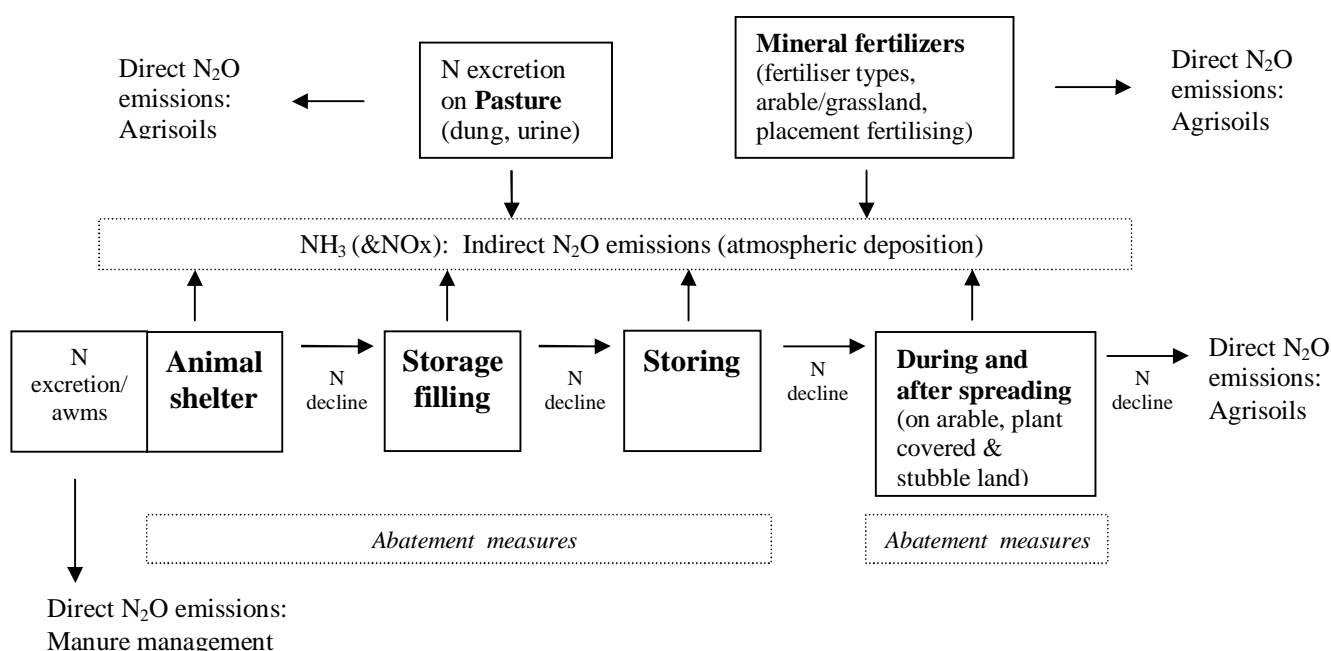


Figure 6.3-2 Nitrogen mass flow in the model.

Direct nitrous oxide emissions from manure management are calculated by multiplying the nitrogen excreted in the animal shelter by an animal group with an IPCC default EF for a certain AWMS (agricultural waste management system). For direct emissions from manure application, the nitrogen amount that is left on the field after volatilisation in each phase is multiplied with the default EF. Direct emissions from pasture and mineral fertilizers are calculated from the nitrogen amount after volatilisation. For indirect emissions (atm. deposition), the model gives the NH_3 emitted during manure management, spreading, on pasture and from mineral fertilizers which is then multiplied with the default EF. Leaching and sewage sludge are not included in the model but are calculated separately.

Methane

Methane emissions from manure management are calculated in the same generic way as emissions from enteric fermentation, i.e. by multiplying the number of the animals in each category with the emission factor for each category (IPCC 2000, Eq. 4.15). In Finland the Tier 2 method is used for all animal categories, which requires developing national emission factors for calculations on the basis of detailed data on animal characteristics and manure management systems. The equations used for calculating methane emissions from manure management are presented in the Appendix_6.

6.3.2.2 Activity data

Animal numbers used for calculating nitrous oxide and methane emissions from manure management are the same as those used for calculating methane emissions from enteric fermentation. The distribution of manure management systems was estimated using data from the Information Centre of the Ministry of Agriculture and Forestry, the results of a questionnaire sent to Regional Employment and Economic Development Centres and to Regional Environment Centres, and estimates of two experts (Ilkka Sipilä and Petri Kapuinen, MTT).

Annual nitrogen excretion per animal has been calculated by animal nutrition experts of MTT Agrifood Research Finland (Nousiainen, J. pers.comm.). The values of animal specific nitrogen excretion rates were based on nutrient balance calculations. Excretion rate was obtained by subtracting the nitrogen included in animal products and growth from the nitrogen intake through feeding. For all the animal groups, excluding horses and fur animals, the main sources of information are the agricultural statistics. Most important of these are the number of farm animals, the milk, meat and egg production and the slaughter weights.

For horses the statistics of Suomen Hippos and in fur animals the pelt production statistics of Finnish Fur Breeders Association were utilised. Nitrogen excretion is in most cases calculated with nitrogen balance estimation and is close to the methods described by Smith and Frost (2000) and Smith et al. (2000). Exceptions are described in the paragraph of the particular animal group. 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) were used. The nitrogen consumption of horses was estimated according to the feeding recommendations and example feeding presented in Saastamoinen and Teräväinen (2007). The calculations are based on the group distribution and estimated use of horses according to the statistics of Suomen Hippos. The nitrogen excretion is the difference between nitrogen intake of horses and nitrogen amount in culled horses (about 7 % of horse population) divided by the horse population.

The feed intake of dairy cows was 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 were divided to slaughtered and recruitment animals. The exact ages of slaughtered animals were available from the year 2000 onwards; in previous years they were estimated according to the situation in 2000 and 2001. With the growth curve, daily weight and growth values can be calculated. The energy requirement is based on these values. The feed nitrogen content was obtained from the feed consumption data of Finnish milk recording that contains also information of growing cattle.

For pigs, the calculation method is close to one presented by Fernández et. al 1999. For sows with piglets, necessary information was obtained from the litter recording scheme of FABA breeding and from the pig production recording of rural advisory centres. For growing pigs, calculations were based on feed conversion results of FABA breeding central station testing, estimated difference in farm conditions and several feeding experiments. The nitrogen content of feed was estimated from the digestible protein recommendations. Also feeding examples (Komulainen 1989, Kyntäjä et al. 1999 and Siljander-Rasi et al. 2006) were utilised.

For sheep, the information of Finnish sheep production recording, example feeding (Savolainen and Teräväinen 2000) and feeding recommendations were used in the nitrogen intake and retention calculations. The wide variation in sheep production systems and seasonality make these calculations challenging.

For poultry, nitrogen intake is estimated with feed consumption per kg eggs, one slaughtered or full grown bird. The feed utilisation values were obtained from commercial poultry breeders and several Finnish feeding experiments. The nitrogen content of feed originates from commercial concentrate manufacturers and feeding recommendations. The nitrogen excretion of other poultry, which includes ducks, geese, ranched pheasant, ranched mallards, guinea fowl, quails, ostriches and emus, was estimated equal to that of laying hens. 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. Nitrogen excretion by reindeer was estimated equal to that of goats.

In the case of animals that live less than one year (swine, poultry), replacement of animals with new ones has been taken into account in the calculations. The reason for the increasing trend in N excretion rates is the increased production level of animals demanding higher nitrogen intake. Thus, nitrogen excretion has increased despite the fact that N utilisation has improved. The need to update the N excretion rates evaluated annually in cooperation with the animal nutrition experts.

Table 6.3-4 Annual average N excretion per animal (kg N/animal/year). (Nousiainen, J.)

Year	Dairy cows	Suckler cows	Bulls	Heifers	Calves	Sows with piglets	Fattening pigs (50- kg)	Boars	Veaned pigs (20-50 kg)	Sheep
1990	91.3	62.5	39.5	47.1	27.2	28.4	18.3	19.6	8.8	8.46
1991	91.5	62.8	40.0	47.8	27.4	28.4	18.0	19.7	8.8	8.51
1992	92.0	63.2	39.9	47.7	27.5	28.1	17.8	19.4	8.7	8.58
1993	93.7	63.5	41.6	49.0	28.5	28.1	17.6	19.3	8.8	8.66
1994	96.1	63.9	42.2	49.9	28.9	28.0	17.5	19.1	8.8	8.73
1995	96.6	64.2	42.3	50.0	29.1	27.5	17.4	19.1	8.5	8.69
1996	96.8	64.6	42.6	50.6	29.3	27.9	17.3	19.1	8.4	8.85
1997	99.4	65.0	43.3	51.1	29.7	27.7	17.3	19.8	8.5	8.86
1998	100.6	65.3	43.6	51.7	30.1	28.1	17.4	19.9	8.5	8.97
1999	103.8	65.6	44.1	52.4	30.9	28.5	17.5	17.9	8.6	9.15
2000	107.7	66.0	45.5	54.1	32.0	28.8	17.5	17.8	8.6	9.32
2001	110.5	66.3	46.6	56.0	32.9	28.4	17.5	18.9	8.6	9.46
2002	112.9	66.7	47.8	58.9	33.9	28.5	17.6	19.2	8.7	9.57
2003	115.4	66.8	48.8	61.5	35.1	28.5	17.5	19.4	8.8	9.60
2004	118.3	68.3	50.1	63.3	36.2	28.9	17.5	19.6	8.8	9.64
2005	120.0	67.8	50.4	63.8	36.6	29.1	17.5	20.1	8.9	9.88
2006	121.7	68.1	51.2	64.9	37.1	29.3	17.6	20.5	8.9	9.97
2007	123.5	68.1	52.2	66.7	38.0	29.2	17.6	20.5	9.0	9.97
2008	124.7	68.7	52.8	66.9	38.3	29.4	17.6	20.3	9.0	9.97

Year	Laying hens	Broilers	Chickens	Turkeys	Other poultry	Horses	Ponies	Minks & fitches	Foxes & racoons
1990	0.6	0.4	0.35	1.1	0.62	59.4	43.4	1.2	2.1
1991	0.6	0.4	0.35	1.2	0.62	59.2	43.2	1.3	2.2
1992	0.6	0.4	0.35	1.2	0.62	59.1	43.2	1.3	2.2
1993	0.6	0.4	0.35	1.3	0.62	59.6	43.4	1.3	2.2
1994	0.6	0.4	0.35	1.2	0.62	60.1	43.9	1.3	2.2
1995	0.6	0.4	0.35	1.3	0.62	60.5	44.4	1.3	2.2
1996	0.6	0.4	0.35	1.3	0.62	60.5	44.2	1.3	2.3
1997	0.6	0.4	0.35	1.3	0.62	60.3	44.4	1.3	2.3
1998	0.6	0.4	0.35	1.3	0.62	60.0	44.3	1.3	2.3
1999	0.6	0.4	0.35	1.4	0.62	60.0	44.2	1.3	2.3
2000	0.6	0.4	0.35	1.4	0.62	60.1	44.1	1.3	2.3
2001	0.6	0.4	0.35	1.4	0.62	60.3	44.1	1.3	2.4
2002	0.6	0.4	0.35	1.5	0.62	60.5	44.2	1.3	2.5
2003	0.6	0.4	0.35	1.5	0.62	60.8	44.2	1.3	2.6
2004	0.6	0.4	0.35	1.5	0.62	61.0	44.0	1.3	2.7
2005	0.6	0.4	0.35	1.5	0.62	61.0	43.6	1.3	2.8
2006	0.6	0.4	0.35	1.5	0.62	60.9	43.5	1.3	2.8
2007	0.6	0.4	0.35	1.5	0.62	61.0	43.3	1.3	2.9
2008	0.6	0.4	0.35	1.5	0.62	60.9	43.2	1.3	3.0

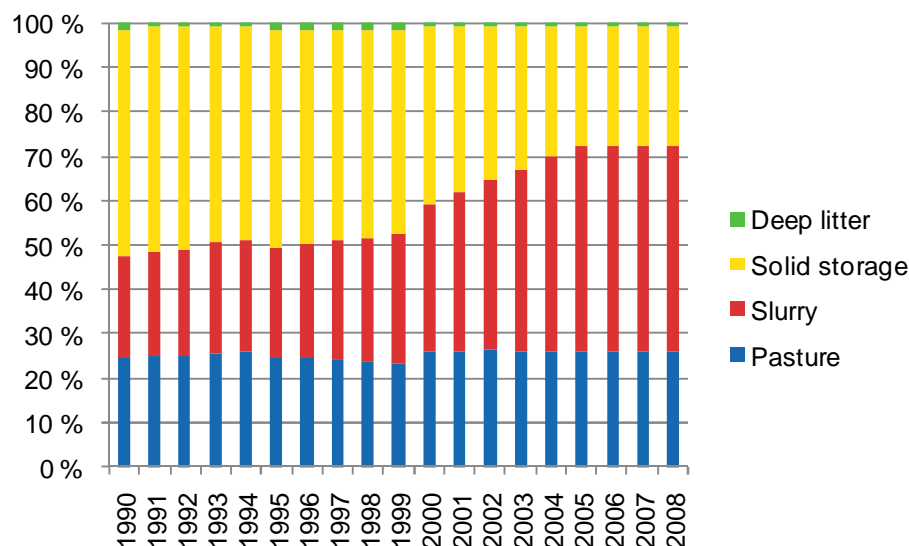


Figure 6.3-3 Fraction of manure of dairy cows in different manure management systems. (Source: Seppänen & Matinlassi (1998); Rural Advisory Centres (ProAgria); MTT Agrifood Research Finland).

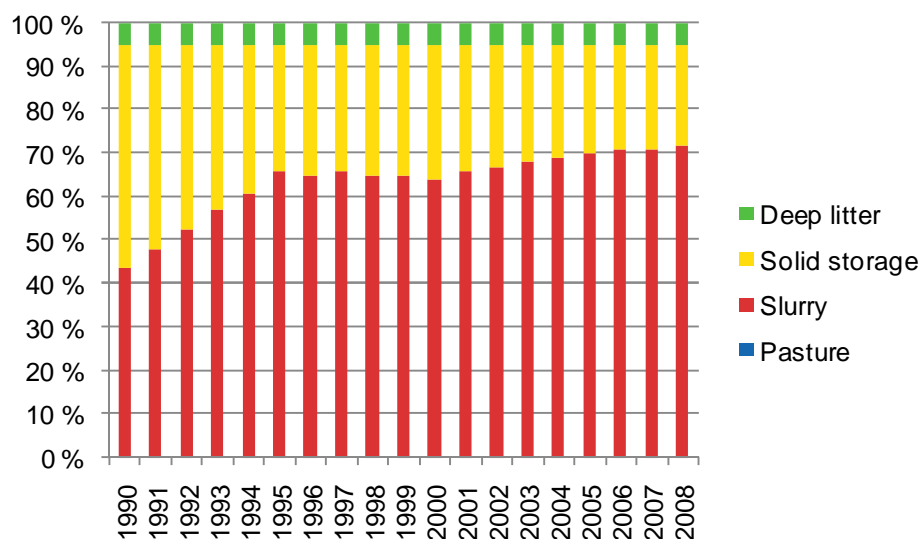


Figure 6.3-4 Fraction of manure of swine in different manure management systems. (Source: Seppänen & Matinlassi (1998); Rural Advisory Centres (ProAgria); MTT Agrifood Research Finland).

Table 6.3-5 Fraction of manure managed in each manure management system (Source: Seppänen & Matinlassi (1998); Rural Advisory Centres (ProAgria); MTT Agrifood Research Finland).*

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Cattle																			
Dairy cows																			
Pasture	0.25	0.25	0.25	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26	0.26
Slurry	0.23	0.23	0.24	0.25	0.25	0.26	0.27	0.29	0.30	0.32	0.33	0.36	0.38	0.41	0.44	0.46	0.46	0.46	0.46
Solid storage	0.51	0.50	0.50	0.49	0.48	0.51	0.51	0.51	0.51	0.51	0.40	0.37	0.34	0.32	0.29	0.27	0.27	0.27	0.27
Deep litter	0.02	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Suckler cows																			
Pasture	0.35	0.35	0.35	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36
Slurry	0.03	0.03	0.03	0.03	0.03	0.03	0.06	0.08	0.11	0.13	0.16	0.17	0.17	0.18	0.18	0.19	0.19	0.19	0.19
Solid storage	0.36	0.36	0.36	0.36	0.36	0.36	0.33	0.31	0.28	0.25	0.23	0.22	0.22	0.21	0.20	0.20	0.20	0.20	0.20
Deep litter	0.26	0.26	0.26	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Bulls (<1 year)																			
Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slurry	0.30	0.32	0.34	0.36	0.38	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Solid storage	0.64	0.62	0.60	0.58	0.56	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54	0.54
Deep litter	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Heifers																			
Pasture	0.36	0.36	0.36	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Slurry	0.19	0.20	0.21	0.22	0.23	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24	0.24
Solid storage	0.43	0.42	0.42	0.41	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Deep litter	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Calves (<1 year)																			
Pasture	0.08	0.08	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	0.07	0.07	0.07
Slurry	0.28	0.29	0.31	0.32	0.34	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Solid storage	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
Deep litter	0.09	0.08	0.07	0.05	0.04	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Other livestock																			
Swine																			
Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slurry	0.44	0.48	0.52	0.57	0.61	0.66	0.65	0.66	0.65	0.65	0.64	0.66	0.67	0.68	0.69	0.70	0.71	0.71	0.72
Solid storage	0.51	0.47	0.42	0.38	0.34	0.29	0.30	0.29	0.30	0.30	0.31	0.29	0.28	0.27	0.26	0.25	0.24	0.24	0.23
Deep litter	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Sheep																			
Pasture	0.36	0.36	0.35	0.34	0.33	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
Slurry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solid storage	0.06	0.06	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	0.07	0.07	0.07	0.07
Deep litter	0.57	0.58	0.59	0.60	0.60	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Goats																			
Pasture	0.36	0.36	0.35	0.34	0.33	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32	0.32
Slurry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solid storage	0.06	0.06	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	0.07	0.07	0.07	0.07
Deep litter	0.57	0.58	0.59	0.60	0.60	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61
Horses																			
Pasture	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36	0.36
Slurry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solid storage	0.64	0.58	0.53	0.48	0.43	0.38	0.38	0.38	0.38	0.38	0.38	0.43	0.48	0.53	0.58	0.64	0.64	0.64	0.64
Deep litter	0.00	0.05	0.10	0.15	0.20	0.25	0.25	0.25	0.25	0.25	0.25	0.20	0.15	0.10	0.05	0.00	0.00	0.00	0.00
Reindeer																			
Pasture	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Slurry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poultry																			
Laying hens																			
Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slurry	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Solid storage	0.95	0.95	0.94	0.94	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.94	0.94	0.95	0.95	0.95	0.95	0.95
Deep litter	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Chickens																			
Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slurry	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Solid storage	0.95	0.95	0.95	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.95	0.95	0.95	0.95	0.95	0.95
Deep litter	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Cockerels																			
Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slurry	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00
Solid storage	0.95	0.95	0.95	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.95	0.95	0.95	0.95	0.95	0.95
Deep litter	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Broiler hens																			
Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slurry	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Deep litter	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00
Broilers																			
Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slurry	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Deep litter	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Turkeys																			
Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slurry	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.00	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	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Deep litter	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	1.00
Other poultry																			
Pasture	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Slurry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Solid storage	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Deep litter	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40

6.3.2.3 Emission factors and other parameters

Nitrous oxide

The IPCC default nitrous oxide emission factors have been used for each manure management system. The manure management systems included in the inventory are pasture, solid storage, deep litter and slurry (Table 6.3-6). Ammonia volatilisation parameters during manure management have been taken from a thorough literature review, including reduction potentials of different abatement measures (Grönroos et al. 2009). EF for dung and deep litter is the same as for solid storage and urine's EF is the same as for slurry.

Table 6.3-6 IPCC default emission factors for nitrous oxide from manure management and related uncertainties.

Manure management system	Emission factor (kg N ₂ O-N/kg)	Uncertainty range of EF	Source of the Uncertainty Estimate
Pasture	0.02	-85% / +15% (beta)	Monni & Syri (2003)
Slurry	0.001	-50% / +100% (lognormal)	Penman et al. (2000)
Solid storage	0.02	-85% / +15% (beta)	Monni & Syri (2003)
Urine	0.001	-50% / +100% (lognormal)	Penman et al. (2000)
Dung	0.02	-50% / +100% (lognormal)	Penman et al. (2000)
Deep litter	0.02	-50% / +100% (lognormal)	Penman et al. (2000)

Methane

The national emission factors for each cattle subcategory have been calculated by using the IPCC Tier 2 methodology (IPCC 2000, Eq. 4.17). Equations are presented in the Appendix_6. In calculation of emission factors, both IPCC default values and national data have been used. Emission factors are presented in Table 6.3-7.

For cattle, emission factors have been calculated by using the IPCC (IPCC 1997; IPCC 2000) default values for ash content of manure, Methane Producing Potential (Bo) and Methane Conversion Factor (MCF). Gross energy intake (GE) has been calculated by using national values for digestible energy (DE%), fraction of animal's manure managed annually in each manure management system (MS), average milk production and animal weight. The same values for gross energy intake (GE) for cattle have been used as in calculating methane emissions from enteric fermentation. Volatile solids excretion (VS_i) has been calculated by using the GE values mentioned above.

For other animals, emission factors have been calculated using the IPCC (IPCC 1997; IPCC 2000) default values for ash content of manure, Methane Producing Potential (Bo), Methane Conversion Factor (MCF) and volatile solids excretion (VS_i). For MCF, a default value of 10% (IPCC 1997) has been used for slurry instead of 39% (IPCC 2000) due to Finland's climatic conditions. Support for the use of this value is found from a Swedish review (Dustan, 2002) as well as from the IPCC 2006 Guidelines (GL06). For deep litter three different values were used, for cattle and swine 10% (see Good Practise Guidance 2000 (GPG2000), pg. 4.37 "MCF's are similar to liquid/slurry", also GL06 supports smaller value than 39%, pg.10.46), horses, sheep and goats 1% (GL06 pg. 10.82) and poultry 1.5% (GPG2000, pg. 4.37). No information about VS_i for reindeer was available so the IPCC default value for goats was used. For fur animals, the VS_i value is based on expert judgement, being 0.17 kg/head/day. No default value for Bo for fur animals exists, so the IPCC default value for poultry was used. For reindeer it is assumed that all manure is deposited on pastures and for fur animals it is assumed that all manure is managed as solid.

Table 6.3-7 National emission factors used for calculating methane emissions from manure management.

Animal category	Emission factor (kg CH ₄ /head/year)
Dairy cows	14.7
Suckler cows	5.3
Bulls	5.1
Heifers	3.0
Calves	2.4
Swine	4.4
Sheep	0.19
Goats	0.12
Horses	1.39
Poultry	0.22
Reindeer	0.12
Minks and fitches	0.13
Foxes and racoons	0.13

6.3.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

Animal numbers and related uncertainties used for manure management were the same as for enteric fermentation. Estimation of uncertainty in the nitrous oxide emission factor for manure management is fairly complicated. Some studies (e.g. Amon et al. 2001; Hüther 1999; Amon et al. 1997) reveal that emissions from solid manure are, in cold climate, smaller than estimated by using the IPCC method (IPCC 2000). The uncertainty in this emission source was therefore modelled with a negatively skewed distribution based on the above-mentioned studies, to implicate the possibility of smaller emissions than estimated. Uncertainty in the emission factors of nitrous oxide could probably be reduced by gathering more national data from gas flux measurements in order to study the suitability of the IPCC default emission factors to the boreal climate.

Animal numbers and related uncertainties used for manure management were the same as for enteric fermentation. 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.

Monte Carlo simulation has been used to combine the uncertainties of each calculation parameter in order to get the total uncertainty of the source category. A detailed description of the uncertainty analysis has been presented in Monni & Syri (2003), Monni (2004) and Monni et al. (2007).

The amount of N excreted annually by the reindeer is very uncertain. Currently, because of lack of data, the value for goats has been used. Also, B_o and VS_i for fur animals and VS_i for reindeer are uncertain. However, the amount of these emissions is very small and therefore the contribution to the total uncertainties is also small.

As the same calculation method has been used for the years 1990-2008, the time series are considered consistent. For some years animal numbers have not been available (e.g. the number of goats in 1991 and the number of broilers in 1991, 1992, 1993, 1994), so linear interpolation of the data from adjacent years has been used to obtain the data.

6.3.4 Source-specific QA/QC and verification

The overview of the QA/QC plan is given in section 1.6.

General (Tier 1) Quality Control (QC) procedures applied to the category Manure management (CRF 4.B):

The QA/QC plan for the agricultural sector includes the QC measures based on the guidelines of the IPCC (IPCC 2000, Table 8.1). These measures are implemented every year during the agricultural inventory. If errors or inconsistencies are found they are documented and corrected. The QC checklist is used during the inventory. More precise information can be found in chapter 6.2.4

Tier 2 QC for activity data:

A checklist is used for ensuring consistency of the activity data in different sections of the agricultural inventory.

Tier 2 QC for emission factors:

It is checked annually if new data for updating emission factors has been published. New national data is compared with the emission factors used in the inventory and the applicability of current emission factors in Finland's circumstances is evaluated. There was no new data available for this inventory for updating the emission factors.

The agricultural inventory has been reviewed several times by the UNFCCC Expert Review Teams, and improvements to the inventory have been made according to the suggestions. No specific verification process has been implemented for the agricultural inventory. However, a case-study between Finland and Germany was arranged in August 2004 where Finland's agricultural inventory was reviewed by the German experts. The purpose of the case-study was to find potential adjustments cases and to test specific methods to calculate adjustments. The experiences of this exercise have been taken into account in the development of the inventory. The inventory was audited by Statistics Finland in autumn 2009 and the audit focused especially on recalculations. The results will help to further improve the inventory.

For the new Nitrogen mass flow model, a thorough literature review was made to update the ammonia volatilization parameters (e.g. the reduction potential of different abatement measures). Ammonia measurements were carried out in animal shelters (pig houses and cow sheds) in order to verify the selected emission factors for ammonia and thus the estimates of indirect nitrous oxide emissions and the mass flow of nitrogen. The results suggest that the emission factors chosen for the model in general represent values typical for Finland. (Grönroos et al. 2009)

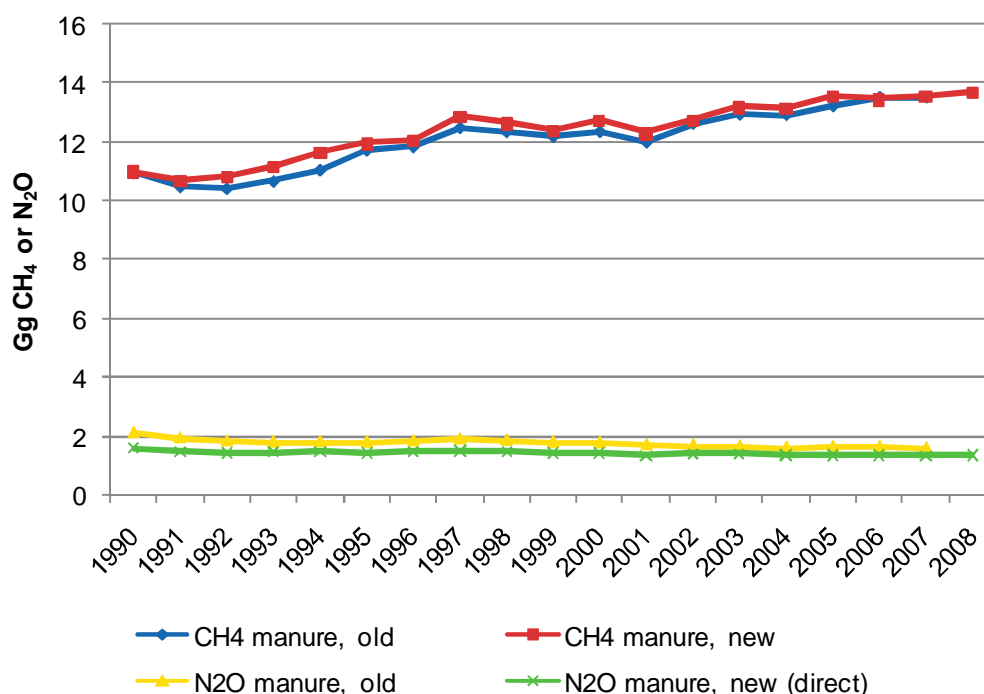
6.3.5 Source-specific recalculations

Animal numbers and shares of manure management systems changed as they are now uniform with the Nitrogen mass flow model. These changes affected both methane and nitrous oxide emissions. Deep litter was added as a new system. VS (GE; weight and pasture time) of cattle changed and new MCF's were added (deep litter) which also changed methane emissions. (MCFs were corrected to CRF tables and are now expressed as per cents.) For years 1990 and 2007 the new methane emission values are almost the same as previously. Nitrous oxide emissions were calculated with the Nitrogen mass flow model, also indirect manure management emissions are calculated (they are reported in CRF 4D Agricultural soils). Nitrogen excretion rates were updated as more precise information e.g. on forage and culling age was obtained. Compared to previous calculation the total animal number and total nitrogen excretion have declined for all years. The share of urine (stored separately) of AWMS nitrogen has declined since 1990. The new nitrous oxide emissions are slightly smaller than previous values.

Nitrogen mass flow model takes into account the volatilisation of ammonia in each step of manure management (animal shelter, filling storage, storing) and the effect of possible abatement measures to volatilisation. This enables to calculate indirect nitrous oxide emissions from AWMS. Urine stored separately is a small adjustment to solid storage emissions (and has EF of liquid).

Table 6.3-8 Changes in the calculation parameters.

Animal numbers	more precise values (less rounded): cattle, sheep, goats, horses, reindeer values updated: fur animals, swine, poultry
Animal groups	swine, new groups are: sows with piglets, boars, fattening pigs, weaned pigs horses divided to horses and ponies
Awms	deep litter added, solid storage contains dung/urine/manure, all awms values updated (also awms indirect N ₂ O calculated, reported in CRF 4D)
Nitrogen excretion	values updated, for goats the value changed considerably and is now a better estimate for Finnish goats
Other parameters	VS (GE; pasture time and weights of cattle updated) new MCFs (deep litter)
EF	CH ₄ EFs changed (as VS and awms changed) N ₂ O EFs for urine (0.001), dung and deep litter (0.02) (default values)
Method	Nitrogen mass flow model for N ₂ O used: <i>The previously used method has been modified and made more complete: the amount of nitrogen excreted/animal group/awms is multiplied with default EFs (more animal subgroups and new AWMS divisions)</i>

**Figure 6.3-5** Previous submission values versus new values, CH₄ and N₂O from manure management.

6.3.6 Source-specific planned improvements

The distribution of manure to different management systems was updated for the Nitrogen mass flow model and therefore also for the inventory. There is a need to update the data regularly also in the future. The data collecting methodology should be improved. There have been discussions between MTT Agrifood Research Finland, the Information Centre of the Ministry of Agriculture and Forestry and Statistics Finland to meet this objective. As the process is slow, no improvements are expected in short term.

6.4 Agricultural Soils (CRF 4.D)

6.4.1 Source category description

Nitrous oxide emissions from agricultural soils are a significant emission source comprising about 60% of total agricultural emissions in 2008, being 3.6 Tg as CO₂ equivalents.

Direct and indirect nitrous oxide emissions from agricultural soils are reported in this category. Direct emissions include emissions from synthetic fertilisers, animal manure applied to soils, crop residues, N-fixing crops, sewage sludge and cultivation of organic soils. Indirect emissions include emissions arising from nitrogen volatilised as ammonia and NO_x as well as nitrogen leached from synthetic fertilisers, manure and sewage sludge applied to soils. Also indirect emissions from manure management are now included.

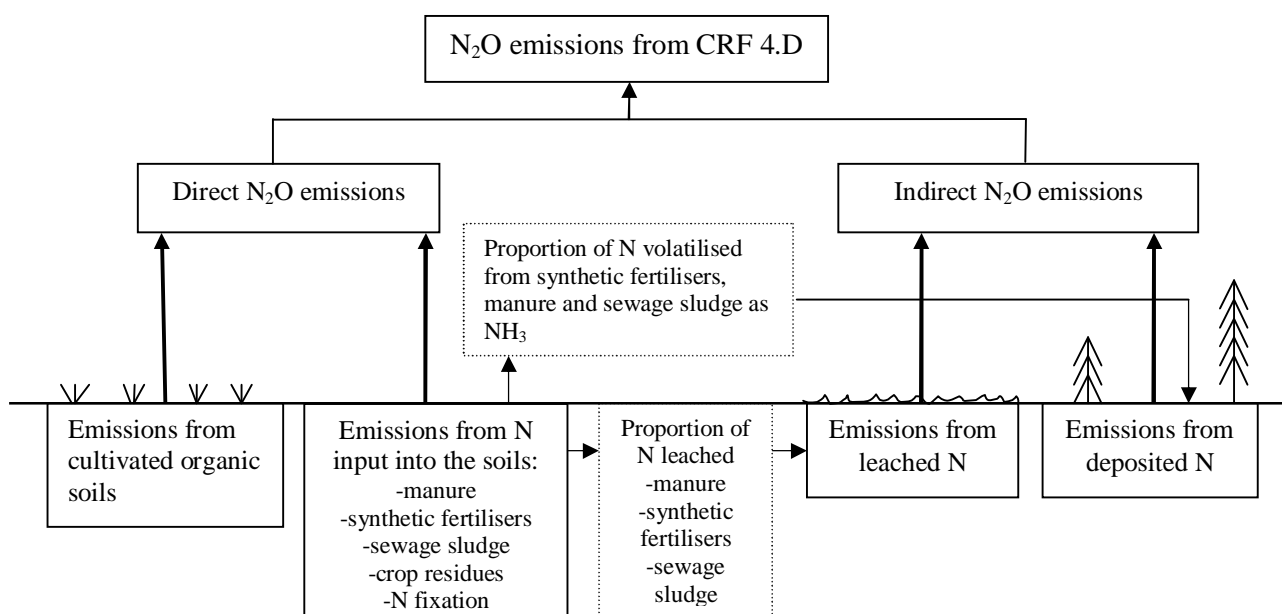


Figure 6.4-1 Reported emissions under the subcategory Agricultural Soils in the Finnish inventory.

Table 6.4-1 Reported emissions under the subcategory Agricultural Soils in the Finnish inventory.

CRF	Source	Emissions reported
4.D 1	Direct Soil Emissions	N ₂ O
4.D 2	Pasture, Range and Paddock Manure	N ₂ O
4.D 3	Indirect Emissions	N ₂ O
4.D 4	Other	NO

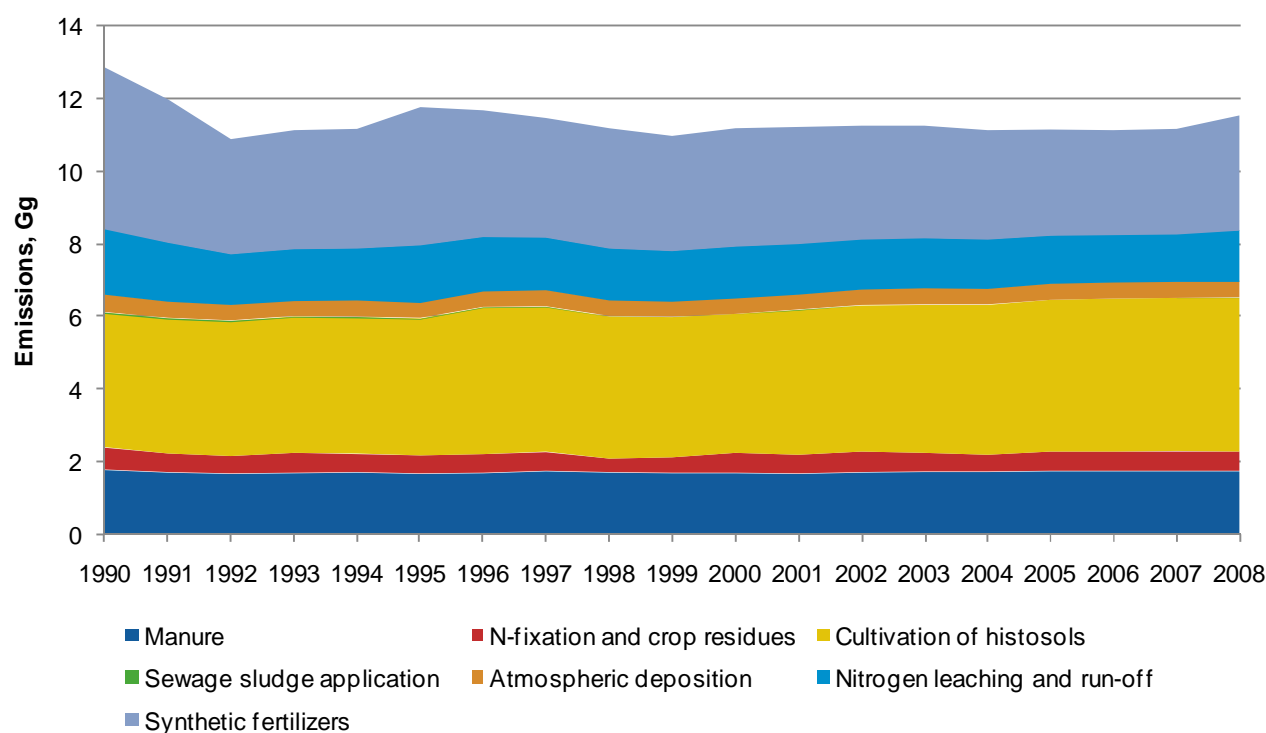
Nitrous oxide is produced in agricultural soil as a result of microbial nitrification-denitrification processes. The processes are driven by drivers like the availability of mineral nitrogen substrates and carbon, soil moisture, temperature and pH. Thus, addition of mineral nitrogen in the form of synthetic fertilisers, manure, crop residue, N-fixing crops and sewage sludge enhances the formation of nitrous oxide emissions (Smith et al., 2004). Nitrous oxide emissions also arise as a result of the mineralisation of soil organic matter, which is particularly intensive in cultivated organic soils.

The emissions have decreased by 10%, from 12.8 Gg in 1990 to 11.5 Gg in 2008 (Table 6.4-2 and Figure 6.4-2). The main reasons causing this reduction 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 sold annually. Some parameters, such as the annual crop yields affecting the amount of crop residues produced, because the fluctuation in the time series but this fluctuation does not have much effect on the overall nitrous oxide emissions trend.

Table 6.4-2 Direct and indirect nitrous oxide emissions from agricultural soils by source category (Gg).

Year	Direct emission sources							Indirect emission sources		Total
	S	MS	MP	C	N	O	SW	A	L	
1990	4.42	1.18	0.59	0.60	0.01	3.68	0.03	0.49	1.81	12.82
1991	3.92	1.12	0.57	0.49	0.04	3.70	0.03	0.46	1.63	11.95
1992	3.16	1.10	0.56	0.44	0.04	3.71	0.02	0.44	1.39	10.86
1993	3.26	1.11	0.57	0.52	0.05	3.73	0.02	0.44	1.43	11.11
1994	3.27	1.13	0.57	0.49	0.02	3.74	0.03	0.45	1.44	11.15
1995	3.78	1.10	0.55	0.49	0.02	3.75	0.02	0.45	1.58	11.74
1996	3.48	1.12	0.55	0.50	0.02	3.77	0.02	0.45	1.49	11.41
1997	3.28	1.17	0.56	0.52	0.02	3.79	0.02	0.46	1.45	11.27
1998	3.29	1.14	0.55	0.37	0.01	3.81	0.01	0.45	1.44	11.07
1999	3.15	1.13	0.55	0.42	0.01	3.85	0.01	0.44	1.39	10.95
2000	3.24	1.13	0.55	0.53	0.02	3.90	0.01	0.44	1.42	11.25
2001	3.21	1.10	0.55	0.51	0.02	3.97	0.01	0.44	1.40	11.20
2002	3.10	1.14	0.56	0.55	0.02	4.01	0.01	0.45	1.39	11.22
2003	3.08	1.17	0.55	0.50	0.02	4.06	0.01	0.46	1.39	11.23
2004	2.99	1.16	0.56	0.45	0.01	4.12	0.01	0.45	1.36	11.10
2005	2.90	1.18	0.56	0.52	0.01	3.75	0.00	0.46	1.33	10.71
2006	2.87	1.17	0.56	0.52	0.01	4.20	0.00	0.45	1.32	11.11
2007	2.88	1.17	0.55	0.54	0.02	4.20	0.00	0.45	1.32	11.14
2008	3.15	1.18	0.56	0.52	0.01	4.22	0.00	0.46	1.41	11.51
Share of total(%) in 2008 *	27.40	10.22	4.83	4.52	0.10	36.70	0.02	3.98	12.24	100.00

* The sum of the shares differs from 100 due to rounding. S=synthetic fertilisers, MS= manure applied to soils, MP=manure deposited on pastures, C=crop residues, N=N-fixation, O=cultivation of organic soils, SW=sewage sludge application, A=atmospheric deposition (includes indirect emissions from manure management), L=leaching and run-off

**Figure 6.4-2** Nitrous oxide emissions from agricultural soils (atmospheric deposition, nitrogen leaching and run-off are indirect emissions, all other direct), Gg.

6.4.2 Methodological issues

6.4.2.1 Methods

Nitrous oxide emissions from agricultural soils have been calculated by using the IPCC methodology. Both direct and indirect emission sources have been included. Detailed equations are provided in the Appendix_6. The calculation methodology has been developed towards a mass flow approach in order to avoid double-counting (see chapter 6.3.2.1 “Introduction of Nitrogen mass flow model”).

Direct emissions have been calculated using Equation 4.20 in the IPCC Good Practice Guidance (IPCC 2000). Indirect emissions have been calculated using Equation 4.32 for atmospheric deposition and 4.36 for leaching and run-off (IPCC 2000). However, due to the use of the Nitrogen mass flow model, adjustments have been done. Synthetic fertilizers are divided in different fertilizer groups and fields in two field types (arable and grass). Emission factors for NH_3 emissions are depend on fertilizer and field type. Placement fertilization (50% less ammonia) is taken into account, too. NO-N loss from synthetic fertilizers is also calculated (0.7% of nitrogen). Nitrogen volatilized during manure management is subtracted from the amount of nitrogen excreted to get the amount applied on fields. The model divides the applied manure between three different field types (arable, plant covered and stubble), and various abatement measures (e.g. incorporation with ploughing, injection) and their ability to reduce ammonia emissions are taken into account. The amount of nitrogen applied on field after excluding volatilized amount is multiplied with the default EF for direct emissions. The nitrous oxide emissions from the atmospheric deposition are calculated for ammonia volatilized in spreading of manure, sewage sludge and mineral fertilizers as well as manure excreted on pastures (see chapter 6.3.2 1, pasture). For leaching and run-off, volatilized nitrogen has been subtracted before applying $\text{Frac}_{\text{LEACH}}$. Nitrous oxide emissions from sewage sludge, crop residues (burned amount subtracted), N-fixation and cultivation of organic soils are part of the direct emissions and they are calculated as before and not with the Nitrogen mass flow model. For sewage sludge, $\text{Frac}_{\text{Gasm}}$ has changed as it is the same as for manure. Nitrous oxide emissions from cultivated organic soils have been calculated by dividing the area into grasses and other crops and using national EFs for both crop types.

6.4.2.2 Activity data

Activity data are national and received mainly from the annual agricultural statistics of the Ministry of Agriculture and Forestry (Table 6.4-3). Other data sources are the Finnish Environment Institute (the amount of nitrogen in sewage sludge) and Finnish Forest Research Institute (area of cultivated organic soils). Animal numbers are the same as those used for calculating enteric fermentation and manure management emissions (Table 6.2-3). The distribution of different manure management systems and the amount of nitrogen excreted per animal are the same as those used for calculating nitrous oxide emissions from manure management. The amount of synthetic fertilisers sold annually has been received from the annual agricultural statistics of the Ministry of the Agriculture and Forestry and the amount of sewage sludge applied annually has been obtained from the VAHTI system (Section 1.4 and Annex 2) see Table 6.4-4. Crop yields of cultivated plants have been taken from agricultural statistics (Ministry of Agriculture and Forestry) (Table 6.4-5). Vegetables grown in the open have also been included in the emission estimate of crop residues. Vegetable yields were taken from literature (Horticultural Enterprise Register) and Yearbook of Farm Statistics (Table 6.4-6). The area of cultivated organic soils was derived as described in chapter 7.1.2. The division of the area to area under grass vs. other crops was obtained from the statistics of the Ministry of Agriculture and Forestry for years 1995 and 2008 and the result for the other years was derived by interpolation or extrapolation.

Table 6.4-3 Activity data sources for calculating nitrous oxide emissions from agricultural soils.

Activity data	Data source
Number of cattle, sheep, goats, poultry, reindeer	Information Centre of the Ministry of Agriculture and Forestry (Matilda Database, Yearbook of Farm Statistics)
Number of horses	Finnish Trotting and Breeding Association (http://www.hippos.fi)
Number of fur animals	Finnish Fur Breeders Association
Distribution of manure management systems	Rural Advisory Centres, MKL (1993); Seppänen & Matinlassi (1998), MTT Agrifood Research Finland
Nitrogen excretion by animal type	MTT Agrifood Research Finland
Amount of sewage sludge applied annually in agricultural soils	VAHTI system
Crop statistics	Information Centre of the Ministry of Agriculture and Forestry (Matilda Database, Yearbook of Farm Statistics, Horticultural Enterprise Register)
Ammonia emission estimates	Nitrogen mass flow model, Grönroos et al.(2009)
Area of cultivated organic soils	Finnish Forest Research Institute

Table 6.4-4 Nitrogen input to soils via synthetic fertilisers, manure and sewage sludge application (Mg N a⁻¹) (the fraction lost as NH₃ and NO_x has not been subtracted).

Year	Synthetic fertilisers ¹	Manure ²	Sewage Sludge ³
1990	228 470	107 132	2 202
1991	202 462	101 677	1 749
1992	163 229	99 569	1 532
1993	168 199	100 721	1 404
1994	169 138	102 329	2 063
1995	195 460	99 559	1 316
1996	179 529	101 177	1 548
1997	169 345	104 403	1 696
1998	169 928	102 519	575
1999	162 700	101 175	644
2000	167 276	101 587	513
2001	165 621	99 490	725
2002	160 403	102 645	616
2003	159 288	104 243	754
2004	154 708	103 907	437
2005	149 562	105 279	143
2006	148 161	104 779	156
2007	148 784	104 535	156*
2008	162 905	107 132	156*

¹ Sales of fertilisers on farms. Source: Yearbook of Farm Statistics 2001 (1990, 1991), 2006 (1992-2006)

² Includes manure applied to agricultural soils as well as deposited on pastures.

³ Source: Finnish Environment Institute, VAHTI system

*Data not available at the time of inventory preparation, assumed to be the same as in 2006

Table 6.4-5 Total yields of the most important crops in Finland in 1990-2008 (Gg a⁻¹).

Year	WW	SW	R	B	O	MC	T	Pe	Po	S	C
1990	137.4	489.5	244.2	1 720.2	1 661.8	37.1	117.0	9.1	881.4	1 125.0	0.2
1991	149.1	281.4	28.2	1 778.8	1 154.9	27.5	94.9	28.3	672.1	1 042.8	0.1
1992	35.2	177.1	26.6	1 330.6	997.6	29.4	132.6	29.1	673.2	1 049.0	0.1
1993	62.1	296.4	62.9	1 678.9	1 202.3	29.8	127.4	30.0	777.2	996.0	0.2
1994	42.3	295.1	22.2	1 858.1	1 149.9	23.6	107.9	13.9	725.6	1 096.9	0.4
1995	52.5	327.0	57.7	1 763.5	1 097.2	30.1	127.9	10.9	798.0	1 110.0	0.2
1996	108.4	350.9	86.9	1 859.6	1 260.8	31.0	89.4	13.3	765.7	896.6	0.2
1997	83.7	380.4	47.3	2 003.5	1 243.4	48.5	92.9	13.1	754.1	1 360.0	0.2
1998	95.9	301.0	49.3	1 316.2	975.1	35.4	63.9	4.2	590.7	892.0	0.1
1999	30.9	223.2	23.6	1 567.7	990.1	43.7	88.3	7.2	791.1	1 172.1	0.2
2000	147.5	390.8	108.2	1 984.8	1 412.8	51.0	70.9	11.7	785.2	1 046.0	0.2
2001	97.1	391.8	64.1	1 786.0	1 287.1	32.9	100.8	11.5	732.8	1 105.2	0.2
2002	84.7	483.9	73.1	1 738.7	1 507.8	38.0	102.8	11.1	780.1	1 066.3	0.2
2003	117.7	561.3	72.8	1 697.4	1 294.5	35.6	93.6	10.2	617.4	892.3	0.4
2004	165.0	617.3	62.4	1 724.7	1 002.4	36.7	74.8	5.6	619.4	1 048.6	0.2
2005	44.8	756.4	32.4	2 101.9	1 073.3	41.4	105.6	8.1	742.7	1 183.3	0.2
2006	62.7	621.4	50.9	1 972.1	1 028.8	43.0	148.3	8.8	575.7	951.9	0.2
2007	154.4	642.4	86.7	1 984.4	1 222.0	33.2	113.5	10.7	701.6	673.1	0.2
2008	87.1	700.5	60.8	2 128.6	1 213.4	24.0	88.9	13.2	684.4	468	0.2

Source: Yearbook of Farm Statistics WW=Winter wheat, SW=Spring wheat, R=Rye, B=Barley, O=Oats, MC=Mixed grain, cereals, T=Turnip rape/rape, Pe=Peas, Po=Potatoes, S=Sugar beet, C=Clover seed

Table 6.4-6 Total yields of the most important vegetables grown in the open in Finland in 1990-2008 (Gg a⁻¹).

Year	Garden peat	White cabbage	Cauliflower	Carrots	Red beet	Swede	Celeriac	Total
1990	5.8	21.1	4.4	31.4	10.7	9.3	1.7	84.3
1991	4.8	20.6	4.4	38.1	11.3	12.0	1.6	92.6
1992	5.4	20.1	5.0	29.7	10.7	9.3	1.8	82.0
1993	6.5	17.6	4.0	36.2	9.6	10.0	1.5	85.5
1994	5.1	23.1	4.4	59.2	13.7	14.8	2.0	122.4
1995	6.4	24.3	4.8	61.3	11.0	12.5	1.5	121.8
1996	9.0	23.1	4.1	53.3	11.7	13.1	1.4	115.7
1997	7.6	28.7	4.6	67.9	14.8	18.3	1.6	143.5
1998	5.2	18.7	4.1	52.3	8.3	10.9	1.5	101.0
1999	6.6	22.4	4.7	61.8	13.6	14.7	0.8	124.6
2000	6.5	20.4	4.9	64.0	12.7	10.1	1.4	120.1
2001	6.6	17.7	4.5	58.3	10.0	11.9	1.1	114.1
2002	6.9	20.0	4.2	58.4	12.4	10.1	1.2	113.3
2003	5.8	19.0	4.0	59.4	12.6	11.5	1.0	113.4
2004	5.9	18.0	3.2	57.0	12.0	15.5	1.1	112.6
2005	4.2	19.3	3.8	67.0	14.0	14.1	0.8	123.3
2006	5.2	17.9	3.6	56.4	12.9	10.2	0.8	106.9
2007	6.4	18.6	3.0	68.2	12.9	13.6	1.0	123.6
2008	5.7	18.8	2.8	60.5	11.0	12.5	0.5	112.0

Table 6.4-7 Area of cultivated organic soils in Finland in 1990-2008 (ha).

Year	Total area of cultivated organic soils, ha	Organic soils on cereals, ha	Organic soils on grass, ha
1990	312 712	141 683	171 029
1991	312 416	143 230	169 185
1992	311 832	144 642	167 190
1993	311 648	146 235	165 413
1994	310 952	147 583	163 370
1995	310 360	148 973	161 387
1996	310 017	150 477	159 539
1997	310 282	152 277	158 005
1998	309 801	153 709	156 092
1999	311 751	156 355	155 396
2000	314 259	159 305	154 954
2001	317 912	162 869	155 043
2002	319 880	165 600	154 281
2003	321 832	168 343	153 489
2004	324 715	171 599	153 115
2005	326 599	174 354	152 245
2006	327 753	176 734	151 018
2007	326 382	177 753	148 630
2008	326 423	179 533	146 890

6.4.2.3 Emission factors and other parameters

IPCC default emission factors have been used for calculating nitrous oxide emissions from agricultural soils (Table 6.4-8). However, the emission factors for organic soils on grass and other crops are based on national data (Monni et al. 2007). The emission factors were calculated on the basis of published results on annual fluxes measured with flux chambers on five different peat fields. There were ten annual flux results measured year-around from grass fields and ten from fields growing other crops. The means of the measurement results minus the proportion of the emissions arising from the use of mineral fertilisers are used as the emission factors.

The parameters used in the Nitrogen mass flow model (e.g. abatement measures for ammonia, $\text{NH}_3\text{-N}$ EFs) can be found in Grönroos et al. 2009 (see chapter 6.3.2.1 “Introduction of Nitrogen mass flow model”). The fractions of volatilised nitrogen have been calculated from the N model. The amount of nitrogen applied to soils has been corrected with the fraction of nitrogen volatilised as NH_3 and NO_x from the synthetic fertilisers ($\text{Frac}_{\text{GASF}}$) and the fraction of nitrogen volatilised as NH_3 and NO_x from manure ($\text{Frac}_{\text{GASM}}$) and sewage sludge ($\text{Frac}_{\text{GASM}}$) (Table 6.4-9). Sewage sludge has the same $\text{Frac}_{\text{GASM}}$ as manure (GPG2000, pg. 4.74). Ammonia from pasture manure now accounts ca. 4.4% of nitrogen (before ca. 33%). $\text{Frac}_{\text{GASF}}$ and $\text{Frac}_{\text{GASM}}$ change yearly due to changes in amounts of volatilized ammonia (and nitric oxide). These fractions are different from earlier submissions, $\text{Frac}_{\text{GASM}}$ is now c. 25% (before c. 33%) and $\text{Frac}_{\text{GASF}}$ c. 1.5% (before 0.6%). $\text{Frac}_{\text{GASM}}$ includes ammonia emissions from manure management. The amount of nitrogen leached has been used for calculating indirect nitrous oxide emissions from leaching and run-off. The values for $\text{Frac}_{\text{GASF}}$, $\text{Frac}_{\text{GASM}}$ and $\text{Frac}_{\text{LEACH}}$ are national values differing from the IPCC default values.

It is estimated that nitrogen leaching is less than the IPCC default value in Finnish conditions. According to Rekolainen et al. (1993) the value is 15% and this value has been used in the inventory. Finland does not assume leaching from deposited nitrogen. In Finland most of the nitrogen is deposited on forest land (and other non-agricultural land). The GPG on LULUCF assumes that leaching from forests is small. According to a Finnish report (Kenttämies & Mattsson 2006), the amount of nitrogen leaching from managed forestland is estimated to be about 0.156 kg/ha in 2005. This is very small figure when compared to leaching from agricultural land (about 16.6 kg/ha in 2007).

IPCC default values (IPCC 2000, Table 4.16), and if a default value was not available, values based on expert judgement, for residue/crop product ratio, dry matter fraction and nitrogen fraction for each crop species have been used (Table 6.4-10).

Table 6.4-8 Emission factors used for calculating direct and indirect nitrous oxide emissions from agricultural soils.

Emission source	Emission factor	Reference
Direct soil emissions		
Synthetic fertilisers	0.0125 kg N ₂ O-N/kg N	IPCC (2000), Table 4.17
Animal wastes applied to soils	0.0125 kg N ₂ O-N/kg N	IPCC (2000), Table 4.17
N-fixing crops	0.0125 kg N ₂ O-N/kg N input	IPCC (2000), Table 4.17
Crop residue	0.0125 kg N ₂ O-N/kg N input	IPCC (2000), Table 4.17
Cultivation of organic soils on cereals	11.7 kg N ₂ O-N/ha/a	Monni et al. (2007)
Cultivation of organic soils on grass	4.0 kg N ₂ O-N/ha/a	Monni et al. (2007)
Atmospheric deposition	0.1 kg N ₂ O-N/kg NH ₃ -N & NO _x -N deposited	IPCC (2000), Table 4.18
Nitrogen leaching and run-off	0.025 kg N ₂ O-N/kg N/a	IPCC (2000), Table 4.18
Sewage sludge spreading	0.0125 kg N ₂ O-N/kg N load	IPCC (1997) (EF ₁)
Animal production		
N excretion on pasture range and paddock	0.020 kg N ₂ O-N/kg N/a	IPCC (1997)

Table 6.4-9 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 _{CLEACH}	0.15	Rekolainen (1989), Rekolainen et al. (1993) Rekolainen et al. (1995)
Fraction of N input that volatilises as NH ₃ and NO _x from synthetic fertilisers.	Fra _{CGASF}	0.015 (2008)	Based on Nitrogen mass flow model, Grönroos et al. (2009)
Fraction of manure N input that volatilises as NH ₃ and NO _x	Fra _{CGASM}	0.25 (2008)	Based on Nitrogen mass flow model, Grönroos et al. (2009)

Table 6.4-10 Residue to crop ratio, dry matter fraction and nitrogen content of crops included in the inventory.

Crop	Res./Crop _i	Fra _{CDM}	Fra _{CNCR}
Winter wheat	1.30 ¹⁾	0.83 ¹⁾	0.0028 ¹⁾
Spring wheat	1.30 ¹⁾	0.83 ¹⁾	0.0028 ¹⁾
Rye	1.60	0.83 ¹⁾	0.0048
Barley	1.20	0.83	0.0043
Oats	1.30	0.83	0.0070
Mixed grain, cereals	1.34 ²⁾	0.83 ¹⁾	0.0140 ²⁾
Turnip rape/rape	3.00 ⁴⁾	0.83 ⁴⁾	0.0150 ⁴⁾
Peas	1.50	0.87	0.0350 ³⁾
Potatoes	0.40	0.45	0.0110
Sugar beet	0.20 ⁴⁾	0.15	0.023 ⁴⁾
Clover seed	1.30 ⁴⁾	0.83 ⁴⁾	0.048 ⁴⁾
Vegetables ⁵⁾	0.20 ⁶⁾	0.15 ⁷⁾	0.015 ⁸⁾

¹⁾ The IPCC default value for wheat used.

²⁾ Average of winter wheat, spring wheat, rye, barley and oats.

³⁾ National value, obtained by expert judgement.

⁴⁾ No IPCC default value available, the value obtained by expert judgement.

⁵⁾ Includes garden pea, white cabbage, cauliflower, carrots, red beet, swede and celeriac.

^{6), 7)} Assumed to be the same as for sugar beet.

⁸⁾ The IPCC default value used.

6.4.3 *Uncertainty and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

Uncertainties in nitrous oxide emissions from agricultural soils were estimated at –60% to +170% for direct emissions and –60% to +240% for indirect emissions. Uncertainty is due to both lack of knowledge of the emission generating processes and high natural variability which make estimation of the average annual emissions factor difficult.

Activity data and related uncertainties used for calculating nitrous oxide emissions from agricultural soils were partly the same as in the calculation of nitrous oxide emissions from manure management (CRF 4.B). Uncertainty estimates of other activity data were based on expert judgement.

The uncertainty estimates of direct emissions from agricultural soils are based on measurement data (see Monni et al. (2007) for more details). For mineral soils, the uncertainty estimate is (–90% to +380%) and for organic soils (–70%...+170%). As there are different EFs for grass and other crops, uncertainty in the shares of area (grass/other crops) is included. This was done by modelling the share of cereals, say A , as a uniform random variable on $[0,1]$, and equating the share of grass with $1-A$. The small change in the amount of crop residues resulting from the inclusion of residue burning in the inventory was considered not to affect the total uncertainty of this category.

Different sensitivity studies have revealed strong sensitivity of the agricultural inventory to the uncertainty of the nitrous oxide emission factor for agricultural soils. In Finland, the uncertainty in the whole greenhouse gas emission inventory containing all sectors and gases is also highly sensitive to the estimated uncertainty of the emission factors for nitrous oxide emissions from agricultural soils.

Due to consistent use of data sources the time series are considered consistent.

6.4.4 *Source-specific QA/QC and verification*

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6.

General (Tier 1) Quality Control (QC) procedures applied to the category Agricultural soils (CRF 4.C):

The QA/QC plan for the agricultural sector includes the QC measures based on the guidelines of the IPCC (IPCC 2000, Table 8.1). These measures are implemented every year during the agricultural inventory. If errors or inconsistencies are found they are documented and corrected. The QC checklist is used during the inventory. More information can be found in chapter 6.2.4.

Tier 2 QC for activity data:

A checklist is used for ensuring consistency of the activity data in different sections of the agricultural inventory.

Tier 2 QC for emission factors:

It is checked annually if new data for updating emission factors has been published. New national data is compared with the emission factors used in the inventory and the applicability of current emission factors in Finland's circumstances is evaluated. There was no new data available for this inventory for updating the emission factors.

The agricultural inventory has been reviewed several times by the UNFCCC Expert Review Teams, and improvements to the inventory have been made according to the suggestions. No specific verification process has been implemented for the agricultural inventory yet. However, a case-study between Finland and

Germany was arranged in August 2004 where Finland's agricultural inventory was reviewed by the German experts. The purpose of the case-study was to find potential adjustments cases and to test specific methods to calculate adjustments. The experiences of this exercise have been taken into account in the development of the inventory. The inventory was audited by Statistics Finland in autumn 2009 and the audit focused especially on recalculations. The results will help to further improve the inventory.

6.4.5 Source-specific recalculations

As the Nitrogen mass flow model was integrated to GHG calculations, all time series for Agricultural soils changed except N-fixation and crop residue. Organic soil time series changed as the area of soil was updated since 1990. See chapter 7.1.2 for details.

Table 6.4-11 Changes in the calculation.

Animal numbers	more precise values (less rounded): cattle, sheep, goats, horses, reindeer values updated: fur animals, swine, poultry
Animal groups	swine: piglets excluded, new groups are: sows with piglets, boars, fattening pigs, weaned pigs horses divided to horses and ponies
Awms	deep litter added, solid storage has subdivisions: dung/urine/manure, all awms% values updated
Nitrogen excretion	values updated
Other parameters	FracGasm, FracGasf, FracGraz changed, share of ammonia volatilised from pasture changed
EF	No change
Method	Nitrogen mass flow model used except for N-fixing, crop residue and sewage sludge: Nitrogen loss as ammonia and nitrous oxide emissions during manure management in animal houses, during storage and application reduce the nitrogen amount from which the direct emissions from manure application in agricultural soils are calculated; for NH ₃ volatilisation of pasture manure, urine and dung volatilisation are now taken into account separately; for synthetic fertilizers fertilizer type field type and placement fertilisation are considered; atmospheric deposition from manure is calculated from the ammonia volatilised during the whole management/application process

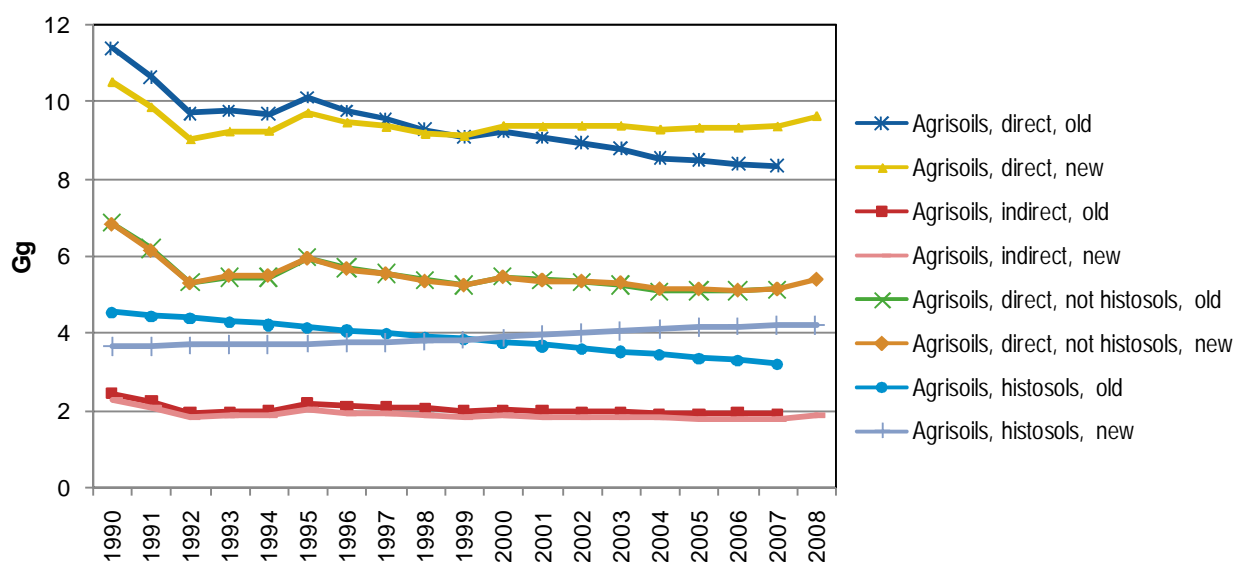


Figure 6.4-3 Time series for Agrisoils. 'New' means new calculations with N flow model integrated and histosol area updated, 'old' means previous inventory emissions.

6.4.6 Source-specific planned improvements

ERT has commented on Finland's method of calculating leaching/run-off. Issue will be investigated for the next submission.

6.5 Field Burning of Agricultural Residues (CRF 4.F)

6.5.1 Source category description

Field burning of crop residues is a source of methane, nitrous oxide, carbon monoxide and nitrogen monoxide. Carbon dioxide is not considered as it is assumed that carbon is reabsorbed to the biomass each growing season. In Finland residue burning occurs only in small scale and it is becoming increasingly rare. Straw is assumed as the most important residue burned. The emissions of cereal straw (wheat, barley, oats, rye) burning are included in the inventory.

Table 6.5-1 Reported emissions under the subcategory Field Burning of Agricultural Residues in the Finnish inventory.

CRF	Source	Emissions reported
4.F 1	Cereals	CH ₄ , N ₂ O
4.F 2	Pulses	NO
4.F 3	Tubers and Roots	NE
4.F 4	Sugar Cane	NO
4.F 5	Other	NE

6.5.2 Methodological issues

6.5.2.1 Methods

The emissions were calculated according to the guidelines in the IPCC 1996 reference manual and the default workbook was used for the calculations. The amount of C and N released from the burned residue was determined based on the C fraction and C/N ratio given in the manual. The N and C values were converted to nitrous oxide and methane emissions by multiplying with the conversion ratios 44/28 and 16/12, respectively.

6.5.2.2 Activity data

The annual crop yields for cereals and other crops were based on data from the Yearbook of Agricultural Statistics. The share of straw burned in 2008 (0.25%) was an estimate made by several experts on crop cultivation in different parts of Finland. The share of burned residue from total cereal residue on the fields for the years 1990-2008 rely on the 2007 estimate and are estimated on the basis of the annual rye yield. The trend of residue burning is assumed to follow the trend of rye crop yield as rye is the most common straw burned on fields. The rye crops fluctuate from year to year. The annual fractions of cereal residue burned are listed in Table 6.5-2. The IPCC default values were used for residue-crop ratio (1.2-1.6), fraction oxidised (0.9), carbon fraction (0.471, average of wheat and barley), nitrogen-carbon ratio (0.012), and dry matter fraction (0.83). Also the default values for emission rates and molecular weight conversion factors were used.

The fraction of burned residue of all residues (IPCC 2000, eq. 4.29, $Frac_{BURN}$) was calculated by dividing the amount of nitrogen in burned straw with the amount of nitrogen in total residue left on the field.

Table 6.5-2 Estimation of the burned fraction.

Year	Rye yield, Gg	Frac of residue burned, cereals	Frac of residue burned, total residue
1990	244.2	0.007	0.00533
1991	28.2	0.001	0.00058
1992	26.6	0.001	0.00048
1993	62.9	0.002	0.00122
1994	22.2	0.001	0.00046
1995	57.7	0.002	0.00115
1996	86.9	0.003	0.00189
1997	47.3	0.001	0.00101
1998	49.3	0.001	0.00108
1999	23.6	0.001	0.00048
2000	108.2	0.003	0.00246
2001	64.1	0.002	0.00137
2002	73.1	0.002	0.00159
2003	72.8	0.002	0.00160
2004	62.4	0.002	0.00139
2005	32.4	0.001	0.00069
2006	50.9	0.001	0.00103
2007	86.7	0.0025*	0.00188
2008	60.8	0.0018	0.00139

* an estimate based on judgement by national experts, other values are inter/extrapolated

6.5.2.3 Emission factors and other parameters

The default values for emission rates (0.007 for N₂O and 0.005 for CH₄) and molecular weight conversion factors were used.

6.5.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

6.5.4 Source-specific QA/QC and verification

QA/QC and verification are the same as in 6.4.4.

6.5.5 Source-specific recalculations

No recalculations were done.

6.5.6 Source-specific planned improvements

No source-specific improvements are planned at the moment.

Appendix_6

The equations used in the calculation of greenhouse gas emissions from the Agriculture sector

1) Equations for calculating methane emissions from enteric fermentation of horse, swine, fur animals and goat

The IPCC Tier 1 approach, Equations 4.12 and 4.13 in IPCC 2000,

Methane emission (Gg/year) = emission factor (*EF*) (kg/animal/year) x number of animals/(10⁶ kg/Gg)

Total CH₄ emissions = $\sum_i E_i$

Index_i = sums all livestock categories and subcategories

E_i = emissions for the *i*th livestock categories and subcategories

2) Equations for calculating methane emissions from enteric fermentation of cattle

In the IPCC Tier 2 approach, the emission factor for each cattle subcategory has been calculated according to Equation 4.14 in the IPCC Good Practice Guidance (IPCC 2000):

$EF = (GE * Y_m * 365 \text{ days/year}) / (55.65 \text{ MJ/kg CH}_4)$, where

GE = Gross energy intake (MJ/animal/day)

Y_m = Methane conversion rate, fraction of gross energy in feed converted to methane (IPCC default value 0.06 used)

The national value for gross energy intake (*GE*) of cattle has been used. The value of *GE* for each cattle subgroup has been calculated by using a slightly modified version of Eq. 4.11 in the IPCC Good Practice Guidance (IPCC 2000).

$GE = \{ [(NE_m + NE_a + NE_l + NE_p) / (NE_{ma} / DE)] + [(NE_g) / (NE_{ga} / DE)] \} / (DE / 100)$

where,

NE_m = Net energy required by the animal for maintenance, MJ/day

NE_a = Net energy for animal activity, MJ/day

NE_l = Net energy for lactation, MJ/day (dairy cows, suckler cows)

NE_p = Net energy required for pregnancy, MJ/day (dairy cows, suckler cows)

NE_g = Net energy needed for growth, MJ/day (bulls, heifers, calves)

Note that the original IPCC equation also has the following terms which have now been excluded: *NE_{mobilised}*, *NE_w*, and *NE_{wool}*

The equations for calculating *NE_m*, *NE_a*, *NE_b*, *NE_p* and *NE_g* are as follows:

$NE_m = C_{fi} * (\text{Weight})^{0.75}$

$NE_a = [C_{ap} * t_p / 365 + C_{ao} * (1 - t_p / 365)] * NE_m$

$NE_l = M_y / 365 * (1.47 + 0.40 * \text{Fat})$

$NE_p = C_p * NE_m$

$NE_g = 4.18 * \{ 0.0635 * [0.891 * (BW * 0.96) * (478 / (C * MW))]^{0.75} * (WG * 0.92)^{1.097} \}$

$$NE_{ma}/DE = 1.123 - (4.092 * 10^{-3} * DE) + [1.126 * 10^{-5} * (DE)^2] - (25.4/DE)$$

$$NE_{ga}/DE = 1.164 - (5.160 * 10^{-3} * DE) + (1.308 * 10^{-5} * (DE)^2) - (37.4/DE)$$

where,

Cf_i = Coefficient, the IPCC default value 0.335 for dairy cattle and the IPCC default value 0.322 for other cattle used

t_p = Length of pasture season, 140 days for suckler cows and heifers, 125 days for dairy cows and 100 for calves

C_{ap} = Coefficient for pasture, the IPCC default value 0.17 used

C_{ao} = Coefficient for stall, the IPCC default value 0.00 used

M_y = The amount of milk produced per year, kg a⁻¹/cow

Fat = Fat content of milk (%)

C_p = Pregnancy coefficient, the IPCC default value 0.10 was used (default for 281 days' pregnancy time)

C = Coefficient related to growth, bulls 1.2, heifers 0.8 and calves an average of these, 1, was used

MW = Mature weight, (see IPCC 2000, p. 4.12)

WG = Average weight gain, (IPCC 2000, p. 4.12) (kg/day), 0 for dairy and suckler cows, 1.1 for bulls, 0.7 for heifers, 0.85 for calves were used

DE = Digestible energy (see IPCC 2000, p. 4.13), the proportion of feed energy (%) not excreted with feces, 70 was used

National data for average milk production, animal weight and fat content of milk and the IPCC default value for methane conversion rate ($Y_m = 0.06$) have been used.

3) Methane emissions from enteric fermentation of sheep and reindeer

$$EF = (GE * Y_m * 365 \text{ days/year}) / (55.65 \text{ MJ/kg } CH_4) \text{ (IPCC)}$$

where

GE = Gross energy intake (MJ/animal/day)

Y_m = Methane conversion rate, fraction of gross energy in feed converted to methane (the IPCC default value 0.06 used)

The equation for calculating the GE for sheep and reindeer (McDonald et al. 1988):

$$GE \text{ (MJ/kg)} = 0.0226 * \text{crude protein (CP)} + 0.0407 * \text{ether extract (EE)} + 0.0192 * \text{crude fibre (CF)} + 0.0177 * \text{nitrogen free extracts (NFE)}$$

where CP, EE, CF and NFE are expressed as g/kg (McDonald et al. 1988, p. 349)

Reindeer

It has been estimated (Nieminen et al., 1998) that reindeer eats lichen in winter (215 days) and hay in summer (150 days) (no other plant species are taken into account). The total number of feed units has been estimated (for male reindeer being 420 for hay and 409 for lichen, for female reindeer 420 for hay and 366 for lichen). The amount of total feed units has been divided with 0.8 feed unit/kg dm.

The GE has been calculated for both hay and lichen. For hay, CP=120, EE=25, CF=360 and NFE=420. For lichen CP=30, EE=20, CF=350 and NFE=580.

For male and female reindeer, the GE (MJ/animal/day) has been calculated as follows:

$$((GE \text{ (MJ/kg) for lichen} * \text{kg dm lichen} + GE \text{ (MJ/kg) for hay} * \text{kg dm hay}) / 365 \text{ days})$$

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 CH₄/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 on the basis of literature (MTT 2004 (feeding tables and feeding recommendations), Maatalouskalenteri 2002). Equation of MacDonald et al. (1988) has been used to calculate the GE for each forage separately. For cereals CP=130, EE=41, CF=79 and NFE=716. For concentrate CP=379, EE=44, CF=126 and NFE=371. For hay CP=120, EE=25, CF=360 and NFE=420. For silage CP=145, EE=40, CF=350 and NFE=390. For pasture CP=180, EE=35, CF=280 and NFE=405. This total GE has been divided with the total amount of each forage (kg dm) to get the annual GE (MJ/kg dm).

The amount of forage (kg dm) consumed annually has been estimated for average sheep (including lambs). This has been multiplied with the GE (MJ/kg dm) to get the GE (MJ/animal/a).

4) Equations for calculating nitrous oxide emissions from manure management

Nitrous oxide emissions from manure management have been calculated as follows:

$$N_2O_Emissions_manure\ management = \sum_{(S)} \{ [\sum_{(T)} (N_{(T)} * Nex_{(T)} * MS_{(T,S)})] * EF_{(S)} \} * 44/28$$

Where,

$N_{(T)}$ = Number of head of livestock species/category T in the country

$Nex_{(T)}$ = Annual average N excretion per head of species/category T in the country, (kg N/animal/year)

$MS_{(T,S)}$ = Fraction of total annual excretion for each livestock species/category T that is managed in manure management system S in the country

$EF_{(S)}$ = Emission factor for manure management system S (kg N₂O-N/kg N)

S = Manure management system

T = Species/category of livestock

Annual average N excretion has been received from MTT Agrifood Research Finland. The distribution of manure management systems is national data, based on Nitrogen mass flow model.

5) Equations for calculating methane emissions from manure management

In the IPCC Tier 2 approach, the emission factor for each cattle subcategory has been calculated according to Equation 4.17 in the IPCC Good Practice Guidance (IPCC 2000):

$$EF_i = VS_i * 365 \text{ days/year} * Bo_i * 0.67 \text{ kg/m}^3 * \sum_{(jk)} MCF_{jk} * MS_{ijk}$$

where,

VS_i = Volatile solid excretion per day on a dry-matter weight basis (kg-dm/day)

Bo_i = Maximum methane producing capacity for manure produced by an animal within defined population i, m³ CH₄/kg VS (IPCC default values used)

MCF_{jk} = Methane conversion factors for each manure management system j by climate region k

MS_{ijk} = Fraction of animal species/category i's manure handled using manure system j in climate region k

For cattle, VS has been calculated with the IPCC equation (IPCC 2000, Eq. 4.16). For other animals (swine, sheep, goats, horses and poultry) IPCC default values for VS have been used. For reindeer no data available so the VS value for goats was used. For fur animal the VS value is based on expert judgement.

$$VS_{cattle} = GE * (1 \text{ kg-dm}/18.45 \text{ MJ}) * (1-DE/100) * (1-ASH/100)$$

where,

GE = Gross energy intake (MJ/animal/day) (see methane emissions from enteric fermentation)

DE = Digestible energy (%) (see methane emissions from enteric fermentation)

ASH = Ash content of manure (%) (IPCC default values used)

Data about the distribution of different manure management systems have been received from Nitrogen mass flow model. For the MCF (slurry) coefficient, the IPCC default value 10% (IPCC 1997) instead of the updated value 39% (IPCC 2000) has been used. For deep litter (cattle, swine) MCF is also 10%, for deep litter (poultry) MCF is 1.5% and for sheep, goats and horses 1%.

6) Equations used for calculating direct and indirect nitrous oxide emissions from agricultural soils

Direct nitrous oxide emissions from agricultural soils include emissions from synthetic fertilisers and manure applied to soils, crop residues, animal production (manure deposited on pasture), sewage sludge applied to soils, N-fixation and cultivation of organic soils. Emissions from manure deposited on pasture are calculated under manure management (Section 6.3).

Direct emissions (IPCC 2000, Eq.4.20)

Nitrous oxide emissions from synthetic fertilisers (IPCC 2000, Eq. 4.22):

Calculated with Nitrogen mass flow model which divides fertilizers to different types and takes into account field type (arable/grass) and placement fertilizing.

$$N_2O_{fert} = N_{fert} * (1 - Frac_{GASF}) * EF * 44/28$$

where,

N_{fert} = The amount of synthetic fertilisers consumed annually (Gg N/year)

$Frac_{GASF}$ = The fraction that volatilises as NH_3 and NO_x

EF = Emission factor (0.0125 kg N_2O -N/kg N-load)

National value c. 0.015 for $Frac_{GASF}$ has been used (from Nitrogen mass flow model).

Nitrous oxide emissions from manure applied to soils (IPCC 2000, Eq. 4.23):

$$N_2O_{manure} = \sum_{(T)} (N_{(T)} * N_{ex(T)}) * (1 - Frac_{GRAZ}) * (1 - Frac_{GASM}) * (1 - Frac_{FUEL-AM}) * EF * 44/28$$

where,

$N_{(T)}$ = Number of head of livestock species/category T in the country

$N_{ex(T)}$ = Annual average N excretion per head of species/category T in the country, (kg N/animal/year)

$Frac_{GRAZ}$ = Fraction of manure that is deposited on pasture

$Frac_{GASM}$ = Fraction that volatilises as NH_3 and NO_x

$Frac_{FUEL-AM}$ = Amount of manure that has been burned for fuel (not existing in Finland)

EF = Emission factor (0.0125 kg N_2O -N/kg N load)

Average annual N excretion per animal is national data (Source: MTT Agrifood Research Finland)

National value c. 0.25 for $Frac_{GASM}$ has been used (See Nitrogen mass flow model).

Nitrous oxide emissions from crop residue (IPCC 2000, Eq. 4.29, modified):

$$N_2O_{CR} = \sum_i (Crop_i * Res_i / Crop_i * Frac_{Dmi} * Frac_{NCRi}) * (1 - Frac_{Burn}) * EF * 44/28$$

where,

$Crop_i$ = Crop production

$Res_i / Crop_i$ = Residue to crop product mass ratio

$Frac_{Dmi}$ = Dry matter content of the aboveground biomass

$Frac_{NCRi}$ = Nitrogen content of the aboveground biomass

EF = Emission factor (0.0125 kg N₂O-N/kg N load)

$Frac_{Burn}$ = Fraction of crop residue that is burned and not left on field (kg N/kg cropres-N)

IPCC default values, and if IPCC default values were not available, national values as $Crop_i$, $Res_i / Crop_i$, $Frac_{Dmi}$ and $Frac_{NCRi}$ have been used (IPCC 2000, Table 4.16, Table 6.5.8, Chapter 6.5). $Frac_{Burn}$ was calculated by dividing the amount of nitrogen in burned straw with the amount of nitrogen in total residue left on the fields.

Nitrous oxide emissions from nitrogen fixation (IPCC 2000, Eq.4.26):

$$N_2O_{BN} = \sum_i [Crop_i * (1 + Res_i / Crop_i) * Frac_{Dmi} * Frac_{NCRi}] * EF * 44/28$$

The parameters used are the same as for calculating emissions from crop residue but only N-fixing crops are included

Nitrous oxide emissions from sewage sludge applied to soils (IPCC 2000, Eq.4.20, modified):

$$N_2O_{sludge} = N_{sludge} * (1 - Frac_{GASM}) * EF * 44/28$$

where,

N_{sludge} = Amount of nitrogen applied annually in sewage sludge, Gg

EF = Emission factor (0.0125 kg N₂O-N/kg N load)

$Frac_{GASM}$ = same as with manure

The amount of nitrogen applied annually in sewage sludge has been received from the Finnish Environment Institute.

Nitrous oxide emissions from cultivated organic soils (IPCC 2000, Eq.4.20, modified):

$$N_2O_{FOS} = F_{OS} * EF * 44/28$$

F_{OS} = Area of organic soils cultivated annually, ha (50% assumed as cereals and 50% grasses)

EF = Emission factor (11.7 kg N₂O-N/ha/year for other crops and 4.0 kg N₂O-N/ha/year for grasses)

The area of cultivated organic soils has been received from MTT Agrifood Research Finland and is based on expert judgement and soil analysis.

Indirect emissions

Nitrous oxide emissions from atmospheric deposition (IPCC 2000, Eq. 4.32):

$$N_2O_{indirect_G} = [(N_{fert} * Frac_{GASF}) + (\sum (N_{(T)} * Nex_{(T)}) + N_{sludge}) * Frac_{GASM}] * EF * 44/28$$

where,

N_{fert} = The amount of synthetic fertilisers consumed annually (Gg N/year)

$Frac_{GASF}$ = The fraction of synthetic fertilisers that volatilises as NH_3 and NO_x

$N_{(T)}$ = Number of head of livestock species/category T in the country

$Nex_{(T)}$ = Annual average N excretion per head of species/category T in the country, (kg N/animal/year)

N_{sludge} = Amount of nitrogen applied annually in sewage sludge, Gg N/year

$Frac_{GASM}$ = The fraction of animal manure that volatilises as NH_3 and NO_x

EF = Emission factor (0.01 kg N_2O -N / kg NH_4 -N & NO_x -N)

Nitrous oxide emissions from leaching and run-off (IPCC 2000, Eq. 4.34, modified):

$$N_2O_{\text{indirect-L}} = [N_{fert} + \sum_T (N_{(T)} * Nex_{(T)}) + N_{sludge}] * Frac_{LEACH} * EF * 44/28$$

where,

N_{fert} = The amount of synthetic fertilisers consumed annually (Gg N/year)

$N_{(T)}$ = Number of head of livestock species/category T in the country

$Nex_{(T)}$ = Annual average N excretion per head of species/category T in the country, (kg N/animal/year)

N_{sludge} = Amount of nitrogen applied annually in sewage sludge, Gg N/year

$Frac_{LEACH}$ = The fraction of N input that is lost through leaching or runoff.

EF = Emission factor (0.025 kg N_2O -N / kg N load)

National value 0.15 for $Frac_{LEACH}$ has been used (See Pipatti, 2001).

7) *Field Burning of Agricultural Residues (cereal straw)* (IPCC 1996, Reference Manual p. 4.81 & Workbook):

$$B_{tot} = \sum_i (Crop_i * Res_i / Crop_i * Frac_{Dmi} * Frac_{Burn} * Frac_{ox})$$

$$C_e = B_{tot} * Frac_C * ER * CR$$

$$N_e = B_{tot} * Frac_C * R_{N/C} * ER * CR$$

Where,

i denotes the different cereal species (rye, barley, oats, wheat)

B_{tot} = Amount of residue biomass burned, as dry matter

$Crop_i$ = Crop production

$Res_i / Crop_i$ = Residue-crop ratio

$Frac_{Dmi}$ = Dry matter content of the aboveground biomass

$Frac_{Burn}$ = Fraction of residue burned

$Frac_{ox}$ = Fraction of residue oxidised

C_e = Carbon emissions as methane (and carbon monoxide)

N_e = Nitrogen emissions as nitrous oxide (and NO_x)

ER = Emission ratio

CR = Conversion ratio

$R_{N/C}$ = Nitrogen-carbon ratio

7 LAND USE, LAND USE CHANGE AND FORESTRY (CRF 5)

7.1 Overview of the sector

7.1.1 Description and quantitative overview

The Land Use, Land-Use Change and Forestry (LULUCF) sector in 2008 as a whole acted as a CO₂ sink of 35.4 million tonnes CO₂ equivalent because total emissions arising from the sector were smaller than the total removals (Figure 7.1-1, Table 7.1-2). The sink in 2008 was approximately 50% the total national emissions without the LULUCF sector.

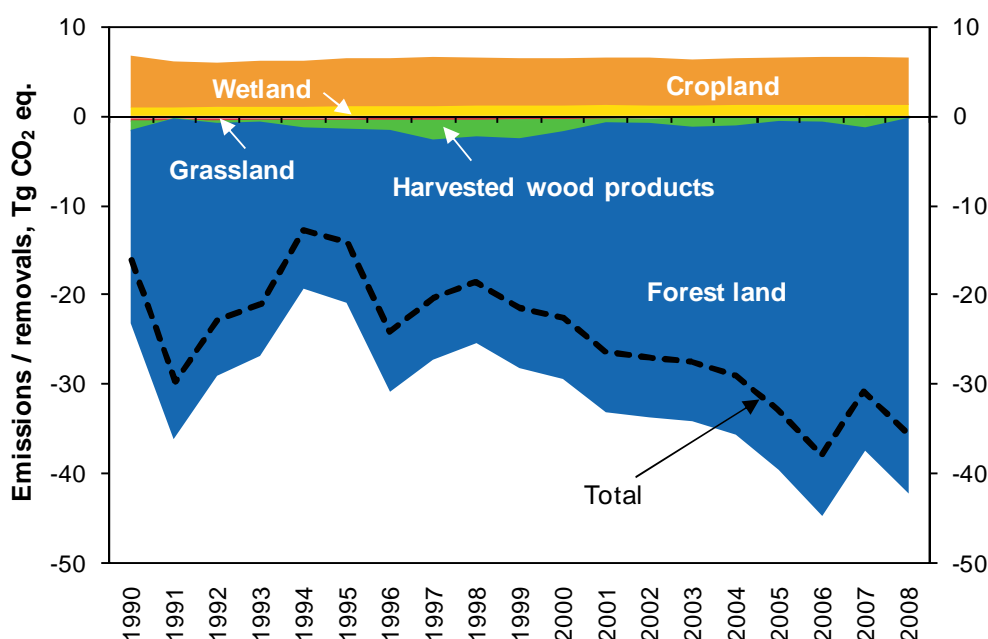


Figure 7.1-1 Net emissions and removals in the LULUCF sector in 1990-2008 by land-use category, Tg CO₂ eq. Positive figures are emissions, negative figures removals. Forest land category includes direct N₂O emission from fertilization and emissions from biomass burning, cropland category CO₂ emission from liming and N₂O emission from disturbance associated with land use conversion to cropland, and wetlands category emissions from drainage of soils.

In the calculation and reporting of emissions and removals from the LULUCF sector the IPCC Good Practise Guidance on Land Use, Land-Use Change and Forestry (IPCC 2003) are implemented. Land area is divided into six land use categories according to GPG LULUCF and into 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 classes are: Forest land, Cropland, Grassland, Wetlands, Settlements and Other land. Emissions and removals from the LULUCF sector are reported for the first time separately for land remaining in the same land-use category and land converted to another land-use category.

The carbon stock changes and greenhouse gas emissions reported under LULUCF sector in Finland are listed in Table 7.1-1. N₂O emissions from disturbance associated with land-use conversion to cropland are reported for the first time in the category CRF 5(III). The LULUCF sector reporting does not include emission estimates from Settlements (CRF 5.E) and Other land (CRF 5.F) land-use categories. In these categories only area data are reported. In addition, N₂O emissions from drainage of forest soils and wetlands (CRF 5(II)), other than those from peat extraction, are not reported. According to the GPG LULUCF, the reporting of these categories is optional. Also national methods to estimate N₂O emissions from drained organic soils are

highly uncertain at the moment, and therefore not applicable. The method is under development to improve the reliability of the estimates.

Finland has prepared estimates for carbon stock changes of Harvested Wood Products (CRF 5.G). The applied method is country-specific and a combination of a flux method and the stock change method. A detailed description of the method, choice of activity data and emission factors is in Section 7.8 Harvested Wood Products.

A general assessment of completeness can be found in Section 1.8 and a more detailed assessment is included in Annex 5.

Table 7.1-1 Reported emissions / removals under LULUCF sector.

CRF	Source	Stock change reported	Emission / removal reported
5.A	Forest land (<i>remaining, converted</i>) - living biomass, DOM and SOM (mineral and organic soils)	carbon / CO ₂	
5.B	Cropland (<i>remaining, converted</i>) - living biomass and SOM (mineral and organic soils)	carbon / CO ₂	
5.C	Grassland (<i>remaining, converted</i>) - living biomass and SOM (mineral and organic soils)	carbon / CO ₂	
5.D	Wetlands (<i>converted</i>) - SOM (peat extraction areas)	carbon / CO ₂	
5.G	Harvested wood products	carbon / CO ₂	
5(I)	Direct N ₂ O emission from fertilization - Forest land		N ₂ O
5(II)	Non CO ₂ emission from drainage of soils - Wetlands (peat extraction areas) ¹		CH ₄ , N ₂ O
5(III)	Non CO ₂ emission from disturbance associated with land use conversion to cropland		N ₂ O
5(IV)	CO ₂ emission from agricultural lime application - Cropland ²		CO ₂
5(V)	Biomass burning - Forest land		CO ₂ , CH ₄ , NO ₂ , NO _x , CO

¹ N₂O emissions from agricultural soils are reported under the Agriculture sector.

² Includes also liming on grasslands.

The LULUCF sector has been a net sink of CO₂ during the whole time series. The large sink is mainly due to the fact that the total increment of the growing stock on forest land has been higher than the total drain.

In 2008 the estimated net sink in living biomass on Forest land was -38 Tg CO₂. The soil organic matter (SOM) pool and the dead organic matter (DOM) pool in mineral forest soils were a combined sink of -9.9 Tg CO₂. In organic forest soils those carbon pools amounted emissions of 6.7 Tg. Minor emission sources in the Forest land category were N fertilisation on forest land (0.035 Tg CO₂ eq.) and biomass burning (0.01 Tg CO₂ eq.).

The high fluctuation in biomass removals in the Forest land category during the period 1990-2008 is mainly caused by the changes in the international market of forest industry products, which affects both the amount of domestic commercial roundwood fellings and the import of roundwood. Another factor affecting the increasing removals trend in Forest land is the increase in the annual increment of the trees. It has risen from 77.7 million m³ in the beginning of the 1990's being nowadays 99.5 million m³. Accelerating tree growth in combination with raising level of cuttings, particularly in the 1990's, has increased production of dead organic matter. This has decreased the CO₂ release from organic soils (peatlands) and increased the CO₂ sink in mineral soils. In the 2000's the cuttings levelled off and the decomposition of the dead organic matter also levelled off the CO₂ sink in mineral soils.

In the Cropland category mineral soils were a sink of 0.9 Tg CO₂ and organic soils a source of 5.5 Tg CO₂ in 2008. Woody living biomass on cropland was a small sink. In addition, emissions from liming in agricultural soils made up about 0.3 Tg CO₂ in 2008. Mineral soils in the Grassland category were a sink of 0.06 Tg and organic soils a source of 0.06 Tg CO₂ in 2008 (Table 7.1-2, Figure 7.1-2).

Emissions from peat extraction areas, reported under the Wetland category, were in 2008 a source of 1.3 Tg CO₂ eq.

In 2008, harvested wood products were a small carbon sink in Finland, 0.1 Tg CO₂ eq. which is only 0.3% of the total sink in the LULUCF sector.

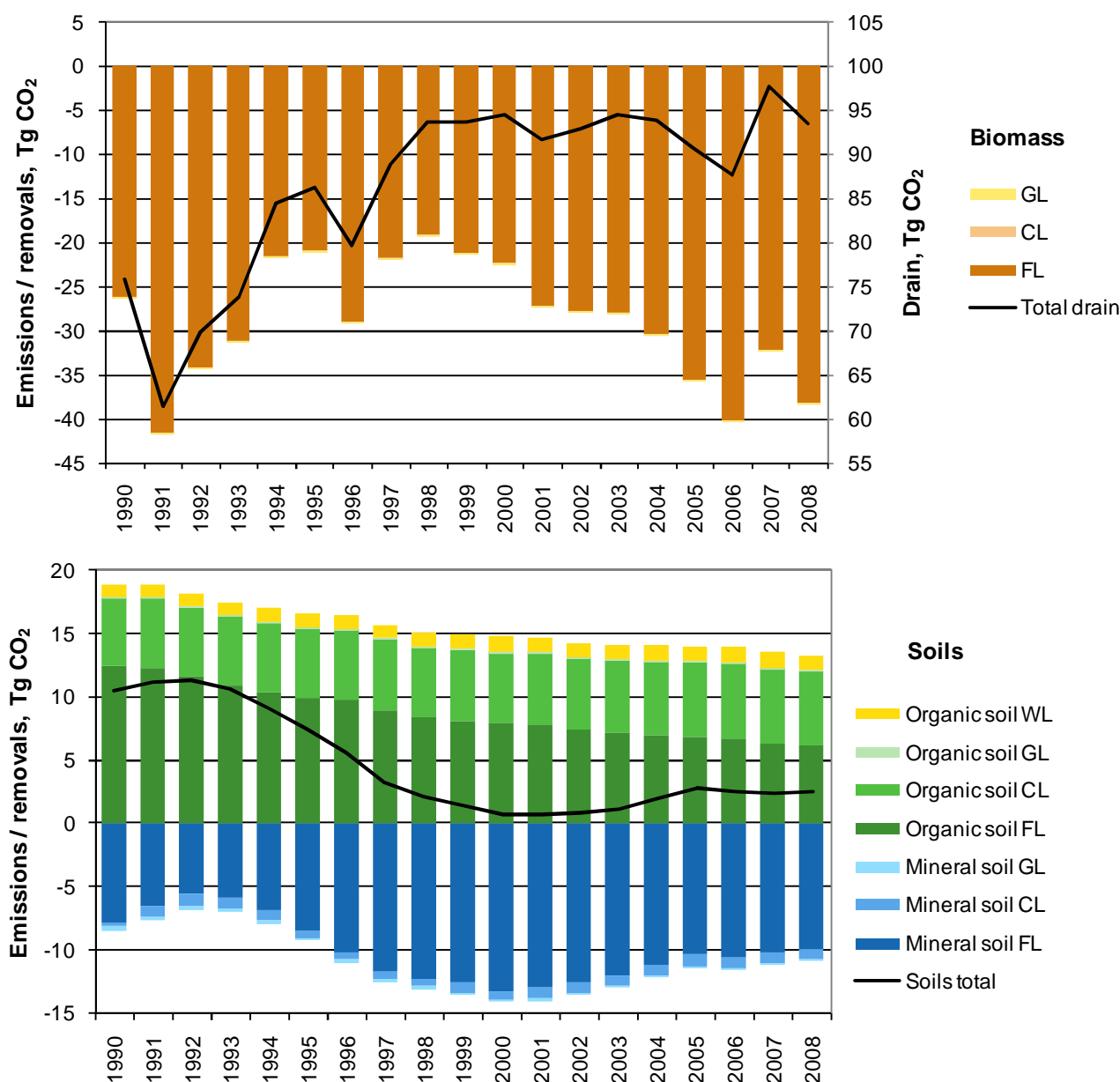


Figure 7.1-2 Emissions (positive sign) and removals (negative sign) from biomass (upper) and from soils (soil and dead organic matter) (lower) in different land-use classes during 1990-2008, Tg CO₂. (FL = Forest land, CL=Cropland, GL=Grassland, WL=Wetland = peat extraction areas).

Table 7.1-2 Greenhouse gas emissions and removals from the LULUCF sector in 1990-2008 (Gg CO₂ eq.) (positive figures indicate emissions, negative removals).

Gg CO ₂ eq.	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Forest land	-21 605	-35 790	-28 231	-26 137	-18 029	-19 505	-29 289	-24 624	-23 079	-25 673	-27 687	-32 400	-32 909	-32 890	-34 565	-39 040	-44 111	-36 121	-41 972
Biomass	-26 260	-41 583	-34 214	-31 339	-21 707	-21 073	-29 063	-21 925	-19 255	-21 279	-22 459	-27 205	-27 807	-28 078	-30 438	-35 616	-40 344	-32 266	-38 263
Mineral soils (soil and dead organic matter)	-7 741	-6 548	-5 605	-5 767	-6 736	-8 426	-10 102	-11 736	-12 227	-12 552	-13 162	-12 996	-12 482	-11 916	-11 108	-10 306	-10 548	-10 209	-9 859
Organic soils (soil and dead organic matter)	12 396	12 341	11 588	10 969	10 414	9 994	9 876	9 036	8 403	8 158	7 934	7 800	7 380	7 104	6 981	6 882	6 782	6 354	6 150
Cropland	5 164	4 718	4 658	4 711	4 666	5 000	4 937	4 989	4 929	4 857	4 918	4 907	4 906	4 877	4 960	5 011	5 085	5 099	5 028
Biomass	-2	-1	-2	-2	-3	-3	-3	-3	-3	-3	-4	-4	-4	-4	-5	-4	-2	-4	-4
Mineral soils (remaining and converted)	-372	-823	-881	-835	-876	-541	-608	-569	-630	-746	-738	-824	-866	-936	-910	-899	-851	-819	-900
Organic soils (remaining and converted)	5 536	5 540	5 539	5 545	5 542	5 541	5 545	5 559	5 559	5 603	5 656	5 731	5 772	5 813	5 870	5 910	5 936	5 918	5 928
Grassland	-264	-254	-242	-229	-224	-223	-214	-210	-208	-192	-175	-158	-132	-106	-79	-53	-27	0	-2
Mineral soils (remaining and converted)	-302	-291	-278	-265	-259	-257	-247	-243	-240	-226	-211	-196	-175	-153	-129	-107	-85	-59	-61
Organic soils (remaining and converted)	38	37	36	35	35	34	33	33	33	35	36	38	42	46	50	54	58	59	59
Wetland	1 011	1 026	1 069	1 088	1 123	1 137	1 169	1 204	1 238	1 256	1 279	1 283	1 263	1 265	1 330	1 315	1 310	1 305	1 308
Organic soil*	1 011	1 026	1 069	1 088	1 123	1 137	1 169	1 204	1 238	1 256	1 279	1 283	1 263	1 265	1 330	1 315	1 310	1 305	1 308
Biomass burning	8	4	13	1	10	7	6	13	2	8	4	5	9	9	4	6	17	7	10
N fertilisation	27	20	9	3	12	6	8	13	13	10	10	11	12	11	12	11	18	17	35
Liming	618	431	273	448	449	386	453	467	428	429	326	395	422	278	252	265	298	249	290
Disturbance associated with land-use conversion to cropland	4	4	4	4	4	4	4	4	4	4	4	5	5	6	6	7	7	7	7
Harvested wood products	-946	307	-225	-93	-756	-870	-1 048	-2 122	-1 766	-2 038	-1 267	-315	-437	-889	-832	-340	-450	-1 211	-95
Total CO ₂ eq.	-15 987	-29 538	-22 675	-20 208	-12 751	-14 062	-23 979	-20 269	-18 443	-21 343	-22 591	-26 273	-26 867	-27 445	-28 917	-32 826	-37 859	-30 655	-35 397

*Includes CO₂, N₂O and CH₄ emissions from peat extraction areas.

7.1.2 Land areas and land-use categories used in the Finnish Inventory

The land areas used in the inventory reporting are consistent with the land-use categories given in the IPCC GPG LULUCF (IPCC 2003). The area estimates for the land-use categories are based on the Finnish National Forest Inventories (NFI) carried out by the Finnish Forest Research Institute. The NFI is a sampling-based forest inventory and it covers all land-use classes. The nationally classified NFI plots are reclassified to the IPCC land-use categories according to the recommendation given by a working group on a follow-up system for land use and land-use changes in Finland (Ministry of Agriculture and Forestry 2005:5). The estimation of areas is based on Finland's official land area published by the National Land Survey of Finland (Table 7.1-3). In this submission the reference date is 1 January 2009 (Land Survey of Finland 1.1.2009). The official area can vary between years and cause recalculation for time series. For that reason is a decision to apply the same area at least for next four submissions has been made. Anyhow, if remarkable changes occur, the new official land area will be used.

The area of peat extraction fields, classified under Wetlands, makes an exception. This are data come from an enquiry by the Association of Finnish Peat industry (1990-2003) and a joint enquiry by Statistics Finland and Finland's environmental administration (starting from 2004).

To produce the area time series for land-use categories the NFI10 data from years 2005–2008 were used. Also NFI7-NFI9 data were utilised to estimate the proportions of remaining and converted areas in each land-use category. These older data were needed because in NFI10 the land use changes were assessed only from the year 1990 onwards. Sample plot data were reclassified according to the IPCC land-use categories and the proportion of each of the six categories was estimated. In Southern Finland the land-use proportions were taken from NFI8-NFI10 for years 1989, 1998 and 2006, which are the average inventory years. The proportions for the other years were interpolated. From the year 2006 onwards the same proportions of land-use categories were applied as in 2006. In Northern Finland the proportions were taken from NFI7-NFI10 for the years 1982, 1993, 2001 and 2007. The interpolation was used the same way as in Southern Finland. All land areas were calculated from NFI10 data and subdivided to the classes among the proportions calculated on the bases of NFI7-NFI10 as described. The area is a product of the proportion of the land-use category and the total land area of a calculation unit. The calculation units, Southern and Northern Finland are presented in Figure 7.1-3. The areas of these units based on the official land area of Finland.

The area estimates for the mineral and organic soils were derived from NFI data and georeferenced soil database. The Finnish soil database includes soil map at scale 1:250 000 and properties of soil (Lilja et al 2006, Lilja et al 2009). The soil database was utilised for the NFI sample plots which did not have the information of soil type (croplands and part of grasslands). In the soil database the polygons smaller than 6.25 ha were merged with adjacent larger polygons. The database was produced by Agrifood Research Finland (MTT), the Finnish Forest Research Institute (Metla) and the Geological Survey of Finland (GTK).

National application of IPCC land-use categories in the Finnish inventory

Forest land. The FAO FRA2005 definition is applied, except for the 0.5 ha minimum area. Forest is a land with a tree crown cover (or equivalent stocking level) of more than 10%. The trees should be able to reach a minimum height of 5 m at maturity in situ. Young natural stands and all plantations established for forestry purposes which have yet to reach a crown density of 10% or tree height of 5 m are included under forest, as are areas normally forming part of the forest area which are temporarily unstocked as a result of human intervention or natural causes but which are expected to revert to forest. The minimum area of 0.25 ha for a forest stand is applied in South Finland and 0.5 ha in North Finland. (See Appendix_7a for how South and North Finland are defined.) For linear formations, a minimum width of 20 m is applied. Parks and yards are excluded regardless of whether they would meet the Forest land definition (Forest Resources... 2000). The FAO forest land covers the nationally defined productive forest land, part of the poorly productive forest land and forest roads. Note that the definition for forest land used under the Convention reporting differs from that used for Kyoto Protocol reporting. Finland prefers to report for UNFCCC all managed forest land under Forest land category.

Cropland. The area of cropland comprises of the area under arable crops, grass (< 5 years), set-aside, permanent horticultural crops, greenhouses and kitchen gardens. **Grassland.** Grassland includes area of grass (≥ 5 years), ditches associated with agricultural land and abandoned arable land. Abandoned arable land in this context means fields which are not used any more for agricultural production and where natural reforestation is possible or is already going on.

Wetlands. Wetlands include peat extraction areas and peatlands which do not fulfil the definition of forest land, cropland, grassland and settlements. Inland waters which comprise of reservoirs and natural lakes and rivers are included in wetlands. Note that emissions are reported only from the peat extraction areas as required in the GPG LULUCF (IPCC 2003).

Settlements. The combined area of NFI built-up land, traffic lines and power lines. Also parks, yards, farm roads and barns are included. Only the areas of settlements remaining settlements and lands converted to settlements are reported.

Other land. Other land includes mineral soils on nationally defined poorly productive forest land, which do not fulfil the threshold values of crown cover or minimum tree height for Forest land. Also unproductive lands on mineral soils are included. Typical sites are rocky lands and treeless mountain areas. Only the total area of other land is reported.

The areas of IPCC land-use categories are given in Table 7.1-3 where the total land area is Finland's official land area. The total area is the official area of Finland including inland waters.



Figure 7.1-3 The calculation units were Southern and Northern Finland.

Table 7.1-3 The areas of IPCC land-use categories in 1990-2008 (1 000 ha). In the last row are given the relative standard errors for the area estimates of land-use categories (%).

	Forest land	Cropland	Grassland	Wetlands	Settlements 1 000 ha	Other land	Total land area	Inland waters	Total area
1990	22 117	2 484	227	3 011	1 305	1 246	30 390	3 453	33 842
1991	22 122	2 482	221	3 010	1 308	1 246	30 390	3 453	33 842
1992	22 132	2 477	215	3 009	1 311	1 246	30 390	3 453	33 842
1993	22 133	2 475	208	3 010	1 318	1 246	30 390	3 453	33 842
1994	22 139	2 471	205	3 009	1 320	1 245	30 390	3 453	33 842
1995	22 143	2 466	203	3 010	1 324	1 245	30 390	3 453	33 842
1996	22 149	2 461	198	3 007	1 329	1 245	30 390	3 453	33 842
1997	22 146	2 462	196	3 006	1 335	1 245	30 390	3 453	33 842
1998	22 143	2 459	194	3 004	1 345	1 244	30 390	3 453	33 842
1999	22 141	2 456	193	3 003	1 352	1 244	30 390	3 453	33 842
2000	22 139	2 456	192	2 999	1 360	1 244	30 390	3 453	33 842
2001	22 132	2 462	190	2 999	1 365	1 242	30 390	3 453	33 842
2002	22 119	2 466	189	2 998	1 376	1 242	30 390	3 453	33 842
2003	22 099	2 470	189	2 999	1 391	1 242	30 390	3 453	33 842
2004	22 087	2 479	187	2 996	1 400	1 241	30 390	3 453	33 842
2005	22 076	2 484	185	2 993	1 412	1 241	30 390	3 453	33 842
2006	22 068	2 483	184	2 990	1 424	1 241	30 390	3 453	33 842
2007	22 063	2 483	183	2 990	1 429	1 241	30 390	3 453	33 842
2008	22 063	2 483	184	2 990	1 430	1 241	30 390	3 453	33 842
Relative standard error, %	0.4	2.0	4.8	2.3	2.6	4.7	-	-	-

The transition areas between all possible land-use categories were calculated on the bases of NFI field data (Table 7.1-4). In NFI10 the land-use changes were assessed on each sample plot for the past 20 years. It is possible that all of the changes in land-use are not perceived in the field. Therefore aerial photographs and thematic maps produced by satellite image classification were utilised to detect the land-use changes which were not found in the field. The satellite images and thematic maps are only additional source of information to minimise the need of aerial photographs. The land-use changes which were found in the image interpretation were confirmed with aerial photographs. The aerial photographs were from year 1990 when available and otherwise from the nearest timepoint from years 1988-1992. The aerial photographs included low and high altitude black and white images and also false colour images. The satellite images were the same as in the multi-source NFI8 and ordered for that purpose at the time. The satellite images were from years 1987-1994. The plots for which the remotely sensed images were required were determined on bases of other variables measured in the field, e.g. age of the stand. Among this determination the land-use change verification with satellite images were needed for approximately 18,000 out of 69,000 of the field plots. After satellite image and thematic map verification it was found that the aerial photographs were needed for about 0.5-1% of the sample plots. The satellite images have been utilised for about 1,000 field plots from which there were 60 plots where aerial photographs were utilised. The use of satellite images is not such time consuming as the aerial photographs, because they have to be rectified to the Finnish uniform coordinate system at first. This land-use change verification with remotely sensed images is an ongoing process and is planned to be continued for the NFI10 plots.

Table 7.1-4 The land-use change matrix for IPCC land-use categories from 1990 to 2008 (1 000 ha) and the relative standard errors of some areas (%). Inland waters are excluded from the matrix.

Final	Initial Forest land	Cropland	Grassland	Wetlands	Settlements	Other land	Final area
Forest land	21 913 (1.0%)	47 (5.1%)	60 (4.3%)	21 (9.3%)	20 (8.6%)	2 (25.0%)	22 063
Cropland	58 (4.5%)	2 405 (3.0%)	5 (8.9%)	12	1	1	2 483
Grassland	4 (9.9%)	23 (12.2%)	156 (6.0%)	0	1	0	184
Wetlands	10 (13.0%)	0	1	2 976 (4.0%)	1	2	2 990
Settlements	126 (3.3%)	11	8	4	1 278 (4.0%)	2	1 430
Other land	0	0	0	0	1	1 240 (6.0%)	1 241
Initial area	22 112	2 486	231	3 014	1 301	1 247	30 390
NET change	-49	-3	-47	-23	128	-6	0

Following changes were made to the reporting of land use and land-use changes compared to the previous submission:

- Land-use categories are reported in sub-categories lands remaining in same category for past 20 years and lands converted to current land use during the past 20 years.
- Inland waters are included in wetlands category.
- Land-use change matrix is established.
- Relative standard errors are estimated for unchanged and converted areas.

7.1.3 Key Categories

The key categories in LULUCF sector in 2008 are summarised in Table 7.1-5.

Table 7.1-5 Key categories in LULUCF sector (CRF 5) in 2008 (quantitative method used: Tier 2).

IPCC source category	Gas	Identification criteria
5.A 1. Forest Land remaining Forest Land - net carbon stock change in living biomass	CO ₂	L, T
5.A 1. Forest Land remaining Forest Land - net carbon stock change in mineral soils	CO ₂	L, T
5.A 1. Forest Land remaining Forest Land - net carbon stock change in organic soils	CO ₂	L, T
5.A 2. Cropland converted to Forest Land - net carbon stock change in organic soils	CO ₂	L, T
5.A 2. Grassland converted to Forest Land - net carbon stock change in living biomass	CO ₂	T
5.A 2. Grassland converted to Forest Land - net carbon stock change in organic soils	CO ₂	L, T
5.A 2. Settlements converted to Forest Land - net carbon stock change in mineral soils	CO ₂	L, T
5.A 2. Wetlands converted to Forest Land / drained-WL - organic soils	CO ₂	L, T
5.B 1. Cropland Remaining Cropland - net carbon stock change in mineral soils	CO ₂	L, T
5.B 1. Cropland Remaining Cropland - net carbon stock change in organic soils	CO ₂	L, T
5.B 2 Forest Land converted to Cropland / organic soils - net carbon stock change in organic soils	CO ₂	L, T

7.2 Forest land (CRF 5.A)

7.2.1 Source category description

The net removals from forest land were -41.9 Tg CO₂ in 2008. The net sink has increased 94% from 1990.

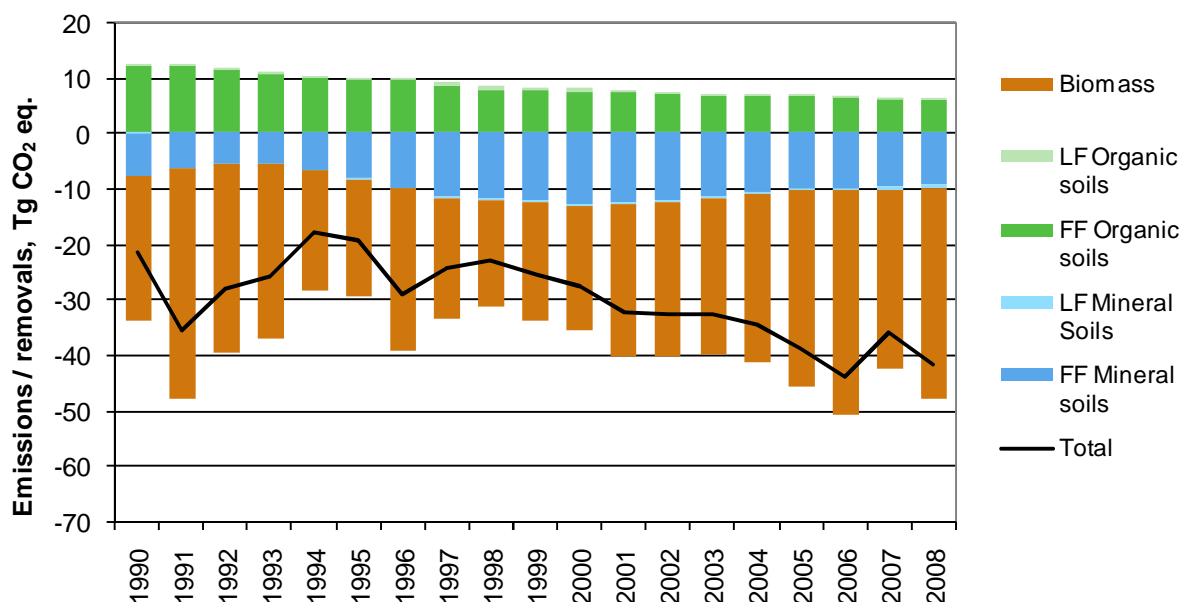


Figure 7.2-1 Emissions (positive sign) and removals (negative sign) in Forest land in 1990-2008 (FF = Forest land remaining Forest land, LF = Land converted to Forest land). Direct N₂O emission from fertilization and emissions from biomass burning are included in total removals amount.

This source category includes CO₂ emissions from changes in carbon stock in living biomass, litter, dead wood and soil organic matter in Forest land remaining forest land (CRF 5.A.1) and Lands converted to forest land (CRF 5.A.2). N₂O emission from fertilization (CRF 5(I)) and emissions from biomass burning (CRF 5(IV)) are also included in the total removals, these emission classes are presented in Section 7.7.

Forest land covers 73% of Finland's land area that is 22 million ha. Characteristic to Finland is a high proportion of peatlands (27%) of which 73% is drained. Main tree species are Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*), Silver birch (*Betula pendula*) and Downy birch (*Betula pubescens*). These four species cover about 95% of the volume and annual increment of the growing stock. All forest land area is considered as managed, including commercially managed forest and protected forest areas as well.

Forest land is defined as land with a tree crown cover (or equivalent stocking level) of more than 10% and an area of more than 0.25 ha in southern Finland and 0.5 ha in northern Finland. The trees should be able to reach a minimum height of 5 m at maturity in situ. Young natural stands and all plantations established for forestry purposes which have yet to reach a crown density of 10% or tree height of 5 m are included under forest, as are areas normally forming part of the forest area which are temporarily unstocked as a result of human intervention or natural causes but which are expected to revert to forest. For linear formations, a minimum width of 20 m is applied. Forest roads are included in the forest land. Parks and yards, for example, are excluded regardless of whether they would meet the forest land definition.

This definition is compatible with the forest land definition reported to the FAO. According to the FRA2005 Country report Finland has reported to use the minimum area of 0.5 ha for forest. Anyhow, in the Country report is an addition: "Information generated from NFI data base. The FRA2005 definition is "Land spanning more than 0.5 hectares...". Finland uses a minimum area of "more than 0.25 ha..." and does not consider the width of the area. It is only defined that the shape of forest land is such that it can be considered forestry land. (FRA2005). Area of forest land was estimated from the NFI data (see Section 7.1.2).

The following carbon stock changes are reported: the combined estimates for above and below ground biomass of the growing stock and the combined estimates for litter, dead wood and soil organic matter. In this report DOM refers to litter and dead wood and SOM to soil organic matter. Carbon stock changes are reported separately on mineral and organic forest soils. Organic soils are considered peatlands as defined 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.

The most important quantity of the total sink in Forest land is the net removals in tree biomass -38.3 Tg CO₂. Minerals soils were also a net sink of 9.9 Tg CO₂, whereas organic soils were a net source of 6.1 Tg CO₂. The living biomass and mineral soils (DOM+SOM) has been a sink during the time series whereas the organic soils have been a source (Table 7.2-1). The soil carbon- and dead organic matter stocks of mineral soils have increased steadily due to fact that soil carbon model has been applied with constant weather data (i.e. the decomposition of organic matter does not increase although measured temperatures have been higher since 2000). The drainage causes the emissions on organic soils. Poorly productive lands were drained in the 1960's and 1970's to amend the site conditions for trees to grow. The effect of increased tree growth increased the litter input to the soil and it can be seen in the time series as a decline trend in the emissions of organic soils.

The CO₂ removals in tree biomass have increased 45% from 26.3 Tg CO₂ in 1990 to 38.3 Tg CO₂ in 2008. The development of the two components, the annual increment of the growing stock and the drain of the growing stock, determines the trend of the sink. The fluctuation in the sink between years is very much affected by the total roundwood removals, which is the main part of the drain (Table 7.2-3). Other components are the harvest residues and natural mortality of trees. The international market situation in forest industry affects to the variation in roundwood removals. The cuttings were at a low level in the first half of the 1990's, being at the lowest level 44.6 million m³ in 1991. In the second half they increased considerably, the highest drain was 70.0 million m³ in 2000. Although, the wood consumption increased in 2006, the total drain still decreased 3%. Imported roundwood and the use of roundwood reserve compensated the domestic commercial roundwood fellings. The situation changed in 2007, the total drain amounted to 73 million m³ and the roundwood was purchased from domestic roundwood markets. The low cutting level at the beginning of the 1990's and mid-2000's can be seen as a high CO₂ sink in biomass (Figure 7.2-1). In 2007 commercial roundwood fellings were at exceptional high level, being 58 million m³. The increase in fellings compared to the earlier year was 14% (Finnish Statistical Yearbook of Forestry 2008). In 2008, the total drain decreased again and the CO₂ removals increased by 19%.

The annual increment of the growing stock has increased almost steadily during the period 1990-2008 (Table 7.2-2). It has risen from 77.7 million m³ in the 8th National forest inventory (1986-1994) to 86.7 million m³ in the 9th inventory (1996-2003) and it still has increased by 14% from the NFI9 to the NFI10 (99.5 million m³) (Finnish Statistical Yearbook of Forestry 2008). The effective forest management activities in the 1960's and the 1970's and the sustainable forest management since then can be seen as a reason to the increased growth in forests. The increased growth of trees has compensated the changes in cuttings. However, the risen level of the cuttings has increased the annual production of the dead organic matter, particularly when the level of the cuttings grew in the mid-1990's.

Forest management activities can also be seen as a cause to the increased CO₂ sink of the mineral soil. The variation in organic soil emission and sinks in the period 1990-2008 is caused mainly by two factors, 1) the drainage of the non-forest sites has caused the transition from non-forest to forest land and thereby the slight increase in the area of the drained organic soils and 2) the increase of the growing stock on organic soils. The first factor has slightly increased the total emissions caused by peat decomposition. The second factor has increased the removal caused by the increased fine root litter production.

Table 7.2-1 Emissions and removals from Forest land Carbon pools in 1990-2008 (Tg CO₂) (positive sign means emissions and negative sign sinks).

Carbon pool	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Mineral soils																			
Biomass	-13.9	-26.6	-20.0	-17.2	-8.5	-7.7	-14.1	-7.6	-5.5	-6.9	-7.7	-11.6	-11.9	-12.0	-13.8	-18.1	-22.0	-14.8	-20.9
Soil and dead organic matter	-7.7	-6.5	-5.6	-5.8	-6.7	-8.4	-10.1	-11.7	-12.2	-12.6	-13.2	-13.0	-12.5	-11.9	-11.1	-10.3	-10.5	-10.2	-9.9
Total of mineral soils	-21.6	-33.1	-25.6	-23.0	-15.2	-16.1	-24.2	-19.3	-17.7	-19.5	-20.9	-24.6	-24.4	-23.9	-24.9	-28.4	-32.5	-25.0	-30.8
Organic soils																			
Biomass	-12.4	-15.0	-14.2	-14.1	-13.3	-13.4	-15.0	-14.3	-13.8	-14.4	-14.8	-15.6	-15.9	-16.1	-16.7	-17.5	-18.4	-17.6	-17.4
Soil and dead organic matter	12.4	12.3	11.6	11.0	10.4	10.0	9.9	9.0	8.4	8.2	7.9	7.8	7.4	7.1	7.0	6.9	6.8	6.4	6.1
Total of organic soils	0.0	-2.7	-2.6	-3.1	-2.9	-3.4	-5.1	-5.3	-5.4	-6.2	-6.9	-7.8	-8.5	-9.0	-9.7	-10.6	-11.6	-11.2	-11.3
Total Forest land	-21.6	-35.8	-28.2	-26.1	-18.1	-19.5	-29.3	-24.6	-23.1	-25.7	-27.7	-32.4	-32.9	-32.9	-34.6	-39.0	-44.2	-36.3	-42.0

7.2.2 Methodological issues

7.2.2.1 Carbon stock changes in living biomass

Methods

The estimation of change in the carbon stock in living tree biomass is consistent with Method I (the so-called default method) in the GPG LULUCF, which requires the biomass carbon loss to be subtracted from the biomass carbon increment for the reporting year (IPCC 2003, Eq 3.22, p. 3.24). The carbon uptake/loss figures were calculated from estimates of the total biomass increment of living trees and from drain estimates based on the National Forest Inventory of Finland (NFI) and on annual statistics on cutting removals. However, the estimates of the biomass stock in the living trees were also required in order to estimate tree litter production, an input to the computations reported in Section 7.2.2.2. These stock estimates, together with NFI estimates of tree stem volume were also used to compute biomass expansion factors for the drain.

Biomass stocks in living trees

To provide the litter production input to the computations of Section 7.2.2.2, 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). For this submission, the data from the NFI8, NFI9 and NFI10 were used. The stock estimates contain only the trees with a height of at least 1.3 m, since smaller trees were not measured in the NFIs.

The stocks by tree species and compartments were estimated separately from the three NFIs for mineral and drained organic soils of Southern and Northern Finland. Each estimate was allocated to the appropriately weighted mean of the measurement dates, and linear interpolation between and beyond these three time points was applied.

The stocks of living tree biomass were estimated separately for Forest land converted from other land-use categories. For forest land converted from Cropland, Wetlands (peat extraction areas), or Settlements, the initial tree biomass was assumed to be zero, and the mean annual increment was estimated as an average of current stocks per area unit divided by the number of years since the conversion. The estimated mean stock for areas with a given number of years since conversion was then obtained by multiplying the mean annual increment by that number. For Forest land converted from Grassland or Wetlands (peatland), the assumption of initial zero biomass is not justified, and the mean stock per area unit was estimated as described above for the whole forest land. The mean stocks were finally multiplied by the annual area estimates of the converted categories.

Biomass increment due to tree growth

The biomass increment of living trees was estimated using tree-level measurements on field sample plots of the NFI and Finnish biomass models (Repola et al. 2007, Repola 2008 and Repola 2009). For this submission, the data come from the NFI8, NFI9 and NFI10. Measurements of five years' increment in the breast-height diameter (DBH) and the height of the trees enabled estimation of biomass five years before the inventory in addition to the current biomass. The differences divided by five served as estimates of annual biomass increments.

The total annual biomass increments of living trees were estimated separately from the three NFIs for mineral and organic soils of Southern and Northern Finland. Each estimate was allocated to the appropriately weighted mean of the mid-points of the five years' period of increment measurements, and linear interpolation between and beyond these three time points was applied. The increment estimates contain only the trees with a height of at least 1.3 m (DBH of 0 cm).

The increments of living tree biomass were estimated separately for Forest land converted from other land-use categories. For Forest land converted from Cropland, Wetlands (peat extraction areas), or Settlements, the initial tree biomass was assumed to be zero, and the mean annual increment was estimated as current

stock per area unit divided by the number of years since the conversion. For Forest land converted from Grassland or Wetland (peatland), this assumption is not justified, and the mean increment per area unit was estimated as described above for the whole forest land. The mean increments were then multiplied by the annual area estimates of the converted categories (Table 7.2-2).

Table 7.2-2 Reported conversion types in category lands converted to Forest land.

Original land-use		Soil type	Drainage	Biomass before conversion
Cropland		mineral	yes	no
		organic	yes	no
Grassland		mineral	no/yes	yes
		organic	no/yes	yes
Wetlands	peat extraction	organic	yes	no
	peatland	organic	yes	yes
Settlements				no

The increment in the remaining forest land was estimated as the difference between the increment in the whole forest land and the sum of the increments over the converted categories.

Table 7.2-3 Biomass increment of living trees in 1990-2008 (Tg/a).

	Mineral soils			Organic soils			Total
	pine	spruce	decid.	pine	spruce	decid.	
1990	16.0	16.1	10.5	5.4	3.1	4.6	55.7
1991	16.2	16.0	10.7	5.5	3.2	4.6	56.2
1992	16.4	15.9	10.9	5.6	3.3	4.7	56.8
1993	16.6	15.8	11.1	5.8	3.4	4.7	57.4
1994	16.8	15.7	11.3	5.9	3.4	4.8	57.9
1995	17.0	15.6	11.5	6.0	3.5	4.8	58.4
1996	17.4	15.6	11.7	6.1	3.6	4.9	59.3
1997	17.8	15.7	12.0	6.3	3.7	5.0	60.5
1998	18.2	15.8	12.3	6.4	3.8	5.1	61.6
1999	18.6	15.8	12.6	6.6	3.9	5.2	62.7
2000	19.1	15.9	12.8	6.7	4.0	5.2	63.7
2001	19.6	16.0	12.9	6.9	4.1	5.2	64.7
2002	20.1	16.1	13.1	7.1	4.2	5.2	65.8
2003	20.6	16.3	13.2	7.3	4.3	5.2	66.9
2004	21.1	16.4	13.3	7.4	4.4	5.1	67.7
2005	21.7	16.5	13.4	7.6	4.5	5.1	68.8
2006	22.2	16.6	13.5	7.8	4.6	5.1	69.8
2007	22.7	16.7	13.6	7.9	4.8	5.1	70.8
2008	23.2	16.8	13.8	8.1	4.9	5.1	71.9

Drain of the growing stock

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 statistics on *commercial removals* are based on the information provided by sampled roundwood purchasers and by Metsähallitus. Since 2000 commercial removals have been 50-58 million m³ annually (Finnish Forest Research Institute 2008). As all important purchasers are included in the sample, the statistics on commercial removals can be considered as very reliable.

The non-commercial roundwood removals refer to logs for contract sawing and fuelwood used in dwellings. The Finnish Forest Research Institute has investigated the volumes of contract sawing and fuelwood at some 10 years' interval. The recent estimate for contract sawing is 1.0 million m³ of logs and for fuelwood 5.2 million m³. For the latter the standard error is 4.9%. Accordingly, the roundwood removals in total have recently ranged from 57 to 62 million m³.

Of felled trees a part or parts of stems are left on ground. The Finnish Forest Research Institute made an investigation on those *harvesting losses*, including those from silvicultural measures, during 1966-1971. The results were presented as percentages of the total felled stemwood volumes (Mikkola 1972). In recent years, annual harvesting losses have been about 6 million m³ and fellings in total 65-69 million m³/a in total.

The volume of *unrecovered natural losses* was estimated by the NFI on the basis of the follow-up of 3,000 permanent sample plots measured in 1985 and 1995. The estimated unrecovered natural losses are 2.8 million m³/a. Recently, the total drain has been 65-73 million m³/a.

The most recent estimate, 4.9 million m³/a, for the volume of *unrecovered natural losses* is based on the NFI9 and NFI10 measurements of permanent sample plots. Recently, the total drain has been 65-73 million m³/a. This information on removals, fellings and drain is available for pine, spruce and broadleaves by forestry centre and concerns total volumes by three tree species groups. Carbon stock changes are reported in mineral and organic soils, but there is no information on the distribution of cutting removals according to the soil type. The following procedure was applied to estimate the distribution.

The annual drain of the growing stock without the natural drain component (i.e. stem removals and the residual stem parts in cuttings) was estimated for the forestry centres by tree species group and separately for intermediate fellings and regeneration fellings as well as mineral soils and organic soils. These figures were estimated for the years 1990-2008. The growing stock drain is published in report (Finnish Forest Research Institute 2008). First, the natural drain component estimated for the 9th NFI was subtracted from the growing stock drain. This component does not include the natural drain removed in the cuttings.

The drain of the growing stock was divided to strata of mineral and organic soils and to intermediate and regeneration fellings applying the yearly areas treated with fellings (Finnish Forest Research Institute 2008), the NFI9 estimates of proportions of felling types on mineral and organic soils, and the NFI9 estimates of average removals in intermediate and regeneration fellings.

1. The annual felling areas were divided to mineral and organic soils and within them to intermediate and regeneration fellings applying the proportions calculated from NFI9 data by forestry centres.
2. The mean volumes of removals in regeneration fellings were estimated from the NFI field plots where regeneration was suggested in the next five years, while the removals in intermediate fellings were estimated from recently treated (0-5 years) forest stands and the removal was estimated to have been 25% of the original growing stock.
3. The total removals by strata were calculated multiplying the strata areas (1) by average removals by tree species (2). The proportions of removals in strata by tree species were used to divide the drain of the growing stock (without natural removals) to the particular strata (Table 7.2-4).

As in the case of the increment, the drain of the growing stock is computed for the combined national productive forest land and poorly productive forest land. The forests belonging to this set but not to FAO forest land are very poorly productive forests, almost never treated with cuttings and in that sense in balance, i.e. the natural mortality of the trees is the same as the increment of the trees. This means that the increment minus drain is about zero and does not affect the CO₂ balance of the growing stock.

Activity data

The method to estimate the time series for Forest land remaining Forest land and Lands converted to Forest land is described in Section 7.1.2 The time interval which a land area stays in a converted category is 20 years. Forest lands are divided into mineral soils and organic soils, method described in Section 7.1.2.

Table 7.2-4 The drain in 1990-2008 (million m³/a).

Year	Mineral soils			Organic soils			Total
	pine	spruce	decid.	pine	spruce	decid.	
1990	18.7	19.6	8.9	2.5	2.8	2.6	55.1
1991	14.4	16.5	7.2	2.0	2.4	2.1	44.6
1992	17.4	18.3	8.0	2.4	2.6	2.3	51.0
1993	18.0	19.6	8.4	2.5	2.8	2.4	53.7
1994	20.5	23.8	8.7	2.8	3.4	2.5	61.7
1995	21.3	23.9	9.4	2.9	3.4	2.7	63.6
1996	20.2	22.1	8.5	2.7	3.1	2.4	59.0
1997	22.0	25.4	9.2	2.9	3.6	2.6	65.7
1998	24.1	25.5	9.9	3.5	3.6	2.8	69.4
1999	24.0	25.7	9.8	3.5	3.7	2.8	69.5
2000	24.3	25.9	9.7	3.5	3.7	2.8	69.9
2001	23.7	24.5	9.7	3.4	3.5	2.9	67.7
2002	24.2	24.8	9.8	3.5	3.5	2.9	68.7
2003	25.1	24.7	10.0	3.6	3.5	2.9	69.8
2004	24.8	25.1	9.9	3.6	3.6	2.9	69.9
2005	23.8	23.7	10.0	3.5	3.4	3.0	67.4
2006	23.8	22.2	9.8	3.5	3.2	2.9	65.4
2007	27.2	24.4	10.7	3.9	3.5	3.2	72.9
2008	26.3	20.5	11.8	4.3	3.1	3.7	69.7

Biomass conversion factors

The stem volumes of the drain were converted to whole tree biomasses and those of the tree compartments using expansion factors computed as ratios of estimated biomass stocks and stem volume stocks Table 7.2-5. The factors computed from the data of each separate inventory were applied for the corresponding years of measurement.

Table 7.2-5 Expansion factors applied to convert stem volumes of the drain into whole tree biomass (Mg/m³).

Tree species	Region	Soil	NFI8	NFI9	NFI10
			1986-1995	1996-2003	2004-2008
pine	south	mineral	0.638	0.633	0.623
		organic	0.6665	0.654	0.639
	north	mineral	0.674	0.670	0.666
		organic	0.703	0.690	0.677
spruce	south	mineral	0.752	0.736	0.732
		organic	0.788	0.785	0.791
	north	mineral	0.851	0.876	0.874
		organic	0.919	0.931	0.947
decid.	south	mineral	0.835	0.833	0.825
		organic	0.854	0.841	0.829
	north	mineral	0.908	0.931	0.921
		organic	0.896	0.897	0.872

The default factor 0.5 was used to convert the whole tree biomass increment/drain to carbon uptake/loss, and

$$CO_2 \text{ emissions/removals} = (\text{carbon uptake by tree growth} - \text{carbon loss due to drain}) * 44/12$$

7.2.2.2 Carbon stock changes in soil, litter and dead wood on Forest land remaining Forest land

Mineral soils

Methods and emission factors

The methodology of estimation of 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 dynamic soil carbon model. For forests remaining as forests, the Yasso model (Liski et al. 2005) was applied. Note that for the lands converted to forest land model version Yasso07 (Liski et al. 2009, Tuomi and Liski 2009) was applied, see Figure 7.2-2.

An aggregated estimate of the litter, dead wood and soil organic matter (DOM+SOM) was provided due to fact that the soil carbon model Yasso estimates carbon stock change for the total of above mentioned components. The Yasso models have been defined to estimate carbon stock change to the depth of 1 metre. The division of soil carbon pools of those models to SOM and DOM is artificial.

The aggregated estimate of carbon stock changes of DOM+SOM were driven by tree- and ground vegetation litter production and were estimated with the Yasso soil model (Liski et al. 2005), which has been developed for applications concerning the decomposition of various litter types and soils (Figure 7.2-2, Table 7.2-8). Mathematical formulations of the processes and the model are available in the Appendix 7b. The Yasso simulations were made separately for the mineral soils of Southern- and Northern Finland.

Before soil carbon stock change simulations three steps of preliminary preparations had to be done:

- i) Estimation of the litter input data from trees, ground vegetation and drain with division into three different decomposition compartments
 - non-woody litter
 - fine woody litter
 - coarse woody litter
- ii) Estimation of weather parameters for Southern and Northern Finland
- iii) Estimation of the initial values of model state variables based on the NFI6 (1971–1976) (sc. spin-up runs to obtain steady state of 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 biomass compartments of living trees and litter production rate coefficients. Biomass compartments were calculated from the sample tree data of NFIs with tree-level biomass models. Fine root biomass was estimated using coefficients that describe the relation between root and leaf biomass (Helmisaari et al. 2007). The biomass estimation is described in Section 7.2.2.1 above.

The litter input was estimated since the 6th National Forest Inventory (NFI6). Harvesting and drain statistics were also used to estimate litter input of these components. The increase of the energy wood use since 2000 was also taken into account by deducting the amounts of harvesting residues used for energy production (Finnish Forest Research Institute 2008). Biomass of the harvesting residues and unrecovered natural losses were estimated with the biomass expansion factors that were estimated with used biomass equations and with the corresponding NFI data. 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 Southern and for Northern Finland on mineral soils. The litter input of the ground vegetation was estimated with litter turnover rates presented by Liski et al. (2006).

The litter production from each tree biomass compartment was calculated using litter production rate coefficients (Table 7.2-6) as follows

$$\text{litter}_i = r_i * W_i,$$

where r_i is the litter production rate of compartment i and W_i is biomass of compartment i (kg). In mineral soils litter production from ground vegetation was assessed based on the vegetation coverage measurements of NFI and biomass models (Muukkonen et al. 2006) (Table 7.2-7).

Table 7.2-6 Litter production rates from biomass compartments of trees (Lehtonen et al. 2004, Muukkonen and Lehtonen 2004, Starr et al. 2005, Liski et al. 2006). Litter production rate for pine needles in drained organic soils is based on recent measurements (Penttilä, unpublished data).

Tree species	Needles	Branches	Bark of stems	Bark of stumps	Roots >2mm	Fine roots
pine, south	0.245	0.02	0.0052	0.0029	0.0184	0.85
pine, north	0.154	0.02	0.0052	0.0029	0.0184	0.85
pine, drained peatlands	0.33	0.02	0.0052	0.0029	0.0184	0.85
spruce, south	0.1	0.0125	0.0027	0	0.0125	0.85
spruce, north	0.05	0.0125	0.0027	0	0.0125	0.85
deciduous, south	0.79	0.0135	0.0029	0.0001	0.0135	0.85
deciduous, north	0.79	0.0135	0.0029	0.0001	0.0135	0.85

Table 7.2-7 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, Southern Finland	50.6	-	Southern Finland	Mineral soils
Total, Northern Finland	66.6	-	Northern Finland	Mineral soils

The weather data applied in the model runs was obtained from data provided by the Finnish Meteorological Institute (FMI). The daily weather data since 1961 was provided with 10*10 km grid covering whole Finland. The 10th National Forest Inventory plots defined as forest according to the FAO definition were thereafter used to estimate "forest weather" of Southern and Northern Finland. The daily weather was fetched from the nearest point from the grid for each NFI plot. After that weighted average weathers were calculated for Southern and Northern Finland. The mean annual weather data used with Yasso model was estimated for Southern and Northern Finland for periods of 1971-2000.

The model initialisation was done with the NFI6 data from (1971-1974) in Southern Finland and from (1975-1976) in the Northern Finland. The average annual litter input of trees, ground vegetation, loggings and natural mortality of those time periods were given to the Yasso model. The model was driven with the given litter and mean weather data of 1961-1990 to the steady state. According to earlier research it was shown that approximately 10 years of simulation since spin-up is enough to cancel out the effect of spin-up level (Peltoniemi et al. 2006). Stock changes in forest soil carbon were reported as 5 years' moving averages. Model predictions were a sum for carbon stock change of dead wood, litter and soil organic matter.

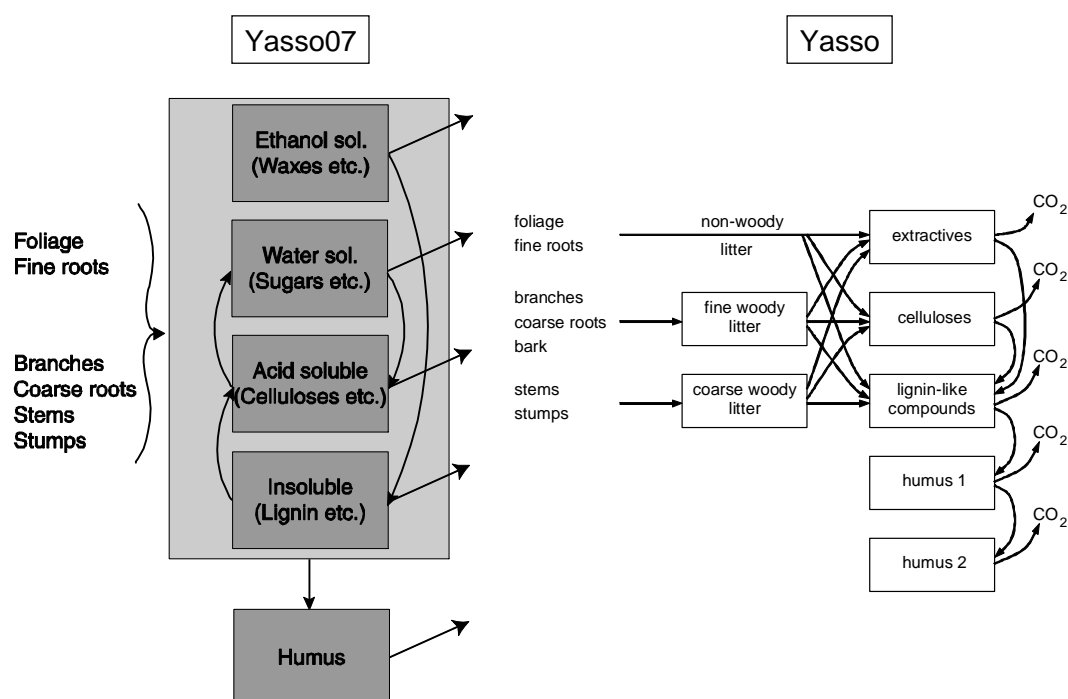


Figure 7.2-2 Flow chart of different versions of Yasso soil carbon model. The boxes represent soil carbon compartments and arrows carbon fluxes (Liski et al. 2005, Liski et al. 2009, Tuomi and Liski 2009).

Table 7.2-8 Parameter values used in the Yasso model for simulations for Forest land remaining Forest land (Liski et al. 2005).

Parameter	Value
a fwl	0.5385
a cwl	0.077
k ext	0.48
k cel	0.3
k lig	0.22
k hum1	0.012
k hum2	0.0012
c nwl-ext	0.29
c nwl-cel	0.48
c nwl-lig	0.23
c fwl-ext	0.03
c fwl-cel	0.66
c fwl-lig	0.31
c cwl-ext	0.03
c cwl-cel	0.71
c cwl-lig	0.26
s hum1	0.6
s hum2	0.36
p ext	0.2
p cel	0.2
p lig	0.2
p hum1	0.2

Annually estimated carbon stock changes in soils are presented as range and average for forests remaining forests and separately for Southern and Northern Finland in Table 7.2-9.

Table 7.2-9 Estimated carbon stock changes of soil organic matter and dead organic matter in mineral soils of forests remaining forests (last 20 years).

Carbon stock change (tons C per ha)	Soil type	Area	Min	Max	Mean
DOM+SOM, mineral soils	Mineral	South	0.10	0.27	0.20
DOM+SOM, mineral soils	Mineral	North	-0.04	0.17	0.09

Activity data

The total area of Forest land remaining Forest land in 1990-2008 was estimated from the NFI10 data (see Section 7.1.2). The time series for mineral soil area could not be estimated from the NFI10 data only because there was no information on soil type for all sample plots transferred from forest land to other land-use. Therefore the proportional distribution of mineral soils was estimated from the NFI8-NFI10 data for years 1990-2008. The area of mineral soil was a product of the proportion and the area of forest land remaining forest land.

Organic soils

Methods and emission factors

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.

Description of decomposition of peat is significant part of estimation of carbon stock changes in the organic forest soils in Finland, and these decomposition estimates were made using emission coefficients (heterotrophic soil respiration). The estimation of emissions and removals on organic soils was done as follows:

$$\text{change in DOM+SOM} = \text{change in DW} + \text{below ground litter input} - \text{emission from soil}$$

The above ground litter pool of organic forest soils were assumed to be in a steady state. The carbon stock change of dead wood on organic soils was based on the measurements of the NFI9 and NFI10. Soil carbon model Yasso was not used here, since model does not operate on organic soils.

Carbon stock changes in organic soils were assessed only in the drained peatlands, while carbon stocks change of soils in undrained peatlands were assumed to be in a steady state (equal to zero).

The decomposition of peat was estimated by multiplying the site-type-specific emission values (Minkkinen et al. 2007) (Table 7.2-10) by the corresponding area estimates provided by the NFI (Table 7.2-12).

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 7.2.2.1 above. Litter inputs to below ground consisted of annual litter production from roots of trees, shrubs and graminoids and roots of trees subjected to cuttings or natural losses. Similarly as in mineral soils, below ground litter production from trees was estimated as a product of biomass estimate and turnover rate (Table 7.2-6). Annual below ground litter production from ground vegetation was estimated according to Laiho et al. (2003) (Table 7.2-7). Stem volume estimates of dead wood were converted to carbon by applying wood density and carbon content estimates by decomposition classes, see Mäkinen et al. (2006).

Table 7.2-10 Carbon emissions ($\text{g C m}^{-2} \text{a}^{-1}$) due to heterotrophic soil respiration from drained organic soils (peatlands) (Minkinen et al. 2007). For 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

Annually estimated carbon stock changes in soils are presented as range and average for forests remaining forests and separately for Southern and Northern Finland in Table 7.2-11.

Table 7.2-11 Estimated carbon stock changes of soil organic matter and dead organic matter in drained organic soils of forests remaining forests (last 20 years).

Carbon stock change (tons C per ha)	Soil type	Area	Min	Max	Mean
DOM+SOM, drained organic soils	Organic	South	-0.57	-0.25	-0.35
DOM+SOM, drained organic soils	Organic	North	-1.07	-0.51	-0.75

Activity data

The total area of Forest land remaining Forest land in 1990-2008 was estimated from the NFI10 data (see Section 7.1.2). The time series for organic soils area could not be estimated from the NFI10 data only because there was no information on soil type for all sample plots transferred from forest land to other land-use. Therefore the proportional distribution of organic soils was estimated from the NFI8-NFI10 data for years 1990-2008. The area of organic soils was a product of the proportion and the area of forest land remaining forest land. Organic soils were further divided into drained and un-drained soils and drained soils to five site types by the fertility of the soil (Table 7.2-12).

Table 7.2-12 Areas of drained organic soils of forests remaining forests (peatlands) by site type (1 000 ha).

Year	Herb-rich type (Rhtkg)	<i>Vaccinium myrtillus</i> type (Mtkg)	<i>Vaccinium vitis- idaea</i> type (Ptkg)	Dwarf shrub type (Vatkg)	<i>Cladina</i> type (Jätkg)
1990	711	1 131	1 513	803	10
1991	696	1 138	1 510	812	12
1992	681	1 145	1 508	821	15
1993	666	1 152	1 506	830	18
1994	666	1 167	1 535	830	21
1995	666	1 182	1 564	830	24
1996	666	1 197	1 593	830	28
1997	665	1 212	1 621	830	31
1998	665	1 226	1 649	830	34
1999	666	1 233	1 667	827	36
2000	667	1 239	1 685	825	38
2001	668	1 245	1 703	822	40
2002	671	1 229	1 689	827	41
2003	674	1 212	1 674	833	41
2004	677	1 195	1 660	839	41
2005	680	1 179	1 646	845	42
2006	683	1 163	1 633	851	42
2007	688	1 150	1 628	860	41
2008	688	1150	1628	860	41

7.2.2.3 Carbon stock changes in soil, litter and dead wood on lands converted to Forest land

Mineral soils

Methods and emission factors

The soil carbon model Yasso07 (Liski et al. 2009, Tuomi and Liski 2009) was applied for the lands converted to forest land, see Figure 7.2-2 (www.ymparisto.fi/syke/yasso). The previous Yasso version is not applicable to converted areas. The Yasso07 model was developed and tested against soil carbon measurements on afforestation and reforestation sites in HILPE project and found to work well. The HILPE project developed the estimation method of carbon stock changes for afforested/reforested croplands and for croplands which formerly have been forest land.

For mineral soils an aggregated estimate of the litter, dead wood and soil organic matter (SOM) was provided due to fact that the soil carbon model Yasso07 estimates carbon stock change for the total of the above mentioned components (DOM+SOM). The division of soil carbon pools of those models to SOM and DOM is artificial.

For lands converted to forest land, model version Yasso07 was applied (Figure 7.2-2 and Table 7.2-13). The model was applied using a similar approach as in the use of the previous version of the Yasso model for forest land remaining forest land (see above).

Before simulations three steps of preliminary preparations were made:

- i) estimation of the litter input data from trees and ground vegetation with division into two different decomposition compartments
 - non-woody litter
 - fine woody litter (mean size 2 cm)
- ii) estimation of the chemical properties of the litter (acid-, water-, ethanol- and non-soluble compounds) and weather data (mean temperature, amplitude and precipitation)
- iii) estimation of the initial values of model state variables that was provided for agricultural lands by MTT Agrifood Finland (Table 7.2-14).

The annual mean temperature, precipitation and amplitudes ($0.5 \times (\text{minimum monthly mean} - \text{maximum monthly mean})$) were estimated for Southern and for Northern Finland (see more detailed description of weather data derivation under section Mineral soils, above). The response of the soil carbon and litter stocks for the land-use change were estimated with Yasso07 and with the average weather of 1971-2000 derived from the NFI 10 plots.

The carbon stock estimates of the previous land-use before conversion were estimated by the MTT Agrifood Finland, by applying Yasso07 model with typical agricultural litter input. For both croplands and grasslands model runs with Yasso07 were made with typical cultivation practises to estimate carbon stocks (Table 7.2-14). For settlements the starting value of soil carbon was assumed to be equal to zero. It is known that part of the settlements converted to forest have the original soil carbon stock different than zero. Due to lack of appropriate estimates for carbon stock of settlements those were assumed to be zero (before conversion to forest).

Table 7.2-13 Parameter values, and their uncertainty used in the Yasso07 model simulations for lands converted to forests (www.ymparisto.fi/syke/yasso/).

Parameter	Value	D 0.99	Unit	Meaning
aA	0.73	[0.62, 0.84]	a-1	decomposition rate of A
aW	5.8	[5.0, 6.6]	a-1	decomposition rate of W
aE	0.29	[0.24, 0.35]	a-1	decomposition rate of E
aN	0.031	[0.027, 0.042]	a-1	decomposition rate of N
p1	0.48	[0.41, 0.54]	.	mass flow from W to A
p2	0.01	[0, 0.16]	.	mass flow from E to A
p3	0.83	[0.60, 0.98]	.	mass flow from N to A
p4	0.99	[0.94, 1]	.	mass flow from A to W
p5	0	[0, 0.08]	.	mass flow from E to W
p6	0.01	[0, 0.21]	.	mass flow from N to W
p7	0	[0, 0.004]	.	mass flow from A to E
p8	0	[0, 0.003]	.	mass flow from W to E
p9	0.03	[0, 0.25]	.	mass flow from N to E
p10	0	[0, 0.007]	.	mass flow from A to N
p11	0.01	[0, 0.031]	.	mass flow from W to N
p12	0.92	[0.79, 0.99]	.	mass flow from E to N
b1	0.096	[0.078, 0.122]	C-1	temperature dependence parameter
b2	-1.4	[-2.4, -0.8]	10-3C-2	temperature dependence parameter
y	-1.21	[-1.06, -1.36]	m-1	precipitation dependence parameter
pH	4.5	[3.7, 5.6]	10-3....	mass flow from A,W,E,N to humus
aH	1.7	[1.4, 1.9]	10-3 a-1	humus decomposition coefficient
roo1	-1.71	[-1.90, -1.50]	cm-1	size dependence parameter
roo2	0.86	[0.76, 0.96]	cm-2	size dependence parameter
r	-0.306	[-0.321, -0.290]	.	size dependence parameter

Table 7.2-14 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.

Original land use	A	W	E	N	humus	total
Cropland SF	6.44	0.84	0.63	35.53	32.24	75.68
Cropland NF	8.36	1.10	0.89	43.10	35.30	88.75
Grassland SF	11.57	1.79	1.47	39.10	33.03	86.96
Grassland NF	15.43	2.44	2.08	40.35	35.85	96.14
Settlements	-	-	-	-	-	0

On lands converted to Forest land litter input given into 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 those NFI10 plots were used. The biomass estimation is described in the section 7.2.2.1 above. This estimation was done separately for forested croplands, grasslands and settlements. Same biomass turnover rates were applied here as for forest remaining forest. The average ground vegetation litter was also applied as an input during the simulations. Yasso07 model runs were made for 20 years to estimate the response of the soil carbon for the land-use change.

Annually estimated carbon stock changes in soils are presented as range and average for lands converted to forests and separately for Southern and Northern Finland in Table 7.2-15.

Table 7.2-15 Estimated carbon stock changes of soil organic matter and dead organic matter in drained organic soils of lands converted to forests (20 years after conversion).

Carbon stock change (tons C per ha)	Activity	Soil type	Area	Min	Max	Mean
DOM+SOM	CL to FL	Mineral	South	-1.46	0.30	-0.29
DOM+SOM	CL to FL	Mineral	North	-1.21	0.43	-0.17
DOM+SOM	GL to FL	Mineral	South	-1.67	-0.14	-0.46
DOM+SOM	GL to FL	Mineral	North	-1.48	0.03	-0.32
DOM+SOM	SL to FL	Mineral	South	5.33	5.33	5.33
DOM+SOM	SL to FL	Mineral	North	6.75	6.75	6.75

Activity data

The method to estimate area of lands converted to forest land during the previous 20 years is described in Section 7.1.2. The area of mineral soils on lands converted to forest land was estimated from the NFI10 data for years 1990-2008.

Organic soils

Methods and emission factors

The emission estimation of organic lands converted to Forest land followed the estimation principles of organic forests remaining forests. The below ground litter input of the trees was derived from the biomass estimates of the corresponding NFI data; for the ground vegetation average estimates of below ground litter were used. The biomass estimation is described in the section 7.2.2.1 above.

The difference between below ground litter input and emissions were estimated for the period of 20 years after conversion and annual average was used in calculation.

Table 7.2-16 The emissions of the original land use on organic soils converted to forests (tons C per ha).

Original land use	Assumed previous emissions of CO ₂ (tons C per ha)	Source
Cropland	4.1	MTT Agrifood Research Finland
Grassland	0.25	(IPCC 2003)
Peat extraction sites	2.6	(Alm et al. 2007)
Wetlands	Depending on the fertility, see Table 7.2-10.	(Minkinen et al. 2007)

For organic lands converted to forests previous emissions were obtained mainly from MTT Agrifood (Table 7.2-16). Those emission factors were inline with the reporting of the emissions of organic grasslands and croplands. Due to use of IPCC default factor for organic grasslands leads to the situation where after reforestation or afforestation litter input of ground vegetation and trees compensate that emission and those soils turn to be a sink of carbon. The usability of that IPCC default emission factor will be evaluated by the MTT Agrifood (Table 7.2-16).

Annually estimated carbon stock changes in soils are presented as range and average for lands converted to forests and separately for Southern and Northern Finland in Table 7.2-17.

Table 7.2-17 Estimated carbon stock changes of soil organic matter and dead organic matter in drained organic soils of lands converted to forests (20 years after conversion).

Carbon stock change (tons C per ha)	Activity	Soil type	Area	Min	Max	Mean
DOM+SOM	CL to FL	Organic	South	-2.96	-2.39	-2.68
DOM+SOM	CL to FL	Organic	North	-2.96	-2.39	-2.68
DOM+SOM	GL to FL	Organic	Finland	1.18	1.18	1.18
DOM+SOM	WL (peat extraction) to FL	Organic	Finland	-1.47	-1.37	-1.42
DOM+SOM	WL (peatlands) to FL	Organic	Finland	-2.54	-2.11	-2.36
DOM+SOM	SL to FL	Organic	South	-2.40	-2.14	-2.28
DOM+SOM	SL to FL	Organic	North	-2.70	-2.41	-2.56

Table 7.2-18 Estimated carbon stock changes of soil organic matter and dead organic matter in organic forest soils converted to Wetlands (peat extraction or peatlands) (20 years after conversion).

Carbon stock change (tons C per ha)	Activity	Soil type	Area	Min	Max	Mean
DOM+SOM	FL to WL (peat extraction)	Organic	Finland	-3.9	-3.9	-3.9
SOM& litter	FL to WL (peatlands)	Organic	Finland	-1.9	-1.9	-1.9

Activity data

The method to estimate area of lands converted to forest land during the previous 20 years has been described in the Section 7.1.2. The area of organic soils on lands converted to forest land and area of drained organic soils was estimated from the NFI10 data for years 1990-2008. The areas of drained soils were divided into five site fertility types.

7.2.3 Uncertainty and time series' consistency

7.2.3.1 Uncertainty for Carbon stock changes in living biomass

Biomass stocks in living trees

The analysis of uncertainty in the estimates of biomass stocks in living trees was based on five years' data from NFI10 (2004-8). Sampling error, due to NFI data being a sample from all forests, was estimated by the standard method of Finnish NFI to be less than 1% for all biomass components.

Model error, due to uncertainty in the parameter values of the biomass models and to the residual variation of the true tree biomass values around the model predictions, was estimated through simulation. Analytical results could not be derived because of the nonlinear (exponential) form of the biomass models. The error distribution of a biomass stock estimate was approximated by the distribution of differences between the actual estimate and 100 simulated estimates containing variation in the applied parameter values and added residual variation. This variation was simulated for the linear predictors (of the logarithmic biomass) from the normal distributions with zero means and standard deviations equal to the standard errors reported by Repola et al. (2007) and Repola (2008, 2009). The standard deviations of the resulting distributions of biomass estimates are reported in Table 7.2-19.

Table 7.2-19 Relative standard errors for NFI10 estimates of biomass stocks in living trees.

Tree species	Soil	Region	Relative standard error, %				
			stem (incl. bark)	branches	needles/ foliage	stump	roots
pine	mineral	south	4	30	128	32	29
		north	4	27	112	30	28
	drained organic	south	4	29	124	31	28
		north	4	27	118	30	28
spruce	mineral	south	3	53	150	55	55
		north	3	50	181	53	54
	drained organic	south	3	52	130	51	53
		north	3	51	119	47	51
deciduous	mineral	south	6	64	200	35	139
		north	5	53	200	32	114
	drained organic	south	6	61	200	34	134
		north	6	54	200	33	121

Biomass increment due to tree growth and the drain of the growing stock

The errors of the tree-level estimates of the current biomass and the biomass five years before the inventory are necessarily highly correlated. Since no information was available on this correlation, it was assumed to be equal to 1. Accordingly, the relative model error in the estimates of biomass increment was assumed to be equal to the relative error in the corresponding biomass stock estimates, and the resulting estimates of error due to parameter uncertainty are reported in column $rse_{I,par}$ of Table 7.2-20.

The error in the biomass increment due to sampling and residual variation is approx. 2% for all tree species groups, and the corresponding error in the drain was assumed to be 5%. Further studies are being conducted in order to estimate the uncertainty in the volume of the drain, although its effect is expected to be minor in comparison to the effect of parameter uncertainty in biomass models.

Net change in biomass of living trees

Because the same models (with the same errors in the parameter values) were used to convert the stem volume of both increment and drain into whole tree biomass, the error in the net change by tree species group was estimated through

$$\text{var}(I - D) = ((I - D) * rse_{I,par})^2 + (I * rse_{I,ran})^2 + (D * rse_{D,ran})^2,$$

where

I and D denote the increment and growth,

$\text{var}(I - D)$ is the square of the total standard error for net change,

$rse_{I,par}$ is the relative standard error of increment due to parameter uncertainty,

$rse_{I,ran}$ is the relative standard error of increment due to sampling and residual variation (2%), and

$rse_{D,ran}$ is the relative standard error of drain due to sampling and residual variation (5%).

Table 7.2-20 An example of error estimation for net change in biomass of living trees in 2008. The applied relative standard errors are based on the whole data of NFI10 (2004-8).

	increment I, Tg	drain D, Tg	change I - D, Tg	rse _{I, par} , %	var(I - D)
pine	31.3	19.8	11.5	12.2	3.3
spruce	21.7	18.1	3.6	25.9	1.9
deciduous	18.9	13.1	5.8	34.2	4.5
Total	71.9	51.0	20.9		9.7

From Table 7.2-20 an estimate of the relative standard error of the total net change for year 2008 can be calculated as

$$\sqrt{\text{var}(I - D)} / (I - D) = 14.9\%$$

However, the increment estimate for 2008 is an extrapolated value based on average five years' increment over the whole five years' data of NFI10. The extrapolation error and the annual variation in tree growth make the error in one year's change estimates essentially larger. In this submission, we have used an assumption that the relative standard error is two times the value obtained with the calculations described above, 30% in the case of the example. The method will be further developed.

7.2.3.2 Uncertainty for Carbon stock changes in soils, litter and dead wood

Peltoniemi et al. (2006) have estimated the uncertainty of analysing soil carbon stock changes with the Yasso model using aggregated inventory data. The uncertainty was analysed with the Monte Carlo method. The conclusion was that the uncertainty of the soil carbon sink was dominated by soil model initialisation, the effect of temperature on decomposition rates and uncertainties concerning drain (tree volume distribution) and litter production (amount of different litter compartments).

The uncertainty concerning model initialisation decreased significantly after a decade of simulation. Peltoniemi et al. reported standard deviation to be 2.6 Tg C a⁻¹ in analysing carbon stock changes of Finland's forest soils with no initialisation of the model and 0.9 with model initialisation.

Uncertainty concerning biomass data basing on expert opinion (Timo Kareinen, Risto Sievänen, pers. comm. 2007) was added to the uncertainty of simulated results, producing an uncertainty estimate of 1.35 Tg C a⁻¹ in mineral soils, yielding 92% relative standard error for the carbon stock change in mineral soils in year 2008. Further, the uncertainty in estimating the decomposition of peat on drained organic soils, basing on the standard deviation of emission coefficients reported by Minkinen (2007, see Table 7.2-10), was added to the total variance estimate yielding 78% relative standard error for carbon stock change in organic soils in year 2008.

7.2.3.3 Time series' consistency

Forest land area, tree biomass and growth of the tree biomass are estimated from NFI data. The time series for the area of Forest land is estimated from the NFI10 data, so the possible inconsistency due to different sample design or different classification between inventories is avoided. Tree biomass and growth of the biomass is estimated from data based on three NFIs. Any inconsistency can not be expected between inventories due to the same methods and tree measurement techniques.

7.2.4 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6.

Finnish Forest Institute (Metla) has set up a management team to guide and supervise the reporting of emissions and removals of LULUCF sector which are under Metla's responsibility. The members have a

wide expertise to measurements and methodology to estimate carbon stock changes and greenhouse gases. All changes in methods, activity data and emission or other factors and parameters are discussed and approved by the management team before they are introduced to the advisory board (see Section 1.6.1). Representatives from Statistics Finland and Agrifood Research Finland are invited to the meetings. Management team meets 2-4 times per year.

Quality control procedures named in IPCC Good Practice Guidance for LULUCF (IPCC, 2003) Table 5.5.1 were done for all calculations.

Tier 2 OQ procedures:

- NFI is the only data source, which covers all land-use categories. Forest and forest land areas were compared to forest areas reported to the FAO. Calculated areas for land-use changes were compared to available statistics (see Chapter 11).
- Only the latest NFI data were used to estimate areas to produce consistent time series. In the previous submission, also older data were used. The FAO definition was not possible to apply consistently to older data.
- To every sample plot in NFI data the IPCC land-use category was determined. That prevents double counting. Summing up the all sample plots was checked, that all plots have IPCC land-use category (no missing data).
- Areas of all land-use categories were estimated in Metla to prevent double-counting or omissions of land areas. MTT use the same areas of cropland and grassland for agriculture sector.
- During the calculation procedure, the areas were summed up to check that all sample plots were included in the calculation: areas of all land-use categories and subcategories sum up to the total land area of Finland.
- Reporting covers the whole Finland, since the NFI has been carried out in whole country.
- All relevant carbon pools are included in forest land reporting. The excluded trees, which height is less than 1.3 m, are not significant part of the living biomass pool. Their proportion of the growing stock is less than 1%, which is about the same of the biomass.
- NFI data is used for area and biomass estimation. NFI is a sampling based inventory. The sampling method is reported in reviewed articles and books. (Tomppo 2006, Heikkinen 2006, Tomppo et al. 1998, Tomppo et al. 2001)
- The aerial photos, satellite images and other material used to assess land-use changes for NFI sample plots are the applied procedure were documented.
- The biomass model implemented in this submission is published in a reviewed article. The development work took two years to implement these models and results were compared to calculation done with the previous Karjalainen and Kellomäki conversion factors. Total biomass was compared biomass calculated by Marklund's models. (Repola 2008, Repola 2009)
- The assumptions and parameters for Yasso soil model were checked. Comparisons between Yasso and Yasso07 were done. (Peltoniemi et al. 2004, Liski et al. 2009)
- Yasso07 model has been tested on the afforestation, reforestation and deforestation sites by Metla and MTT in sc. HILPE project. Preliminary results of this comparison of model results against soil carbon measurements indicate that model performs adequately.

The data based on forest statistics were produced by the Finnish Forest Research Institute, Forest Information Service. Data descriptions are available (in Finnish) including the applied definitions, methods of data compilation, reliability and comparability (<http://www.metla.fi/metinfo/tilasto/hakkuut/>, <http://www.metla.fi/metinfo/tilasto/metsienhoito/>).

The Finnish Forest Research Institute and University of Helsinki have established a network of monitoring of drained organic soils; this network is mainly aimed for GHG monitoring (C-Mon). The existence of this network allows the quality control measures in future, when emission from drained organic soil will be evaluated.

7.2.5 Source-specific recalculations including changes made in response to the review process

In this submission Finland reports first time the carbon stock changes for lands remaining in the same land use and for lands converted to the current land use as the ERT has recommended. Due to this, the whole time series for activity data (areas) and for carbon stock changes in living biomass, litter dead wood and soils were recalculated.

The following changes are done since the previous submission:

- Time series for forest land area is recalculated.
- Emissions and removals are reported separately for forest land remaining forest land and lands converted to forest land.
- National biomass models for pine, spruce and broadleaved trees are implemented. The same models are applied to estimate changes in tree biomass and biomass stock for different tree compartments for soil computations. The volume of the drain is converted to whole tree biomass using biomass conversion factors computed as a ratio of estimated biomass stock and stem volume.
- Carbon stock change in litter and dead wood are reported as combined estimate with carbon stock change in soils.
- Yasso07 version is implemented to estimate carbon stock changes for lands converted forest land.
- The uncertainty estimations for all carbon pools are revised.

Area of forest land

Time series for areas of forest land was recalculated and forest land was reported in sub-categories forest land remaining forest land and lands converted to forest land. The method how time series were estimated was changed. For the previous submission time series was established as follows:

- Area of forest land was estimated from NFI8, NFI9 and NFI10 data for the mid-year of each inventory for 13 georeferenced Forestry Centre regions and Åland Islands
- Areas between mid-years was interpolated
- sum of regional areas was the estimate for the whole country.

In the present submission time series was established as follows:

- Area of forest land was estimated from NFI10
- The proportions of forest remaining forest land and converted to forest land were estimated from NFI7, NFI8, NFI9 and NFI10 data for the mid-year of each inventory for Southern and Northern Finland
- Areas between mid-years was interpolated
- Sum of Southern and Northern Finland areas was the estimate for the whole country.

Justification for the applied method: The Finnish NFI is a sample based inventory system in which the main proportion of sample plots are measured as temporary plots. Thereby the sampling is different in different inventories. The sampling error for forest land area is 1% or about 200,000 ha. The net-change between 1990 and 2008 has been about 50,000 ha (Table 7.2-21). When we use data from different sampling, it is not easy to say whether the estimated change is due to the sampling error or the real change in forest land area. To decrease the effect of the sampling error, only the NFI10 data were used to establish the time series for forest land area as well for other land-use categories.

Table 7.2-21 The difference in forest land area between 2009 and 2010 submissions (1 000 ha).

Year	Forest land area in 2009 submission	Forest land area in 2010 submission	Difference in forest land area 2010-2009
1990	21 770	22 117	347
1991	21 828	22 122	294
1992	21 887	22 132	245
1993	21 945	22 133	188
1994	22 003	22 139	136
1995	22 061	22 143	82
1996	22 119	22 149	30
1997	22 181	22 146	-35
1998	22 243	22 143	-100
1999	22 312	22 141	-171
2000	22 374	22 139	-235
2001	22 421	22 132	-289
2002	22 446	22 119	-327
2003	22 438	22 099	-339
2004	22 338	22 087	-251
2005	22 239	22 076	-163
2006	22 139	22 068	-71
2007	22 039	22 063	24

Carbon stock changes in living biomass

Time series for the biomass increment and drain in living trees were recalculated using new Finnish tree-level biomass models. In earlier submissions, expansion factors developed for the stock were also applied for the increment. With the new models, estimates of biomass increment are on a more reliable basis, and all results concerning living tree biomass are derived using the same models. Furthermore, the date to which the increment estimates from each inventory were allocated, was changed to correspond better to the actual period from which the increment was assessed. Since it was earlier allocated according to the measurement dates, this results in practise in an average shift of 2.5 years backwards (Table 7.2-22).

Table 7.2-22 The difference in CO₂-uptake and release in tree biomass between the 2009 and 2010 submissions (Gg CO₂).

Year	uptake in 2009 submission	uptake in 2010 submission	difference in uptake 2010- 2009	release in 2009 submission	release in 2010 submission	difference in release 2010-2009
1990	98 490	102 005	3 515	72 141	75 735	3 594
1991	99 679	103 052	3 373	58 630	61 456	2 826
1992	100 869	104 102	3 233	66 657	69 871	3 214
1993	102 059	105 149	3 090	70 425	73 788	3 363
1994	103 248	106 197	2 949	80 557	84 464	3 907
1995	104 493	107 244	2 751	83 129	86 142	3 013
1996	105 738	108 804	3 066	76 969	79 708	2 739
1997	107 115	110 843	3 728	85 934	88 881	2 947
1998	108 776	112 882	4 106	90 424	93 586	3 162
1999	110 587	114 921	4 334	90 447	93 600	3 153
2000	112 757	116 890	4 133	91 139	94 387	3 248
2001	114 977	118 747	3 770	88 231	91 497	3 266
2002	117 116	120 604	3 488	89 469	92 750	3 281
2003	119 247	122 461	3 214	90 910	94 336	3 426
2004	121 263	124 323	3 060	91 021	93 837	2 816
2005	123 279	126 180	2 901	87 764	90 514	2 750
2006	125 296	128 037	2 741	85 062	87 642	2 580
2007	127 312	129 894	2 582	94 646	97 577	2 931

Carbon stock change in dead wood, litter and soils

The sinks and emissions of soil, litter and dead wood carbon were recalculated. The main reason for new estimates was the application of Finnish biomass models instead of Swedish biomass models. At the same time also biomass and litter estimation was linked directly with tree-level measurements of NFI and whole sink/emission estimation procedures were taken from excel to linux server with appropriate software. Also the steady state of soil carbon model Yasso was estimated with NFI6 data instead of estimating litter input of forests during 1800s (Table 7.2-23). According to the Peltoniemi et al. (2006) the impact of initial carbon stock of the simulation cancels out during a decade. In the GHG inventory LULUCF sector of Finland the NFI6 data from 1970s was used to initialize Yasso model.

Table 7.2-23 The difference in the soil and dead wood carbon sinks and emissions on forest land remaining forest land between 2009 & 2010 submissions on mineral and on organic soils (Tg CO₂).

Year	2009 submission, mineral soils	2010 submission, mineral soils	Difference	2009 submission, organic soils	2010 submission, organic soils	Difference
1990	-5.7	-7.7	2.0	8.8	12.0	-3.2
1991	-5.3	-6.5	1.2	8.6	12.0	-3.4
1992	-5.7	-5.6	-0.1	8.4	11.2	-2.8
1993	-6.6	-5.7	-0.9	8.2	10.6	-2.4
1994	-8	-6.6	-1.4	7.8	10.0	-2.2
1995	-9.2	-8.3	-0.9	7.4	9.5	-2.1
1996	-10.4	-9.9	-0.5	7.0	9.4	-2.4
1997	-10.6	-11.5	0.9	6.8	8.5	-1.7
1998	-10.5	-12.0	1.5	6.5	7.9	-1.4
1999	-10.8	-12.3	1.5	6.3	7.6	-1.3
2000	-10.3	-12.9	2.6	6.2	7.4	-1.2
2001	-9.4	-12.7	3.3	6.1	7.3	-1.2
2002	-8.6	-12.1	3.5	6.1	7.0	-0.9
2003	-7.6	-11.6	4.0	6.1	6.7	-0.6
2004	-6.6	-10.7	4.1	6.1	6.7	-0.6
2005	-6.8	-9.9	3.1	5.9	6.6	-0.7
2006	-6.4	-10.1	3.7	5.9	6.6	-0.7
2007	-6.1	-9.8	3.7	5.9	6.2	-0.3

7.2.6 Source-specific planned improvements

The method to estimate areas and uncertainties for land use conversions will be further improved. The cross-checking of land-use changes in the NFI10 sample plot data continues.

The biomass conversion factors for felled trees will be developed based on the measured permanent sample plots of the NFI9 and the NFI10.

According to the consistency check by the EU it was noted that Finland reports a constant and high accumulation of soil carbon. This issue has been noted by the Finnish Forest Research Institute and the applicability of the soil carbon model Yasso07 with annual weather data for forests remaining forests will be studied and evaluated. The study will analyse how the model could be best implemented to the Finnish conditions. The aim is to develop a uniform soil carbon modelling approach across the LULUCF sector (including forests and agricultural soils).

7.3 Cropland (CRF 5.B)

7.3.1 Source category description

Carbon stock changes in soils and living biomass as well as emissions from liming are reported under the Cropland category. The total net emissions from croplands in 2008 were 4.9 Tg and 6.0 Tg in 1990. The emissions from cultivated organic soils were 5.5 Tg. Emissions from liming were 0.3 Tg in 2008. The sink from woody living biomass on cropland is very small, 2.6 Gg CO₂ in 2008.

The area of cropland comprises of the area under arable crops, grass (≤ 5 years), permanent horticultural crops, greenhouses, kitchen gardens and set-aside. The area of cropland is now divided in land remaining cropland and converted to cropland.

The amount of CO₂ emitted from soils is affected, for example, by the type and amount of organic material input, disturbance, soil properties and climatic variables (IPCC, 1997). Soils may act as sources of or sinks for CO₂ depending on the conditions. Agricultural practices and lime application affect the amount of CO₂ released from agricultural soils.

Croplands have been a net source of CO₂. The mineral soils have mainly been a sink for CO₂ and the organic soils have been an increasing source. Emissions from liming have decreased slightly as the usage of lime has declined (Figure 7.3-1).

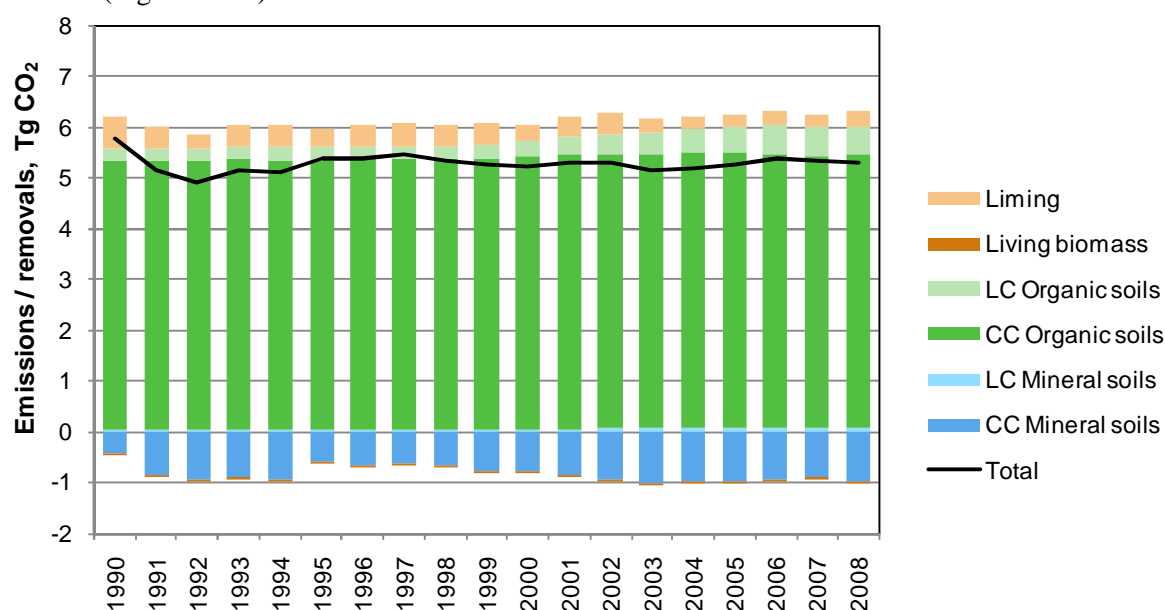


Figure 7.3-1 Emissions and removals in cropland 1990-2008, Gg CO₂ (CC = cropland remaining cropland, LC Land converted to cropland).

7.3.2 Methodological issues

7.3.2.1 Carbon stock changes in living biomass

Methods and emission factors

The biomass of apple trees and currants are taken into account in the calculation. The method corresponds to a Tier 2 method of the IPCC (IPCC 2003). The annual carbon stock change is determined as the difference between biomass accumulation and its loss removals of old plants. The emissions are allocated to cropland remaining cropland also in the case that cropland was converted to other land use categories.

$$\Delta C C C C_{LB} = \sum_i (C_{ai} - C_{di})$$

$$B_{hi} = d_i * w_i * Frac_{Dm} * Frac_C$$

$$G_i = B_{hi} / H_{ci}$$

$$C_{ai} = A_i * G_i$$

$$C_{di} = A_{ci} * B_{hi}$$

Where,

i denotes the plant species (currants, dwarfish apple trees, vigorously growing apple trees)

$\Delta C C C C_{LB}$ = Annual change in carbon stocks in living biomass, tonnes C/a

C_{ai} = Carbon accumulation in a year

C_{di} = Carbon decline in a year

B_{hi} = Aboveground 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 aboveground biomass

$Frac_C$ = Carbon fraction

G_i = Biomass accumulation rate, tonnes C/ha/a

H_{ci} = Harvest cycle, a

A_i = Area of growing plants

A_{ci} = Size of cleared area (plants removed)

Parameters used for determining the carbon stock changes in living biomass for apple trees and currants are presented in Table 7.3-1. Apple trees were divided to vigorously-growing and dwarfish trees and typical average values for apple trees and black, red, green or white currant bushes were estimated. The background information (e.g. density, mature weight, dry matter) for the coefficients in Table 7.3-1 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 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 years 1998-2008. The dwarfish trees have started to come to the market in 1997.

Table 7.3-1 National coefficients for living apple trees and currants (cropland remaining cropland).

	Aboveground biomass carbon stock at harvest (tn C/ha)	Harvest cycle (a)	Biomass accumulation rate (tn C/ha/a)	Biomass carbon loss (tn C/ha)
Vigorously-growing apple trees	18	35	0.514	18
Dwarfish apple trees	21	18	1.167	21
Currants	4.02	17	0.236	4.02

The removal of biomass in *forest land converted to cropland* is reported under forest land remaining forest land. An increase in carbon stock for the first year after the conversion from *forest land to cropland* was estimated using the Tier 1 methodology. The amount of carbon added as crop biomass was 5 t C/ha as suggested in Table 3.3.8 of the GPG LULUCF (IPCC 2003).

Activity data

The Information Centre of the Ministry of Agriculture and Forestry collects data of the area of apple trees and currants (Table 7.3-2).

Table 7.3-2 Areas of apple trees and currants in 1990-2008, ha.

	Vigorously-growing apple trees	Dwarfish apple trees	Currants
1990	380	0	1 407
1991	361	0	1 598
1992	348	0	1 550
1993	354	0	1 534
1994	377	0	1 497
1995	419	0	1 535
1996	437	0	1 723
1997	447	0	1 772
1998	446	18	1 793
1999	446	33	1 867
2000	457	49	1 976
2001	464	67	2 259
2002	473	87	2 373
2003	486	110	2 451
2004	487	133	2 485
2005	489	157	2 443
2006	462	173	2 342
2007	453	196	2 264
2008	447	221	2 190

7.3.2.2 Carbon stock changes in soil

Mineral soils

Methods and emission factors

Calculation of CO₂ emissions from mineral soils of *cropland remaining cropland* is based on changes in the carbon stocks resulting from changes in land-use and management activities over a period of 20 years according to the Tier 1 method (IPCC 2003). The reference carbon stock values for each soil type are multiplied with the IPCC default management and input factors for each soil and land-use type. The change in carbon stocks between the inventory year and 20 years before the inventory year is calculated for each soil type, land-use, management and input category. Changes in carbon stocks of all soil and land-use categories are summed to gain the net carbon stock change for mineral soils. CO₂ emissions for each inventory year are calculated by multiplying the carbon stock change during a 20-year time period by -1 and the coefficient 44/12 and dividing this by 20.

The default carbon stock change factors (IPCC, 2003) for temperate wet climate were used for estimating the effect of land use, management and input on carbon stock changes in mineral cropland soils (Table 7.3-3).

Table 7.3-3 Carbon stock change factors used in calculating CO₂ emissions from Cropland remaining cropland (Source: IPCC, 2003).

	C stock (t/ha)	F _{LU} ^a	F _{MG} ^b	F _I ^c
Sandy soils				
Crops				
Full tillage				
Medium input	71	0.71	1.0	1.0
High input	71	0.71	1.0	1.38
Reduced tillage	71	0.71	1.09	1.0
No-till	71	0.71	1.16	1.0
Fallow	71	0.82	1.0	1.0
High activity soils				
Crops				
Full tillage				
Medium input	95	0.71	1.0	1.0
High input	95	0.71	1.0	1.38
Reduced tillage	95	0.71	1.09	1.0
No-till	95	0.71	1.16	1.0
Fallow	95	0.82	1.0	1.0

^aStock change factor for land use or land-use change type.^bStock change factor for management regime^cStock change factor for input of organic matter

Carbon stock changes in *forest land converted to cropland* on mineral soils were estimated using the Yasso07 model (Figure 7.2-2 and Table 7.2-13). The results for the simulation of forest soil carbon stocks were used as the initial state values and they represent the typical forest soil carbon stocks of south and north Finland (Table 7.3-4). The carbon input values were derived from the average yields of a typical crop rotation together with unpublished data on the carbon fractions (Karhu et al., manuscript). Annually estimated carbon stock changes in soils are presented as range and average for forest lands converted to cropland and separately for Southern and Northern Finland in Table 7.3-5.

Table 7.3-4 Parameters used in the Yasso model simulations for forest land converted to cropland.

Parameter	C stock in the initial state (t/ha)		Input ^a (t/ha)
	South Finland	North Finland	
Total C	90.01	86.99	1.86
Acid soluble	10.61	9.20	0.69
Water soluble	1.41	1.23	0.44
Ethanol soluble	1.15	1.02	0.12
Non-soluble	44.55	39.51	0.61
Humus	32.28	35.03	-

^aThe average annual input of a crop rotation**Table 7.3-5** Estimated carbon stock changes of soil organic matter and dead organic matter in mineral forest soils converted to cropland (20 years after conversion).

Carbon stock change (tons C per ha)	Activity	Soil type	Area	Min	Max	Mean
DOM+SOM	FL to CL	Mineral	South	-2.30	1.01	-0.58
DOM+SOM	FL to CL	Mineral	North	-0.75	1.41	-0.07

Carbon stock changes in *grassland converted to cropland* on mineral soils were calculated using the Tier 1 method for calculating the carbon stocks before and after the land use change (IPCC 2003). The difference in the carbon stocks divided by 20 was reported as the annual stock change. The average annual change per hectare is 1.2 t C.

Activity data

The area estimates for cropland remaining cropland and the conversions were obtained from the NFI (Table 7.1-2). The percentage distribution of different mineral soil types is estimated so that the proportion of sandy soils is 64% and that of the high activity soils 36% (Table 7.3-6). The estimate for the proportion of sandy and high activity soils is based on the data on soil type distribution of the soil fertility samples taken from farms in 1998-2002 and analysed in the largest laboratories performing such analyses in Finland. Low activity soils as defined by the IPCC (IPCC, 2003) are not found in Finland (Yli-Halla et al., 2000).

The area estimate of no-till agriculture before 2005 is based on expert judgement (Mikkola et al. 2005) as well as the area of reduced tillage for the whole time series (Smith et al. 2004). From 2005 onwards, the statistics on the no-till area are available from the Information centre of the Ministry of Agriculture and Forestry. In the category of full tillage, the area is divided into medium input and high input so that the area of organic farming found in the statistics of the Ministry of Agriculture and Forestry is considered the area receiving high input.

Table 7.3-6 Distribution of areas of soil types, management and input on mineral cropland remaining cropland (1 000 ha) (Yearbook of Farm Statistics; Mikkola et al. 2005).

	1990	2000	2008
Sandy soils	1381.37	1362.51	1358.30
Crops	1278.09	1260.19	1183.20
Full tillage	1134.44	1021.93	818.93
Medium input	1131.03	953.46	765.70
High input	3.40	68.47	53.23
Reduced tillage	143.13	214.70	271.95
No-till	0.52	23.56	92.32
Fallow	103.28	102.32	175.10
High activity soils	764.20	751.17	752.90
Crops	707.06	694.76	655.84
Full tillage	627.59	563.40	453.93
Medium input	625.71	525.65	424.42
High input	1.88	37.75	29.51
Reduced tillage	79.18	118.37	150.74
No-till	0.29	12.99	51.17
Fallow	57.14	56.41	97.06

Organic soils

Methods and emission factors

Organic soils are determined as those containing more than 20% organic matter in the top 20 cm layer. Thus, both mull soils and peat soils are considered organic.

Emissions from organic soils are calculated using the following equation (IPCC 2003):

$$\Delta C_{ccOrganic} = A * EF$$

$\Delta C_{ccOrganic}$ = Annual CO₂ emissions from cultivated organic soils in cropland/grassland

A = Land area (ha)

EF = Emission factor (t C ha⁻¹ a⁻¹).

The amount of carbon released is converted to CO₂ by multiplying with 44/12.

For calculating CO₂ emissions from *cropland remaining cropland* on organic soils, national emission factors are used for organic soils under grass or other crops (Table 7.3-7). The emissions from organic *forest soils* or

grassland soils converted to cropland were calculated using the mean emission factor for cultivation of grass or other crops on organic soils (4.9 t C/ha).

Table 7.3-7 Emission factors used for calculating CO₂ emissions from cropland on organic soils.

Emission source	EF (t C/ha/a)	Reference
Grass	4.1	Maljanen et al. (2007)
Other crops	5.7	Maljanen et al. (2007)

Activity data

The area estimate of cultivated organic soils was derived as described in chapter 7.1.2. The proportions of grass and other crops grown on organic soils were obtained from the agricultural statistics for the years 1995 and 2008 and the values for the other years were derived by linear interpolation and extrapolation.

7.3.2.3 CO₂ emissions from liming

Method

The emissions reported under Cropland remaining Cropland include liming on croplands, grasslands and forest lands. No lime application is assumed in land converted to Cropland. The emissions from liming have been calculated using the IPCC method described in the GPG LULUCF (IPCC 2003) and data from the Finnish Liming Association. Limestone (CaCO₃), dolomite (MgCa(CO₃)₂) and briquette lime were included. The amount of lime sold annually is multiplied with 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 CO₂ by multiplying with 44/12.

Emission factors

IPCC default emission factors are used for calculating CO₂ emissions from agricultural lime application. The emission factors are 0.12 for limestone and 0.13 for dolomite and 0.12 for briquette lime (IPCC 2003). According to the IPCC all the carbon in the lime is assumed to be released to the atmosphere during the same year it is applied to soil. However, due to the improved soil conditions after liming less CO₂ could be emitted into the atmosphere. Since there are currently no studies in Finland which could be used to re-evaluate the conversion factors for lime application the assumption that all carbon is released is used in the calculations.

Activity data

The amount of lime sold annually has been used as activity data (Table 7.3-8). Thus, also the amount applied on forest soils is included in these figures. The data have been received from the Finnish Liming Association. The emissions from both limestone and briquette lime have been combined in the CRF table for limestone since they both have the same emission factor.

Table 7.3-8 The amount of lime sold annually for agriculture and estimated to be applied to Finnish fields in 1990-2008 (1 000 t/year) (Source: Finnish Liming Association).

Year	Limestone + briquette lime	Dolomite
1990	631.0	713.8
1991	433.0	505.2
1992	435.5	170.6
1993	706.9	287.6
1994	709.0	286.7
1995	610.1	245.9
1996	713.8	291.8
1997	739.3	297.7
1998	675.4	273.7
1999	677.3	274.5
2000	516.0	207.4
2001	623.5	252.8
2002	665.6	271.2
2003	439.1	177.1
2004	400.4	158.5
2005	420.7	167.1
2006	470.4	191.5
2007	390.8	160.9
2008	453.1	189.1

7.3.3 Uncertainty and time series' consistency

7.3.3.1 Carbon stock changes in living biomass

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

7.3.3.2 Carbon stock changes in soils

Uncertainty in the area of organic cropland was estimated at $\pm 30\%$ for 1990 and $\pm 20\%$ for 2003 based on expert judgement. This estimate would improve if the method for collecting the data on the area of organic soils is improved. The uncertainty estimate for the CO₂ emission factor for organic soils was $\pm 90\%$ according to the IPCC Good Practice Guidance for LULUCF (IPCC, 2003). For mineral soils, uncertainty in emissions/removals was estimated at $\pm 100\%$. This estimate is preliminary and could be revised by developing a more detailed model for the estimation of uncertainties. A correlation of 0.8 was estimated between emissions/removals from mineral soils between the two years (1990 and 2003). This assumption could also be revised by using a more detailed model for uncertainties.

The area estimates in the category Cropland are mainly based on the national forest inventory. Since the time series were estimated from the NFI10 data the possible inconsistency due to different sample design or different classification between inventories was avoided. However, there are subdivisions based on expert judgement like areas under reduced tillage and no-till agriculture but the effects of these on the net carbon stock change of the whole category is of minor importance.

Since the calculation method for cropland remaining cropland is Tier 1 while the method for the area of forest land converted to cropland is Tier 3 the calculation is not totally consistent.

7.3.3.3 CO₂ emissions from liming

The uncertainty in activity data for liming is estimated at $\pm 20\%$ based on expert judgement. The uncertainty estimate for the emission factor is negatively skewed (-20 to +3%), because more than 100% of the carbon cannot be released, but the amount can be smaller.

The amount of lime applied annually has been received from the Finnish Liming Association for the whole time series, so in that sense the time series could be considered consistent. However, because the estimation of the amount of lime applied annually to agricultural soils is based on sales statistics, not on the amounts applied, it causes some additional uncertainty in this emission source category.

7.3.4 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6.

The QA/QC plan for the LULUCF category (Cropland, Grassland) includes the QC measures based on the IPCC (IPCC 2000, Table 8.1, p. 8.8-8.9). These measures are implemented every year during the inventory. Potential errors and inconsistencies are documented and corrections are made if necessary. The files and documents used in preparation of the inventory are archived annually and back-up copies are made daily.

The comments received about QA from the reviews of the inventory are taken into account when developing the inventory.

The suitability of the Yasso07 model for simulating carbon stock changes in forest land converted to cropland was investigated in a separate project. The results of the project will be published as a peer-reviewed article; thus the verification of the method will be done according to the Tier 2 QA methodology.

7.3.5 Source-specific recalculations including changes made in response to the review process

The time series for cropland remaining cropland was recalculated since the area estimate was updated due to division of the area to remaining and converted. All area estimates are now derived using the NFI data in a consistent way (see Chapter 7.1.2). The area estimate and the distribution of cultivated organic soils into different crop types were updated and the whole time series was recalculated. Since the area of organic soils has been increasing during the latest years the development of the emissions was turned from a decreasing trend to a more stable situation. The emissions from land converted to cropland were added and the respective changes in carbon stocks were estimated using Yasso07 model (conversions from forest) or the Tier 1 methodology (other conversions). Share of dwarfish apple trees was updated which affected the carbon stock change of living biomass. The changes in emissions due to the above mentioned changes in the calculation are illustrated in Figure 7.3-2.

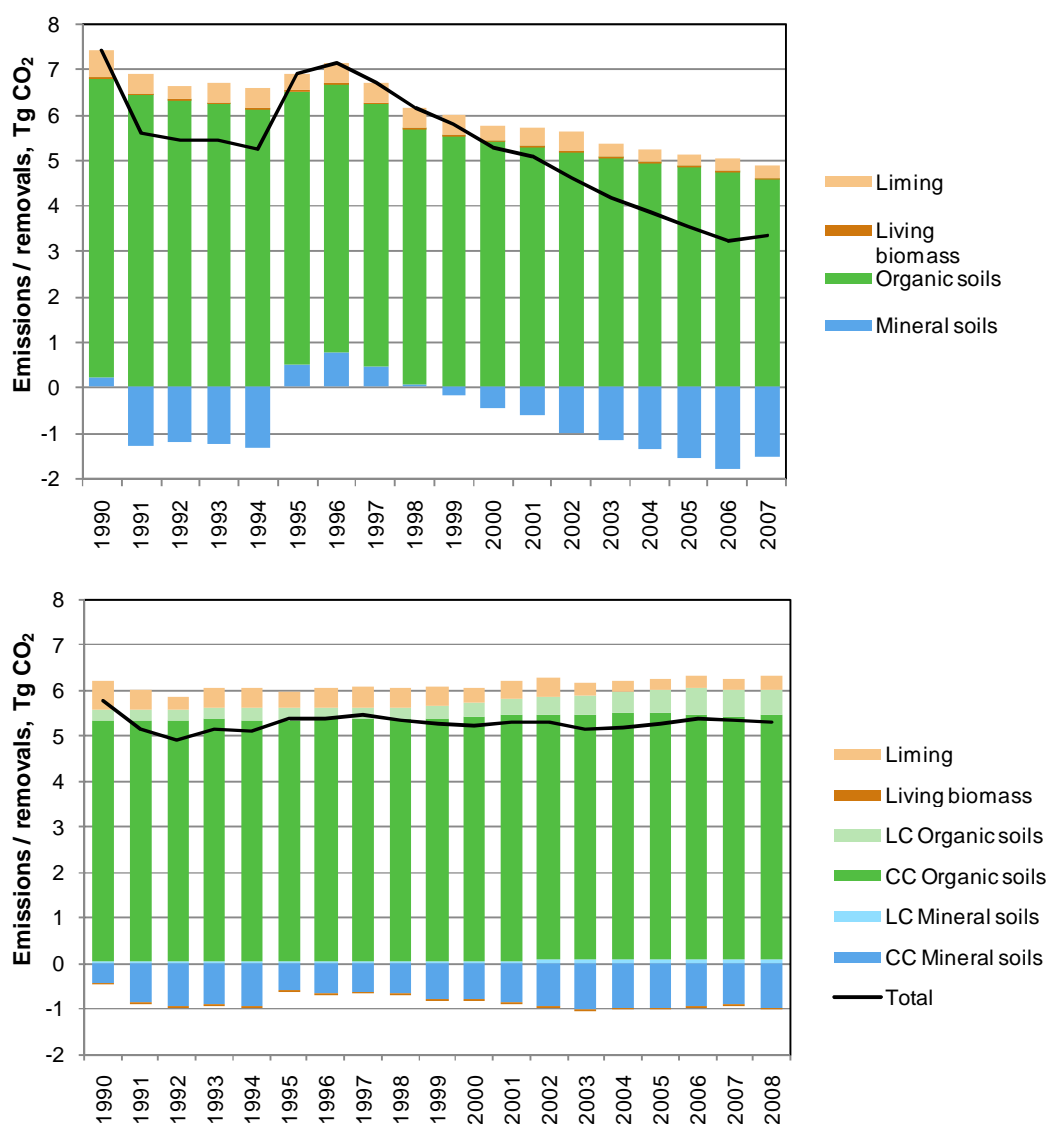


Figure 7.3-2 Emissions from croplands in the previous (upper) and current (lower) submission.

7.3.6 Source-specific planned improvements

The suitability of the Yasso07 – model for estimating carbon stock changes in agricultural soils will be investigated in an ongoing project.

Part of the CO₂ emissions from liming will be allocated to deforestation in the next submission.

7.4 Grassland (CRF 5.C)

7.4.1 Source category description

Carbon stock changes in organic and mineral grassland are reported under the Grassland category. The emissions of organic soils on grasslands were 0.06 Tg CO₂ in 2008 and the sink of mineral soils was 0.06 Tg CO₂. The net sink from grasslands was 0.002 Tg CO₂ in Finland in 2008.

In Finland there are no large grazing land areas or permanent grasslands. Therefore the Grassland category comprises of grasslands and meadows more than five years old together with the abandoned agricultural area which cannot yet be included in the Forest land category (FAO forest definition). The area is now divided between grasslands remaining grasslands and land converted to grasslands.

The amount of CO₂ emitted from soils is the result of changes in the carbon stocks of the soils. The soil carbon balance is affected by the type and amount of organic matter input, disturbance, soil properties and climatic variables (IPCC, 1997), for example. Soils may act as a source or sink of CO₂ depending on the conditions.

The sink from grasslands on mineral soils have decreased since 1990 (Figure 7.4-1). The reasons for the decrease are the increased areas of the conversions from forest land to grassland (increasing source) and the decrease in the area of cropland converted to grassland (decreasing sink).

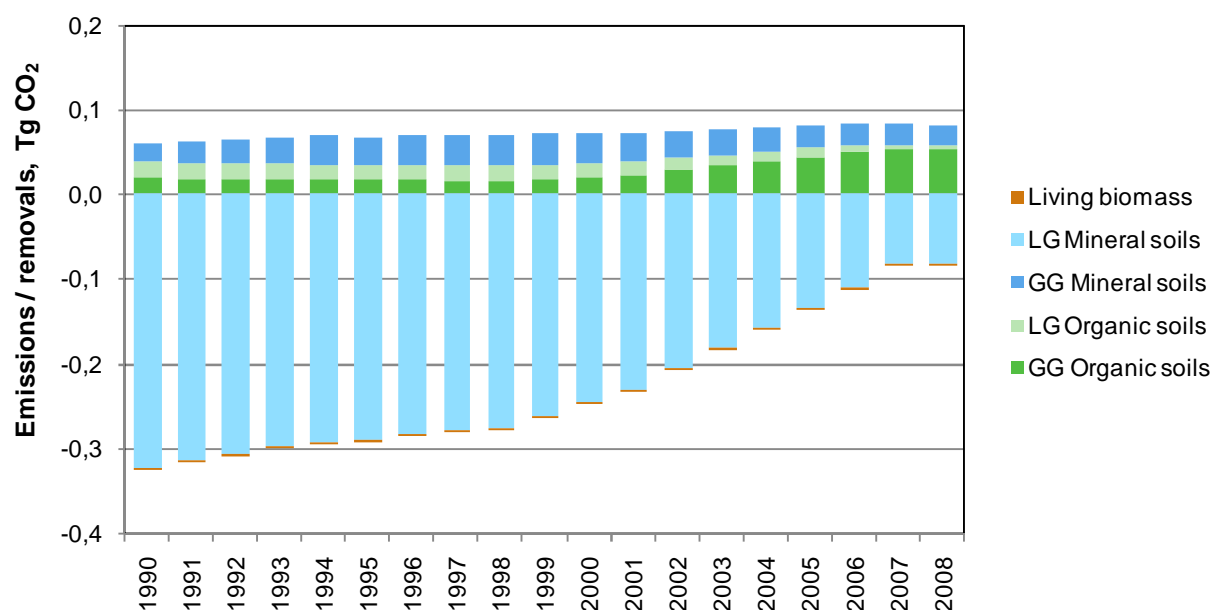


Figure 7.4-1 Emissions and removals in grassland 1990-2008, Tg CO₂ (GG= grassland remaining grassland, LG= land converted to grassland)

7.4.2 Methodological issues

7.4.2.1 Carbon stock changes in living biomass

Estimates for carbon stock changes in living biomass in *grasslands remaining grasslands* have not been included in the inventory yet. The removal of biomass in the area of *forest land converted to grassland* is reported under forest land remaining forest land. An increase in carbon stock for the first year after the conversion from *forest land to grassland* was estimated using the Tier 1 methodology. The amount of carbon added as crop biomass was 8.5 t C/ha as suggested in Table 3.4.9 of the GPG LULUCF (IPCC 2003).

7.4.2.2 Carbon stock changes in soil

Mineral soils

Methods and emission factors

CO₂ emissions from *grassland remaining grassland* on mineral soils are calculated by using methods described in Chapter 3 of the Good Practice Guidance for Land Use, Land-Use Change and Forestry (Equation 3.4.9B in IPCC 2003). The methodology used corresponds to the Tier 1 level method of the IPCC GPG LULUCF. Carbon stocks are estimated in each soil type category of the mineral soils in the inventory year and 20 years prior to that. The default carbon stocks for grasslands are multiplied with the stock change factor for each soil type. Changes in carbon stocks of all soil types are summed to gain the net carbon stock change for mineral soils. The sum of stock changes in each category is multiplied with -1 and divided by 20 to obtain the annual emission to be reported.

IPCC default carbon stocks for high activity and sandy grassland soils for wet temperate climate were used together with the default carbon stock change factors for nominally managed and improved grassland (Table 7.4-1).

Table 7.4-1 Carbon stocks and stock change factors used in calculating CO₂ emissions from grassland remaining grassland (Source: IPCC, 2003)

	C stock (t/ha)	F _{LU} ^a	F _{MG} ^b	F _I ^c
Sandy soils				
Nominally managed	71	1	1	1
Improved	71	1	1.14	1
High activity soils				
Nominally managed	95	1	1	1
Improved	95	1	1.14	1

^aStock change factor for land use or land-use change type.

^bStock change factor for management regime

^cStock change factor for input of organic matter

Carbon stock changes in *forest land converted to grassland* on mineral soils were estimated using the Yasso07 model (Figure 7.2-2 and Table 7.2-13). The results for the simulation of forest soil carbon stocks were used as the initial state values and they represent the typical forest soil carbon stocks of south and north Finland (Table 7.4-2). The carbon input values were derived from the average yields of agricultural grasses together with unpublished data on the carbon fractions (Karhu et al., manuscript). Annually estimated carbon stock changes in soils are presented as range and average for forest lands converted to grassland and separately for Southern and Northern Finland in Table 7.4-3.

Table 7.4-2 Parameters used in the Yasso model simulations for forest land converted to grassland.

Parameter	C stock in the initial state (t/ha)		Input ^a (t/ha)
	South Finland	North Finland	
Total C	90.01	86.99	4.33
Acid soluble	10.61	9.20	1.81
Water soluble	1.41	1.23	1.87
Ethanol soluble	1.15	1.02	0.32
Non-soluble	44.55	39.51	0.33
Humus	32.28	35.03	-

^a The annual input of agricultural grass species

Table 7.4-3 Estimated carbon stock changes of soil organic matter and dead organic matter in mineral forest soils converted to grassland (20 years after conversion).

Carbon stock change (tons C per ha)	Activity	Soil type	Area	Min	Max	Mean
DOM+SOM	FL to GL	Mineral	South	-0.19	-0.01	-0.15
DOM+SOM	FL to GL	Mineral	North	0.17	1.77	0.51

Carbon stock changes in *cropland converted to grassland* on mineral soils were calculated using the Tier 1 method (IPCC 2003). The carbon stocks before and after the land use change were determined by using the average carbon stocks for sandy and high activity soils together with the carbon stock change factors for tilled cropland with medium input (Table 7.3-3) and nominally managed grassland (Table 7.4-1). The annual stock change per hectare was calculated from the difference in the carbon stocks of cropland and grassland divided with 20. The area converted was multiplied with the annual change (1.2 t C/ha) to obtain the annual stock change.

Activity data

The area estimate of grasslands was derived from the NFI data as described in section 7.1.2. The division of *grassland remaining grassland* to high activity and sandy soils is done according to the description in Section 7.3 Cropland. The area was also divided between nominally managed and improved grassland (Table 7.4-4). The area estimates of *land converted to grassland* are presented in chapter 7.1.2.

Table 7.4-4 Distribution of areas of soil types and management on grassland remaining grassland (1 000 ha).

	1990	2000	2008
Sandy soils			
Nominally managed	52.4	44.3	43.9
Improved	19.8	17.6	19.5
High activity soils			
Nominally managed	27.0	22.8	22.6
Improved	10.2	9.0	10.0
Organic soils	20.4	22.6	57.6
Total	129.9	116.3	153.7

Organic soils

Methods, emission factors and activity data

Organic soils are determined as those containing more than 20% organic matter in the top 20 cm layer. Thus, both mull soils and peat soils are included.

Emissions from organic soils are calculated using the following equation (IPCC, 2003):

$$\Delta C_{ccOrganic} = A * EF$$

$\Delta C_{ccOrganic}$ = Annual CO₂ emissions from cultivated organic soils

A = Land area (ha)

EF = Emission factor (t C ha⁻¹ a⁻¹).

The amount of carbon released is converted to CO₂ by multiplying with 44/12.

For organic soils the default emission factor of the IPCC (0.25 t C /ha/a) for grasslands is used, (IPCC, 2003, Table 3.4.6). The calculation method is same for the remaining and converted areas.

7.4.2.3 CO₂ emissions from liming

Emissions from the total amount of lime used annually in Finland are reported under cropland remaining cropland. In practice, the grassland area consists mostly of abandoned fields which are not limed.

7.4.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

Uncertainty in the area of organic grassland was estimated at ±30% based on expert judgement. The uncertainty estimate for the CO₂ emission factor for organic soils is ±90% according to the IPCC Good Practice Guidance for LULUCF (IPCC, 2003). For mineral soils, uncertainty in emissions/removals was estimated at ±100%. This estimate is preliminary and could be revised by developing a more detailed model for the estimation of uncertainties. A correlation of 0.8 was estimated between emissions/removals from mineral soils between the two years (1990 and 2003). This assumption could also be revised by using a more detailed model for uncertainties.

The time series of emissions from grasslands is consistent.

Since the calculation method for grassland remaining grassland is Tier 1 while the method for the area of forest land converted to grassland is Tier 3 the calculation is not totally consistent.

7.4.4 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6.

The QA/QC plan for the LULUCF category (Cropland, Grassland) includes the QC measures based on the IPCC (IPCC 2000, Table 8.1, p. 8.8-8.9). These measures are implemented every year during the inventory. Potential errors and inconsistencies are documented and corrections are made if necessary. The files and documents used in preparation 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 was compiled for the verification of the use of Yasso model for calculating the carbon stock changes in the case of forest land converted to grassland. The results of the project will be published as a peer-reviewed article; thus the verification can be considered as Tier 2 QA process.

7.4.5 Source-specific recalculations including changes made in response to the review process

The area estimates of both mineral and organic grasslands were updated. All area estimates are now derived using the NFI data in a consistent way (see Chapter 7.1.2). The total area of grasslands was diminished because areas like small roads and buildings were left out. The emissions were divided between grassland remaining grassland and land converted to grassland. The Yasso07 model was used for the calculations of forest land converted to grassland and the Tier 1 methodology was used for other conversions. The decreasing trend in the sink of mineral soils converted to grassland is the result of increase in the area of forest land converted to grassland (increasing source) and the decrease in the area of cropland converted to grassland (decreasing sink). The changes in emissions due to the changes in calculation are illustrated in Figure 7.4-2.

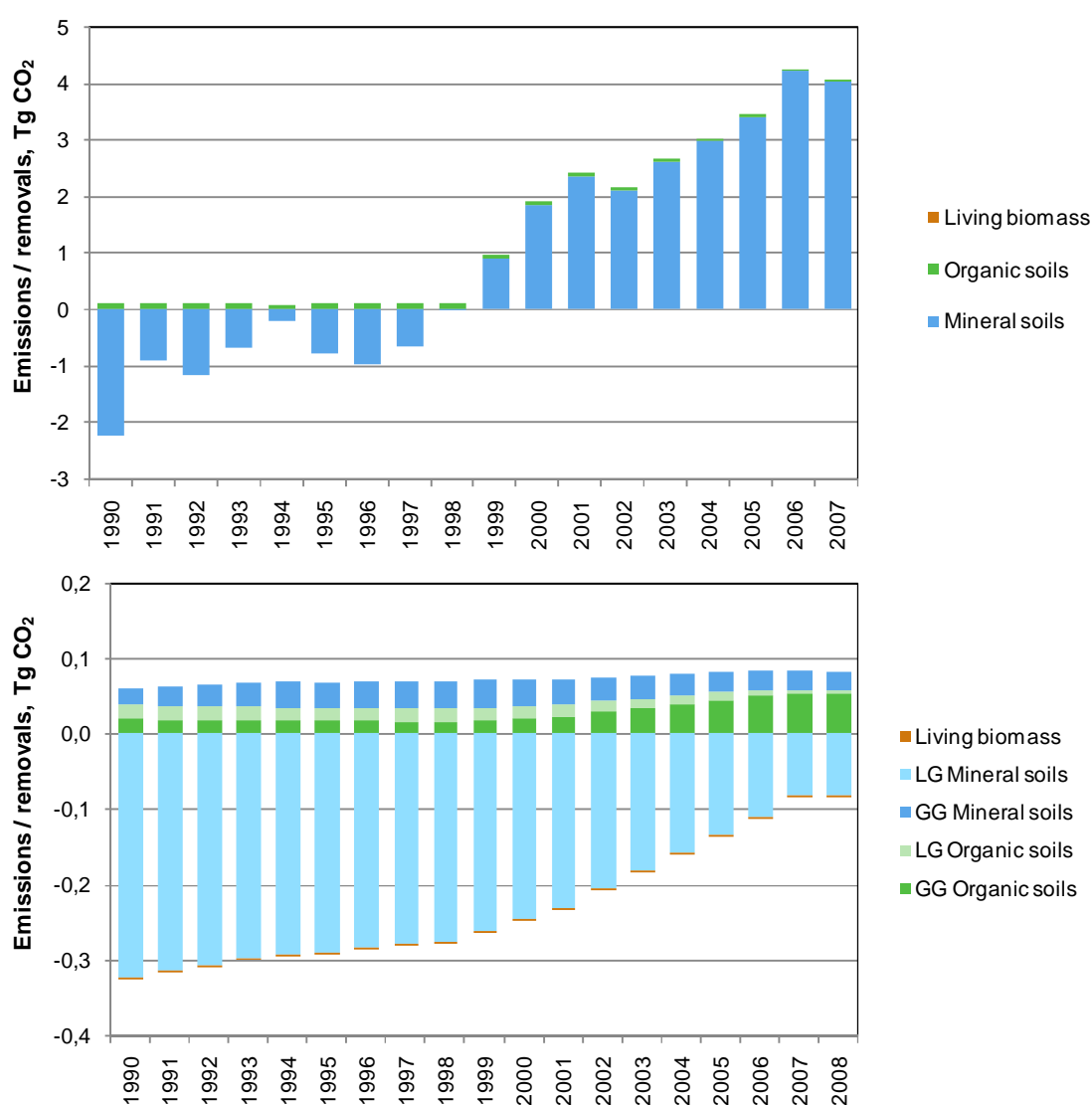


Figure 7.4-2 Emissions from grasslands in the previous (upper) and current (lower) submission.

7.4.6 Source-specific planned improvements

The possibility to use the Yasso07 model for estimating carbon stock changes in grassland remaining grassland will be examined in an ongoing project. The EF for grasslands on organic soils will be updated with national data if possible.

7.5 Wetlands (CRF 5.D)

7.5.1 Source category description

According to the IPCC GPG LULUCF wetlands include land that is covered or saturated by water for all or part of the year and that does not fall into the forest land, cropland, grassland or settlement categories (IPCC, 2003). Wetland are reported in sub-categories Wetlands remaining Wetlands (CRF 5.D.1) and Lands converted to Wetlands (CRF 5.D.2).

Named subgroups belonging to managed Wetlands are peat extraction areas and reservoirs. A method to estimate emissions from Wetlands remaining Wetlands is given in Appendix 3a.3 and therefore the reporting of them is not mandatory. In the category land converted to Wetlands Finland reports emissions from peat extraction areas. Reservoirs have been constructed before year 1990. Area of natural lakes and rivers, (unmanaged Wetlands) comes from the statistics on Finland's land and water areas (Land Survey of Finland 1.1.2009). The total area of inland waters is reported in CRF Table 5.D.1.

Finland reports CO₂ emissions from peat extraction fields in Category CRF 5.D 2.5 (Other Land converted to Wetlands). N₂O and CH₄ emissions from peat extraction areas are reported in Category CRF 5 (II). However, the description of the method and activity data of all three gases related to peat extraction fields are given in this section. These emissions comprise of 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. Emissions from unmanaged wetlands are not reported.

The old and new production fields are reported under the same category. When forest land is converted to peat extraction the carbon stock change in living tree biomass is reported under the forest land category, since the removed timber is included in harvesting statistics. Change in carbon stock due to the other removed living biomass is not reported.

Emission inventory of peat extraction sites was improved during the 2008. Both activity data and emission factors were re-evaluated. The activity data originates from the enquiry of the Association of Finnish Peat industry (1990-1996), while after that data originate from the VAHTI system. The activity data was complemented with the work of Thule Institute (Mäenpää and Jutila 2008), resulting that the land areas of peat extraction have increased compared to previous submissions. Emissions factors were also updated in a way that takes into account emissions from stockpiles, ditched and extraction areas - also the latest research was used to derive annual CO₂, CH₄ and N₂O fluxes.

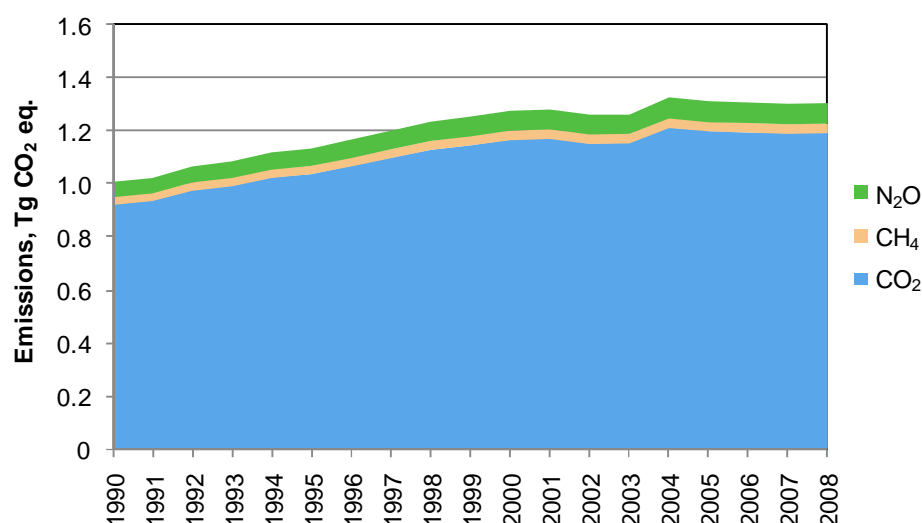


Figure 7.5-1 Emissions from the peat extraction areas between 1990 and 2008.

Emissions of 2008 from peat extraction have increased similarly as in the previous submissions, total emissions being 20% larger than in 1990 (Figure 7.5-1, Table 7.5-1). Increase in the emissions is caused by the expansion of the peat production areas, and emissions follow directly the changes in the annual production area.

Table 7.5-1 Greenhouse gas emissions from peat extraction in 1990-2008 (Gg CO₂ eq.).

	CO ₂	CH ₄	N ₂ O	Total
1990	922	30	58	1 011
1991	936	30	59	1 026
1992	976	32	62	1 069
1993	993	32	63	1 088
1994	1 024	33	65	1 123
1995	1 037	33	66	1 137
1996	1 067	34	69	1 169
1997	1 098	35	71	1 204
1998	1 129	36	73	1 238
1999	1 146	36	74	1 256
2000	1 166	37	75	1 279
2001	1 171	37	75	1 283
2002	1 152	37	74	1 263
2003	1 154	37	74	1 265
2004	1 213	38	80	1 330
2005	1 199	37	79	1 315
2006	1 194	37	78	1 310
2007	1 190	37	78	1 305
2008	1 193	37	79	1 308

Key categories

CO₂ emissions from peat extraction were found to be a key category in 2008 based on level assessment.

7.5.2 Methodological issues

7.5.2.1 Methods

The emissions were calculated by multiplying area estimates with national emission factors. Emissions of stockpiles and ditches are included in the inventory.

7.5.2.2 Emission factors and other parameters

The CO₂ emission factor describing the changes in soil organic matter due to oxidation of peat in the aerobic layer on the land during peat extraction based on the recent research (Alm et al. 2007).

Carbon dioxide emissions from the soil are proportional to the soil surface layer temperature and soil moisture. Therefore, a statistical relationship of CO₂ evolution with soil temperature at 5 cm depth and position of the water table was established. It is assumed that the sites studied represent the behaviour of similar sites elsewhere in Finland, but the summertime (snow-less period) CO₂ emission controlled by temperature and soil moisture regimes are typical for the location. Using 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 to correspond to the measured long-term average monthly temperatures. Winter time (snow-covered period) gas emissions were calculated using the averages of observed values. The soil moisture was accounted for by computing the CO₂ 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 year.

Emission factors for CO₂ were computed for 11 locations (weather stations) in Finland. The locations were pooled into climatic zones and the corresponding summertime CO₂ emissions averaged over the zone. Three zones were defined: North boreal, Middle boreal and South boreal. Separate CO₂ emission factors are provided for the North boreal, Middle boreal and South boreal vegetation zones (water table 40 cm) (Table 7.5-2).

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.

Emission factors for stockpiles and ditches as well as emission factors for CH₄ and N₂O are based on national measurements (Nykänen et al. 1996, Alm et al. 2007). For stockpiles it was assumed that 70% of those exist from June to August in the full extend (92 days), while between September and April those are used for the energy production (and therefore estimated average wintertime existence for a stockpile is 4 months, being 122 days). To ensure energy security approximately 30% of stockpiles are kept a year round (365 days), and originating emissions were estimated accordingly. Daily estimates for CO₂ fluxes for stockpiles during a summer day were 83 and a winter day 139 kg CO₂ eq./ha, for methane values were 0.003 and 0.21 kg CH₄ eq./ha and for nitrous oxide those were 0.002 and 0.0004 kg N₂O eq./ha, respectively. Summertime flux rates were used for the period between May and August, while winter time estimates were applied for the period between September and April.

Table 7.5-2 Emission factors used in calculation of emissions from peat production sites (kg CO₂ eq./ha/year). (Nykänen et al. 1996, Alm et al. 2007).

Source of flux	Share of area	CO ₂ emissions			CH ₄ emissions			N ₂ O emissions		
		South Boreal	Middle Boreal	North Boreal	South Boreal	Middle Boreal	North Boreal	South Boreal	Middle Boreal	North Boreal
Stockpiles	2 %	293 955	293 955	293 955	6 275	6 275	6 275	910	910	910
Ditches	7 %	90	90	90	3 724	3 724	3 724	1	1	1
Production	91 %	9 860	9 460	8 400	105	105	105	961	961	961
Total emissions	100 %	14 615	14 250	13 282	468	468	468	895	895	895

7.5.2.3 Activity data

Annual area data were received from the enquiry of the Association of Finnish Peat Industry (1990–1995) and from VAHTI system since 1996. Since data from VAHTI system was not covering all peat production areas it was complemented and evaluated by the Thule Institute (Mäenpää and Jutila 2008). Industrial peat production areas include active and temporarily set-aside peat extraction fields and abandoned, non-vegetated emptied peat extraction areas (Table 7.5-3). For non-vegetated emptied peat extraction areas the emission factors of production fields were used. In 1990, 7.3% of the Finnish peat production areas are

situated in the North boreal, 67.7% in Middle boreal and 25% in the South boreal vegetation zones and in 2008 those values were 7.8%, 67.8% and 24.4% respectively (VAHTI system, Mäenpää and Jutila 2008).

The area data for the years 1990–1995 originate from the Association of Finnish Peat Industry, which carried out in February 2005 an inquiry to the peat producers of the peat extraction areas under their possession in 1990–2004. However, this inquiry did not cover small producers, who are not members of the Association of Finnish Peat Industry, thus the area data had to be complemented with the missing share of small producers. The share of small producers was estimated from the environmental permit system of Finland's environmental administration, which covers all peat producers in Finland. The share of small producers was estimated at 14% from all the Finnish peat producers and this share was added to the activity (area) data. It is assumed that the share of small producers has been constant throughout the time series. Area data for the years 1996–2007 have been obtained from the VAHTI system. It includes information on the environmental permits of peat producers. Data collection has started in the year 1996, however, only from the year 2004 onwards this procedure have been supervised nationally and thus been under adequate control.

Table 7.5-3 Area of industrial peat production including abandoned, non-vegetated production areas in Finland in 1990–2008 (1 000 ha).

Year	Peat extraction fields	Abandoned non-vegetated areas	Total
1990	64.4	0.3	64.7
1991	64.9	1.1	66.0
1992	67.5	1.4	68.9
1993	68.0	2.3	70.3
1994	70.1	2.5	72.6
1995	70.4	3.5	73.8
1996	71.6	4.7	76.3
1997	73.2	5.6	78.8
1998	75.4	5.6	80.9
1999	76.7	5.4	82.0
2000	78.5	4.8	83.3
2001	79.1	4.5	83.5
2002	78.1	4.1	82.2
2003	78.6	3.5	82.1
2004	78.5	9.8	88.3
2005	77.8	9.4	87.2
2006	77.6	9.2	86.8
2007	77.4	9.0	86.5
2008	76.5	10.8	87.2

7.5.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

The uncertainty associated with peat extraction area depends on several sources of variation. The most important source of uncertainty is associated with CO₂, by volume the most important GHG-species emitting from the extraction areas. For CO₂ emission dynamics, the effect of summertime (May–October) temperature 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 variation in temperature was assessed by weather simulation based on statistics from the reference period of 1961–1990. The simulated temperature was used in regression transfer models to estimate the contribution of long-term weather variation in CO₂. Standard deviation of the simulated fluxes varied from 6 to 8 % of the cumulative summertime emission. The SD of CO₂ emissions measured in wintertime is c.a. 10%. The fluxes of CH₄ and N₂O vary in a complex way and the range of observations around the mean is skew. Thereby the uncertainties cannot be simply estimated by combining the variances. If the uncertainty for summertime CO₂

emission is estimated using 2SD ($\pm 12\text{--}16\%$), the contribution of winter CO₂, and non-CO₂ emissions (CH₄, N₂O) with lower emission rates can be expertly deemed to increase that uncertainty to $\pm 25\%$ CO₂ equivalents. In rare occasions the emissions of CO₂ from the extraction field could rise by about 200% (Alm et al. 2007), but most of the available data, however, support the present lower emission factors.

In earlier submissions a subset of the present data was used. An older dataset (Nykänen et al. 1996) appeared to represent the low end of CO₂ emissions, exceeded by the majority of the new data (Alm et al. 2007). Similarly, the information of proportions of peat extraction field, stockpile area and ditch area were updated with updated and representative information received from Finnish peat producers. The uncertainty associated with peat production area is estimated at $\pm 15\%$. The uncertainty estimate covers possible errors or misunderstandings in responses to the survey.

Area data for the years 1990–1995 are based on a one-time questionnaire and data for the earlier years are probably not as accurate as for the most recent years. Data for the years 1996–2006 originate from VAHTI system and these were re-evaluated by the Thule Institute, while year 2008 originates directly from VAHTI system. It takes into account all peat producers, even the small ones.

7.5.4 Source-specific QA/QC and verification

The quality objectives and the QA/QC plan for the Finnish greenhouse gas inventory at the national inventory level are presented in Section 1.6.

Quality control procedures named in IPCC Good Practice Guidance for LULUCF (IPCC, 2003) Table 5.5.1 were done. Especially the land area data obtained from VAHTI system was critically reviewed to ensure best possible coverage of peat extraction sites of whole Finland.

7.5.5 Source-specific recalculations

New information was received concerning the area data for the 2007, including the re-evaluation of the VAHTI data with completing the missing data. Also new emission factors for ditches and production fields of peat extraction fields were applied for methane based on the latest scientific research (Alm et al. 2007) (Table 7.5-4).

Table 7.5-4 Effects of recalculations on methane emissions between 2009 and 2010 submissions.

Year	Effect on methane emissions		
	2009 submission	2010 submission	Difference
1990	98	30	67
1991	100	30	69
1992	104	32	72
1993	106	32	74
1994	110	33	77
1995	111	33	78
1996	115	34	81
1997	119	35	84
1998	122	36	86
1999	124	36	87
2000	126	37	89
2001	126	37	89
2002	124	37	87
2003	124	37	87
2004	133	38	96
2005	132	37	94
2006	131	37	94
2007	129	37	92

7.5.6 Source-specific planned improvements

No planned improvements.

7.6 Settlements (CRF 5.E) and Other land (CRF 5.F)

Areas of settlements comprise nationally defined build-up land, traffic lines and power lines. Other land includes a part of the mineral soils of poorly productive forest land, which do not fulfil the threshold values of forest land, and barren mineral soils of unproductive land.

The method to estimate areas and areas for land-use categories is described in Section 7.1.2.

Parties do not have to prepare estimates for categories contained in Appendixes 3a.2, 3a.3 and 3a.4 of the IPCC Good Practice Guidance for LULUCF.

7.7 Non-CO₂ emissions

7.7.1 Direct N₂O emissions from fertilisation (CRF 5 (I))

7.7.1.1 Source category description

This source category covers direct nitrous oxide emissions from forest fertilisation (CRF 5 (I)) (Figure 7.7-1). Forest fertilisation distinguishes between growth and forest vitality fertilisations. Nitrogen fertilisers are mainly used to increase growth. There are fertilisers applied only to forest and fertilisers, like saltpetre and urea, used both in agriculture and forestry. The amount of these two fertilisers used in forestry is based on expert judgement. This category includes N₂O emissions from fertilization application on both, lands remaining as forests and lands converted to forests.

N₂O emissions from fertilisation have decreased 32% from year 1990 to 2008. The trend after the slowdown in the beginning of the 1990's seems to be towards slightly increasing usage of fertilisers.

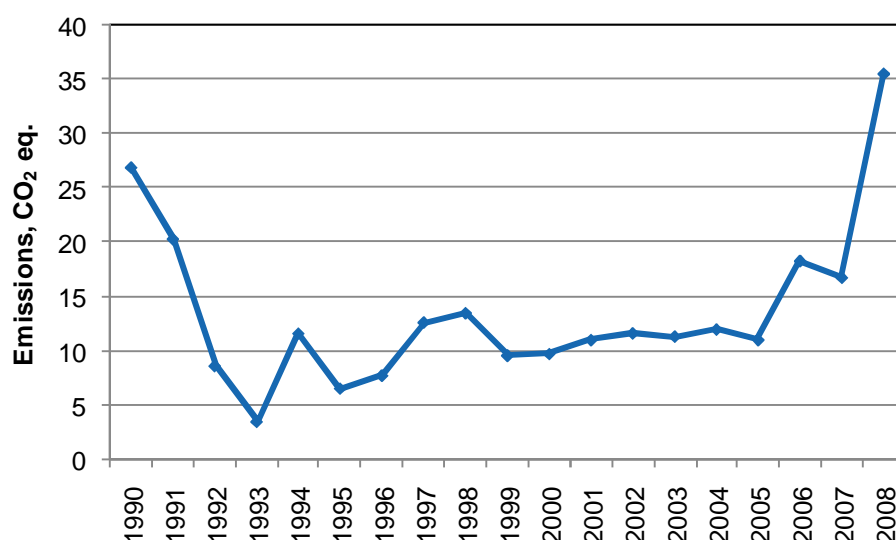


Figure 7.7-1 N₂O emissions from forest fertilisation (Gg CO₂ eq.).

7.7.1.2 Methodological issues

Methods

The IPCC default method (Tier 1) is used to estimate N₂O emissions from forest fertilisation (IPCC, 2003). Equation 3.2.18 is applied with country-specific activity data and the IPCC default emission factor.

Emission factors and other parameters

The default emission factor of 1.25% is used (IPCC, 2003).

Activity data

The used amount of nitrogen for forest fertilisation is based on the annual sale statistics on forest fertilisers, from which the amount of nitrogen is derived (Table 7.7-1). The information is produced by Yara Suomi Oy, previously Kemira GrowHow Oyj. This company delivers almost 100% of fertilisers applied to forest.

Table 7.7-1 The estimated amount of nitrogen (N) applied to forest in 1990-2008 (1 000 kg/year) (Source: Yara Suomi Oy, previously Kemira GrowHow Oyj).

Year	N (1 000 kg/year)
1990	4 404
1991	3 324
1992	1 408
1993	565
1994	1 897
1995	1 066
1996	1 262
1997	2 063
1998	2 206
1999	1 564
2000	1 588
2001	1 800
2002	1 900
2003	1 850
2004	1 957
2005	1 800
2006	2 993
2007	2 742
2008	5 818

7.7.1.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

For the estimation of uncertainties, the same estimates for the activity data ($\pm 10\%$) and the emission factor (-90 to $+380\%$) were used as in the Agriculture sector.

In the beginning on the 1990's the sales statistics of forest fertilisers has been registered concerning fertilising year (starting from the beginning of July), while the recent years statistics concern calendar year. This inconsistency is considered as marginal due to fact that year of purchasing fertilisers may not be the year of the use.

7.7.1.4 Source-specific QA/QC and verification

General Quality Control procedures (Tier 1)

Quality control procedures named in IPCC Good Practice Guidance for LULUCF (IPCC, 2003) Table 5.5.1 were done and nitrogen fertilizer providers were interviewed. Also nitrogen fertilization quantities reported here were compared to total of annual fertilization areas from statistics (Finnish Forest Research Institute 2008). It was confirmed that all data used in this section cover whole land area of Finland.

The sale statistics on N fertilizers applied to forest land and agricultural lands were gross-checked. Any discrepancy was not found.

7.7.1.5 Source-specific recalculations

No recalculations have been carried out.

7.7.1.6 Source-specific planned improvements

No planned improvements.

7.7.2 Non-CO₂ emissions from drainage of soils (CRF 5 (II))

In this submission Finland reports in CRF Table 5 (II) non-CO₂ emissions, that is, N₂O and CH₄, from peat extraction areas. CO₂ emissions from peat extraction areas are reported under category 5D. Wetlands. Source category description and methodological issues are given in Section 7.5 Wetlands (CRF 5.D). Emissions from other drained areas are not reported. Parties do not have to prepare estimates for categories contained in Appendixes 3a.2, 3a.3 and 3a.4 of IPCC Good Practice Guidance for LULUCF. At this point sufficient information is not available to prepare Finnish estimates.

7.7.3 N₂O emissions from disturbance associated to land use conversion to cropland (CRF 5 (III))

7.7.3.1 Source category description

Emissions of N₂O following the conversion of forest land and grassland to cropland are reported under this category. The emissions from forest land converted to cropland were 0.015 Gg and those from grassland converted to cropland 0.008 Gg in 2008. There has been an increasing trend in these emissions since the converted area has increased in 1990-2008.

7.7.3.2 Methodological issues

Methods

N₂O emissions from forest land and grassland converted to cropland were calculated according to equations 3.3.14 and 3.3.15 of the GPG LULUCF (IPCC, 2003):

$$N_{2O_{net-min}} - N = EF_1 * N_{net-min}$$

where

$N_{2O_{net-min}} - N$ = additional emissions arising from the land use change, kg N₂O-N a⁻¹

EF_1 = IPCC default EF, 0.0125 kg N₂O-N/kg N

$N_{net-min}$ = N released annually by net soil organic matter mineralization, kg N a⁻¹

$$N_{net-min} = \Delta C * 1 / C:N \text{ ratio}$$

where

ΔC = carbon loss from soil as a result of conversion, kg C a⁻¹

C:N ratio = ratio of C to N in soil organic matter, kg C/kg N

Emission factors and other parameters

The default emission factor of 1.25% is used (IPCC, 2003). In the case of forest land converted to cropland a national value for the C:N ratio was used. Based on published data for the C:N ratio of 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., manuscript) a value 21.4 was obtained. For grassland converted to cropland, the default C:N ratio of 15 was used.

Activity data

The area estimate was obtained as described in Section 7.1.2. The reduction of C stock due to conversion was determined as described in section 0.

7.7.3.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

For the estimation of uncertainties will be updated for the submission of April 15.

The time series is consistent.

7.7.3.4 Source-specific QA/QC and verification

Quality control procedures named in IPCC Good Practice Guidance for LULUCF (IPCC, 2003) Table 5.5.1 were done.

7.7.3.5 Source-specific recalculations

The whole time series was added to the submission.

7.7.3.6 Source-specific planned improvements

No improvements are planned at the moment.

7.7.4 Biomass burning (CRF 5 (V))

7.7.4.1 Source category description

This source category includes greenhouse gas emissions (CO₂, CH₄, N₂O) and other air emissions (NO_x and CO) from biomass burning on forest land comprising wildfires and controlled burnings (Table 7.7-2). 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. In the statistics all wildfires are classified as forest fires and for this reason it is not possible to separate wildfires on wetlands from fires on forest land. Classifying land area by IPCC land-use category, forest fires can happen on Forest land, Wetlands and Other land. All wildfires are reported under category 5.A 1 Forest land remaining Forest land.

Compared to previous submission, following changes were made:

- The mean biomass estimates used in the emission estimation of wilfires were obtained with similar methodology as mean biomass under forest land (see Section 7.2).

Table 7.7-2 Emissions from biomass burning (Gg).

Year	Greenhouse gases			Other gases	
	CO ₂	CH ₄	N ₂ O	CO	NO _x
1990	3.86	0.02	0.0001	0.15	0.00
1991	2.02	0.01	0.0001	0.08	0.00
1992	9.70	0.04	0.0003	0.37	0.01
1993	0.00	0.00	0.0000	0.00	0.00
1994	7.22	0.03	0.0002	0.28	0.01
1995	4.78	0.02	0.0001	0.18	0.01
1996	4.32	0.02	0.0001	0.16	0.00
1997	10.73	0.05	0.0003	0.41	0.01
1998	0.87	0.00	0.0000	0.03	0.00
1999	5.76	0.03	0.0002	0.22	0.01
2000	3.48	0.02	0.0001	0.13	0.00
2001	1.75	0.01	0.0001	0.07	0.00
2002	5.53	0.02	0.0002	0.21	0.01
2003	6.79	0.03	0.0002	0.26	0.01
2004	3.40	0.01	0.0001	0.13	0.00
2005	4.49	0.02	0.0001	0.17	0.00
2006	14.51	0.06	0.0004	0.55	0.02
2007	5.46	0.02	0.0002	0.21	0.01
2008	8.55	0.04	0.0003	0.33	0.01

CO₂ emissions are reported only from wildfires. CO₂ emissions from cutting residues are reported in carbon stock changes in dead organic matter (litter) and to avoid double-counting, those emissions are excluded from here.

7.7.4.2 Methodological issues

Methods

The default IPCC method was used with national activity data and IPCC default emission factors. Equation 3.2.9 was used to estimate annual losses of carbon and Equation 3.2.19 to estimate non-CO₂ emissions from carbon released (IPCC, 2003).

Wildfires

The mean biomass of the growing stock on forest land by tree species groups were estimated from the NFI8, NFI9 and NFI10 data (See the methods described in Section 7.2).

The biomass of understorey was added to the total biomass. The used biomass of field layer was 782 kg ha⁻¹ and bottom layer 1,534 kg ha⁻¹ (Muukkonen et al. 2006). The estimated average biomass per hectare on burned area has been approximately 60 tonnes. The combustion efficiency is based on expert judgement¹⁰ and it was assumed that 7.5% (±2.5%) of tree biomass, 20% (±10%) of field layer biomass and 12.5% (±7.5%) of bottom layer biomass would burn. The IPCC default carbon fraction (50%), emission ratios and N/C ratio were used.

The estimates of emissions are slightly overestimated due to the fact that wildfires also include fires on treeless wetlands, but biomass burned is estimated applying the mean volume of the growing stock of forest land. The activity data came from statistics compiled on burned area and they are annually published in the Forest Statistical Yearbook.

¹⁰ Ilkka Vanha-Majamaa (Finnish Forest Research Institute) and Timo Heikkilä (Ministry of the Interior), 2007

Controlled burning

Controlled burning means in this context 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 basing on NFI data of mature stands. Estimates were made separately for South and North Finland.

The volume of cutting residues was calculated by multiplying the mean volume with dry crown mass. The used crown mass (kg) per mean volume (m³) after final cut of mature stand was (Hakkila 1991):

	<u>South Finland</u>	<u>North Finland</u>
Scots pine	82.1	107.4
Norway spruce	164.4	217.5
Broad-leaved trees	82.8	120.1

The used biomass for bottom layer was 1,935 kg ha⁻¹ and for field layer 770 kg ha⁻¹ (Muukkonen et al. 2006). It was assumed according to expert judgement¹¹ that 25% ($\pm 5\%$) of tree biomass, 20% ($\pm 10\%$) of field layer biomass and 12.5% ($\pm 7.5\%$) of bottom layer biomass would burn. The IPCC default carbon fraction (50%), emission ratios and N/C ratio were used.

The activity data came from statistics compiled on burned area and they are annually published in the Forest Statistical Yearbook.

Emission factors and other parameters

Default emission factors from the GPG LULUCF (IPCC 2003, Table 3A.1.15, p. 3.185) were applied, namely 0.012 for CH₄, 0.007 for N₂O, 0.121 for NO_x and 0.06 for CO. For the N/C ratio the IPCC default value of 0.01 was also used.

Activity data

The time series of burned area are based on the areas of prescribed burnings and wildfires published annually in the Finnish Statistical Yearbook (Table 7.7-3). The information source for the area of wildfires is the Ministry of the Interior. The area of prescribed burnings comes from the information compiled from forestry organisations and companies that carry out prescribed burnings. The statistics are compiled by the Finnish Forest Research Institute.

¹¹ Ilkka Vanha-Majamaa (Finnish Forest Research Institute) and Timo Heikkilä (Ministry of the Interior), 2007

Table 7.7-3 Burned forest area in 1990-2008 (ha).

Year	Wildfires	Controlled burning
1990	434	3 754
1991	226	1 445
1992	1 081	2 047
1993	0	963
1994	798	1 668
1995	526	1 395
1996	473	896
1997	1 171	1 013
1998	95	622
1999	623	1 322
2000	374	472
2001	187	2 286
2002	590	2 010
2003	720	1 343
2004	351	216
2005	489	1 065
2006	1 595	1 032
2007	570	477
2008	825	434

7.7.4.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

Uncertainty in activity data (area) for biomass burning is estimated at $\pm 10\%$ based on expert judgement. Uncertainty concerning combustion efficiencies in combined is 10%. Uncertainties in emission factors ($\pm 70\%$) are based on the IPCC Good Practice Guidance for LULUCF (IPCC, 2003).

7.7.4.4 Source-specific QA/QC and verification

General QC procedures (Tier 1)

Quality control procedures named in IPCC Good Practice Guidance for LULUCF (IPCC, 2003) Table 5.5.1 were done. Possible overlapping in emission/removal estimation with other sources has been checked. Land areas of wildfires and controlled burning were reviewed with latest statistics (Finnish Statistical... 2008). It was confirmed that all data used in this section cover whole land area of Finland.

7.7.4.5 Source-specific recalculations

The mean biomass of the growing stock on forest land was estimated with the Finnish biomass equations. Thereby the time series of the emissions from wildfires and controlled fires were recalculated (Table 7.7-4).

Table 7.7-4 The difference in the emissions biomass burning between 2009 and 2010 submissions, including CO₂, CH₄ and N₂O emissions (Gg CO₂ eq.).

Year	2009 submission	2010 submission	Difference
1990	7.67	8.33	-0.67
1991	3.59	3.93	-0.34
1992	11.50	13.08	-1.58
1993	1.21	1.21	0.00
1994	8.76	9.87	-1.11
1995	6.27	6.99	-0.71
1996	5.26	5.88	-0.63
1997	11.56	13.07	-1.51
1998	1.58	1.70	-0.12
1999	7.13	7.89	-0.76
2000	4.01	4.46	-0.45
2001	4.31	4.54	-0.23
2002	7.79	8.50	-0.72
2003	8.09	8.97	-0.88
2004	3.50	4.02	-0.52
2005	5.71	6.13	-0.42
2006	15.94	17.12	-1.19
2007	5.99	6.59	-0.61

7.7.4.6 Source-specific planned improvements

To complete the activity data, the restoration burnings will be added to the inventory when the data are available for the whole country.

7.8 *Harvested Wood Products (CRF 5.G)*

7.8.1 *Source category description*

In 2008, harvested wood products were a small carbon sink in Finland, 0.1 Tg CO₂ eq. which is only 0.3% of the total sink in the LULUCF sector.

The category Harvested Wood Products (HWP) includes basically the carbon balance of all wood products which are in use in Finland, calculated by the Stock Change Approach (SCA). HWP are divided in solid wood products (sawnwood, wood-based panels and round timber in long-term use, e.g. poles) and paper products (paper and paperboard). The balance is converted to Gg CO₂; emissions are reported as positive and removal as negative numbers. The changes of roundwood stocks and their carbon balance are not taken into account in the reporting. Furniture, wooden packages are also excluded from the estimate, but fittings are included. Carbon balance of HWP in solid waste disposal sites is also excluded from the estimate. As the SCA is used in the reporting, the only variable to be estimated is Variable 1A, described in the 2006 IPCC Guidelines (IPCC 2006, Table 12.1, p. 12.8, in this report see Table 7.8-2). Neither Variable 1B is needed because of exclusion of solid waste disposal sites from HWP reporting. The other variables in that table, required in reporting using the other approaches, are on the side estimated by the HWP worksheet of the 2006 IPCC Guidelines, but they are not needed in the Finnish reporting. See Table 7.8-2.

In accordance with the 2006 IPCC Guidelines emissions of non-CO₂ greenhouse gases from HWP are reported under other sectors such as Energy.

The estimated trend in carbon stocks in wood products are shown in Table 7.8-1. According to the estimate wood products have been a sink for CO₂ except in 1991. It can be noted that the annual carbon balance of wood products varies substantially. Major reason for this is the first-order decay pattern in the HWP worksheet (algorithm of the model, see Pingoud et al. 2006): The real consumption of wood products (i.e. the input flow of the HWP pool in the model) varies notably annually, whereas the decay estimated by the model is directly proportional to the HWP pool varying much less annually. As a result the estimated total HWP balance during periods when consumption is low and the HWP pool turns even to a source of CO₂. For instance, in the early 1990s there was a deep economic recession in Finland (see Chapter 2). The activities in the construction sector declined including consumption of wood products, which is can be seen as an emission from HWP in 1991.

In reality, the annual variations in the carbon balance of HWP may be smaller, but the general trend over decades based on direct stock inventories (see next section) is more accurate. The average annual removal of HWP including both solid wood and paper is thus around -450 Gg CO₂/a during the reporting period.

Table 7.8-1 Estimated net emissions and removals of Harvested wood products by category in 1990-2008, CO₂ (Gg).

Year	Solid wood products	Paper products	Total
1990	-809	-136	-946
1991	279	28	307
1992	-153	-71	-225
1993	139	-233	-93
1994	-525	-232	-756
1995	-296	-574	-870
1996	-383	-665	-1 048
1997	-1 483	-639	-2 122
1998	-1 584	-182	-1 766
1999	-1 887	-152	-2 038
2000	-908	-359	-1 267
2001	-445	130	-315
2002	-856	419	-437
2003	-1 199	309	-889
2004	-989	157	-832
2005	-511	170	-340
2006	-521	127	-394
2007	-1 284	64	-1 220
2008	167	-262	-95

7.8.2 Methodological issues

7.8.2.1 Methods

The emission/removal from harvested wood products is estimated by the stock change approach and, further, only HWP in use are considered. The emission/removal from HWP in solid waste disposal sites is excluded from the reporting. Thus the only HWP variable needed in estimation of the emission/removal is variable 1A (Table 7.8-2), the reported emission being = $-44/12 \cdot \Delta C_{HWP,DC}$ (given in Gg CO₂/a).

The method used in estimation of emission/removal from harvested wood products is a country-specific Tier 3 method (Method D) described shortly in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The method is a combination of the First order decay method (IPCC 2006, p.12.16) (flux methods) and a direct inventory of harvested wood products (Method A, IPCC 2006, p. 12.15):

1) The carbon stock of *solid wood products* in Finland has been estimated on 5-year intervals based on building stock and other statistics. The stock in the other, non-inventory years is then estimated by fitting first the HWP worksheet of the 2006 IPCC Guidelines to the direct inventories and then estimating by the fitted HWP worksheet the carbon stock and its annual change in other years. The HWP model was thus used as an interpolation/extrapolation tool to the direct stock inventories.

2) The carbon stock in *paper products* and its annual change is estimated straightforwardly by the HWP worksheet with default parameters. This part of the estimation is thus a Tier 1 level method.

The sum of the estimated annual stock change in *solid wood products* and *paper products* in use is the HWP variable 1A (Table 7.8-2).

Table 7.8-2 The HWP variables associated with the HWP reporting. When applying the Stock Change Approach for HWP in use only the variable 1A has to be estimated. (IPCC 2006, Table 12.1)

Variable definition	Variable names	
	HWP in "products in use"	HWP in SWDS
Annual change in carbon stock in a) HWP in use and b) in HWP in solid waste disposal sites in the reporting country, this wood carbon that came from <u>domestic consumption</u> of products, $\Delta\text{CHWP}_{\text{DC}} = \Delta\text{CHWPIU}_{\text{DC}} + \Delta\text{CHWP}_{\text{SWDS}_{\text{DC}}}$	Variable 1A $\Delta\text{CHWPIU}_{\text{DC}}$	Variable 1B $\Delta\text{CHWPSWDS}_{\text{DC}}$
Annual change in carbon stock in a) HWP in use, and b) in HWP in solid waste disposal sites where the wood in the products came from <u>domestic harvest</u> - trees harvested in the reporting country, this includes exported HWP to other countries, $\Delta\text{CHWP}_{\text{DH}} = \Delta\text{CHWPIU}_{\text{DH}} + \Delta\text{CHWP}_{\text{SWDS}_{\text{DH}}}$	Variable 2A $\Delta\text{CHWPIU}_{\text{DH}}$	Variable 2B $\Delta\text{CHWPSWDS}_{\text{DH}}$
Carbon in annual imports of HWP to the reporting country including all wood-based material - roundwood, solidwood products, paper, pulp and recovered paper	P_{IM}	
Carbon in annual exports of HWP from the reporting country including all wood-based material - roundwood, solidwood products, paper, pulp and recovered paper	P_{EX}	
Carbon in annual harvest of roundwood for products - wood removed from harvest sites in the reporting country including fuel wood	H	

The estimation method is described in detail in the following.

The stock inventory

The method for performing direct stock inventories of harvested wood products in use in Finland is described in Appendix_7c. Inventories of carbon stock in wood products have been performed earlier regarding the years 1980, 1990, 1995, and 2000 (Pingoud and Perälä 2000, Pingoud et al. 2001, Pingoud et al. 2003). For the Finnish greenhouse gas inventory a new stock inventory of 2005 was performed. The inventories of 1995, 2000, and 2005 are relatively comprehensive – including all construction wood and wood products in fittings – and were utilized in estimation of the carbon balance in HWP. Paper products are excluded from these inventories. The earlier inventories of 1980 and 1990 were not used, because they were incomplete including only the housing stock.

Using the stock inventory results to fit the HWP worksheet model

The HWP worksheet (IPCC 2006) is a tool for estimating the annual development of carbon balance in HWP – using any of the alternative HWP approaches. The carbon stock in the model consists of two components: 1) solid wood products and 2) paper products, both having different half-lives. The basic algorithm for estimation of carbon stock in wood products and its change is described next equations.

Starting with $i=1900$ and continuing to present year, compute:

$$C(i+1) = e^{-k} * C(i) + \left[\frac{(1 - e^{-k})}{k} \right] * \text{Inflow}(i)$$

$$\Delta C(i) = C(i+1) - C(i)$$

$$\text{With } C(1900) = 0.0$$

Note: for an explanation of technique used in first equations to estimate first-order decay see Pingoud and Wagner (2006).

Where:

i = year

$C(i)$ = the carbon stock of the HWP pool in the beginning of year i , Gg C

k = decay constant of first-order decay given in units, a^{-1} ($k = \ln(2) / HL$, where HL is half-life of the HWP pool in years. A half-life is the number of years it takes to lose one-half of the material currently in the pool.)

$Inflow(i)$ = the inflow to the HWP pool during year i , Gg C a^{-1}

$\Delta C(i)$ = carbon stock change of the HWP pool during year i , Gg C a^{-1}

The stock change approach was applied in the HWP inventory of Finland. This means that HWP stocks under consideration are the domestic ones, i.e. those which within national boundaries. The Inflow to the domestic solid wood and paper product pools in HWP model is here is the annual apparent consumption (=production+imports-exports) of solid wood products and paper products converted to carbon flows. These inflows are estimated based on activity data (production in Finland, imports and exports; the time series are downloadable from the FAO databases, being identical to Finnish national statistics) and carbon conversion factors of the different products. The calculations of solid wood and paper using the HWP model differ from each other in how the emission factor (half-life) is estimated:

- 1) Solid wood products: No default values for emission factors in the HWP worksheet model were used. Instead the factors were chosen so that the model results could be fitted to the direct stock inventories of solid wood stocks. The direct inventories provided an estimate of the solid-wood product-stock in 1995, 2000, and 2005. The first order decay model combined with the above inventories was applied to estimate the *annual* stock change from 1990 to 2006. The worksheet was first fitted to the inventory results so that the model gave exactly the same carbon stock of solid wood products in 1995, 2000, and 2005 as the inventories. This could be done by adjusting the half-life of the solid wood products in the worksheet. To obtain an exact fit to the inventories, a slight modification has to be made to the original worksheet enabling a varying half-life for solid wood. Three half-life parameters were used: half-life from 1900 to 1995, half-life 1995-2000, and half-life 2000-2006. By the fitted model the carbon stock of solid wood products in all the years 1990-2006 (not only those years of direct stock inventories: 1995, 2000, 2005) could then be estimated as well as the annual change in their carbon stock.
- 2) Paper products: As there were no country-specific methods applicable for direct estimation of paper stocks, the default emission factor given in the 2006 IPCC Guidelines was used in the HWP worksheet was straightforwardly applied in the estimation of the paper stock and its annual change.

The total carbon balance of HWP was then estimated as a sum of the carbon stock change of the two components.

7.8.2.2 Emission factors and other parameters

The basic inflows were estimated in Finnish case based on the activity data downloaded from the FAO databases and the default conversion factors (IPCC 2006, Table 12.4). The emission factor, i.e., the half-life of paper products was assumed to be the default value = 2 years (IPCC 2006, Table 12.2). For solid wood products the half-life was chosen so that a fit with direct inventory of solid wood products in Finland could be obtained.

Emission factors

For paper products the default half-life equal to 2 years (IPCC 2006, Table 12.2) was used.

For solid wood products a modification to the original IPCC model was made, as mentioned above. The three half-life parameters were chosen so that the model could be fitted to the results of the direct inventory of solid wood products. The fitted parameters are as follows:

Half-life 1900-1995: 14.8 years

Half-life 1995-2000: 16.0 years

Half-life 2000-2005: 10.5 years

From the above parameters it can be seen that in the early 2000s an essentially lower half-life in the IPCC model gave the best fit to the direct inventory of solid wood products. The major reason for this is the increasing export of secondary wood products in the 2000s (A-L. Perälä, personal communication, Oct 2007). Increasing share of primary solid wood products such as sawn wood and wood-based panels consumed in Finland has been exported as pre-fabricated houses, windows, doors, furniture etc. The HWP model of the IPCC, however, uses as activity data only the consumed primary products and cannot take into account the above indirect export. The influence of this export flux can only be described by a more rapid decay i.e. a shorter half-life in the model.

Other parameters

In addition, the IPCC model needs as input parameter the estimated annual rate of increase for industrial roundwood production for the period 1900 to 1961. For this period there are no activity data at the FAO database (FAOSTAT). The default value for Europe, 0.0151 was chosen (IPCC 2006, Table 12.3). The model also uses factors to convert the product-m³ and -tonne values of the activity data to carbon tonnes. The default values (IPCC 2006) were used.

The data needed in the direct stock inventory are described in Appendix_7c.

7.8.2.3 Activity data

The HWP model of the IPCC requires activity data since 1961, i.e. production, import and export data of HWP, which can be downloaded from the FAO statistical data bases (FAOSTAT). The previous activity data 1900-1960 also needed in the model calculations are approximated by assuming that the consumption is correlated with the average annual increase in industrial roundwood production in Europe during that time period (IPCC 2006, Table 12.3). The time series until 2005 are currently (Oct 2007) available at the FAO Forestry database. The data for the year 2006 were downloaded from the UNECE Timber Committee Forest Product Statistics (UNECE 2007). The data in the FAOSTAT and the UNECE databases equals to the national data.

7.8.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

- The estimated emissions and removals from HWP are a sum of two components, solid wood products and paper products. The emission/removal estimate from solid wood products is based on direct inventories of the construction wood stock, which have been performed from the base years 1995, 2000, and 2005. The overall accuracy of these stock inventories was estimated to be $\pm 11\%$ (see Appendix_7c).
- Because of the features of the first-order decay model (see 7.8.1) the *annual* emission/removal estimates of solid wood products are more uncertain than the estimated accuracy of the stock inventories. The individual years can be over- or underestimated, but the estimate over the above 5-year periods is as accurate as the stock inventories. The accuracy of the inventory made in 2005 is estimated to be $\pm 11\%$ (for more details, see Appendix_7c).

- The emission/removal estimate of paper products could not be verified against any direct inventories and is thereby much more uncertain. Only default parameters given in (Pingoud et al. 2006) could be used in the HWP worksheet. The default half-life of 2 years in Table 12.2 (Pingoud et al. 2006, p. 12.17) is estimated to be too long for the average paper consumption in Finland. According to the estimate paper products would contribute to about 15% of the total removal due to HWP during the period 1990-2008. Decreasing the half-life of paper from 2 years to 0.5 years would decrease the removal due to paper products by 84%, but this would decrease the *total* removal due to HWP during 1990-2008 by less than 12% only. This could be the uncertainty bound downwards that could be added to uncertainty bound of the direct stock inventories
- Some solid wood product stocks are excluded from the estimate: roundwood stocks, furniture and packages:
 - The roundwood stocks vary more by season than by year the summer stocks being in general higher than winter stocks (Finnish Forest Research Institute 2008). Since 1990 the stocks have been varying between 17 Mm³ and 6 Mm³, which correspond to about 3.4 Mt C and 1.2 Mt C. In addition, there has been a declining trend in the roundwood stocks: the winter stocks (of 31 December) have declined from 12.7 Mm³ (1990) to 7.0 Mm³ (2005), i.e. 5.7 Mm³ or about 1.1 Mt C, which annually would mean an additional emission of about 0.08 Mt C/a or 280 Gg CO₂/a.
 - The wood furniture stock is most likely an order of magnitude smaller than that of construction wood. The same applies likely to the carbon stock change in furniture.
 - The packages are a short-term HWP stock, and its change was assumed to have a minor influence on the HWP balance.
- A major carbon stock not included in the reporting is HWP in solid waste disposal sites. This stock is decaying very slowly if not at all in the anaerobic conditions. According to the EU legislation it is not any more allowed to dispose organic wastes into solid waste disposal sites. Consequently the former accumulation of HWP into disposal sites has also been strongly reduced. Thus the annual removal has most likely been declining in the 2000s. It is presumable that HWP in solid waste disposal sites would currently still be a small removal.
- Some systematic errors to the emission/removal estimates could be caused by uncertain values of the conversion factors (e.g. carbon content in m³ of wood product). In this HWP reporting the default conversion factors given in the IPCC 2006 Guidelines were used, as no more elaborated information was available for the reporting. The uncertainty range from this is of the order of $\pm 10\%$ in the direct inventory of construction wood.
- The Finnish reporting is based on the Stock Change Approach, but with the IPCC model also the emissions/removals by the other approaches are estimated. The uncertainties of the Tier 3 method when applied to the different approaches could be characterized as follows: 1) Using SCA the uncertainty is much lower than using the others. The most important solid wood stock and its change could be estimated from direct country specific statistics and then fit the worksheet model to these stock inventories; 2) In the Atmospheric Flow Approach (AFA) significant uncertainties would have been involved with the trade flows of secondary products, which are a component of the Variables 3 and 4 in Table 7.8-2. There are no statistics available to estimate the amount of wood in production or trade flows of secondary wood products, only monetary values are available. 3) The Tier 3 method cannot be applied to Production Approach (PA), as it is not possible to make any direct inventories of solid wood stocks in the export markets. However, the emission/removal of HWP can be estimated very roughly by assuming that the exported wood products have a similar lifecycle than those consumed in Finland.

The rough uncertainty bound of the HWP emissions/removals 1990-2008 could be, based on the discussion above, of the order of $\pm 25\%$.

7.8.4 Source-specific QA/QC and verification

Here the outline of the 2006 IPCC Guidelines, Vol. 4, Chapter 12, p. 12.23 (IPCC 2006) is followed:

1. The country data have been checked. The best activity data (regarding variable 1A) are available at the FAO data base (FAOSTAT) except for the year 2006, which could be found from UNECE website (UNECE 2007). 2006 and 2007 data were changed in the UNECE database, new updated data were applied for 2010 submission.
2. There is some uncertainty regarding the conversion factors (densities etc.). The exact Finnish mix of wood products (e.g. panel products) was not used in determining the factors. As an approximation the default parameters given in Table 12.4 (IPCC 2006) were used.
3. Disposal of HWP into solid waste disposal sites was not considered in the reporting study and this kind of cross-checking was not applied.
4. A modified HWP worksheet model based on the worksheet of the 2006 IPCC Guidelines (IPCC 2006) was fitted by adjusting the half-life of solid wood products to the real inventory data of solid wood products.

This inventory data is believed to be the most reliable data regarding the solid wood product stock in Finland and the emissions/removals from this stock during the 5-year periods between the sequential inventories. A similar fitting procedure could not be applied to paper products, but their contribution to the HWP emissions/removals is much less than that of solid wood products.

7.8.5 Source-specific recalculations

The figures for roundwood, sawnwood, panels, paper and paperboard were checked from the UNECE statistics and updated numbers for 2006 and 2007 were applied.

7.8.6 Source-specific planned improvements

In the 2009 submission, several subjects of planned improvements were given but which now are not represented. The listed planned improvements were more a general description of how the estimation of carbon stock of harvested wood products should be improved. At the moment there are not enough resources to improve this field of reporting.

Appendix_7a

National forest inventory

The National Forest Inventory (NFI) is a sampling-based forest inventory system. The sampling design has been fitted to the variability of land-use classes and variation of the structure of the growing stock in different parts of Finland. The first inventory was carried out in 1921-1924 and since then ten inventories have been completed. The 11th inventory was launched in 2009 and the field measurements will be completed in 2013. The first four NFIs were made as line surveys, whereas in latter inventories sample plots are located in clusters.

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 plots within a cluster varies in different parts of the country according to spatial variation of forests and density of road network. Finland was divided into six sampling regions since the 9th inventory (Fig. 1_App_7a).

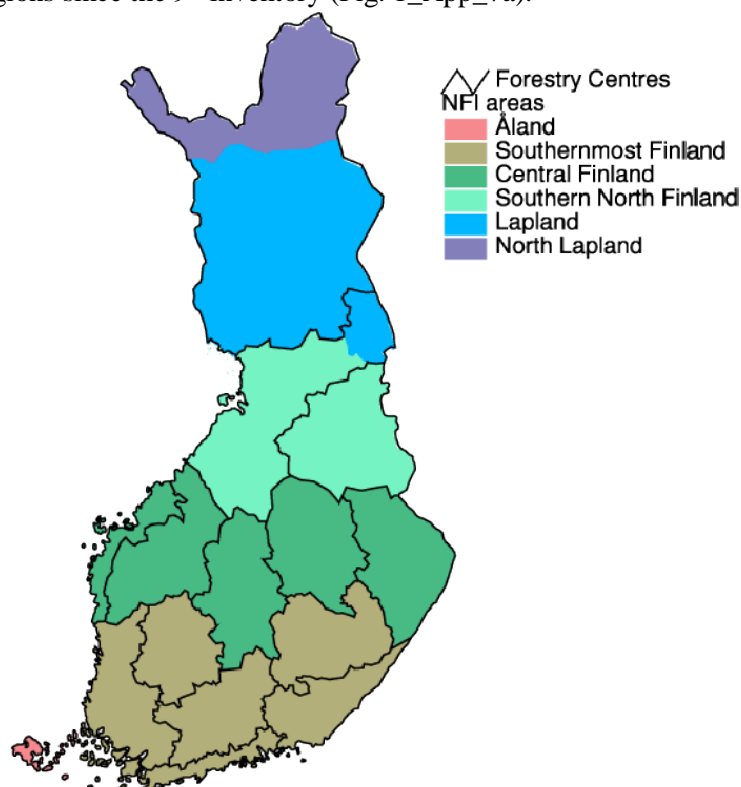


Figure 1_App_7a. Six sampling regions (NFI areas) and boundaries of forestry centres.

On the sample plots, tree and stand level information is assessed and measured. Stand level variables describe such as forest site, growing stock, forest health and previous and proposed cuttings. The most important site description variables for the GHG inventory are land-use class, both national and FAO definitions are applied, and site class and soil type, which separate mineral soils from organic soils. In addition, the conversions between land-use classes are assessed. Trees to be measured on sample plots, so-called tally trees, are sampled with an angle gauge (relascope). A tally tree should be at least 1.3 m tall and the minimum diameter at the height of 1.3 meter is 0 cm. The measured variables are tree species, diameter at breast height, quality class and crown story class. Height, diameter at 6 m, thickness of bark, 5 years' increment of diameter and height are measured from sample trees and these variables are applied in volume and biomass estimations alongside 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 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 total area of Finland is classified into ten land classes, of which eight are actual land categories. The land classes are:

Productive forest land where the mean annual increment of the growing stock with bark over the rotation period is at least 1 m³/ha

Poorly productive forest land where the increment is less than 1 m³/ha but at least 0.1 m³/ha.

Unproductive land where the increment is less than 0.1 m³/ha, typically open bogs and open rocky lands.

Forest roads, depots, etc.

Agricultural land includes cropland, grassland, other land needed for agriculture and agro-buildings except farmhouses

Build-up land includes all settled areas, farmhouses, factory areas, peat extraction areas and gravel pits.

Traffic lines include roads, railroads, airfields and other areas needed for their use.

Power lines electric lines, water mains and natural gas lines with the width of at least 5 m.

Inland waters consist of streams and rivers with a width of at least 5 m, ponds, lakes and reservoirs.

Salt water.

The area estimation is based on the total land area and on the number of centre points of sample plots falling in the stratum of interest (Tomppo 2006). 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. a Forestry Centre region).

The method to estimate sampling error for area estimates is described by Heikkinen (2006).

Appendix_7b

Mathematical formulation of the YASSO model

Mathematical formulation of the YASSO model:

$$\frac{dx_{fwl}}{dt} = u_{fwl} - a_{fwl} x_{fwl}, \quad (1)$$

$$\frac{dx_{cwl}}{dt} = u_{cwl} - a_{cwl} x_{cwl}, \quad (2)$$

$$\frac{dx_{ext}}{dt} = u_{nwl} c_{nwl_ext} - c_{fwl_ext} a_{fwl} x_{fwl} + c_{cwl_ext} a_{cwl} x_{cwl} - k_{ext} x_{ext}, \quad (3)$$

$$\frac{dx_{cel}}{dt} = u_{nwl} c_{nwl_cel} - c_{fwl_cel} a_{fwl} x_{fwl} + c_{cwl_cel} a_{cwl} x_{cwl} - k_{cel} x_{cel}, \quad (4)$$

$$\frac{dx_{lig}}{dt} = u_{nwl} c_{nwl_lig} - c_{fwl_lig} a_{fwl} x_{fwl} + c_{cwl_lig} a_{cwl} x_{cwl} + p_{ext} k_{ext} x_{ext} + p_{cel} k_{cel} x_{cel} - k_{cel} x_{cel}, \quad (5)$$

$$\frac{dx_{hum1}}{dt} = p_{lig} k_{lig} x_{lig} - k_{hum1} x_{hum1}, \quad (6)$$

$$\frac{dx_{hum2}}{dt} = p_{hum1} k_{hum1} x_{hum1} - k_{hum2} x_{hum2}, \quad (7)$$

where

$u_i(t)$ = the input of litter type i to the system (i = non-woody litter (nwl), fine woody litter (fwl) or coarse woody litter (cwl)),

$x_i(t)$ = the weight of organic carbon in woody litter compartment i at time t (i = fine or coarse woody litter),

a_i = the rate exposure of woody litter i to microbial decomposition,

$x_j(t)$ = the weight of organic carbon in decomposition compartment j at time t (j = extractives (ext), celluloses (cel), lign-like compounds (lig), humus (hum1) or more recalcitrant humus (hum2),

c_{ij} = the concentration of compounds j in litter type i ,

k_j = the decomposition rate of compartment j , and

p_j = the proportion of mass decomposed in compartment j transferred to a subsequent compartment ($1-p_j$ is the proportion removed from the system).

Appendix_7c

A direct carbon inventory of wooden materials in Finnish construction in 2005

Introduction

In this document the method of performing a direct carbon stock inventory of wood products in use in Finland is described. The procedure of estimating the carbon stock of year 2005 is presented in detail, but a similar procedure has been used in earlier stock inventories. The method is country-specific and based on national statistics.

Inventories of the building stock were earlier carried out of the years 1980, 1990, 1995 and 2000 (Pingoud et al. 2001 and 2003). Since 1995 these inventories include an estimate of the complete wood product stock including wood used, for example, in bridges, poles, buildings without permits etc. (but excluding paper). The objective of the subsequent inventories is to create a time series by which the yearly change in carbon stocks in Finland can be estimated. This report includes in addition to the 2005 inventory an update of the 2000 inventory and the time series of inventories 1995, 2000, and 2005. The time series of inventories are presented in Tables 2_App_7c and 3_App_7c. These numbers were utilised, together with the HWP worksheet of the 2006 IPCC Guidelines (IPCC 2006), to estimate time series of carbon balance in harvested wood products from 1990 to 2006.

Use of wooden materials in Finnish building construction is common compared with many other European countries. About 70% of sawn wood consumption in Finland was end-used in the construction area in 2005. This means wood in new buildings, renovation sector, windows, doors, kitchen equipments, wood in civil engineering area and equipments to yards and gardens. In addition, furniture, packages and construction products (like wooden buildings, windows, doors etc.) are produced for export. These wood products are not included in the estimate. Further, the exported final products are neither compiled in the FAO trade statistics, which causes a systematic error in the input data of HWP worksheet model, discussed in the HWP inventory chapter 7.8.

The building stock in Finland is very well known unlike in many other countries. VRK (National register centre) maintains the building stock register and Statistics Finland publishes the Building stock statistics. The VTT Business Intelligence Group has used the building stock statistics during the last decades and developed it further to a more detailed database including some additional building types.

The direct stock inventory of wood products has been performed at the VTT by Senior Research Scientist Anna-Leena Perälä and Systems Specialist Harri Nuuttila.

Methods

The inventory of wooden materials in Finnish construction in 2005 is based on several data sources: 1) the building stock register, maintained by the Finnish Population Register Centre (VRK) and corresponding statistics collected by Statistics Finland (Statistics Finland, 2006a), 2) the statistics on construction and housing (Statistics Finland 2006b) and 3) the construction and housing yearbook 2005 (Statistics Finland 2006c) and 4) the data base of VTT Business Intelligence Group. The statistics of building stock include information on floor areas in different building types, divided into 15 main type categories (Statistics Finland 2006).

The building-stock statistics do not include free-time residential buildings (holiday homes), which are an important sector of Finnish wooden construction. Also different types of outbuildings and buildings used for agricultural production are out of the official buildings stock statistics. Those building types have been included, however, in the new building registers during many years.

The statistics on construction and housing (Statistics Finland 2006b) includes, for example, the information on new building permits in 15 type categories. The statistics cover the construction of all new buildings and extensions, and the resulting stock of new dwellings. Building permits include information about the gross floor area (m²) and building volume (m³). In official Finnish building permits, information on bearing frame materials has been collected since 1952 and on main facade material since the beginning of the 1980s. During last years wood in bearing construction and facades in new building has increased slightly.

The land use and building statute (Statutes of Finland 895 1999) define when a building permit is required in Finland. There are no exactly-defined limits for small buildings being optional in the Finnish communes. About 87% of the communes have some limits to outbuildings without building permit to building statistics. That area varies between 7-150 m² according to an enquiry (Suomen kuntaliitto, 2003). A typical small outbuilding without fireplace and with a square area between 8-10 m² does not need a building permit in most communes. In agricultural areas the limits are higher. The small outbuildings are typically wooden in Finland. In addition, only a notice-type planning permission for minor construction is required in building of some special structures, such as stands, platforms and sheds. This is not a building permit and is thus not included in the statistics on construction and housing.

The information of the above statistics, results of specific enquiries and other information on construction are regularly combined at the VTT Business Intelligence Group to constitute a more detailed database on Finnish building stock, new buildings, construction materials, working man-years and input-output analyses on how the construction field influences the Finnish society. The database is more detailed than the official stock statistics. For example, more building types are included in the database than in the official statistics. The building stock part of the database and the new construction part are updated yearly nowadays. The database is used regularly in various assessments and prognoses concerning the construction industry of Finland. Most of these assessments are confidential and unpublished. The inventory of the wood product pool and its C content, considered in this study, is only one of the many applications of the above database.

On the basis of statistics and individual sample surveys in Finland VTT has estimated for its stock database the average floor heights of each building type in each age class (i.e. decade of construction). As the official statistics on building stock includes only floor areas, these are converted to building volume using the average floor heights. In the database, buildings are divided into separate parts (bearing frames, facades, floors, roofs etc.) and classified according to building type and age class. For each building type and age class, the use of different construction materials in separate parts of buildings is estimated with the aid of sample surveys and information gathered from building permits. The estimate of wooden materials in permanent use is also based on estimates of material losses during construction. Technical changes and consumer trends have had an important impact on material use in Finnish buildings during recent decades.

The calculation of the carbon stock in wood products is based on the quantities of sawn wood, wood-based panel products and bearing logs (especially in the case of free-time residential buildings) in buildings and their carbon content. The major tree species, used as raw materials in the Finnish wood-products industry, are spruce (*Picea abies*) and pine (*Pinus sylvestris*), whereas the average share of hardwood, mainly birch (*Betula sp.*), is just 5%, used predominantly in plywood industry. The volume of wooden products has been estimated in dry matter weight of products per building-m³ in each type and age class. The carbon content of wood products was estimated to be 50% of their dry weight. The total carbon stock is calculated by the formula

$$C = \sum_{i,j} [A_{ij}(S_{ij} + P_{ij})]$$

where

C = total C reservoir of wooden materials in building stock (t C),

A_{ij} = building stock of building type i in age class j (building-m³)

S_{ij} = amount of C in sawn wood and logs in building type i and age class j (t C / building-m³)

P_{ij} = amount of C in wood-based panels in building type i and age class j (t C / building-m³)

and where age class j refers to the decade of its construction.

In addition to Finnish building stock the amounts of wood products and their carbon stock in gardens (e.g. fences and yard equipment) were approximately estimated on the basis of specific amount (sawn wood

m³/building m³) in different building types. All building types have different quantities of sawn wood in yard structures, the amount of which was estimated from cost specifications of building construction in Finland.

The above carbon stock inventories were performed for the years 1980, 1990, 1995 and 2000. The inventories of 1980, 1990, and 1995 have been published previously (Pingoud et al. 2000 and 2001). The summary results of the 2000 inventory have been presented in Pingoud et al. (2003, p. 31). The inventory for 2005 was carried out in 2007, and the results (Figure 2_App_7c and 3_App_7c) – together with the summary results of the previous inventories (Figure 1_App_7c) – are presented at the end of this Appendix.

The basis of this latest inventory (2005) was extended in the same way as in the 1995 and 2000 inventories and the inventory method applied was exactly the same. The stock of sawn wood in buildings not subject to building permits (for example the small buildings and some agricultural building types), was also included as well as the estimated quantities of wood used in civil engineering structures. The above buildings are not within the official statistics of building stock. This extended stock is substantial, because in Finland there are many rural areas and much space is available to build many kinds of outbuildings. This estimate is based on statistics of production, import and export of playhouses, small shelters and storehouses etc. and on samples of their number and construction on building sites.

Sawn wood is also used in civil engineering: in bridges, docks, poles and piers. A coarse approximation of wooden stock in civil engineering was based on its estimated capital value in transportation networks, telecommunications networks, energy and water supply networks and others (VTT, 2007). The amount of sawn wood (m³) per capital value (EUR) was approximated in these infrastructure sectors. Also annual reports of Kestopuu Co (e.g. Kestopuu 2006) include statistics of poles and piers and sawn wood during many decades. Additional information could be obtained from some confidential reports about the end use of sawn wood and wood-based panels in civil engineering area, made at VTT.

Carbon stock in Finnish building stock in 2005

The carbon pool has been increasing during last decades. The C content of the dry matter weight of wood products has been 50% in all calculations. Cubic metres of wooden products have been changed first to dry weight and then to carbon stock. Dry density of sawn wood is assumed to be 450 kg/m³ and wood based panels between 300-700 kg/m³. The stock of wooden products includes the end use of products. So, all residuals have taken away from calculations. The carbon pool accounted for by sawn wood, logs and wood-based panels in building stock and garden construction was 8.4 Mt C in 1980, 10.3 Mt C in 1990, 11 Mt C in 1995, 11.5 Mt C in 2000 and 12.3 Mt C in 2005 (Figure 1_App_7c). The total stock including civil engineering and house construction not subject to permission is given from 1995, 2000 and 2005. The estimated total carbon stock in 2005 was 18.6 Mt C. The average annual increase in building stock has been 0.15 Mt C/year during 1980 to 2005.

The total carbon stock used in construction (including construction with and without building permits, and civil engineering) was estimated to be 18.6 Mt C in 2005 (Figure 2_App_7c). Most important carbon stock comes from detached houses. Important sectors are also small buildings, free-time buildings and agricultural and other separate buildings. Use of wood products in smaller buildings is more important at the level of Finland than big wooden buildings. However there are good examples in new construction in Finland to build big buildings from wood-based materials. Civil engineering area total is also an important carbon stock but this area is divided to very many products. About 65% of the wooden stock is constructed after 1970. It should also be noted that almost all timber used for construction until 2005 was grown in Finnish forests. In addition a clear majority of sawn timber is exported.

In 2005 Finland had a building stock of 1.94 billion m³. Of this stock about 42% consisted of housing, 21% industrial and storage buildings, 18% public and commercial buildings and 19% other building.

It is typical in Finland to construct wooden buildings. More than 30% of the construction wood in the building sector are localised in detached houses (Figure 3_App_7c). Free-time residential buildings (holiday homes), agricultural buildings, and other small buildings are also important C pools. Sawn-wood products form a much larger stock than wood-based panels. However, in Finland relatively little wood is currently used in public, commercial and industrial buildings. Apart from houses the entire civil engineering sector is

an important C pool of sawn wood products, but the use of wooden products varies considerably in different sites.

Uncertainty and time series' consistency of calculations

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

VTT Business Intelligence group has used and developed building stock data during last years in many public and private research commissions. There are still uncertainties in the estimates of building stock, small buildings and civil engineering area.

Stock loss in buildings varies between 0.3-2% depending on building type, the average being about 1% (Heljo, Nippala, Nuuttila, 2005). VTT Business Intelligence group has developed also building stock analyses in many other research reports (Vainio et al, 2006), (Vainio et al, 2002) and (Perälä, 2006).

The accuracy of the total inventory in 2005 appears to be of the order of $\pm 11\%$, because the use of treated wood is known on the basis of production statistics and the use of wooden materials in sectors outside construction is known (Table 1_App_7c). Uncertainty of dwelling estimates vary between $\pm 4\% \dots \pm 6\%$ and in non-residential buildings the uncertainty is a bit higher. The civil engineering area and other use of wood are most uncertain.

The building stock in Finland is very well known by decades, if we compare the situation to many other countries. Almost 65% of the building stock has been built after 1970. The uncertainty in building stock is on the average $\pm 7\%$. Earlier decades are more uncertain than the newer building stock. The dwelling stock is more accurate than industrial, agricultural and other building stocks.

Table 1_App_7c. Uncertainty of building stock in 2005 in Finland. (VTT 2007)

	%
Dwellings	$\pm 4\% \dots \pm 6\%$
Non-residential	$\pm 6\% \dots \pm 9\%$
Civil eng. other	$\pm 11\% \dots \pm 20\%$
Total building stock	$\pm 11\%$

On one hand, the estimate of the official building stock is more accurate than before, on the other hand, the building control has made it easier to build small buildings without official building permit decreasing the accuracy, because this information is not collected to the official building statistics.

The age-distribution of the wood product stock (Figure 3_App_7c) refers to the construction year of the building. However, the present way of compile statistics places an old house with new extensions to the age-class of the old building, although for example the extension would be much larger than the original building. One building type can change to another building type during its life time. For instance, a former single family house can be now storage building.

Conclusions

Carbon stock of wood products in building stock and other construction use has increased during 2000-2005 0.21 Mt/year. That carbon stock has increased continuously during last decades. There is still potential to increase the use of wood, but the competition with other materials is hard. Also building costs effect to decision makers, which material is used in dwellings and other buildings.

The building stock in 2005 is more accurate than in the earlier inventories. On the other hand, new small buildings need not always building permits and those must estimated separately.

Uncertainty of calculations varies between ± 4 and $\pm 20\%$ in different areas, being an average $\pm 11\%$. Calculations are more accurate in dwellings like in non-residential buildings. The uncertainty is highest in civil engineering area and in small buildings.

More value-added wooden products like pre-fabricated houses, windows, doors etc., are also produced in Finland. In case they are exported rather often also abroad, their carbon stock is not included to the inventory, as they are not situated in Finland.

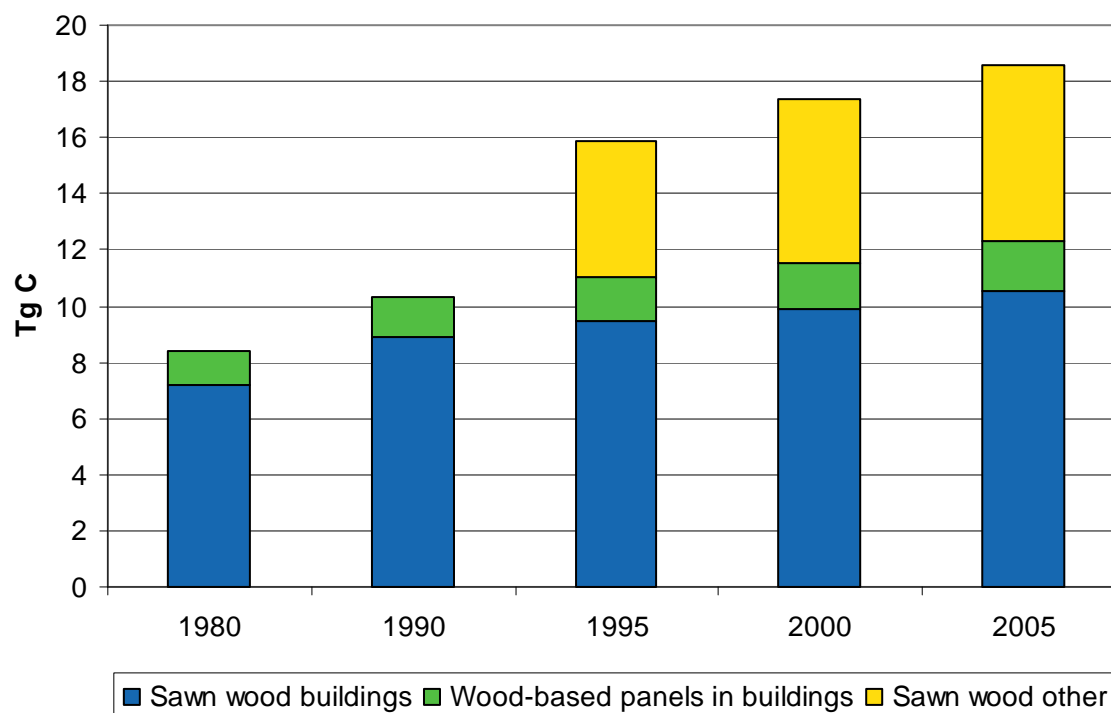


Figure 1_App_7c. Carbon storage of wooden products in Finnish construction.

Table 2_App_7c. Carbon stock by building types in Finland in 2005 (1 000 t C).

	1940's and older	1950's	1960's	1970's	1980's	1990's s	2001-2005
Detached houses	1470	704	546	934	1109	678	454
Attached houses	16	10	39	159	285	123	58
Blocks of flat	90	71	136	167	94	86	45
Free-time buildings	359	161	235	324	324	529	136
Commercial, public buildings	83	48	60	101	126	88	65
Industry, stories	71	34	138	272	151	42	34
Agricultural, other	320	151	122	214	301	305	204
Buildings, no permits	120	208	340	308	315	415	350
Gardens	75	40	80	85	175	440	450
Civil engineering	57	288	582	538	660	555	250

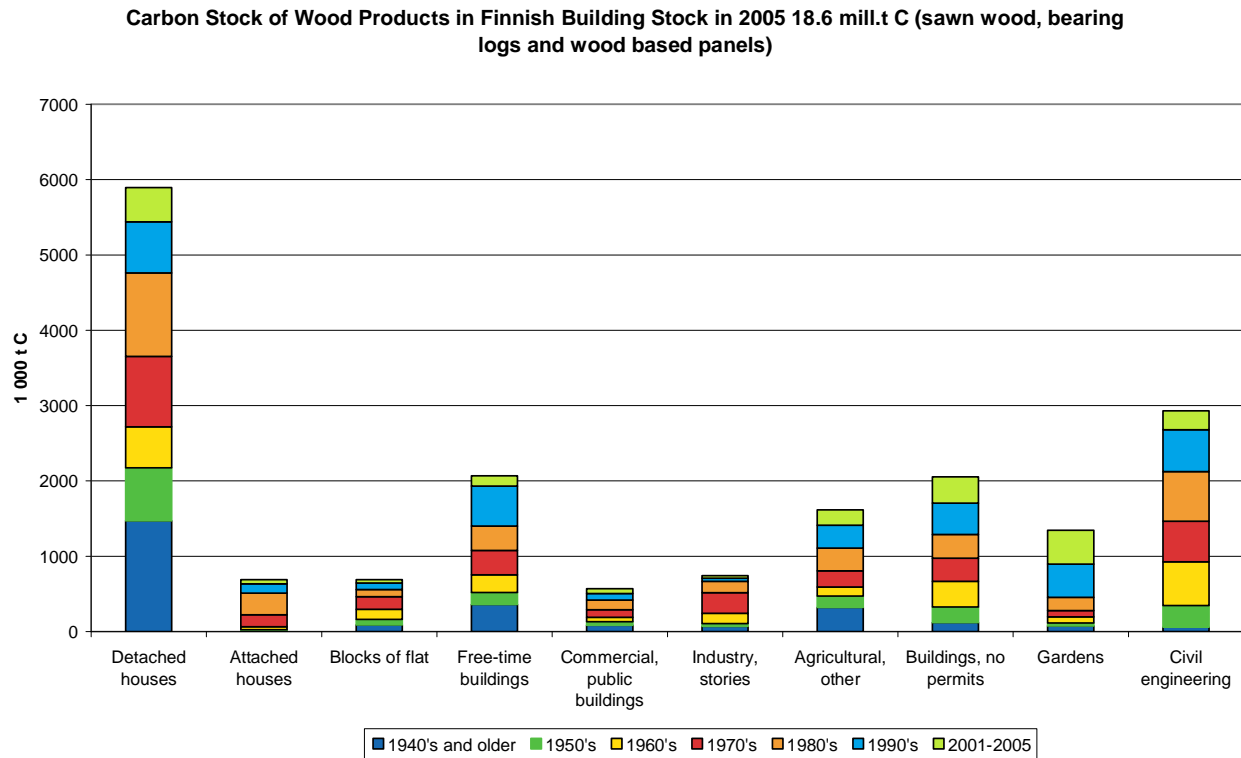


Figure 2_App_7c. Carbon stock by building types in Finland in 2005.

The Share of Carbon Stock by Decades in the Whole Finnish Buildings Stock in 2005 (18.6 mill.t C)

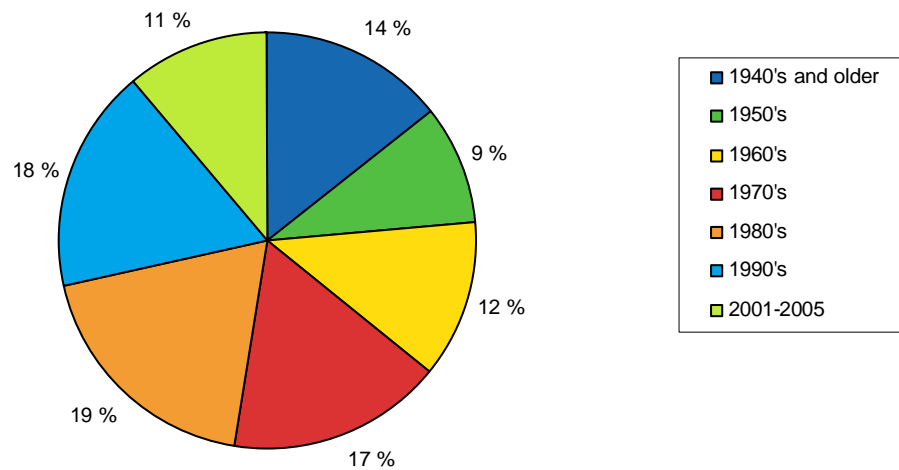


Figure 3_App_7c. Carbon stock in Finnish building stock by decades in 2005.

Table 3_App_7c. Time series of inventories of wood product stock in 1995, 2000, and 2005. Whole Wooden Material in Finnish Building Stock (sawn wood, bearing logs, wood based panels, dry weight, 1 000 t).

	2005								2000								1995							
	2001- 2005	1990' s	1980' s	1970' s	1960' s	1950' s	1940' s and older	Total	1990's	1980's	1970's	1960's	1950's	1940's and older	Total	1991- 1995	1980' s	1970' s	1960' s	1950' s	1940' s and older	Total		
Detached houses	909	1356	2217	1867	1092	1408	2939	11789	1562	2233	1691	1071	1536	2867	10960	882	2438	1737	1030	1313	2655	10054		
Attached houses	116	246	571	318	78	20	33	1381	291	550	293	68	20	39	1261	173	602	277	66	19	25	1162		
Blocks of flat	89	172	188	335	271	142	179	1377	174	182	344	249	131	177	1258	158	257	287	226	111	127	1165		
Free-time buildings	272	1057	647	648	469	321	719	4134	327	653	670	512	366	943	3472	313	693	708	473	396	610	3193		
Commercial, public buildings	130	175	253	202	121	96	165	1141	228	255	191	122	116	200	1112	189	345	140	92	85	139	990		
Industry, stories	69	84	302	544	277	68	142	1486	135	336	661	339	97	163	1732	24	132	238	131	42	31	598		
Agricultural, other Buildings, no permits	408	611	601	428	245	301	640	3233	842	683	471	220	239	761	3216	692	1056	607	346	366	533	3600		
Gardens	700	830	630	615	680	415	240	4110	992	630	630	720	450	270	3692	300	700	700	800	500	300	3300		
Civil engineering	900	880	350	170	160	80	150	2690	1000	360	180	180	100	180	2000	200	400	200	200	120	200	1320		
Total	500	1110	1320	1075	1165	575	115	5860	1170	1500	1270	1355	665	139	6100	944	1676	1416	1508	740	150	6434		
Total	4093	6521	7080	6203	4557	3426	5322	37201	6722	7383	6402	4837	3719	5740	34803	3874	8299	6309	4872	3692	4769	31816		
Total (%)	11	18	19	17	12	9	14	100	19	21	18	14	11	16	100	12	26	20	15	12	15	100		

Table 4_App_7c. Time series of inventories of wood product stock in 1995, 2000, and 2005. Carbon Stock of Finnish Building Stock (1 000 t C).).

	2005								2000								1995							
	2001 - 2005	1990's	1980's	1970's	1960's	1950's	1940's and older	Total	1990's	1980's	1970's	1960's	1950's	1940's and older	Total	1991-1995	1980's	1970's	1960's	1950's	1940's and older	Total		
Detached houses	454	678	1109	934	546	704	1470	5894	781	1117	846	535	768	1434	5480	441	1219	869	515	656	1327	5027		
Attached houses	58	123	285	159	39	10	16	690	145	275	147	34	10	20	630	87	301	138	33	9	12	581		
Blocks of flat	45	86	94	167	136	71	90	688	87	91	172	125	66	89	629	79	129	143	113	55	63	582		
Free-time buildings	136	529	324	324	235	161	359	2067	164	326	335	256	183	472	1736	157	347	354	236	198	305	1597		
Commercial, public buildings	65	88	126	101	60	48	83	571	114	127	96	61	58	100	556	94	172	70	46	43	70	495		
Industry, stories	34	42	151	272	138	34	71	743	68	168	330	170	48	82	866	12	66	119	65	21	16	299		
Agricultural, other Buildings, no permits	204	305	301	214	122	151	320	1617	421	342	236	110	120	381	1608	346	528	304	173	183	267	1800		
Gardens	350	415	315	308	340	208	120	2055	496	315	315	360	225	135	1846	150	350	350	400	250	150	1650		
Civil engineering	450	440	175	85	80	40	75	1345	500	180	90	90	50	90	1000	100	200	100	100	60	100	660		
Total	250	555	660	538	582	288	57	2930	585	750	635	678	332	70	3050	472	838	708	754	370	75	3217		
	2047	3260	3540	3101	2279	1713	2661	18600	3361	3691	3201	2418	1860	2870	17401	1937	4149	3155	2436	1846	2385	15908		
Total (%)	11	18	19	17	12	9	14	100	19	21	18	14	11	16	100	12	26	20	15	12	15	100		

8 WASTE (CRF 6)

8.1 Overview of the sector

Emissions from the waste sector were 2.2 Tg CO₂ eq. in 2008. This was 3% of the total greenhouse gas emissions in Finland. Solid waste disposal on land (landfills and dumps) causes relatively large CH₄ emissions in Finland while emissions from wastewater handling and from composting are smaller (Figure 8.1-1).

In the Finnish inventory emissions from the Waste Sector cover CH₄ 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 CH₄ emissions from municipal (domestic and commercial) and industrial wastewater handling plants and uncollected domestic wastewaters. N₂O emissions are generated from nitrogen input of fish farming as well as domestic and industrial wastewaters discharged into waterways.

NM VOC emissions from solid waste disposal sites and wastewater handling as well as NM VOC, CH₄ and N₂O emissions from composting are also estimated in the Finnish inventory. General assessment of completeness could be found in Section 1.8 and more detailed assessment is included in Annex 5.

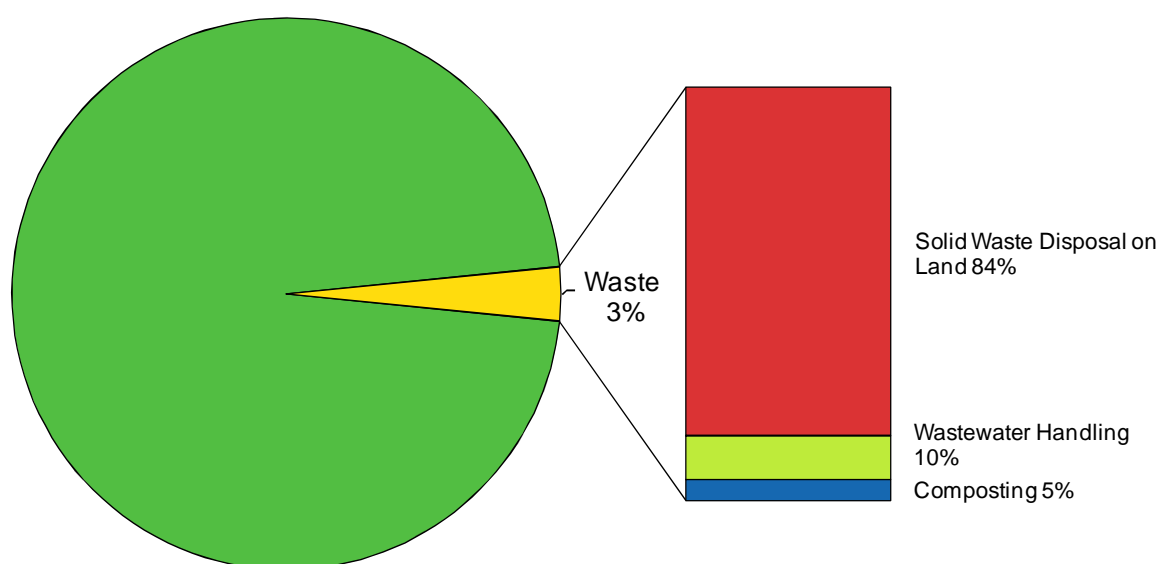


Figure 8.1-1 Greenhouse gas emissions from the Waste Sector in 2008 compared with the total greenhouse gas emissions in Finland.

CH₄ emissions from landfills are the most important greenhouse gas emissions in the waste sector. Solid waste disposal on land contributes over 84%, waste water handling about 10% and composting 5% of this sector's total emissions. Since 1990 these emissions have decreased 45% (Figure 8.1-2). At the beginning of the 1990's, around 80% of the generated municipal waste was taken to solid waste disposal sites (landfills). After the implementation of the new Waste Act (1994) and the Landfill Directive (1999/31/EC) minimisation of waste generation, recycling and reuse of waste material, landfill gas recovery and alternative treatment methods to landfills have been endorsed. Similar developments have occurred in the treatment of industrial waste, and municipal and industrial sludges. While the emissions from solid waste disposal on land have decreased, the emissions from composting have increased during the last years. In addition, the increase of waste incineration has decreased the emissions from landfills in 2008. Implementation of landfill gas recovery has significant impact on emissions. The increase of emissions in 2006 followed from increased amount of waste landfilled and a low landfill gas recovery rate due to (temporary) technical problems in one important landfill gas recovery plant.

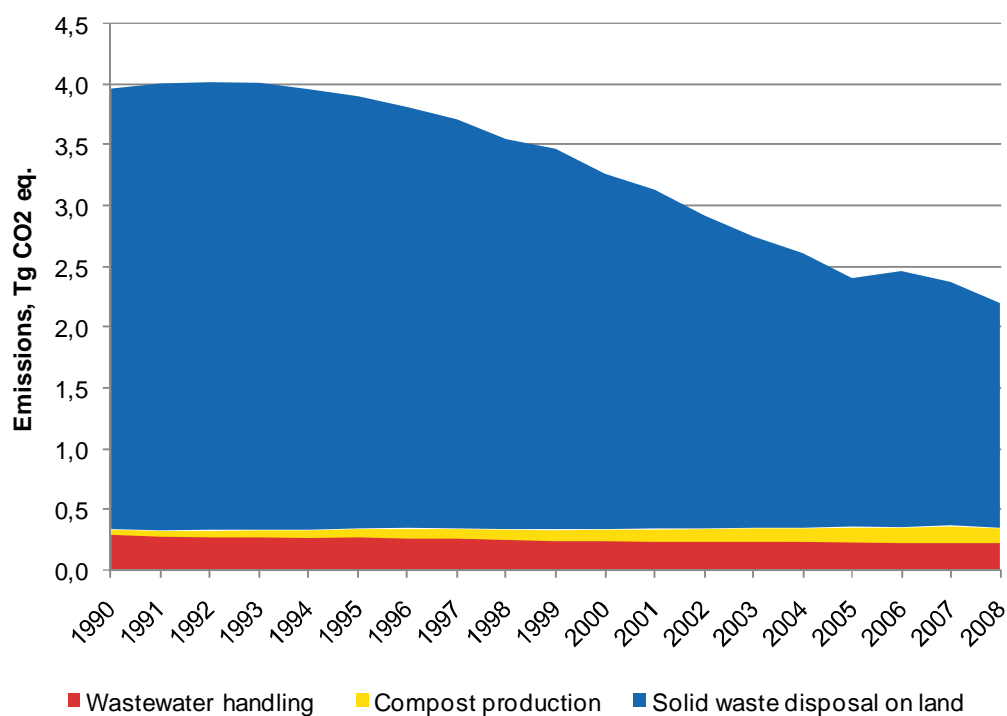


Figure 8.1-2 Trend in the Waste Sector's emissions in 1990-2008 (Tg CO₂ eq.).

The emission trend in the Waste Sector by subcategory and gas is presented in Table 8.1-2.

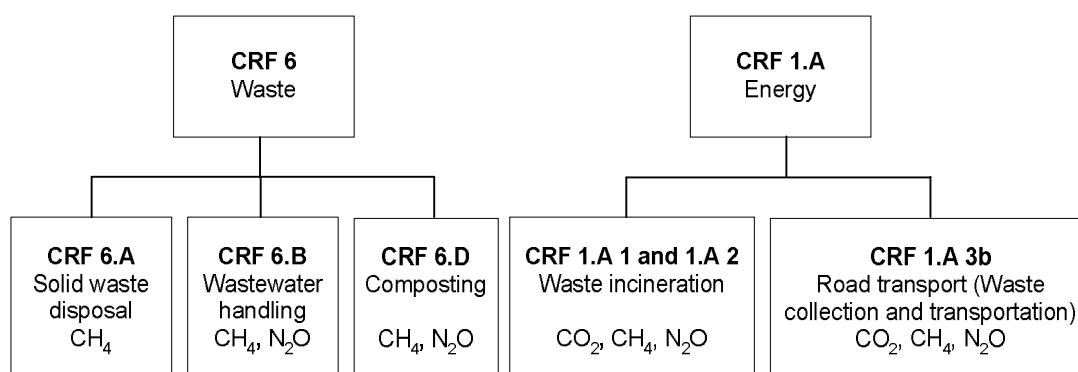


Figure 8.1-3 Emissions from waste handling and their reporting categories in the national greenhouse gas inventory.

Key categories

The key categories in the waste sector in 2008 are summarised in Table 8.1-1.

Table 8.1-1 Key categories in Waste Sector (CRF 6) in 2008 (quantitative method used: Tier 2).

Source Category	Gas	Criteria
6.A. Solid Waste Disposal on Land	CH ₄	L, T
6.B 2 Domestic and Commercial Wastewater: densely populated areas	N ₂ O	L
6.D Other: compost production	CH ₄	T

Table 8.1-2 Emissions in the Waste Sector by source and gas in 1990-2008 (Tg CO₂ eq.).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Solid waste disposal on land	3.64	3.68	3.70	3.69	3.63	3.57	3.47	3.37	3.22	3.14	2.93	2.80	2.58	2.40	2.26	2.05	2.11	2.01	1.85
Methane	3.64	3.68	3.70	3.69	3.63	3.57	3.47	3.37	3.22	3.14	2.93	2.80	2.58	2.40	2.26	2.05	2.11	2.01	1.85
Wastewater handling	0.30	0.28	0.28	0.28	0.27	0.28	0.27	0.26	0.25	0.25	0.24	0.24	0.24	0.24	0.24	0.23	0.23	0.23	0.23
Methane	0.15	0.14	0.14	0.15	0.14	0.15	0.14	0.14	0.14	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13	0.13
Nitrous oxide	0.14	0.14	0.13	0.13	0.13	0.13	0.12	0.12	0.12	0.11	0.11	0.11	0.11	0.11	0.11	0.10	0.10	0.10	0.10
Compost production	0.04	0.05	0.05	0.06	0.06	0.07	0.08	0.08	0.08	0.09	0.09	0.10	0.10	0.11	0.11	0.12	0.12	0.14	0.12
Methane	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06	0.07	0.06
Nitrous oxide	0.02	0.02	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.07	0.06
Total	3.97	4.01	4.03	4.02	3.97	3.91	3.82	3.72	3.55	3.48	3.27	3.14	2.92	2.75	2.61	2.41	2.46	2.38	2.20

8.2 Solid Waste Disposal on Land (CRF 6.A)

8.2.1 Source category description

The emission source includes CH₄ emissions from solid waste disposal sites from disposal of solid municipal, industrial, construction and demolition wastes, and municipal (domestic) and industrial sludges.

Table 8.2-1 Reported emissions under the subcategory Solid Waste Disposal on Land in the Finnish inventory.

CRF	Source	Emissions reported
6.A 1	Managed Waste Disposal on Land	CH ₄
6.A 2	Unmanaged Waste Disposal Sites	IE, NO
6.A 3	Other	
	Construction and Demolition Waste	CH ₄
	Industrial Solid Waste	CH ₄
	Industrial Sludge (d.m.)	CH ₄
	Municipal Sludge (d.m)	CH ₄

Emissions from solid waste disposal on land have decreased by 49% since 1990. The trend in CH₄ emissions from solid waste disposal on land is presented by subcategory in Figure 8.2-1 and Table 8.2-2.

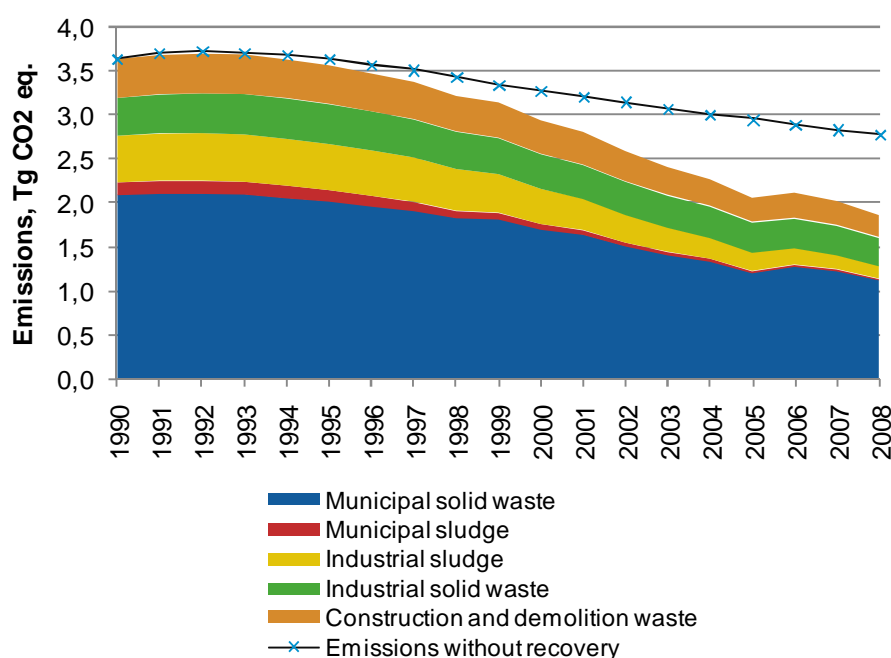


Figure 8.2-1 Methane emissions from solid waste disposal on land and in 1990-2008 (Tg CO₂ eq.).

8.2.2 Methodological issues

8.2.2.1 Methods

Emissions from solid waste disposal on land have been calculated using the First Order Decay (FOD) method, which is the IPCC Tier 2 method given in the IPCC Good Practice Guidance (GPG 2000).

IPCC Equations 5.1 and 5.2 (GPG 2000) have been used as a basis for the calculations. Equation 5.1 has been slightly modified, so that the term $MCF(t)$ (Methane correction factor in year t) has been substituted by the term $MCF(x)$ in the calculation of the methane generation potential $L_0(x)$. Calculations are not made separately for each landfill but the total waste amount and the average common MCF value for each year have been used. It has been thought that the situation in year t defines the MCF to be used for the emissions caused by waste amounts landfilled in the previous years (and degraded later in year t) as well. In Finland this is also valid for closed landfills (which have been unmanaged when used) because all the closed landfills have been covered at present. The modified equation can be seen in the Appendix_8a at the end of Chapter 8.

Table 8.2-2 Emission from solid waste disposal on land in 1990-2008 by subcategory (Tg CO₂ eq.).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Municipal solid waste	2.09	2.11	2.10	2.09	2.05	2.01	1.96	1.91	1.83	1.82	1.70	1.64	1.50	1.41	1.33	1.20	1.27	1.22	1.12
Municipal sludge	0.15	0.15	0.15	0.15	0.15	0.13	0.12	0.10	0.09	0.07	0.06	0.05	0.04	0.04	0.03	0.03	0.02	0.02	0.02
Industrial sludge	0.53	0.54	0.54	0.54	0.54	0.53	0.52	0.50	0.48	0.44	0.40	0.36	0.32	0.28	0.24	0.21	0.19	0.16	0.14
Industrial solid waste	0.43	0.44	0.45	0.45	0.45	0.45	0.44	0.43	0.42	0.41	0.39	0.38	0.37	0.36	0.36	0.35	0.34	0.33	0.32
Construction and demolition waste	0.44	0.45	0.45	0.45	0.45	0.44	0.43	0.43	0.41	0.40	0.38	0.37	0.34	0.32	0.30	0.27	0.29	0.27	0.25
Total	3.64	3.68	3.70	3.69	3.63	3.57	3.47	3.37	3.22	3.14	2.93	2.80	2.58	2.40	2.26	2.05	2.11	2.01	1.85

8.2.2.2 Emission factors and other parameters

The parameters used in the calculation are mainly IPCC default values and IPCC 2006 values. Some country-specific emission parameters (factors) are used (Table 8.2-3). The choices of the parameters are in full agreement with the information and data ranges given in the Good Practice Guidance (IPCC 2000).

Table 8.2-3 Emission factors and parameters used in calculations (country-specific (CS) expert estimations or IPCC default values (D)).

Factor/parameter	Value	Type of emission factor
DOC (Fraction of degradable organic carbon in municipal solid waste)	Between 0.172 and 0.186	D/CS Based on waste composition, varies in time series
DOCF (Fraction of DOC dissimilated)	0.5	CS
F (Fraction of methane in landfill gas)	0.5	D
OX (Oxidation factor)	0.1	CS
Methane generation rate constants; k1 = wastewater sludges, food waste k2 = wood waste, de-inking sludge k3 = paper waste, textile waste k4 = garden waste, napkins, fibre and coating sludges More detailed categories see Table 8.2-5.	k1 = 0.185 k2 = 0.03 k3 = 0.1 k4 = 0.06	D/CS IPCC 2006 Guidelines
MCF (Methane correction factor)	In 1990: 0.982 In 1991: 0.985 In 1992-1996: 0.988 In 1997-2001: 0.994 In 2002-2007: 1.0	D/CS; weighted mean value of the default values of 1 and of 0.4. Varies between the years, is 1 after 2002.

The historical development from 1948 to 1990 (until 1948 MCF is 0.4) of the methane correction factor is presented in Table 8.2-4. Between the years presented in the table MCF is linearly growing. The weighted mean values of the MCF presented in Table 8.2-4 are obtained respectively (e.g. the share of the waste amount under degradation is 0.99 from managed landfills and 0.01 from unmanaged shallows resulting to the weighted value of 0.994 in 1997-2001).

Table 8.2-4 The historical development of MCF.

	1948	1970	1983	1986	1990
Weighted MCF	0.4	0.796	0.952	0.97	0.982
Share of managed (MCF=1) SWDS	0	0.66	0.92	0.95	0.97

The use of other values than the IPCC default values is justified by international and national research. The IPCC default values generally overestimate the emissions and therefore a lower DOC_F value (0.5), based on the outcomes of several expert meetings, have been chosen. This value is also consistent with the fact that the conditions at most Finnish landfills are not optimal for methane generation. For instance, many of the landfills are shallow and the mean temperature has been found to be between 10-15°C (Väisänen 1997). OX is chosen to be 10% of the CH_4 generated at landfills based on international research (e.g. Oonk & Boom 1995).

DOC fractions of different types of waste are based on the IPCC 2006 default values and national research data (Isännäinen 1994) and measurements made in industry (revised DOC value for de-inking sludges) (Huttunen 2008). For MSW IPCC 2006 default values of DOC fractions (wood 0.43, paper 0.4, napkins and textiles 0.24, food 0.15 and garden 0.2) are used and, in addition, the waste subgroup Other organic has the DOC fraction of 0.1. The waste composition of MSW is presented in Table 8.2-6. The waste compositions and DOC values of construction and demolition waste (mixed) are based on research by VTT Technical Research Centre of Finland (Perälä & Nippala 1998, Perälä 2001).

Table 8.2-5 The waste groups and the waste subgroups and the corresponding *DOC* and *k* values.

Waste group and subgroups	<i>DOC</i>	<i>k</i>	Reference
Solid municipal waste			
Textiles	0.24	0.06	IPCC 2006
Food	0.15	0.185	IPCC 2006
Paper	0.4	0.06	IPCC 2006
Wood	0.43	0.03	IPCC 2006
Garden	0.2	0.1	IPCC 2006
Napkins	0.24	0.1	IPCC 2006
Mixed packaging	0.1	0.06	IPCC 2006
Other organic	0.1	0.1	Expert knowledge
Municipal sludge (from dry matter)			
Handling plants	0.5	0.185	Expert knowledge
Septic tanks	0.5	0.185	Expert knowledge
Sand separation	0.1	0.185	Expert knowledge
Industrial sludge (from dry matter)			
Pulp and paper (mainly wastewater sludges)	0.45	0.185	Isännäinen
Other industry (mainly wastewater sludges)	0.45	0.185	Expert knowledge
De-inking (pulp industry)	0.1	0.03	Huttunen
Fibre and coating (paper industry)	0.1	0.1	Expert knowledge
Solid industrial waste			
Textile	0.24	0.06	IPCC 2006
Food	0.15	0.185	IPCC 2006
Paper	0.4	0.06	IPCC 2006
Wood	0.43	0.03	IPCC 2006
Garden	0.2	0.1	IPCC 2006
De-inking reject	0.1	0.06	Expert knowledge
Oil	0.1	0.1	Expert knowledge
Green liquor sludge (from dry matter)	0.02	0.03	Expert knowledge
Mixed packaging and other organic (slowly)	0.1	0.06	Expert knowledge
Other organic (moderately degrading)	0.1	0.1	Expert knowledge
Construction and demolition waste			
Plastics	0		IPCC 2006
Other inert	0		IPCC 2006
Asphalt and tar	0.02	0.06	
Wood	0.43	0.03	IPCC 2006
Mixed (years 1997-1999)	0.0996	0.03	Perälä & Nippala
Mixed (years 2000-2007)	0.1384	0.03	Perälä
Total (years 1990-1996)	0.096-0.106	0.03	Calculated
Paper (packaging)	0.24	0.06	IPCC 2006
Textile (packaging)	0.43	0.06	IPCC 2006
Other (packaging)	0.1	0.06	
Industrial and municipal inert waste			
Plastics	0		IPCC 2006
Other combustible	0		IPCC 2006
Other non-combustible	0		IPCC 2006
Ash	0		IPCC 2006
Other sludges (mainly from inorganic processes)	0		IPCC 2006
Other inert waste			
Mine	0		IPCC 2006
Soil	0		IPCC 2006

The waste composition of solid municipal waste is calculated according to the estimated composition of generated municipal waste and separately collected waste fractions (top-down approach). Especially from paper and paperboard there is wide information on domestic consumption and recycling. However, 2006-2008 data is considered less reliable, yet, and recalculation might be needed in the forthcoming submissions.

Together with the work done for waste composition the landfilled waste amounts was re-estimated. Both in generated and in landfilled waste amounts there was found double counting for MSW with industrial waste in the base year and this amount of MSW are now smaller than in the previous submissions.

Table 8.2-6 The estimated waste composition of solid municipal waste.

Waste type	Composition of mixed MSW (%)						
	1990-1993	1994-1996	1997-1999	2000-2002	2003-2005	2006-2007	2008
Paper and paperboard	14.9	18.3	21.3	16.5	18.5	22.7	20.8
Food	38.5	39.2	37.9	39.8	37.5	36.2	35.1
Garden	9.1	8.6	7.6	8.2	7.8	7.4	8.8
Plastics (inert)	5.9	6.2	6.5	6.4	7.1	7.3	7.9
Glass (inert)	1.6	1.2	1.1	1.2	1.5	0.8	0.5
Textiles	2.0	1.8	1.5	1.7	1.7	1.6	1.7
Napkins	2.5	3.1	3.3	3.5	3.8	3.6	2.9
Wood	6.1	3.7	3.0	3.4	3.2	2.6	2.2
Other – inert	15.8	14.6	14.4	15.6	16.0	15.0	16.8
Other – organic	3.6	3.4	3.4	3.7	2.9	2.8	3.3

Table 8.2-7 DOC-values of municipal solid waste.

	Period													
	1990-1993	1994-1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Mixed MSW	0.176	0.180	0.185	0.185	0.185	0.173	0.173	0.173	0.176	0.176	0.176	0.186	0.186	0.177
Total MSW	0.176	0.180	0.184	0.184	0.184	0.172	0.173	0.172	0.175	0.174	0.175	0.185	0.186	0.177

8.2.2.3 Activity data

The activity data used in the calculation are taken from the VAHTI system (see Chapter 1.4 and Annex 2). It includes information on all landfills in Finland excluding Åland which is estimated according to the population. The VAHTI contains data on the total amounts of waste taken to landfills from 1997 onwards. In the VAHTI the waste amounts are registered according to the EWC (European Waste Catalogue) classification (both EWC 1997 and EWC 2002). Sampling routines have been developed to convert the classification of the VAHTI system to the classification used in the emission estimations. Corresponding data (but with volume units and the waste classification is less detailed) for the years 1992-1996 were collected to the Landfill Registry of the Finnish Environment Institute. The activity data for municipal waste for the year 1990 are based on the estimates of the Advisory Board for Waste Management (1992) for municipal solid waste generation and treatment in Finland in 1989 with the correction of double counting in paper waste. The disposal data (amount and composition) at the beginning of the 1990's for industrial, construction and demolition waste are based on surveys and research by Statistics Finland (Isaksson 1993; Puolamaa et al. 1995), VTT Technical Research Centre of Finland (Perälä & Nippala 1998; Pipatti et al. 1996) and the National Board of Waters and the Environment (Karhu 1993). For base year activity data Isaksson (1993) and Pipatti et al. (1996) are used for construction and demolition waste, Karhu (1993) is used for industrial sludges and Puolamaa et al. (1995) is used for solid industrial waste.

The amount of landfilled waste in 1990-2008 is presented in Table 8.2-8.

The corresponding DOC tonnes are given in Table 8.2-9. 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. 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 Figure 8.2-2.

Data on landfill gas recovery are obtained from the Finnish Biogas Plant Register (Kuittinen & Huttunen 2009) and presented in Table 8.2-10 and in Appendix_8b (volume of collected gas by plant/site). The great increase in the amounts of recovered methane at the beginning of 2000 comes from the regulations of landfill gas recovery (Council of State Decree 861/1997 on Landfills). A list of landfill gas recovery plants is attached in Appendix_8b.

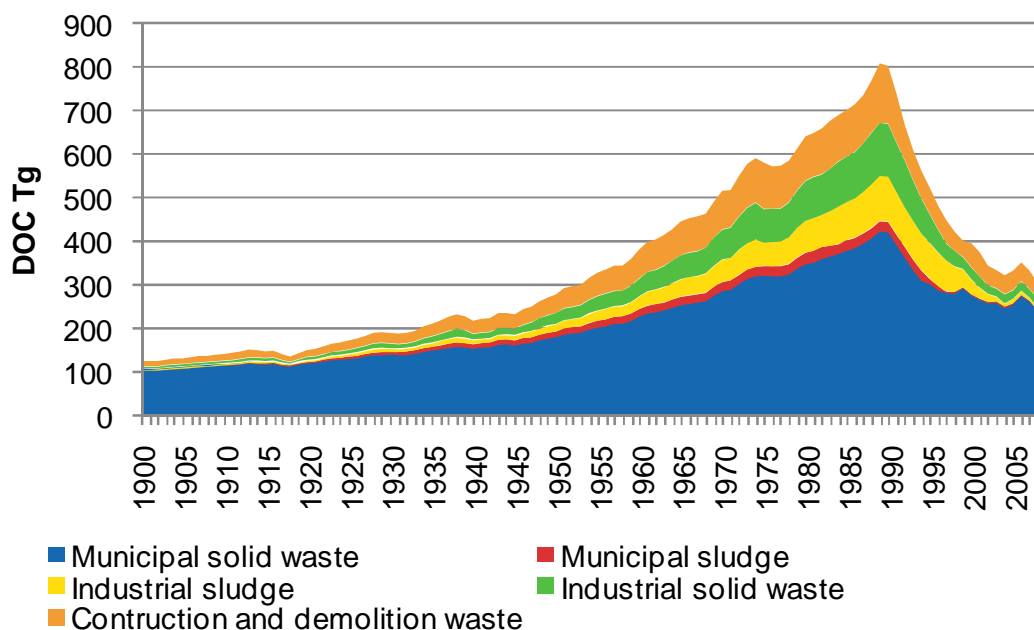


Figure 8.2-2 The DOC Tg of the five waste groups starting from the year 1900.

Table 8.2-8 Landfilled waste in 1990-2008 (1 000 t). (VAHTI system, Landfill Registry of the Finnish Environment Institute, Advisory Board for Waste Management 1992, Vahvelainen & Isaksson 1992, Isaksson 1993, Pipatti et al. 1996, Puolamaa et al. 1995, Perälä & Nippala 1998, Karhu 1993. Directly or indirectly interpolated values are presented in italics).

Waste group	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Municipal solid waste	2 400	2 230	2 070	1 909	1 725	1 682	1 599	1 535	1 528	1 586	1 602	1 542	1 507	1 488	1 423	1 462	1 485	1 411	1 358
Municipal sludge (d.m.)	47	48	48	47	46	25	21	7	6	5	6	8	6	6	6	6	5	4	4
Municipal sludge (wet m.)	498	504	510	505	501	298	212	84	71	67	70	79	66	63	58	53	51	39	27
Industrial sludge (d.m.)	337	318	299	285	268	260	248	229	182	140	118	97	65	42	29	48	44	32	15
Industrial sludge (wet m.)	1 193	1 129	1 065	999	935	881	790	695	606	559	550	329	209	198	127	161	144	119	49
Industrial solid waste	2 135	2 107	2 079	1 892	1 706	1 519	1 332	1 146	1 345	2 316	2 390	2 659	2 562	3 041	4 781	4 682	5 142	2 996	3 435
Constr. and demol. waste	1 262	1 110	781	667	639	637	567	540	438	415	454	457	377	401	373	390	353	336	331

Table 8.2-9 Landfilled waste in 1990-2008 (1 000 DOC t).

Waste group	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Municipal solid waste	422	392	364	336	311	303	288	282	282	292	276	266	259	260	248	255	275	262	240
Municipal sludge	24	24	24	24	23	12	10	3	3	3	3	4	3	3	3	3	3	2	2
Industrial sludge	103	97	91	87	84	81	76	70	57	41	33	24	18	10	5	9	10	6	5
Industrial solid waste	121	115	108	94	80	66	52	38	35	27	27	25	19	18	21	19	20	19	19
Constr. and demol. waste	134	113	81	69	64	61	55	54	44	38	56	56	44	42	43	44	43	42	37

Table 8.2-10 Landfill CH₄ recovery in 1990-2008 (Gg) and the number of operating CH₄ recovery plants (Kuittinen & Huttunen 2009).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Recovery (Gg)	0	0.54	1.10	0.75	1.96	2.84	4.30	6.34	10.16	9.58	16.24	18.83	26.93	31.83	34.76	42.51	36.64	38.73	43.82
Number	0	1	1	2	3	4	6	8	9	10	12	13	26	27	29	33	33	33	33

8.2.3 *Uncertainty and time series' consistency*

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

The uncertainty in solid waste disposal is assessed by replacing the parameters of the FOD model with probability density functions describing the uncertainty. As a result of simulation, uncertainty in the emission estimate of CH₄ from landfills contained an uncertainty of around $\pm 40\%$ in 2007. The correlation between uncertainties in emissions in 1990 and 2007 was 0.9 according to simulations. This correlation was also included in the KASPER model (model for the estimation of total uncertainty in the inventory).

In Finland, the historical waste amount is assessed starting from the year 1900. The uncertainties in historical activity data (estimated on the basis of different weighting of the population and GDP that are assumed to be good indicators of the amount of waste) are large but the amount of waste produced at the beginning of the 1900's was fairly small, thus reducing the significance of large uncertainties. The uncertainty estimates of the current amounts of waste are based on differences between different statistics and complemented with expert judgement.

In the case of municipal sludge, the uncertainties in both historical and current activity data are quite large. On the other hand, the amount of industrial waste can be fairly accurately estimated based on industrial production, and therefore these uncertainties are the smallest in historical years.

Parameters of the FOD model contain higher uncertainties than activity data. Uncertainties are mainly due to lack of knowledge of the waste degradation process. It is also unclear if the parameters of the model are suitable for Finnish conditions. The uncertainties in other calculation parameters of the FOD model are estimated using measurement data, IPCC default uncertainties and expert judgement.

In Finland, the amount of landfill gas recovered is obtained from the Finnish Biogas Plant Register, and this figure is considered accurate. An interesting note is that methane recovery describes the reduction of emissions compared with the situation where gas is emitted. In this case, the emission reduction is accurately known, though total emissions contain higher uncertainties.

The uncertainty in the fraction of methane in landfill gas is based on knowledge of a possible theoretical amount of methane in landfill gas. Uncertainty based on this estimate ($\pm 20\%$) is also very close to the variation of methane content in landfill gas obtained according to measurements done in different landfill sites in Finland. It is, however, estimated that uncertainties in measurements may be fairly large.

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).

8.2.4 *Source-specific QA/QC and verification*

General (Tier 1) Quality Control (QC) procedures applied in category CRF 6.A.

- Documentation on activity data and emission factors was cross-checked with the corresponding data on MS Access tables and calculation models.
- A sample of input data from each source category was cross-checked for transcription errors.
- Part of emission estimations (methane generation potential) was reproduced.
- Units and conversion factors were checked
- Database data relationships and data fields were checked. Database and data processing steps were documented.
- Consistency of DOC values in different groups (source categories) was checked.

- Data aggregation and transcription from lower reporting levels to higher levels were checked.

Tier 2 QC for activity data

The MSW generation rate and the MSW disposal rate of the inventory were compared with the corresponding default values of the Revised 1996 IPCC Guidelines. 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 cross-checked with the data of previous years. The errors and faults discovered were corrected and documented. The most significant of them were checked either from the Regional Environment Centres or from the companies that manage the landfills in question.

The corrected activity data (from the Vahti database) of the landfilled municipal solid waste used in EU submission for the year 2008 has been delivered to Statistics Finland which compares this data with their own observations on the same initial data. The results from this QA procedure will be completed before the inventory is submitted to UNFCCC. The activity data of the landfilled municipal solid waste has been at the same level as the waste statistics delivered to Eurostat by Statistics Finland. However, the preliminary data of the year 2008 by Statistics Finland differs accustomed more (approximately 3.5%) from the activity data of the inventory. The measurements of the landfill gas recovery of the largest solid waste disposal site in Finland has been studied more accurately (a visit on site) in 2009. 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.

The common principles of QA/QC of the inventory as well as the archiving guidelines of the waste sector are presented in Chapter 1.6.

Tier 2 QC for emission factors

Country-specific emission factors were cross-checked 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 Good Practice Guidance (without the modification explained in Section 8.2.2).

8.2.5 Source-specific recalculations

An error in transferring data (dry matter of paper waste in industrial solid waste) from data base calculations to the emission model has been corrected for the years 1997-2007 (affecting to the interpolated values of 1993-1996, also).

The dry matter DOC content of de-inking sludge has been revised to 0.1 for the whole time. Apparently, the previous value of 0.3 has contained of fossil carbon, also.

8.2.6 Source-specific planned improvements

The composition of MSW will be re-evaluated in the next submission. Specially, in the years 2006-2008 there are unreliable data on the domestic consumption of paper and board.

The need for new composition data for mixed construction and demolition waste is under consideration.

8.3 Wastewater Handling (CRF 6.B)

8.3.1 Source category description

The emission sources cover municipal (domestic) and industrial wastewater handling plants and uncollected domestic wastewaters for CH₄ emissions. N₂O emissions are generated from nitrogen input of fish farming as well as from domestic and industrial wastewaters into waterways.

Table 8.3-1 Reported emissions under the subcategory Wastewater Handling in the Finnish inventory.

CRF	Source	Emissions reported
6.B 1	Industrial Wastewater	CH ₄ (N ₂ O not estimated)
6.B 2	Domestic and Commercial Wastewater	CH ₄ , N ₂ O
6.B 3	Other	
	N Input from Industrial Wastewater	N ₂ O
	N Input from Fish Farming	N ₂ O

Emissions from wastewater handling have been decreased by 23% since 1990. Emission trends by sources are presented in Figure 8.3-1. The overall trend in domestic wastewaters (the most significant source) is degreasing due to downward trend of population in uncollected wastewaters (methane) and due to nitrogen purification in collected wastewaters.

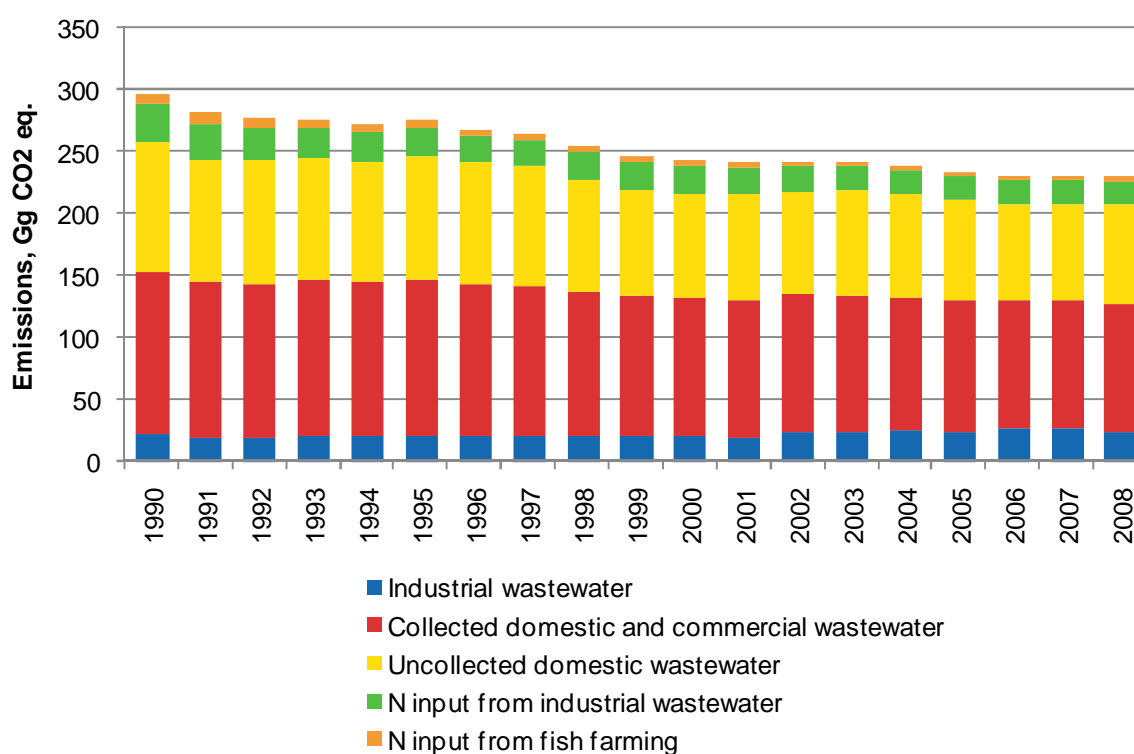


Figure 8.3-1 Emissions from wastewater handling by emission source in 1990-2008 (Gg CO₂ eq.).

Emission trends from wastewater handling by subcategory and gas are presented in Table 8.3-2.

8.3.2 Methodological issues

Methods

A national methodology that corresponds to the methodology given in the Revised (1996) Guidelines is used in the estimation of the CH₄ emissions. The emissions from municipal wastewater treatment are based on the

BOD₇ load (Biochemical Oxygen demand, 7-day test) of the wastewaters. The BOD₇ measurements are converted to the BOD₅ load (5-day test) by dividing them with factor 1.17 (Finnish Water and Waste Water Works Association 1995). The emissions from industrial wastewater treatment are based on the COD load (Chemical Oxygen demand). These DC (Degradable Organic Component) values of wastewaters with shared methane conversion factors have been used for both wastewater and sludge handling. The emissions from sludge disposal on land are, however, estimated and reported in the Solid waste disposal on land (landfills) subsector.

The equations used for calculating CH₄ emissions from domestic (not including uncollected domestic wastewater) and industrial wastewater treatment are described in the Appendix_8a.

The parameters are based on expert opinions (Jouttijärvi et. al. 1999). The IPCC Guidelines have only two default values for the methane conversion completely aerobic or anaerobic. The DC values of wastewaters with shared methane conversion factors have been used for both wastewater and sludge handling. The estimated methane conversion factors for collected wastewater handling systems (industrial and domestic) are low in Finland because the handling systems included in the inventory are either aerobic or anaerobic with complete methane recovery. In recent years there have been only 2-4 industrial plants using anaerobic waste water treatment. All the municipal waste water 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 waste water treatment plants). For uncollected domestic wastewaters the Check method with the default parameters (IPCC Good Practice Guidance) has been used. Septic tanks used in Finland are quite small (about 3 m³) having short delay times (Santala 2008), thus the emissions estimated according to IPCC 2006 Guidelines would be on the same level as the estimations according to the Check method. There are no plant-specific measurements for the degradable organic component of sludge in Finland. Especially for domestic wastewater there are good measurement results for DC of wastewaters in Finland.

In Finland, the N input from fish farming and from municipal and industrial wastewaters into the waterways is collected into the VAHTI system. For municipal wastewaters the measured values have been considered more reliable than the N input according to population data. In addition to the IPCC approach, the nitrogen load from industry and fish farming was also taken into account.

The Revised (1996) Guidelines present a methodology to calculate the N₂O emissions from sewage in the Agriculture sector. The IPCC methodology is very rough and the N input into waterways is based on population data. In Finland, the N input from fish farming and from municipal and industrial wastewaters into the waterways is collected into the VAHTI system and these values are based on concentration measurements. For uncollected wastewaters the nitrogen load is based on population data and protein consumption (FAO 2004 and Tike 2009).

The assessed N₂O emissions cover only the emissions caused by the nitrogen load to waterways. In addition to the emissions caused by the nitrogen load of domestic and industrial wastewaters, the emissions caused by the nitrogen load of fish farming have also been estimated.

N₂O emission estimations are consistent with the IPCC method for discharge of sewage nitrogen to waterways:

$$\text{Emissions (Gg N}_2\text{O)} = \text{Nitrogen load into waterways (kg)} * EF_{N_2O \text{ sewage}} * 10^{-6} * 44/28$$

Where

$$EF_{N_2O \text{ sewage}} = \text{Emission factor (kg N}_2\text{O-N/kg N load), IPCC default} = 0.01$$

Table 8.3-2 Emissions from wastewater handling in 1990-2008 by subcategory (Tg CO₂ eq.).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Methane emissions (Total)	0.154	0.145	0.144	0.147	0.144	0.147	0.143	0.141	0.138	0.134	0.132	0.130	0.135	0.134	0.132	0.131	0.130	0.130	0.127
Collected dom. & com. wastewater	0.014	0.013	0.012	0.012	0.012	0.013	0.012	0.013	0.013	0.013	0.013	0.013	0.014	0.014	0.014	0.015	0.014	0.015	0.015
Uncollected domestic wastewater	0.118	0.112	0.113	0.115	0.111	0.113	0.110	0.109	0.105	0.100	0.098	0.097	0.096	0.096	0.093	0.092	0.089	0.088	0.088
Industrial wastewater	0.022	0.020	0.019	0.020	0.021	0.021	0.021	0.020	0.020	0.020	0.021	0.020	0.024	0.024	0.025	0.024	0.027	0.027	0.024
Nitrous oxide emissions (Total)	0.144	0.137	0.134	0.128	0.128	0.129	0.125	0.123	0.117	0.112	0.112	0.112	0.107	0.108	0.106	0.103	0.101	0.100	0.103
Collected dom. & com. wastewater	0.075	0.071	0.070	0.070	0.071	0.071	0.070	0.069	0.062	0.060	0.060	0.061	0.058	0.061	0.059	0.056	0.054	0.053	0.056
Uncollected domestic wastewater	0.030	0.028	0.029	0.027	0.027	0.028	0.028	0.028	0.028	0.026	0.025	0.026	0.025	0.025	0.025	0.025	0.024	0.024	0.025
N input from industrial wastewater	0.030	0.029	0.027	0.025	0.024	0.023	0.021	0.021	0.022	0.022	0.022	0.021	0.020	0.019	0.019	0.019	0.020	0.020	0.019
N input from fish farming	0.008	0.009	0.008	0.007	0.006	0.006	0.006	0.005	0.005	0.005	0.005	0.005	0.004	0.003	0.004	0.003	0.003	0.003	0.003
Total wastewater	0.297	0.282	0.278	0.276	0.272	0.276	0.268	0.264	0.255	0.246	0.244	0.242	0.242	0.242	0.238	0.234	0.231	0.231	0.230

Emission factors and other parameters

Emission factors for municipal (domestic) wastewaters are IPCC default factors for the maximum methane producing capacity $B_o = 0.625 (= 2.5 * 0.25)$ kg CH₄/kg BOD and country-specific, based on expert knowledge, for the methane conversion factor $MCF = 0.01$.

For the industrial wastewaters the emission factor is the IPCC default for the maximum methane producing capacity $B_o = 0.25$ kg CH₄/kg COD and a country-specific emission factor based on expert knowledge for the methane conversion factor $MCF = 0.005$.

In the Check method and in the N₂O calculation the emissions factors are the IPCC default factors.

Activity data

Activity data are based on

- municipal (domestic and commercial) wastewater: Population (Check method); the BOD (BOD₇) values and N input values of wastewaters from the VAHTI system (1998-2008) and from the Water and Sewage Works Register (1990-1997).
- industrial wastewater: the COD values of wastewaters from the VAHTI system and from the Register for Industrial Water Pollution Control (1990-1995, published in reports by Repo and Hämäläinen (1996), Repo et al. (1999) and Hämäläinen (2007). Incoming COD loads are calculated from the measured out coming COD values (VAHTI system) using partly estimated efficiencies of wastewater treatment plants and partly the efficiency values from the VAHTI system.

Both built-in queries in the VAHTI operating system and own sampling routines from the VAHTI system have been used for activity data. The results from these queries have been compared with each other and with the results from the above-mentioned Registers.

Nitrogen load from fish farming has been taken from the mimeograph series of the Finnish Environment Institute (Repo & Hämäläinen 1996 and Repo et. al. 1999) and from the summary calculations by M.-L. Hämäläinen from the Finnish Environment Institute (Hämäläinen 2009).

The collected BOD and COD values and Nitrogen input values are presented in Table 8.3-3 and Table 8.3-4, respectively. The population having uncollected domestic wastewater handling system and the protein consumption per person are presented in Table 8.3-5.

Table 8.3-3 BOD₅ and COD loads in 1990-2008 (1 000 t).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Collected BOD ₇ load (municipal wastewater)	121	118	107	109	110	113	110	112	112	118	118	118	125	127	125	130	123	132	125
Collected BOD ₅ load (municipal wastewater)	103	101	92	93	94	97	94	96	96	101	101	101	108	109	107	112	106	113	108
Uncollected BOD ₅ load (domestic wastewater)	23	22	22	23	22	22	22	22	21	20	19	19	19	19	18	18	18	18	17
COD load (industrial wastewater)	847	749	736	769	814	810	784	770	778	779	791	755	932	904	962	900	1 025	1 026	915

Table 8.3-4 N input from wastewater in 1990-2008 (1 000 t).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
N input from collected municipal wastewater	15.4	14.6	14.4	14.3	14.6	14.6	14.4	14.0	12.6	12.3	12.2	12.4	11.9	12.4	12.0	11.4	11.1	10.7	11.4
N input from uncollected domestic wastewater	6.2	5.8	5.9	5.6	5.5	5.8	5.7	5.8	5.7	5.3	5.2	5.2	5.1	5.2	5.2	5.1	5.0	5.0	5.1
N input from industrial wastewater	6.2	6.0	5.5	5.0	4.9	4.8	4.3	4.4	4.6	4.4	4.5	4.3	4.1	4.0	3.9	4.0	4.0	4.1	4.0
N input from fish farming	1.7	1.8	1.6	1.4	1.2	1.2	1.2	1.1	1.0	0.9	1.0	1.0	0.7	0.6	0.7	0.7	0.7	0.7	0.7

Table 8.3-5 Population (1000 persons) having uncollected wastewater handling system and protein consumption (g/persons/a).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Population (1000 persons)	1 067	1 013	1 023	1 041	1 003	1 024	999	983	950	907	884	877	871	866	840	835	807	801	797
Protein consumption (g/persons/a)	100.3	98.2	98.7	91.7	94.5	97.4	98.4	100.7	102.5	100.9	100.4	102.3	101.0	103.4	105.0	104.5	105.1	107.5	108.5

8.3.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

For the purposes of uncertainty estimation, emissions from wastewater management are divided into the following subgroups: Industrial Wastewater (CH₄ and N₂O separately), Domestic and Commercial Wastewater from densely populated areas (CH₄ and N₂O separately), Domestic and Commercial Wastewater from sparsely populated areas (CH₄ and N₂O separately) and N input from Fish Farming (N₂O). The uncertainty in wastewater treatment was -50% to +140% in the 2008 inventory.

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. To decrease uncertainty further, more measurement data would be needed.

For the uncertainty estimate, CH₄ emissions from domestic wastewaters are divided into two subcategories, i.e. densely and sparsely populated areas, because these two subcategories are calculated using different methods. For densely populated areas, activity data (BOD) are fairly accurately known (-5% to +10%) due to the accurate measurement data of both incoming and outgoing wastewater flows from waste treatment plants. For B₀ the IPCC default uncertainty ($\pm 30\%$) is used and the uncertainty estimate for MCF is based on expert judgement (-50% to +100%).

For sparsely populated areas, the IPCC check method is used in inventory calculations. The uncertainty in the activity data estimate ($\pm 15\%$) is larger than in densely populated areas, because the estimate is based on the population rather than on the measured BOD. The emission factor uncertainty, however, is estimated fairly low in the Check method used for sparsely populated areas (-30% to +20%) and the uncertainty distribution is negatively skewed, because the emission factor of the Check method is likely to overestimate emissions.

Uncertainty in this sector is dominated by the uncertainty in the N₂O emission factor (-90% to +380%). The methane conversion factor (MCF) is the second most important factor in terms of uncertainty.

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

8.3.4 Source-specific QA/QC and verification

General descriptions of QA/QC and verification procedures are presented in Chapter 1.6.

General (Tier 1) Quality Control (QC) procedures applied in category CRF 6.B.

- Documentation on activity data and emission factors was cross-checked with the corresponding data in the calculation model.
- A sample of input data from each source category was cross-checked for transcription errors.
- Units and conversion factors were checked
- Consistency of EF values of N₂O and DOC values in different source categories was checked.
- Data aggregation and transcription from lower reporting levels to higher levels were checked.

8.3.5 Source-specific recalculations

Recalculations have been made for nitrous oxide emissions in uncollected domestic wastewater handling (2003 and 2005-2007) for more accurate activity data due to preliminary and corrected information on protein consumption.

The indicative value of population in rural areas has been revised for more accurate calculation of uncollected wastewaters (methane and nitrous oxide). Some specifications in this revision are needed in the next submission yet.

8.3.6 Source-specific planned improvements

The activity data in the VAHTI system are being checked (load versus concentration values), which may cause recalculations in the future. The population under wastewater treatment plants according to Vahti database will be used in the calculation of population under uncollected wastewaters when the shortcomings of this information source are solved.

8.4 Waste Incineration (CRF 6.C)

Emissions of greenhouse gases CO₂, N₂O and CH₄ from Waste Incineration (CRF 6.C) are reported in the energy sector (CRF 1.A) in the Finnish inventory. There is no waste incineration on landfills in Finland and waste incineration for energy production is included in the energy sector. Waste incineration without energy recovery is nearly zero in combustion plants and it is also included in the energy sector. Waste incineration in households is quite small. In annual reporting of the recycling of wastepaper (according to the decision of the Council of State 883/1998) the incineration of wastepaper is estimated to be only 23,000 tons. The incineration of paper and paperboard in households is estimated to be 31,000 tons together.

8.5 Composting (CRF 6.D)

8.5.1 Source category description

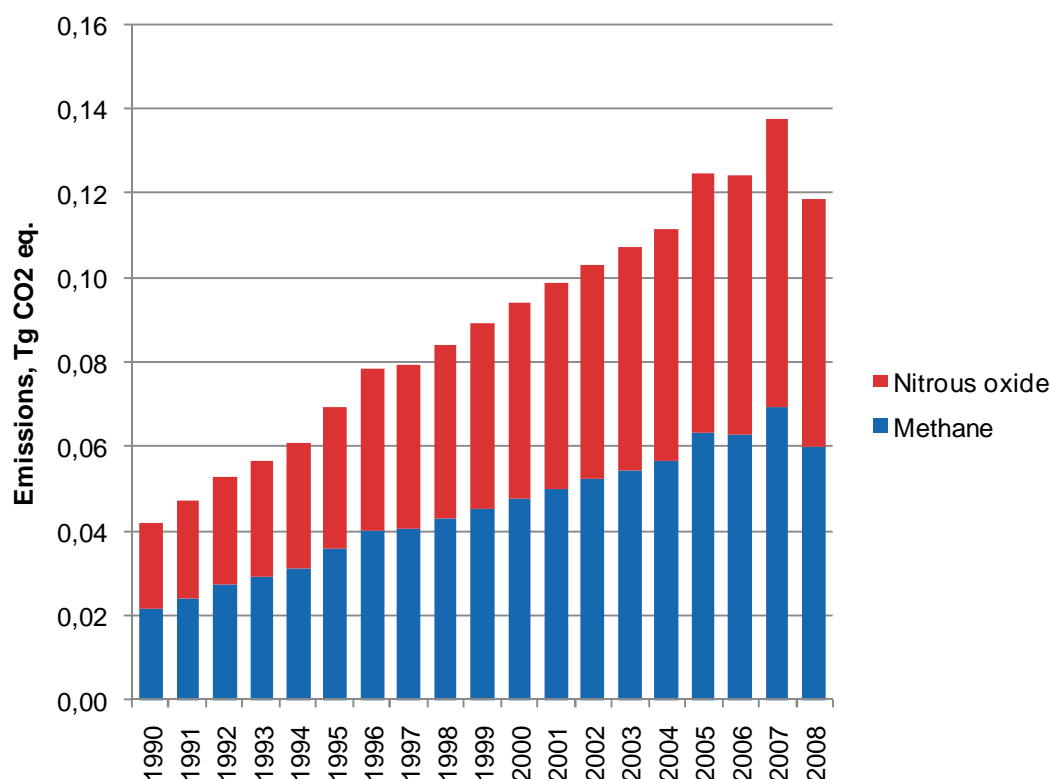


Figure 8.5-1 Greenhouse gas emissions from composting in 1990-2008 (Gg CO₂ eq.).

Emissions of greenhouse gases N₂O and CH₄ from composting are estimated. The emission source includes emissions from composting of biowastes (municipal solid waste, municipal and industrial sludges and industrial solid waste including construction and demolition waste).

Table 8.5-1 Reported emissions under the subcategory Composting in the Finnish inventory.

CRF	Source	Emissions reported
6.D 1	Composting of biowastes	
	Municipal solid waste	CH ₄ , N ₂ O
	Municipal sludge	CH ₄ , N ₂ O
	Industrial sludge	CH ₄ , N ₂ O
	Industrial solid waste, constr. waste	CH ₄ , N ₂ O

Emissions from composting have been increased over doubly since 1990, being 5% of the Waste sector's emissions in 2008. The trend in emissions is presented by subcategory in Table 8.5-3 and in Figure 8.5-1. The waste amounts with auxiliary matter (20%-30%) in composting are presented in Table 8.5-4, correspondingly. The emission fluctuations in recent years may originate from errors in activity data (new composting code in Vahti registry) and this matter will be checked in the next submission.

8.5.2 Methodological issues

Methods

Emissions from composting have been calculated using the method given in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006).

$$\text{Emissions (Gg CH}_4 \text{ or Gg N}_2\text{O)} = AD * EF / 1000000$$

where

AD = Waste amount with auxiliary matter (t)

EF = emission factor (g CH₄ or g N₂O /kg waste treated)

Emission factors

Emission factors in composting are presented in Table 8.5-2.

Table 8.5-2 Emission factors in composting (g CH₄/kg waste treated, g N₂O/kg waste treated) (IPCC, 2006).

	CH ₄ emission factor	N ₂ O emission factor
Municipal solid waste, Industrial solid waste	4	0.3
Municipal sludge, Industrial sludge (d.m.)	10	0.6

Activity data

Activity data are based on the VAHTI system and the Water and Sewage Works Register. The activity data for composted municipal biowaste for the year 1990 are based on the estimates of the Advisory Board for Waste Management (1992) for municipal solid waste generation and treatment in Finland in 1989. Data on 1997, 2004 and 2005 are from the VAHTI system and the intermediate years have been interpolated. In addition, composted solid biowaste in 1991-1996 has been interpolated using auxiliary information from the National Waste Plan until 2005 (Ministry of the Environment 1998).

8.5.3 Uncertainty and time series' consistency

Quantitative estimates of uncertainty are provided in Annex 6. The annex also documents assumptions made for the analysis. An overview is provided in section 1.7.

The VAHTI system had no treatment code solely for composting for the years 1997-2005 and the new code for composting was introduced in 2006 and the use of this code might have been slightly unreliable, still. This has meant manual work in estimating the activity data and the uncertainties ($\pm 30\%$) in activity data are somewhat higher than in the activity data on landfilled wastes.

Calculating method for composting is the same through whole time series. Time series for activity data is gathered in a consistent manner (e.g. waste groups) but the origin of the activity data varies (see previous chapter).

8.5.4 Source-specific QA/QC and verification

General (Tier 1) Quality Control (QC) procedures applied in composting.

- Documentation on activity data and emission factors was cross-checked with the corresponding data in the calculation model.
- A sample of input data from each source category was cross-checked for transcription errors.

- Units and conversion factors were checked
- Data aggregation and transcription from lower reporting levels to higher levels were checked.

8.5.5 Source-specific recalculations

No recalculation has been made since the previous submission.

8.5.6 Source-specific planned improvements

Composting data in Vahti database under the new composting code (years 2006-2008) will be checked in the next submission when there are enough consecutive years in the database to estimate the potential shortcomings in this data.

Table 8.5-3 Emissions from composting in 1990-2008 by subcategory (Tg CO₂ eq.).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Methane emissions	0.022	0.024	0.027	0.029	0.031	0.036	0.040	0.040	0.043	0.045	0.048	0.050	0.052	0.054	0.057	0.063	0.063	0.069	0.060
Municipal solid waste	0.005	0.006	0.006	0.006	0.007	0.009	0.010	0.012	0.013	0.014	0.015	0.016	0.017	0.018	0.018	0.020	0.018	0.024	0.022
Municipal sludge	0.013	0.015	0.017	0.019	0.020	0.023	0.026	0.025	0.026	0.026	0.027	0.027	0.028	0.029	0.029	0.033	0.029	0.028	0.026
Industrial sludge	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.002	0.002	0.003	0.003	0.004	0.004	0.005	0.005	0.007	0.010	0.011	0.007
Industrial solid waste, constr. waste	0.001	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.004	0.004	0.006	0.006	0.005
Nitrous oxide emissions	0.020	0.023	0.026	0.028	0.030	0.034	0.038	0.039	0.041	0.044	0.046	0.048	0.051	0.053	0.055	0.061	0.061	0.068	0.059
Municipal solid waste	0.006	0.006	0.007	0.007	0.008	0.010	0.011	0.013	0.014	0.016	0.017	0.018	0.019	0.019	0.020	0.022	0.020	0.026	0.024
Municipal sludge	0.011	0.013	0.015	0.017	0.018	0.020	0.023	0.022	0.023	0.023	0.024	0.024	0.025	0.025	0.026	0.030	0.026	0.025	0.023
Industrial sludge	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.001	0.002	0.002	0.003	0.003	0.004	0.004	0.005	0.006	0.009	0.010	0.006
Industrial solid waste, constr. waste	0.001	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.007	0.007	0.005
Total composting	0.042	0.047	0.053	0.057	0.061	0.070	0.078	0.079	0.084	0.089	0.094	0.099	0.103	0.107	0.112	0.125	0.124	0.137	0.119

Table 8.5-4 Composted waste with auxiliary matter in 1990-2008 by subcategory (1 000 t).

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Municipal solid waste	60	66	72	77	83	102	122	141	154	167	180	190	199	209	218	233	213	280	263
Municipal sludge (d.m.)	60	72	83	90	97	110	123	120	123	125	128	131	133	136	138	159	138	135	124
Industrial sludge (d.m.)	13	12	12	12	12	12	12	7	10	13	15	18	21	23	26	32	47	53	33
Industrial solid waste	12	13	14	16	17	18	19	21	24	28	31	34	38	41	45	45	75	75	57

Appendix_8a

The equations used in calculating emissions from the Waste sector (CRF 6)

Solid waste disposal on land (CRF 6.A)

The modified Equation 5.1 (IPCC 2000) is as follows:

$$\text{CH}_4 \text{ generated in year } t \text{ (Gg / year)} = \sum_x [A * k * SW(x) * L_0(x) * e^{-k(t-x)}]$$

for x = initial year to t ,

where

t = year of inventory

x = years for which input data should be added

$A = (1 - e^{-k}) / k$; normalisation factor which corrects the summation

k = Methane generation rate constant (1 / year)

$SW(x)$ = amount of waste disposed at SWDS in year x (Gg / a)

$L_0(x) = MCF(t) * DOC(x) * DOCF * F * 16 / 12$ (Gg CH₄ / Gg waste)

$L_0(x)$ is methane generation potential

where

$MCF(t)$ = Methane correction factor in year t (fraction)

$DOC(x)$ = Degradable organic carbon (DOC) in year x (Gg C / Gg waste)

$DOCF$ = Fraction of DOC dissimilated

F = Fraction by volume of CH₄ in landfill gas

16 / 12 = Conversion from C to CH₄

Emissions according to Equation 5.2 in GPG (2000) are calculated as follows:

$$\text{CH}_4 \text{ emitted in year } t \text{ (Gg / a)} = [\text{CH}_4 \text{ generated in year } t - R(t)] * (1 - OX)$$

where

$R(t)$ = Recovered CH₄ in inventory year t (Gg / a)

OX = Oxidation factor (fraction)

Wastewater handling (CRF 6.B)

Equations used in calculating CH₄ emissions from domestic (not including uncollected domestic wastewater) and industrial wastewater treatment are as follows:

$$\text{Emissions (Gg CH}_4\text{)} = \text{Organic load in wastewaters} * B_0 * MCF / 1000000$$

where

B_0 = Maximum methane producing capacity (kg CH₄ / kg BOD or kg COD)

MCF = Methane conversion factor (fraction)

CH₄ emissions from uncollected domestic wastewater are estimated according to the Check method:

$$\text{Emissions (Gg CH}_4\text{)} = P * D * SBF * EF * FTA * 365 / 1000000$$

where

P = Population with uncollected wastewaters (septic tanks)

D = Organic load kg BOD /person /day, default = 0.06 kg BOD /person /day

SBF = Fraction of BOD that readily settles, default = 0.5

EF = Emission factor (kg CH₄ / kg BOD), default = 0.6

FTA = Fraction of BOD in sludge that degrades anaerobically, default = 0.8

Appendix_8b

List of landfill gas recovery plants and volume of collected gas in 2008 (Kuittinen et al, 2008)

Name of a plant	Volume of collected gas, 1 000 m ³
Vuosaari, Helsinki	1 152
Seutula, Vantaa	1 683
Kiertokapula, Hyvinkää	1 400
Kiertokapula, Hämeenlinna	1 400
Porvoo	600
Espoo, Ämmässuo	68 257
Espoo, Mankkaa	1 173
Tampere	2 900
Oulu	7 400
Kerava	540
Lappeenranta	300
Lohja	320
Joensuu	3 284
Pori	800
Simpele	400
Lahti	3 370
Jyväskylä	3 100
Nokia	1 200
Kouvola	1 300
Iisalmi	800
Järvenpää	100
Mikkeli	720
Raisio	286
Rovaniemi	1 668
Turku	1 550
Uusikaupunki	0
Kajaani	700
Myllykoski Paper, Anjalankoski	700
Kuopio, Silmäsuu	800
Kuopio, Heinälamminrinne	1 200
Anjalankoski	600
Vaasa	600
Imatra	508

Methane content of the landfill gas is estimated to be 50% and the density of methane is estimated to be 0.718 kg/m³.

9 OTHER (CRF 7)

Finland does not report any emissions under the Other sector.

10 RECALCULATIONS AND IMPROVEMENTS

10.1 Explanations and justification for recalculations, implications on emission levels and trends including time series' consistency

The driving forces in applying recalculations to Finland's greenhouse gas inventory are the implementation of the guidance given in the IPCC Good Practice Guidance reports (IPCC 2000; IPCC 2003) and the recommendations from the UNFCCC inventory reviews. The recalculations made since the previous inventory submission are described in detail in the sector Chapters 3-9. The reasoning and impact of the recalculations for the years 1990-2007 can also be found in CRF tables 8(a)s1-8(a)s2 and 8(b) of the relevant years.

The most important recalculation in **the Energy Sector (1.A)** was the update of N₂O emissions factors used in the LIISA road transport model to follow the COPERT 4 program, as recommended by the ERT. Some minor corrections were also made in the point sources' data (activity, combustion technology or allocation) to increase consistency in plant level data (mainly in categories 1.A 1 and 1.A 2). The data in the space heating model was updated, which affected sub-categories of 1.A 4. These corrections were in some cases reflected also in category 1.A 5, which includes residuals of certain fuels. The oxidation factor of light fuel oil used in one sub-category of 1.A 5 was corrected for 1990 and 1991. In addition some preliminary fuel consumption figures for 2007 were substituted with final data. Calculation method of transferred CO₂ was developed to be more transparent.

In **Energy Sector (1.B)** estimates of carbon dioxide emissions from flaring are now calculated using data from VAHTI system and emission factors of used fuels in ILMARI calculation system.

Under **Industrial processes** (CRF 2) several corrections were done to the amounts of used limestone and sodium carbonate in Mineral products. Also the emission factor of a nitric acid plant was corrected for one year. In hydrogen production activity data of a company were corrected for year 2006. In iron and steel production the time series data of one plant were checked and revised (see more details in chapter 4.4.2.6). Some of the changes were reflected in the Energy sector 1.A 2a. In the F-gases category recalculations were made for HFC emissions from foam blowing and SF₆ emissions from electrical equipment due to modification of the calculation models.

In the **Agriculture sector** (CRF 4) the time series of most emissions were recalculated as the calculation model was harmonized with the calculation of ammonia emissions. The reason was to use up-to-date values for the most important parameters and to ensure that the same activity data is used for both GHG and ammonia emission inventories.

In the **LULUCF** sector (CRF 5) recalculations have been made in CRF 5.A, CRF 5.B, CRF 5.C, CRF 5.D, CRF 5 (II), CRF 5(V). The main reason for recalculations in all land-use categories is that each category is for the first time divided between land remaining in and land converted to the sub-category in question. This division is in accordance with GPG LULUCF 2003 and has been requested by the ERT. In the category CRF 5.A a method was changed in the tree biomass estimation. Finnish biomass equations are applied in a consistent way throughout the reporting calculations. Also a full set of NFI10 data was available for biomass and litter fall estimation that has an influence on both sinks in tree biomass and soil carbon.

In the categories CRF 5.D and CRF 5(II) new emission factors for methane emissions from peat extraction areas were applied and a corrected time series for area data was used. In the category CRF 5(V) the mean biomass estimates were based on updated estimation methods using country-specific biomass equations.

The area of croplands and grasslands was divided between the remaining and converted sub-areas as was requested in several previous reviews of the inventory. All area estimates were updated which caused changes in all time series for soil carbon. A small change in the amount of living biomass resulted from the

updating of the share of dwarfish apple trees. Also the area estimates for Settlements (CRF 5.E) and Other land categories (CRF 5.F) were recalculated.

In the **Waste sector** (CRF 6) recalculations have been made for nitrous oxide and methane emissions in uncollected domestic wastewater (CRF 6.B 2) for the years 2002-2007 to improve the accuracy of activity data (minor changes in population between rural and densely populated areas). Also, minor corrections in protein consumption have been done (CRF 6.B 2) for the years 2003 and 2005-2007 according to the latest publication (Tike 2009) for this data. In addition, recalculations have been made for methane emissions for the years 1990-2007 in solid waste disposal on land (CRF 6.A 3) due to new and more accurate information on DOC content of de-inking sludge.

Table 10.1-1 Recalculations made for the 2009 inventory submission by CRF category and their implications to the emission level in 1990 and 2007.

CRF Category	Recalculation	Reason for the recalculation	Implication to the CRF category level (Gg CO ₂ eq.)		Implication to the Total emission level without LULUCF (%)	
			in 1990	in 2007	in 1990	in 2007
1. Energy			-60.47	-445.53	-0.09	-0.57
1.A. Fuel combustion			-61.63	-441.82	-0.09	-0.56
1.Energy Industries	Corrections in plant level data (activities, combustion technology, allocation)	Correction of errors (time series consistency).	0.00	33.14	0.00	0.04
2. Manufacturing industries and construction	Corrections in plant level data (activities, combustion technology and allocation). Revision in sector 2.C is reflected in this sector. 2007: Calculation method for transferred CO ₂ was developed.	Correction of errors (time series consistency).	-61.74	36.38	-0.09	0.05
3. Transport	Updates in LIISA model (Road Transport)	Recommendation by the ERT: use of emission factors from COPERT 4.	0.09	-482.15	0.00	-0.62
4. Other sectors	Reallocation of fuels due to updated data.	Update of data in space heating model.	0.00	-58.01	0.00	-0.07
5. Other	1990: correction of oxidation factor 2007: Reallocation of fuels due to updated data. Corrections in other subcategories are partly reflected in this subcategory.	Erroneous oxidation factor in one fuel and subcategory in 1990-1991. Update of data in space heating model.	0.02	28.83	0.00	0.04
1.B. Energy - Fugitive emissions	Flaring emissions of a company have been made consistent with energy calculations.	Consistency between sectors 1.A and 1.B	1.17	-3.71	0.00	0.00
2. Industrial Processes			73.94	3.55	0.10	0.00
A. Mineral products	Limestone and dolomite use Glass production	Calculation errors were corrected. New activity data was received.	-0.02	6.39	0.00	0.01
B. Chemical industry	Nitric acid production Hydrogen production	Calculation errors were corrected.	0.00	-3.26	0.00	0.00

CRF Category	Recalculation	Reason for the recalculation	Implication to the CRF category level (Gg CO ₂ eq.)		Implication to the Total emission level without LULUCF (%)	
			in 1990	in 2007	in 1990	in 2007
C. Metal Production	Revision of time series of one plant. Correction of transcription error.	Recommendation by the ERT: 'The ERT reiterates the recommendations from the previous review that Finland continue to monitor and verify CO ₂ emissions from iron and steel production to the extent possible.' The calculations were checked and more consistent source data was chosen for one plant (from several available data sets).	73.96	0.42	0.10	0.00
F. Consumption of Halocarbons and SF ₆	HFCs from foam blowing 2000-2007 SF ₆ from electrical equipment 2003-2007	Tier 2 model was improved to better assess the changes of gas amount banked in foams and its effect on the emission level. Tier 3c model was improved, because the previously used model gave negative emission estimates.	0.00	13.58	0.00	0.02
3. Solvent and other product use			0.00	0.00	0.00	0.00
4. Agriculture			-509.77	192.40	-0.72	0.25
A. Enteric Fermentation	Whole time series: animal numbers, animal groups, cattle weight, length of pasture season updated	N mass flow model integrated	-9.91	8.71	-0.01	0.01
B. Manure Management	Whole time series: animal numbers, animal groups, awms, Nex, VS (GE) updated, new MCFs added, EFs for urine/dung/deep litter	N mass flow model integrated	-174.23	-81.47	-0.25	-0.10
D. Agricultural Soils	In addition to subjects mentioned above (4B), FraCGasm, FraCGasf, FraCGraz changed and more detailed calculation	N mass flow model integrated New info of histosol areas	-325.62	265.17	-0.46	0.34

CRF Category	Recalculation	Reason for the recalculation	Implication to the CRF category level (Gg CO ₂ eq.)		Implication to the Total emission level without LULUCF (%)	
			in 1990	in 2007	in 1990	in 2007
	of emissions from pasture and mineral fertilizers					
F. Field Burning of Agricultural Residues			0.00	0.00	0.00	0.00
5. Land use, Land Use Change and Forestry			1 787.51	-5 385.96		
A. Forest land	Activity data (area) for whole time series: C-stock changes in living biomass, litter, dead wood and soils	Recommended by ERT: forest land were divided into sub-categories remaining and converted. New national biomass models were applied. New initialisation of soil model.	1 619.00	-3 285.95		
B Cropland	Whole time series, soil and living biomass	New area data + division to remaining and converted, share of dwarfish apple trees updated	-1 631.05	2 022.09		
C. Grassland	Whole time series	New area data + division to remaining and converted	1 867.05	-4 057.10		
D. Wetlands	Area of peat extraction field in 2007 New emission factors for CH ₄	Area data were completed Latest research results of CH ₄ emissions were applied	-67.49	-74.17		
G. Harvested Wood Products	Activity data corrected 2006-2007	Updated data from UNECE database	0.00	9.16		
6. Waste			-9.21	-52.40	-0.01	-0.07
A. Solid Waste Disposal on Land	DOC-content of industrial de-inking sludge for 1990-2007	New and more accurate information on DOC-content of de-inking sludge.	-9.21	-49.32	-0.01	-0.06
B. Wastewater Handling	Activity data (population) for uncollected domestic wastewater for 2002-2007	Minor change in population data between rural and densely populated areas	0.00	-3.09	0.00	0.00
D. Composting			0.00	0	0.00	0.00

10.2 Implications for emission levels

See Section 10.1.

10.3 Implications for emission trends, including time series' consistency

See Section 10.1.

10.4 Recalculations, including in response to the review process, and planned improvements to the inventory

Statistics Finland co-ordinates the development of the inventory's different sectors. Each organisation participating in the inventory preparation bears the primary responsibility for the development of its own sector. The advisory board of the inventory handles horizontal development projects and the resources needed for development.

The development of the greenhouse gas inventory aims to improve the calculation and reporting of the inventory so that the inventory fulfils the quality objectives set for it and produces accurate estimates for the total emissions of greenhouse gases in different emission categories.

Statistics Finland collects the different horizontal development needs and those detected in different calculation sectors and the planned or proposed improvement measures, to compile a yearly inventory improvement plan. The inventory improvement plan is discussed in the advisory board set up by Statistics Finland before starting the next calculation round.

Table 10.4-1 summarises the sectoral improvement needs for the forthcoming inventories recognised by the Finnish experts responsible for the calculations and brought out in the review processes. More detailed information about planned improvements can be found under the sectoral chapters.

Table 10.4-1 Sector-specific improvement needs of Finland's national greenhouse gas inventory.

CRF category	Planned improvement	Tentative time schedule
CRF 1.A.3 (Transport)	Using emission data for aviation from Eurocontrol's sources	Starting from the 2009 submission (depending on the internal bureaucracy of EUROCONTROL)
CRF 1.A.3 (Transport)	Improving the calculation of emissions from leisure boats (continued). Adjusting the model to follow the changes due to new boat register.	2010-2011
CRF 1	A national reference calculation for CO ₂ emissions from energy combustion	2011 submission
CRF 4 (Agriculture)	CRF 4.B (Manure management) The methods to update the distribution of different manure management systems regularly will be explored.	2011
CRF 5 (LULUCF)	The methodology for estimating carbon stock changes in Cropland and Grassland will be reviewed.	2010 submission
CRF 5 (LULUCF)	Further development of methodology to identify transitions between land-use categories with NFI field data to fulfil demands of KP 3.3 reporting. With a possibility to have an additional sampling.	2010 - 2014
CRF 5 (LULUCF)	Investigation on the possibility to use NFI sample plot data with forests statistics to quantify annual drain.	2010 - 2014
CRF 5 (LULUCF)	Investigation on the possibility to use NFI sample plot data to estimate the division of drain between remaining and conversion classes.	2010 - 2014
CRF 5 (LULUCF)	Analyzing the sensitivity, uncertainty and applicability of Yasso07 soil carbon model. This is done in order to have a consistent soil carbon estimation method for whole LULUCF sector.	2010
CRF 6 (Waste)	CRF 6.A (Solid waste disposal on land) The waste composition data will be checked especially for last 3-4 years.	2011 submission
CRF 6 (Waste)	CRF 6.A (Solid waste disposal on land) The need for new composition data for mixed construction and demolition waste is under consideration.	2012-2013 submission
CRF 6 (Waste)	CRF 6.B (Wastewater Handling) The activity data in the Vahti system for wastewater handling will be checked	2011 submission
CRF 6 (Waste)	CRF 6.D (Composting) The activity data will be checked	2011 submission

CRF category	Planned improvement	Tentative time schedule
	especially for the years 2006-2008 (the effect new treatment code in Vahti registry)	

Table 10.4-2 summarises Finland's responses to the review of the initial report under the Kyoto Protocol and the 2007 inventory submission. Only issues which were not resolved during the review are addressed in the table. Some recommendations of the expert review team (ERT), like those relating to the QA/QC system, have been grouped into one comment in the table.

Table 10.4-2 Response to the review of the 2009 inventory submission (ARR 20 April 2010).

CRF	Comment	Finland's response	Where in NIR
1	However, some additional information on AD and EFs in the energy sector (see paras, 36, 37 and 39 below) would increase the transparency. The ERT encourages Finland to continue to improve transparency in its next annual submission.	Some text and tables have been added to the NIR.	3.2.2.2 and 3.2.2.4 tables 3.2-7, 3.2-8 and 3.4-2.
1	Better explain the difference between the result of using the reference and sectoral approaches.	Some text and tables have been added to the NIR; the subject would require a lot of extra work to be solved completely.	3.7
1	Include an explanation of the net calorific values use for the entire time-series.	Some text has been added to the NIR. The default NCVs are in most cases constant over time. For certain fuels this will be considered in the following submissions. The matter about NCV has been described in the NIR.	3.2.2.2 and 3.2.2.4
1	Include the results of QA activities and completed QC checkings in the next annual submission.	QC checklists are too large to be included in the NIR; they also contain confidential data. Summaries of QA activities and QC checks are included in the NIR.	3.2.4
1	Transparency is generally good on methods, although information on AD and EFs is limited. A single table is provided in the energy sector on the EFs used by Finland. Previous review reports had recommended that Finland provide entire time-series data on EFs and the ERT reiterates that recommendation.	In most cases the emission factors do not depend on time, but on technology and/or fuel type. Some text has been added to explain this subject.	3.2.2.2, 3.2.4 and 3.8
	Finland provided limited information on the methodology in the NIR, and the ERT noted that the information provided is not sufficiently transparent to be fully reviewed. The ERT recommends that in the next annual submission the description should be improved and clarified by providing further information on the process and storage of CO ₂ by the process, and by providing specific information on the data used in the calculation method provided in the NIR, and on how the information provided in the NIR is reported in the CRF tables.	The information on the methodology has been described more transparent way.	3.2.7 and appendix 3c
	Finland indicated that the production data have been cross-checked with the EU ETS data for the years 2005, 2006 and 2007 and that the difference is small. The ERT appreciates the additional clarification provided by Finland. The ERT further recommends that Finland include this information as already planned by the Party, as well as additional information and as specifically detailed data as possible, in its next annual submission. Finland should also expand upon its explanation on the small differences between the production data and EU ETS data for available years.	The information on cross-checkings has been described more transparent in the NIR.	3.2.7
1.A 2	For AD, in the response to a question raised during the review, Finland explained that, owing to confidentiality, it was not able to include a table in the NIR with disaggregated fuel types (i.e., not grouped by solid, liquid, gaseous, etc.) by category. The ERT recommends that Finland investigate the possibility to include a table containing data on fuel consumption by overall categories in the energy sector. Finland noted this recommendation during the review week and stated that it will try to publish these data in the next annual submission.	Some more disaggregated fuel AD tables have been included for 1.A 1, 1.A 2, 1.A 4 and 1.A 5 subcategories showing the most important fuels for each subcategory.	Tables 3.2-7, 3.2-8 and 3.4-2.
1.A 3	The transport category, unlike the other categories, does not contain specific information on	Information on recalculations, uncertainties and QA/QC do	3.3

CRF	Comment	Finland's response	Where in NIR
	recalculations, uncertainties and QA/QC. The ERT recommends that, for transparency and consistency, such information, as provided in the rest of the energy sector, be provided for transport.	exist on pages 85, 89, 94 and 98 for each transport mode respectively. However this is not shown on contents page because they are on the fourth index level and contents page only shows down to the level three.	
1	Finland has explained the recalculation in the relevant category in the energy sector, but provided little quantitative information. The recalculation chapter shows quantitative results for the categories. The ERT encourages Finland to summarise information on energy sector recalculation in the recalculation chapter.	Summary information on recalculation has been included in the chapter 10.	10.1-1
1.B 2	Finland reported indirect CO ₂ emissions from the oxidation of fugitive CH ₄ and NMVOCs under the category other (fugitive emissions from oil natural gas and other sources) based on guidance contained in the 2006 IPCC Guidelines. The ERT noted that Finland cited studies from the Netherlands and the United States of America on the fossil carbon content fraction of NMVOCs. The ERT encourages Finland to further clarify any assumptions that are derived from these studies as used in the calculations	The carbon content fraction of NMVOCs under the sector Fugitive emissions from oil and natural gas was inaccurately referred. The default fossil carbon content fraction of NMVOCs was used according to the 2006 IPCC Guidelines for all sectors since country specific analysis is not available. The NMVOC speciation profile in the 2006 IPCC Guidelines is either based on the EMEP/CORINAIR Emission Inventory Guidebook or on limited published national analyses. The description of the carbon content selection will be improved in the forthcoming NIR.	3.6.2, 4.3.5, 5.2.2, 5.3.3
2	Finland provided good category-specific explanations of uncertainties consistently across the industrial processes sector. Uncertainty estimates were provided, although the basis for such estimates was not identified, whether expert judgement or otherwise. The ERT recommends that the Party provide the basis for the uncertainty estimates in the next annual submission.	For NMVOC calculations the basis of uncertainty estimated are available in the Finnish Informative Inventory Report (IIR) under the CLRTAP.	4.2.3.4, 4.2.4.4, 4.2.5.4, 4.2.7.4, 4.3.3.4, 4.4.2.4, and 4.3.4.4 see also FIN_key_categories_and_uncertainties.xls of the submission.
2.B 2	Finland responded to issues raised in previous reviews by providing appropriate explanations in its 2009 submission. The Party mentioned estimates of emissions from nitric acid production as an area for further improvement.	No mentioning about that emissions calculation of nitric acid production is an area of further improvement has ever been raised. On the contrary Finland has explained that there are no more information could be given do to confidentially reasons.	4.3.2.2
2.B 2	Finland explained in the NIR that the decreasing trend is due to changes in the production process and the closing down of old plants. The ERT reiterates the recommendation from the previous review that Finland provide complete trends of EFs and relevant data calculations to the extent possible in its next annual submission in order to improve transparency.	More specific data of plant level emission factors can't be described due to confidential reasons, but they had been available in the previous in-country review in May 2007.	4.3.2.2
2.C 1	However, all values of the CO ₂ IEF (0.48-0.68 t/t) are among the highest values of reporting Parties (0.005-1.73 t/t). The ERT reiterates the recommendations from the previous review that Finland continue to monitor and verify CO ₂ emissions from iron and steel production to the extent possible.	Starting from 2005, EU ETS data has been used to determine total emissions of the sector. For the previous years, all possible data sources have been used to produce comparable time series. All that has been done in the most detailed plant level data. Emissions have been verified using reference	4.4.2.3, 4.4.2.5 and 4.4.2.6

CRF	Comment	Finland's response	Where in NIR
		calculations whenever it has been possible (i.e. when necessary data have been available). The description has been improved and additional tables have been included in the NIR. Time-series data of one plant were checked and revised.	
2.F 1	Given the observed large inter-annual changes in emission estimates: 1990/1996 (ranging between .7.1 per cent and 4,090.7 per cent), 2001/2002 (.29.7 per cent) and 2005/2006 (.15.2 per cent), and the indication in the NIR that some of the major importers of refrigerants in Finland did not respond to the survey, the ERT recommends that Finland investigate further ways of collecting AD for F-gases in order to improve the accuracy and completeness of this category.	The low response activity of the 2008 survey was due to the implementation of an internet-based electronic data collection system. In the 2009 survey the response activity improved considerably and all of the major importers responded. Therefore further ways of collecting AD are not considered necessary.	Section 4.6.2.3
2.F 1	The ERT further recommends that Finland investigate the possibility of disaggregating emission data for all refrigeration and air conditioning subcategories (domestic, commercial, industrial, mobile, etc.).	Emissions are not calculated disaggregated for each equipment subcategory because it would increase the companies' reporting burden. In addition, the respondents do not generally have data to support reporting at the level of subcategories. Current data gathering produces higher response activity and less uncertain activity data.	Section 4.6.2.1
2.A 4	The ERT reiterates the recommendation from the previous review that Finland check the nature of soda ash use by industry to ascertain the lack of CO ₂ emissions from such activities.	The checkings have been done earlier, the descriptions in the NIR have been improved.	Section 4.2.5.3
2.F 7	Finland indicated during the review that this notation key was an error and that it should have been not occurring (.NO.) instead. The ERT recommends that Finland correct this error in its next annual submission.		
4	As indicated in previous S&A reports, all inter-annual changes of the N ₂ O IEF for 'Solid storage and dry lot' have been identified as outliers and range between -0.3% and 0.5%. In addition, all values of the N ₂ O IEF, except for 2001, 2002 and 2004, have been identified as outliers (0.0202-0.0203 kg N ₂ O-N/kg N). They are among the highest of reporting Parties (0.0054-0.0212 kg N ₂ O-N/kg N) and higher than the IPCC default value (0.020 kg N ₂ O-N/kg N). Finland has responded to this issue in previous S&A reports.	The IEF should be 0.020. There seems to be an error in the time series (transfer error to the Reporter) for N ₂ O emissions from solid storage. The emissions were reported slightly higher than they should be. The difference ranges between c. 0.02-0.03 Gg per year for solid storage emissions. The error will be corrected in the next inventory.	Table 6.3-6
4	The changes in emissions from synthetic fertilizers between 1990 (4.46 Gg) and 1991 (3.95 Gg); 1991 and 1992 (3.18 Gg); 1994 (3.30 Gg) and 1995 (3.82 Gg) have been identified as outliers. The 1991 value is 11.4% lower than the 1990 value; the 1992 value is 19.4% lower than the 1991 value and the 1995 value is 15.6% higher than the 1994 value.	The outliers are due to changes in the amount of nitrogen sold in synthetic fertilisers annually. The annual amounts sold between 1990-1995 are: 228.5; 202.5; 163.2; 168.2; 169.1 and 195.5 Gg N/a.	Table 6.4-4
4	All values of the N ₂ O IEF for 'Cultivation of histosols' (7.85 kg N ₂ O-N/kg N) have been identified as outliers. They are among the lowest of reporting Parties (1.98-9.22 kg N ₂ O-N/kg N) and lower than the IPCC default value (8 kg N ₂ O-N/kg N).	The value 7.85 is an average of two national emission factors based on research (4.0 and 11.7 kg N ₂ O-N/ha, NIR pp. 221 - 222).	Table 6.4-8
4	The trend in N ₂ O emissions from 'Atmospheric deposition' is unstable with the following inter-	The deposition fluctuates due to differences in the annual	Table 6.4-4

CRF	Comment	Finland's response	Where in NIR
	annual changes identified as outliers: 199/1991 (-6.7%), 1994/1995 (4.7%) and 1996/1997 (4.6%).	amount of synt. fertilisers, manure (animal numbers) and sewage sludge spread on fields.	
4	The trend in N ₂ O emissions from 'Nitrogen leaching and run-off' is in general decreasing over the time period 1990-2007. The 2007 value (1.3 Gg) is 27.3% lower than the 1990 value (1.8 Gg). The following inter-annual changes have been identified as outliers: 1990/1991 (-9.6%), 1991/1992 (-15.1%) and 1994/1995 (10.6%).	The trend fluctuates due to differences in the annual amount of synt. fertilisers, manure (animal numbers) and sewage sludge spread on fields. For example, the amount of synt. fertilisers and sewage sludge used on fields in 1990 has been larger than in 2007.	Table 6.4-4
5	Finland reports that the method to estimate converted areas is under development and will be ready for the 2010 inventory submission. The ERT notes this planned improvement of the Finnish land-use system and recommends that Finland provide in its next annual submission detailed information on land conversion, including the information needed for reporting on activities under Article 3, paragraph 3, of the Kyoto Protocol and on forest management as an elected activity under Article 3, paragraph 4.	In 2010 submission, Finland reports information on land conversions.	Chapter 7
5A	The ERT welcomes the efforts to reduce uncertainty and recommends that Finland improve time-series consistency by applying a single and consistent forest definition, especially with regard to reporting on activities under Article 3, paragraphs 3 and 4, of the Kyoto Protocol.	The forest definition is applied consistently for whole time series for LULUCF and KP-LULUCF reporting, even though different forest definition is used under UNFCCC and KP reporting.	Sections 7.1.2, 7.2.1 and 11.1.1.
5B	The change in net carbon stock change in living biomass between 2006 (0.00020 Mg C/ha) and 2007 (0.00034 Mg C/ha) has been identified as an outlier. The 2007 value is 66.0% higher than the 2006 value. In addition, the following inter-annual changes have been identified as outliers: 1990/1991 (-95.7%), 1991/1992 (1,322.4%), 1992/1993 (59.7%) and 2005/2006 (-49.7%). The 2007 value is 96.4% higher than the 1990 value (0.00017 Mg C/ha).	Between years 1994 and 2004 there has been only increase in plant area whereas in 1990 - 1993 and 2005 - 2007 there has also been clearings of fruit yards (currants and/or apple trees) with varying intensity, and therefore some loss in plant area which has caused fluctuations in the net carbon stock for these years.	Table 7.3-2
5B	As indicated in previous S&A reports, the trend in net carbon stock changes in mineral soils shows some large fluctuations. The change between 1990 (-0.031 Mg C/ha) and 2007 (0.209 Mg C/ha) has been identified as an outlier. The 2007 value is 783.1% higher than the 1990 value. In addition, the following inter-annual changes have been identified as outliers: 1990/1991 (691.0%), 1994/1995 (-140.5%), 1995/1996 (-57.3%), 1997/1998 (90.8%), 1998/1999 (494.0%), 1999/2000 (162.2%) and 2001/2002 (59.6%). Finland has responded to this issue in previous S&A reports.	Finland has responded to this issue in previous S&A reports. Since we do not know the area that has remained cropland there are different areas for the reporting year and 20 years before that. That causes remarkable fluctuation which will be corrected for the next submission.	Chapter 7.3.2.2
5C	Finland reports net removals for the years 1990-1997 and net emissions for 1998-2007. The change in net CO ₂ emissions/removals between 1990 (-2,131 Gg) and 2007 (4,239 Gg) has been identified as an outlier. The 2007 value is 290.4% higher than the 1990 value. In addition, all inter-annual changes, except for 2006/2007, have been identified as outliers and range between -424.6% and 963.8%.	Finland has not been able to divide emissions from 5.C to land remaining Grassland and land converted to Grassland categories due to lack of reliable activity data. In the Cropland and Grassland categories mineral soils have sometimes been sinks, sometimes sources during 1990 - 2007 (Table 7.1_1, Figure 7.1_1). This is due to the fact that according to the Tier 1 methodology changes in the area of cropland or grassland in 20 years affect the calculated carbon stock. If the area is	Chapter 7.4.2.2

CRF	Comment	Finland's response	Where in NIR
		smaller in the reporting year than 20 years earlier, a decrease in the carbon stock is reported. Finland will report revised emissions with new activity data in the next submission	
5C	The trend for net carbon stock change in mineral soils is generally decreasing. The change between 1990 (1.07 Mg C/ha) and 2007 (-3.15 Mg C/ha) has been identified as an outlier. The 2007 value is 393.6% lower than the 1990 value. In addition, all inter-annual changes, except for 2001/2002, 2003/2004 and 2006/2007, have been identified as outliers and range between -14,156.0% and 205.2%.	Finland has not been able to divide emissions from 5.C to land remaining Grassland and land converted to Grassland categories due to lack of reliable activity data. In the Cropland and Grassland categories mineral soils have sometimes been sinks, sometimes sources during 1990-2007 (Table 7.1_1, Figure 7.1_1). This is due to the fact that according to the Tier 1 methodology changes in the area of cropland or grassland in 20 years affect the calculated carbon stock. If the area is smaller in the reporting year than 20 years earlier, a decrease in the carbon stock is reported. Finland will report revised emissions with new activity data in the next submission	Chapter 7.4.2.2
5G	The ERT invites Finland to explain why it uses FAO rather than country-specific data and to provide basic information on the stock change data in the main part of the NIR as well as in an annex.	The data in the FAOSTAT and the UNECE databases equals to the national data.	Section 7.8.2.3
6.A	Paragraph 75 (ARR 2008). Recommendation to implement QA procedures, at least for key categories, for the future inventory submissions.	A QA procedure is implemented between Finnish Environment Institute and Statistics Finland concerning activity data of municipal solid waste. General QA procedures of the inventory are presented in Section 1.6.	Section 1.6 and Section 8.2.4
6.A	Paragraph 76 (ARR 2008). To provide more explanation on some uncertainty estimates based on expert judgment used in the tier 2 uncertainty assessment.	The Tier 2 is based on country-specific estimates on the uncertainties, not the IPCC defaults, except in cases where IPCC defaults have been used in the calculation. Details of the uncertainty estimates can be found in the reference Monni & Syri, 2003, p. 60 onwards. The reference was provided to the ERT during the review.	Reference Monni & Syri, 2003, p. 60 onwards
6.A	Paragraph 77 (ARR 2008). To improve the transparency of historical waste amount data	Improved explanations are added	Section 8.2.2.3 and Figure 8.2-2
6.A	Paragraph 78 (ARR 2008). To explain how the average MCF has been derived	Improved explanations are added	Section 8.2.2.2 and Table 8.2-4
6.A	Paragraph 79 (ARR 2008). To update information on waste composition for 1990-2006	Revised waste composition time series were implemented in the 2009 submission. The revision is based on a top-down approach.	Section 8.2.2.2, Tables 8.2-6 and Table 8.2-7
6.B	Paragraph 80 (ARR 2008). To explain the expert judgment of low MCF values	The estimated methane conversion factors for collected wastewater handling systems (industrial and domestic) are low in Finland because the handling systems included in the inventory are either aerobic or anaerobic with complete	Section 8.3.2

CRF	Comment	Finland's response	Where in NIR
		methane recovery. In recent years there have been only 2-4 industrial plants using anaerobic waste water treatment. All the municipal waste water 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 waste water treatment plants).	
6.B	Paragraph 81 (ARR 2008) and Paragraph 83 (ARR 2009). To use the IPCC method based on the maximum CH ₄ producing capacity and the weighted average MCF (for uncollected wastewaters)	Finland has used the Check method (GPG 2000) for uncollected wastewaters. The emissions estimated according to IPCC 2006 Guidelines would be on the same level because septic tanks used in Finland are quite small (about 3 cubic meters) having short delay times.	Section 8.3.2

11 KP-LULUCF

11.1 General information

Under Article 3, paragraph 3, of the Kyoto Protocol (KP), Finland reports emissions and removals from afforestation (A), reforestation (R) and deforestation, and under Article 3, paragraph 4 emissions and removals from forest management (FM). The estimates for emissions and removals under Articles 3.3 and 3.4 are prepared and reported consistent with the IPCC GPG LULUCF 2003 and Decisions 15/CMP.1 and 16/CMP.1 of the KP.

There are no emissions reported under Articles 3.3 and 3.4 that would overlap with those reported under KP Annex A. Agricultural non-CO₂ emissions are reported under the agriculture sector, with the exception of N₂O emissions from disturbance associated with land conversions from forest to cropland which are reported under D. N₂O emissions from N fertilisation of forest soils are included under FM. These emissions include also N fertilisation of lands included under AR.

Net emissions from Article 3.3 activities were 1,816 Gg CO₂ eq (Table 11.1-1). Afforestation and reforestation resulted in a net removal of 1,077 Gg CO₂ eq. and deforestation a net emission of 2,893 Gg CO₂ eq. The area subject to AR was 149,000 ha in the end of the first year of the commitment period (Table 11.4-1). Until 2000, the annual AR area varied between 8,000 ha to 15,000 ha but has after that began to lessen being annually about 3,000 ha in the 2000's. The trend in D areas is reversed. In the 1990's, an average annual D area was about 9,000 ha, whereas in the 2000's it was 16,000 ha. In the end of 2008, the area deforested since 1 January 1990 was 227,000 ha. Transition from forest to built-up land and infrastructure, that is land-use changes from forest land to settlements, has been the most important activity under deforestation.

Net removals from Article 3.4 activity FM were 39,891 Gg CO₂ eq. in 2008 (Table 11.1-2).

Table 11.1-1. Net emissions and removals from the activities under Articles 3.3 in 1990-2008, Gg CO₂.

	Afforestation /Reforestation				Deforestation								
	Biomass	Mineral soils	Organic soils	Total	Biomass	Agricultural biomass	Mineral soil + litter	Organic soil + litter	Dead wood	Conversion to cropland	Total	Conversion to	
		SOM+DOM	SOM+DOM									peat extraction ¹	
												CH4	N2O
	Gg CO2 eq.				Gg CO2 eq.								
1990	0	-14	5	-9	786	-39	5	15	17	0	784	0	0
1991	-56	-47	13	-89	571	-29	6	23	15	0	586	0	0
1992	-108	-96	14	-191	960	-31	12	31	11	0	984	0	0
1993	-191	-162	13	-341	1 541	-50	19	65	27	0	1 603	1	2
1994	-267	-233	17	-482	705	-7	19	65	9	1	791	1	2
1995	-318	-300	10	-608	966	-16	21	70	16	1	1 058	1	2
1996	-364	-318	14	-669	921	-36	21	93	13	1	1 013	1	2
1997	-428	-355	19	-764	1 510	-92	27	146	29	1	1 621	2	3
1998	-473	-392	37	-828	2 066	-82	33	176	41	1	2 236	2	4
1999	-530	-399	50	-879	1 329	-52	38	192	24	2	1 532	2	4
2000	-568	-428	79	-917	1 963	-93	49	214	27	2	2 163	2	4
2001	-613	-438	90	-961	1 524	-108	59	262	30	3	1 768	3	5
2002	-630	-434	97	-968	2 365	-122	69	321	39	3	2 675	3	5
2003	-646	-437	93	-990	3 342	-181	90	381	53	4	3 689	3	6
2004	-664	-435	91	-1 008	2 212	-85	92	414	37	4	2 674	3	6
2005	-680	-437	91	-1 026	2 227	-85	95	463	37	5	2 742	3	6
2006	-689	-441	88	-1 041	2 242	-85	97	496	37	5	2 792	3	6
2007	-713	-426	88	-1 052	2 257	-85	99	529	37	5	2 842	4	7
2008	-739	-426	88	-1 077	2 272	-85	101	562	37	7	2 893	4	7

¹ CH4 and N2O emissions from land-use conversion from forest to peat extraction are not reported in the CRF tables but given in this table.

Table 11.1-2. Net emissions and removals from the activities under Articles 3.4 in 1990-2008, Gg CO₂.

	Forest Management							
	Biomass	Mineral	Organic	Biomass burning			Fertili-	Total
		soils	soils				zation	
		SOM+DOM	SOM+DOM					
		CO2			CH4	N2O	N2O	
Gg CO2 eq.								
1990	-27 376	-8 248	12 908	4	4	0	28	-22 680
1991	-42 426	-7 155	12 820	2	2	0	22	-36 735
1992	-35 373	-6 170	12 024	10	3	0	9	-29 496
1993	-33 034	-6 172	11 363	0	1	0	3	-27 839
1994	-22 472	-6 809	10 617	7	2	0	12	-18 642
1995	-22 057	-8 147	10 018	5	2	0	6	-20 173
1996	-29 936	-9 523	9 722	4	1	0	6	-29 725
1997	-23 383	-10 860	8 714	11	2	0	12	-25 504
1998	-21 248	-11 116	7 944	1	1	0	12	-24 407
1999	-22 427	-11 205	7 621	6	2	0	9	-25 994
2000	-24 176	-11 537	7 321	3	1	0	9	-28 379
2001	-28 418	-11 159	7 119	2	3	0	12	-32 441
2002	-29 831	-10 486	6 778	6	3	0	12	-33 518
2003	-31 054	-9 769	6 578	7	2	0	12	-34 223
2004	-31 991	-8 857	6 528	3	1	0	12	-34 304
2005	-37 857	-8 038	6 503	4	1	0	12	-39 373
2006	-42 157	-8 162	6 477	15	2	0	19	-43 805
2007	-33 851	-7 806	6 077	5	1	0	16	-35 558
2008	-38 332	-7 479	5 876	9	1	0	34	-39 891

11.1.1 Definition of forest and any other criteria

Under the KP Finland has defined forest as a land with 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, planted or seeded stands established for forestry purposes which have yet to reach a crown density of 10 percent or tree height of 5 m are included under forest, as are areas normally forming part of the forest area which are temporarily unstocked as a result of human intervention or natural causes but which 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 Elected values for forest parameters.

Parameter	Selected value
Minimum area	0.5 ha
Minimum width	20 m
Minimum tree crown cover	10%
Minimum tree height	5 m

The elected forest parameters were reported in Finland's initial report under the Kyoto Protocol (Table 11.1-3). The UNFCCC and the Kyoto Protocol reporting are not fully comparable. The difference between the UNFCCC reporting and the Kyoto Protocol reporting is that a minimum area of 0.25 ha is used in the Convention reporting to cover all forest land (see Section 7.1.2 and Section 7.2.1). Forests with an area less than 0.5 ha are excluded from the Kyoto Protocol reporting to fulfil the definition of the initial report. The area of forest has been estimated from the NFI data, where the minimum width has been set to 20 m.

Exclusion of small forests (area less than 0.5 ha). NFI sample plots that were located in these small forests have been identified using GIS analysis. The digital vector map data coming from the National Land Survey was rasterised to the 20 m pixel size covering whole country. The rasterisation was carried out earlier in Metla for multi-source forest inventory purposes. That raster map includes information on land-use and the size of forest area 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 forest less than 0.5 ha on the map were also visually double-checked. Otherwise, the classification relied on field assessments on the land-use. A general comparison between the field plot data and raster map data was done. The proportion of sample plots, which were discovered to be in under 0.5 ha forests, was 0.1%.

Forest area in 1990 and 2005 reported under the Kyoto Protocol has been compared with the forest land area under the UNFCCC reporting, with the forest area provided to FAO for the Global Forest Resource Assessment 2005 (FRA 2005) and with the combined national forest land and poorly productive forest land area reported by the NFI (Table 11.1-4). The KP forest area is smaller than the UNFCCC Forest land area as it should be, taking the differences in the definitions into account. The FRA 2005 area is greater than Forest land area since the forests less than 0.5 ha are included (see Section 7.2.1). 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 1_App_7a). The minimum area for forest land and poorly productive forest land is not exact but a guide of 0.25 ha for southern parts of Finland and 0.5 ha for northern Finland are given. The principle to estimate areas is the same for each reporting, but the time series have been produced in different ways and the combination of NFI data have also been different. The diverse total land areas are presented in Table 11.1-4. Due to the improved geodetical methods Finland's official land area has changed from year to year. Despite that, generally the forest resource results have not been recalculated employing the corrected land area unlike for the UNFCCC and the KP reportings.

Table 11.1-4 Comparison of the KP forest area with areas reported to the UNFCCC and to the FAO FRA2005 assessment, and with the aggregate national forest land and poorly productive forest land area.

Reporting	Forest area		Total land area	
	1990	2005	1990	2005
KP (FM+AR)	22 104	22 060	30 390	30 390
UNFCCC (Forest land)	22 117	22 076	30 390	30 390
FRA2005 (Forest)	22 194	22 500	30 459	30 447
National forest land + poorly productive forest land	23 057 ¹	22 820 ²	30 459 ¹	30 415 ²

¹ NFI8, measured in 1986-1994 (Tomppo et al. 2001).

² NFI10, measured 2004-2008 (Source: Finnish Forest Research Institute/ National Forest Inventory).

11.1.2 Elected activities under Article 3, paragraph 4, of the Kyoto Protocol

Finland has elected to account emissions and removals from Article 3, paragraph 4 activity forest management (FM). The definition of forest management is interpreted in using the broader approach as described in the *GPG LULUCF 2003*. All forests fulfilling the definition of forest, as given above, are considered as managed and are under forest management. Forest management activities are not identified in stand-level or landscape-level but in two larger land areas subject to forest management and which geographical boundaries are defined and reported (Figure 11.2-1).

11.1.3 Description on how the definitions of each activity under Article 3.3 and each elected activity under Article 3.4 have been implemented and applied consistently over time

Afforestation/reforestation and deforestation (ARD) areas have been estimated from a database based on the 10th forest inventory (NFI10). The database contains sample plot data, stand-level data and tree data. The land use at the end of 1989 for each sample plot has been derived from the information of land use and land-use changes assessed in the field and with aerial photos, satellite images and digital map data. The time series for ARD activities were established from data using the same principles and definitions for forest and ARD activities. The NFI will continue to monitor forest and other land uses during the first and subsequent commitment periods. The forests, other land use and land-use changes will be monitored every year in the whole country, excluding the most northern part of Lapland and Åland Islands, which are monitored once every five years.

Time series for the FM area have been estimated from the same database as the ARD areas. The forest area estimation has been made backwards starting from the year 2008. The total forest land area under KP (FM+AR) for 2008 was calculated using method described above. The forest area for the preceding year was calculated by subtracting the AR area from and adding the D area to the forest total area of the following year. The FM area at the end of 1989 was the same as the forest area.

11.1.4 Description of precedence conditions and/or hierarchy among Article 3.4 activities, and how they have been consistently applied in determining how land was classified

Finland has elected to report forest management under Article 3.4 activities. Therefore there is no need to build up a hierarchy between forest management and other Article 3.4 activities. To ensure that the reported forest management activities have occurred on forest land, the total land area was classified into six land-use categories as for the UNFCCC reporting, and each land area was classified only under one land-use category (Section 7.1.2). Land-use areas were calculated from the NFI10 data and every sample plot or to be precise the mid-points of sample plots, were classified under one IPCC land-use category.

11.2 Land related information

Finland implements the Reporting Method 1 for lands subject to Article 3.3 and Article 3.4 activities. The area of Finland is divided in two regions of which Region 1 covers the southern part of Finland and Region 2 the northern part of Finland (Fig. 11.2-1). Ecological considerations and 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 Figure 1_App_7a). These areas include multiple units of land subject to Afforestation/Reforestation and Deforestation and land areas subject to Forest management. In the reporting, the same geographical boundaries were used for Article 3.3 and Article 3.4 activities. Approach 3 is used for representing the land areas.

Data for land use and land-use changes were obtained by the National Forest Inventory (NFI). NFI is a sampling based inventory system and it covers all land-use categories. Sampling unit for area estimation is a point. In a sample plot, the point is the midpoint of the plot. The midpoint determines to which land-use category, land-use change type or to which activity the area belongs.

11.2.1 Spatial assessment unit used for determining the area of the units of land under Article 3.3

The spatial assessment unit to determine the area of units of land under Article 3.3 is 0.5 ha, which is the same as the minimum area of forest.

11.2.2 Methodology used to develop the land transition matrix

In the forest inventory database is information on the IPCC land use and land-use change category for each sample plot. The data in the database were measured in 2005-2009. The annual land-use change areas were calculated for 1990-2008. For years 2004-2008 a five years average for land-use changes was applied because, for example, for 2008 only one year NFI data were available. Applying data from only one or two years, the ARD area estimates would be highly uncertain and they could vary much between reporting years. The matrix was developed adding and subtracting the conversion areas to and from land-use category areas. The matrix was first developed for the period from 1 January 1990 to 31 December 2007 and then for the year 2008 (Table 11.2-1). The method will be developed to produce annual area data on land-use changes for the commitment period.

Table 11.2-1 Land-use transition matrix for 2008 (1 000 ha).

	Article 3.3 activities		Article 3.4 activities				Other	Total (beginning of 2008)
	A/R	D	FM	CM	GM	RV		
Article 3.3 activities	A/R	146	0					146
	D		211					211
Article 3.4 activities	FM		15	21 873				21 889
	CM	NA	NA		NA	NA	NA	NA
	GM	NA	NA		NA	NA	NA	NA
	RV	NA			NA	NA	NA	NA
Other	3	0	0	0	0	0	11 593	11 596
Total (end of 2008)	149	226	21 873	0	0	0	11 593	33 841

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 to the NFI sample plots. In the field, the sample plots have been located by GPS whereupon it was possible to place them in regions.

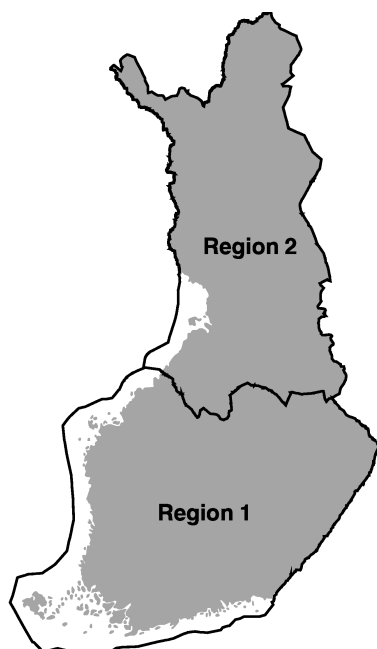


Figure 11.2-1 Geographical locations of the two reporting regions and their identification codes.

11.3 Activity-specific information

11.3.1 Methods for carbon stock change and GHG emission and removal estimates

11.3.1.1 Description of the methodologies and the underlying assumptions used

Carbon stock changes in living trees

The total biomass increment in all forests was obtained by assuming that the mean increment per area unit is the same as in the forest land under UNFCCC reporting. This mean increment was multiplied by the area estimate of all forests included in Kyoto Protocol reporting (excluding small forests with areas less than 0.5 ha) to obtain the total increment. (See Section 7.2.2.1)

Afforestation sites were classified according to the identified land-use change and the mean increment was estimated for each type of afforestation in the same way as that of the sites converted to forest land in UNFCCC reporting based on the afforested NFI plots (since 1990, for details, see Section 7.2.2.1). Again, these mean increments were multiplied by the appropriate area estimates, and the results summed 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.

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 multiplying the respective area estimate by the mean tree biomass stock in forests, where the given type of deforestation is likely to occur. For example, only forests with sufficiently fertile soil were included, when estimating the mean biomass loss for forests converted to cropland.

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.

Carbon stock changes in soil, litter and dead wood

For carbon stock change estimation for soil, litter and dead wood same methodology was used as in the reporting under the UNFCCC. The soil carbon model Yasso was applied for mineral soils under forest management activity, while Yasso07 model was applied for mineral soil areas under land use change (here afforestation, reforestation and deforestation). Justification for the use of Yasso07 model for soils under article 3.3 activities has been given under section 7.2.2.3.

For the organic soil under forest management, emissions were estimated similarly as those under UNFCCC reporting. The main principle was to deduct belowground litter input from the emissions of peat decomposition. This approach was also used for afforestation, reforestation and deforestation sites. For the details of methods, see UNFCCC reporting methods Sections 7.2.2.2 and 7.2.2.3.

The emissions due to removal of dead wood pool during the deforestation to agriculture were estimated based on the dead wood measurements of the NFI10. The methodology of the estimation of carbon stock of that lost dead wood pool is similar as in the UNFCCC reporting concerning the dead wood carbon pool change on the organic forest land (see section 7.2.2.2.).

Other GHG emissions

Direct N₂O emissions from N fertilization under FM were estimated applying the same method as under CRF 5(I) Category (Section 7.7.1). The emissions are reported for the whole country under FM because the activity data were not able to divide between Region 1 and Region 2 and the data could not be allocated for AR and FM areas separately.

N₂O emissions from disturbance associated with land use conversion to cropland were estimated with the same method as described in Section 7.7.3.

GHG emissions from biomass burning were estimated with the same method as described in Section 7.7.4. All emissions are reported under FM and for whole country under the Region 1. The activity data did not allow separate allocation for AR and FM areas.

11.3.1.2 Justification when omitting any carbon pool or GHG emissions/removals from activities under Article 3.3 and elected activities under Article 3.4

For afforestation and reforestation sites, the accumulation of dead wood was assumed to be marginal during the 1990-2008. On afforested or reforested sites the accumulation of dead wood starts after natural mortality or thinning occur; it is very unlikely to have significant natural mortality or thinning on these sites. The estimation of carbon stock change of dead wood was therefore excluded from the reporting. This results in minor underestimations of the dead wood sink in the AR lands.

N₂O emissions from drainage of soils from land under FM are not reported in Table 5(KP-II)2. The method to estimate these emissions is given in Appendix 3a.2 of IPCC GPG LULUCF and therefore it is optional for a Party to report the emissions from this source. At the moment, national methods to estimate N₂O emissions from drained organic soils are highly uncertain, and therefore not applicable. A new method and emission factors for this source are under development.

Emissions from liming are not reported under Article 3.3. This is consistent with UNFCCC reporting, where all liming is assumed to occur in Cropland remaining Cropland.

For deforestation sites where the new land use is peat extraction, carbon stock changes are reported in CRF table 5(KP-I)A.2. Under the UNFCCC reporting also CH₄ and N₂O-emissions are reported in the CRF tables, but not under the Kyoto Protocol, since there is no place for them in the reporting tables. The estimates for CH₄ and N₂O-emissions from deforested peat extraction sites have been provided as additional information in the NIR (see Section 11.4.4).

11.3.1.3 Information on whether or not indirect and natural GHG emissions and removals have been factored out

Finland has not factored out removals from elevated carbon dioxide concentrations, indirect nitrogen deposition or the dynamic effects of age structure resulting from activities prior to 1 January 1990. The IPCC do not give methods for factoring out. For the first commitment period, the effect of indirect and natural removals will be considered through the cap under Article 3.4 credits from FM. For Finland the cap is 0.16 Mg C yr⁻¹.

11.3.1.4 Changes in data and methods since the previous submission (recalculations)

Not relevant as this reporting was not part of the previous submission.

11.3.1.5 Uncertainty estimates

The uncertainties were not estimated separately for lands under FM. It was assumed that uncertainty estimates for forest land apply also for lands under FM (Section 7.2.3). The relative standard error for carbon stock change in living biomass was 30%, 92% for carbon stock changes in mineral soils and 78% for organic soils.

The estimates for Article 3.3 activities are expected to be much higher. It can be considered that the given uncertainty estimates cover the uncertainty of all gains and all losses in living tree biomass under FM and ARD.

The method for uncertainty estimation will be further developed.

11.3.1.6 Information on other methodological issues

Finland has decided to account for the emissions and removals under Article 3 paragraphs 3 and 4 at the end of the commitment period. Finland will further develop the methods for area estimation as well the methods to estimate emissions and removals of greenhouse gases and their uncertainties. For that reason, the estimates presented in this submission for 2008, may change for the final report of the commitment period.

The NFI measures one fifth of the sample plots of one inventory cycle during one year. This causes that the representativeness of one sample plot is much higher for the latest years than for the previous ones. The number of the sample plots for the last years of the commitment period will be increased, provided resources are available, to improve the accuracy of the estimates for these years. The argument for applying NFI data is that it is the only continuous inventory and monitoring system in Finland that covers all land uses and gives reliable estimates for the landuse areas and tree growth. It is also a system, which can produce the input data for the soil model.

11.3.1.7 The year of the onset of an activity, if after 2008

Not relevant as the reporting is for the year 2008.

11.4 Article 3.3

Finland reports all emissions by sources and removals by sinks from AR activities under Category A.1.1 Afforestation/Reforestation: units of land not harvested. Finland interprets harvesting as clear cutting done on short rotation forests and thinnings are not included (IPCC GPG LULUCF 2003, p. 4.55). Forests afforested or reforested since 1990 have not reached the regeneration age by the first commitment period. According to guidance for good silviculture, the rotation time varies from 50 to 160 years depending on the tree species, site fertility and the geographical location of a forest.

Finland has subdivided the ARD areas according to the land-use change and soil types. Emissions and removals are reported for seven AR types and eight D types. The subdivision name refers to the initial (AR) or current (D) land-use category. The AR types and their codes in CRF tables are:

- Cropland, mineral soils (CLmin)
- Cropland, organic soils (CLorg)
- Grassland, mineral soils (GLmin)
- Grassland, organic soils (GLorg)
- Wetlands, peat soil (WLorg)
- Wetlands, peat extraction (WLpeat)
- Settlement, mineral soils (SLmin).

The D types are:

- Cropland, mineral soils (CLmin)
- Cropland, organic soils (CLorg)
- Grassland, mineral soils (GLmin)
- Grassland, organic soils (GLorg)
- Wetlands, peat soil (WLorg)
- Wetlands, peat extraction (WLpeat)
- Settlement, mineral soils (SLmin)
- Settlement, organic soils (SLorg).

The areas of Article 3.3 activities are estimated as described in Section 11.2.2. The cumulative sum of areas afforested/reforested and deforested since 1990 is given in Table 11.4-1.

The afforested and reforested areas given in Table 11.4-1 have been compared with the statistics on afforestation of arable land (Finnish Forest Research Institute 2008). The reported AR areas and the afforested areas from statistics are presented below in Table 11.4-2. The reported conversion area from cropland and grassland to forest is less than in the statistics. First reason is that the minimum area reported in statistics is unknown and it can be assumed it is smaller than 0.5 ha. In addition, the areas that have been converted to other land use after afforestation or reforestation are missing from the reported AR areas.

The deforested areas were also compared to the forest statistics of other cuttings, which include e.g. felling done along ditch and road construction lines and fellings when clearing for agricultural purposes (Finnish Forest Research Institute 2008). The deforested areas of the report and statistics resemble each other by magnitude despite from the difficulties in comparison (Table 11.4-3). It is not evident whether all areas converted to settlements are included in the statistics. At least the conversions from forest to wetlands (drained peatlands) are not included in.

Table 11.4-1 Cumulative sums of areas under Article 3.3 activities Afforestation/Reforestation and Deforestation 1990-2008 (ha).

	Afforestation/Reforestation			Deforestation		
	Region_1	Region_2	Total	Region_1	Region_2	Total
1990	8 682	2 919	11 601	3 697	2 504	6 201
1991	14 594	6 701	21 295	6 214	4 624	10 838
1992	26 397	10 048	36 445	12 220	4 624	16 844
1993	35 214	14 649	49 863	20 665	8 409	29 074
1994	41 472	18 820	60 292	24 834	8 825	33 659
1995	47 811	22 155	69 966	30 246	10 093	40 339
1996	57 927	25 125	83 052	35 297	11 762	47 059
1997	64 979	27 644	92 623	43 141	16 347	59 488
1998	73 184	31 827	105 011	53 746	21 401	75 147
1999	77 817	34 743	112 560	60 506	23 919	84 425
2000	84 387	39 360	123 747	71 584	25 586	97 170
2001	86 981	41 043	128 024	79 188	29 773	108 961
2002	89 877	41 877	131 754	91 734	34 374	126 108
2003	92 369	43 127	135 496	108 334	41 079	149 413
2004	94 651	43 589	138 240	119 558	45 299	164 857
2005	96 933	44 051	140 984	130 782	49 519	180 301
2006	99 215	44 513	143 728	142 006	53 739	195 745
2007	101 497	44 975	146 472	153 230	57 959	211 189
2008	103 779	45 437	149 216	164 454	62 179	226 633

Table 11.4-2 Comparison of reported afforestation and reforestation areas to the statistics.

Year	AR of cropland and grassland	AR total	Afforestation of arable land in Metla statistics
1990	8.8	11.6	8.5
1991	8.0	9.7	10.5
1992	12.4	15.2	17.1
1993	10.3	13.4	17.7
1994	6.8	10.4	8.8
1995	6.4	9.7	4.1
1996	9.7	13.1	9.0
1997	7.2	9.6	9.3
1998	8.2	12.4	7.1
1999	5.9	7.5	6.2
2000	6.3	11.2	5.8
2001	1.9	4.3	6.0
2002	2.9	3.7	2.7
2003	3.3	3.7	2.0
2004	2.1	2.7	2.4
2005	2.1	2.7	2.3
2006	2.1	2.7	2.3
2007	2.1	2.7	3.1
2008	2.1	2.7	3.5
All	108.6	149.2	128.4

Table 11.4-3 Comparison of reported deforestation areas to the statistics.

Year	Deforestation	Deforestation in Metla statistics	Difference
1990	6.2	4.1	2.1
1991	4.6	3.7	0.9
1992	6.0	4.6	1.4
1993	12.2	8.0	4.2
1994	4.6	13.7	-9.1
1995	6.7	5.7	1.0
1996	6.7	5.1	1.6
1997	12.4	5.0	7.4
1998	15.7	6.1	9.6
1999	9.3	4.8	4.5
2000	12.7	8.3	4.4
2001	11.8	11.2	0.6
2002	17.1	11.6	5.5
2003	23.3	11.1	12.2
2004	15.4	14.7	0.7
2005	15.4	8.8	6.6
2006	15.4	9.6	5.8
2007	15.4	9.7	5.7
2008	15.4	10.7	4.7
All	226.6	156.5	70.1

11.4.1 Information that demonstrates that the activities under Article 3.3 began on or after 1 January 1990 and before 31 December 2012 and are direct human-induced

Changes in forest area were detected on NFI sample plots. The land-use category in the end of 1989 was assessed either during field measurements or by interpretation based on aerial photos and satellite images. Since the land-use category just before 1 January 1990 was known, the reported land-use changes have occurred after that. The type of each land-use change since 1990 is known and the changes, which were not directly human-induced, have been excluded from the reporting. Not directly human-induced changes occur when due to the land lift seawater turns to land and thereafter gradually to forest. Also, the conversion from Other land to Forest land was excluded since that transition type is not human induced but a natural occurrence.

The reported AR activities are directly human induced since those activities are based on decisions not to continue the previous activities but the forest management activities. That means the area is changed to the forestry land and the Forest Act is applied to the area since then (Forest Act 1093/1996). Usually the area is planted or seeded. In some cases the area can be left to forest naturally, if it is surrounded by one owner's forest and the edge forest is not too far. This method is carried out in arable lands where natural seedlings grow up instantly when the farming has ended. Another case is a wetland on which a sparse tree cover has been before drainage. The drainage changes site's water conditions and enhances tree growth and vitality. The change to forest does not happen as quickly as on arable lands and needs maintenance of the drainage and other silvicultural activities. The unit of land is not accounted as AR area until it is evident the seedlings (planted, seeded or natural origin) are expected to reach the parameter thresholds of forest at maturity. The assessment of the situation is made in the NFI sample plot in the filed.

The reported D activities are direct-human induced. A plan approved by authorities or a permit is needed to change the land use from forest to other use (Land Use and Building Act 132/1999, Forest Act 1093/1996). Forest owners have to give an announcement to forestry authority with due permits, when a forest area is felled to change the land use. Depending on the conversion type the permits may needed from agricultural, environmental or local administrations. For all reported D types a permission is needed except for the

conversion from forest to wetlands (WLog). That conversion is contrary to the conversion from wetlands to forest (WLog). The area has met the definition of forest after the drainage but according to the current forest management guidelines the area is considered to be unprofitable and FM practices are no longer applied. Because the drainage is not maintained, the ditches will be blocked or filled up 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 prevention of insect and fungus disturbances in forest binds owner to remove the rest of the damaged trees. After that, the re-establishment work should be started immediately if possible.

Finnish forest area is treated with clear cuttings of 110,000 to 160,000 ha annually (Finnish Forest Research Institute 2008). 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 reliably. Clear signs of a land-use change can be seen in the surrounding and location of the area: constructions, stacked cutting residuals, the area is under a regional or a town plan. Re-establishment of a forest usually starts within 2 years after the harvesting. The Forest Act lays down provisions to finish the establishment of a new forest within three years after the regeneration cutting.

11.4.3 Information on the size and geographical location of forest areas that have lost forest cover but which are not yet classified as deforestation

Clear-cut forest areas, which have not classified as deforestation, were classified as temporarily unstocked forest. The area of these forests is 180,000 ha in Region 1 and 110,000 ha in Region 2.

11.4.4 Emissions and removals under Article 3.3

The AR activities were a net sink of -1,078 Gg CO₂ eq. in 2008 and the D activities a net source of 2,886 Gg CO₂ eq. (Table 11.4-4).

Table 11.4-4 Net emissions and removals under Article 3.3, Gg CO₂ eq. in 2008.

		CO ₂	Other gases
Afforestation/Reforestation	Region 1	-738	
	Region 2	-339	
	Total	-1 078	
Deforestation	Region 1	2 242	5.5
	Region 2	579	0.3
	Total	2 821	5.8
Total		1 743	5.8

Common reporting format does not allow reporting of CH₄ and N₂O emissions from lands deforested to peat extraction. The net emissions of these lands have been given in the Table (11.4-5)

Table 11.4-5 Net emissions of CH₄ and N₂O from lands deforested to peat extraction since 1990, Gg CO₂ eq. in 2008.

	Deforestation 1990-2008 (ha)	Emissions (CH ₄)	Emissions (N ₂ O)	Total
Region 1	6 148	2.88	5.50	8.38
Region 2	1 669	0.78	1.49	2.27

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

The forest area in the end of 2008 was calculated from forest inventory database. That area was followed to the end of 1989 by adding D areas and subtracting AR areas (see Sections 11.2.2 and 11.4.1). Forests in 1 January 1990 were under FM since Finland considers all forests are under FM activities. Area is not able to leave out from FM area and therefore all activities have occurred in or after 1990 and have been human-induced.

11.5.2 Information relating to Forest Management

Finland interprets the definition for Forest management using the broad approach. The FM is a system of forest management practices, which occur inside two identified area, Region 1 and Region 2 (Figure 11.2.1). In commercially managed forests felling for natural and artificial regeneration, site preparation, drainage, planting, seeding, thinnings, pruning, fertilization, harvesting of cutting residues and conservation of important habitats are practices in stand-level. The Forest Act, the Forest Degree and Forest management guidance guide these activities in practice. The National Forest Programme, Regional Forestry Programmes and the management plan for state-owned forests give the lines to the sustainable forest management in Finland. Protected forest areas are also covered by management plans which are prepared for national and regional level, landscape-level and for individual conservation areas. All forests, commercially managed and the protected areas as well are under fire prevention. In some extend the fires inside protected areas are allowed, but generally all fires are put out as soon as possible due to the fire follow-up system.

Area under forest management 1989-2008 is given in Table 11.5-1.

Table 11.5-1 Area of Forest management since 31.12.1989 (1 000 ha).

	Region_1	Region_2	Total
1989	11 557	10 541	22 098
1990	11 553	10 539	22 092
1991	11 550	10 537	22 087
1992	11 545	10 537	22 082
1993	11 536	10 533	22 069
1994	11 533	10 533	22 065
1995	11 528	10 531	22 059
1996	11 523	10 530	22 052
1997	11 515	10 525	22 040
1998	11 504	10 520	22 024
1999	11 497	10 518	22 015
2000	11 486	10 516	22 002
2001	11 479	10 512	21 991
2002	11 467	10 507	21 974
2003	11 450	10 500	21 950
2004	11 439	10 496	21 935
2005	11 428	10 492	21 920
2006	11 416	10 488	21 904
2007	11 405	10 484	21 889
2008	11 394	10 479	21 873

11.5.2.1 That the definition of forest for this category conforms with the definition in item 11.1 above

Forest management activity is practiced on the forest area as defined above. The area of forest and the area under FM in the end of 1989 are equal. The area under FM was calculated from the same forest inventory database as the forest area.

11.5.2.2 That forest management is a system of practices for stewardship and use of forest land aimed at fulfil relevant ecological (including biological diversity), economic and social functions of the forest an a sustainable manner (paragraph 1(f) of the annex to decision 16/CMP.1 (land use, land-use change and forestry))

Private forest owners manage 65% of Finland's forests and the state and forest companies own the rest. In general, private forest owners and forest companies manage their forest for wood production. Wood production also important area of operation in state-owned forest but the ecological and social functions are also at priority. Biological diversity plays a significant role also in private and companies' forest. The Forest Act and Forest Decree regulate all forests.

The Forest Act lays down provisions on management and utilisation of forest. The purpose of the Act is to promote economically, ecologically and socially sustainable, management and utilisation of the forests in such a way that forests provide a sustainable satisfactory yield while biological diversity is being maintained. (Forest Act 1093/1996) Forests to which the Forest Act is not applied are under the Nature Conservation Act (protected areas), the Land Use and Building Act (protection areas) and the Act on Wilderness Reserves.

The Forest Act applies to forests in areas classified as forestry land. The Act lay down provisions on changing the form of land use, regional target programme for forestry, fellings and regeneration of forest, safeguarding the diversity of forest nature, timberline forests and protection zones, supervisions of the law and legal consequences.

The regional forestry administration, thirteen Forestry Centres, draw up a target programme for forestry with general objectives to promote sustainable management and use of forests. Forestry Centres monitor the implementation of the forestry programme. The Ministry of Agriculture and Forestry prepare the National Forest Programme, which the Finnish Government approves. The present programme extends until 2015.

Forestry Centre, among other things, gives guidance to private forest owners on forest management, conservation of forest nature and supervises the Forest Act within its own region. Metsähallitus is responsible over the sate-owned forests. In both, private owned forests and state-owned forests, the silvicultural measures are implemented according to the silvicultural guidelines, which are based on long-term practical experience and research results.

11.5.3 Emissions and removals from Forest Management

Forest management was a net sink in 2008. The net removals from carbon stock changes were -39,921 Gg CO₂ and emissions from biomass burning and N fertilization was 36 Gg CO₂ eq. (Figure 11.5-2).

Table 11.5-2 Net removals and emissions under forest management in 2008 (Gg CO₂ eq.).

	Gg CO ₂ eq.
Carbon stock changes	
Region 1	-23 489
Region 2	-16 432
Other gases	36
Total	-39 885

11.6 Other information

11.6.1 Key category analysis for Article 3.3 activities and elected activities under Article 3.4

Key category analysis for KP-LULUCF was performed according to section 5.4 of the IPCC good practice guidance for LULUCF (IPCC 2003). The key categories, also reported in CRF table NIR.3, are CO₂ removals due to afforestation/reforestation and CO₂ emissions from deforestation. CO₂ removals due to forest management is also a key category.

11.7 Information relating Article 6

No projects under Article 6 are implemented in Finland.

12 Information on accounting of Kyoto units

12.1 Background information

The standard electronic format tables are included in the submission for the second time (see SEF_FI_2010_1_12-42-45 11-1-2010.xls.). The SEF tables include information on the AAU, ERU, CER, t-CER, l-CER and RMU in the Finnish registry 31.12.2009 as well as information on transfers of the units in 2009 to and from other Parties of the Kyoto Protocol.

More detailed information is provided in SIAR Report 2010 FI.

12.2 Summary of information reported in the SEF tables

The total number of AAU units in the registry at the end of the year 2009 corresponded to 350,805,692 tonnes CO₂ eq., of which 281,659,205 units were in the Party holding account, 34,298,085 units in the entity holding accounts 27, units in the other cancellation accounts and 34,848,375 units in the retirement account.

The number of units of ERU in registry corresponded to 34,384 tonnes CO₂ eq., of which 16,884 units were in the Party holding account and 17,500 units in the entity holding accounts.

The units of CERs in the registry corresponded to 3,493,884 tonnes CO₂ eq., the division between the Party holding account and the entity holding accounts was 175,655 units and 2,166,948 units, respectively. In addition, 5,175 CER units were in the other cancellation accounts and 1,146,106 CER units in the retirement account.

The registry did not contain any RMUs, t-CERs or l-CERs. And no units were in the Article 3.3/3.4 net source cancellation accounts and the t-CER and l-CER replacement accounts.

The total amount of the units in the registry corresponded to 354,334,960 tonnes CO₂ eq. Finland's assigned amount is 355,017,545 tonnes CO₂ eq.

12.3 Discrepancies and notifications

No discrepancies and notifications occurred in 2009.

12.4 Publicly accessible information

Following information is publicly accessible through the user interface of the registry:

Public information required by Decision 13/CMP.1:

Account information

JI projects in Finland

Holding and transaction information of units

Account holders authorised to hold Kyoto units in their account

Public information required by Commission regulation (EC) No 2216/2004 (in addition to the above-mentioned public information):

Installation and permit details

Information about verified emissions, surrenders and compliance status of installations

National allocation plan for Finland (NAP)

Registry fees

Kyoto units that can be held in the accounts

Other public information:

Allocated allowances vs. verified emissions (in Finnish only)

Approvals and authorisations concerning JI projects given by the Ministry of the Environment (in Finnish only)

Approvals and authorisations concerning CDM projects given by the Ministry for Foreign Affairs of Finland (in Finnish only).

12.5 Calculation of the commitment period reserve (CPR)

Finland's assigned amount is 355,017,545 tonnes of CO₂ eq. and the commitment period reserve, calculated as 90% of the assigned amount amounts to 319,515,790 tonnes of CO₂ eq.

The commitment period reserve has not changed since the previous submission, as 100 per cent times the most recent inventory would amount to a higher value (2008 inventory: 70,125,545 tonnes of CO₂ eq. times five equals 350,627,723 tonnes of CO₂ eq.).

12.6 KP-LULUCF accounting

Finland has elected accounting of all KP-LULUCF activities at the end of the commitment period. No information on the accounting of the KP-LULUCF is therefore included in the SEF tables.

In Table 12.6 data on accounting for the KP-LULUCF activities based on the reporting for the year 2008 are given. According to this information, Finland would at the end of the commitment period be able to issue RMUs corresponding to the amount of 2.9 Tg CO₂ eq., which is Finland's cap value for forest management for the whole commitment period

Table 12.6-1 Information table on accounting for activities under Articles 3.3 and 3.4 of the Kyoto Protocol.

GREENHOUSE GAS SOURCE AND SINK ACTIVITIES	Emissions/ removals in the base year	Net emissions/removals		Accounting Parameters	Accounting Quantity
	2008	Total			
	(Gg CO ₂ equivalent)				
A. Article 3.3 activities					
A.1. Afforestation and Reforestation					-1 077
A.1.1. Units of land not harvested since the beginning of the commitment period		-1 077	-1 077		-1 077
A.1.2. Units of land harvested since the beginning of the commitment period		NA	NA		
A.2. Deforestation		2 893	2 893		2 893
B. Article 3.4 activities					
B.1. Forest Management (if elected)		-39 891	-39 891		-4 749
3.3 offset ⁽³⁾				1 816	-1 816
FM cap ⁽⁴⁾				2 933	-2 933
B.2. Cropland Management (if elected)		NA	NA	0	0
B.3. Grazing Land Management (if elected)		NA	NA	0	0
B.4. Revegetation (if elected)		NA	NA	0	0

13 Information on changes in national system

No changes in the national system under Article 5, paragraph 1, of the Kyoto Protocol have been implemented.

14 Information on changes in national registry

During summer 2009 the national registry authority, the Finnish Energy Market Authority changed the software used for Finland's emissions trading registry. Before the registry software change, software called Greta was used by the Finnish registry. Greta software was developed by Defra (Department for Environment, Food and Rural Affairs of UK). The software currently in use, the CR software is developed by the European Commission.

The decision for the change was based mainly on the need to take more a robust, less expensive, and better supported software into use. Also, the user interface of the CR software is more user-friendly and certain repetitive operations are more easy and flexible to carry out.

Whereas Greta software was a closed system (apart from the user interface components) based on .NET and Microsoft technologies (MS IIS and MS SQL database), the CR is an open-source software (based on J2EE, using WebLogic and Oracle database), provided free-of-charge for EU members states. Due to the fact, that the CR software is open source, all developments and fixes carried out by any countries for the CR software are freely available for others as well. The access to the source code of the software also enables more efficient problem solving and localizations.

In addition, some of the heaviest functionalities related to registry activities, which require a lot of processing, are more optimized in the CR software than in the Greta software, thus making it easier to perform these activities.

There are several localizations implemented to the Finnish registry software (current version CR v3.1 FI 1.0). These localizations are related to the user interface and user authentication. The business logic and message processing of the software has not been modified. Some of the most essential localizations are:

Strong authentication of the registry users. The functionality is based on the banking system in Finland, as the users use their personal bank credentials to login to the registry.

Requests for a personal account opening are restricted for users that are using strong authentication.

Operator holding accounts can only be requested to be opened by admin users.

Account representatives can request (from the administrator) their personal information to be concealed.

The user interface of the software is translated to Finnish and Swedish, and the graphical design has been localized.

In addition to the localizations described above, some additional localisations are planned to be implemented to the registry software during 2010.

The process of changing the registry software from Greta software to CR registry has included the following high-level steps:

Creating the needed migration scripts, in order to transfer the registry database from Greta to CR.

Developing the localizations of the FI CR registry software.

Testing the localized CR internally.

Completing the official ITL and CITL acceptance tests (Annex H and ETS test, respectively) with the localized CR software.

Performing the Go-live migration for the production registry instance.

The description of the functions of national registry and its conformity with the Data Exchange Standard (DES) under the Kyoto Protocol in accordance with the Guidelines in the Annex of the Decision 15/CMP.1 on reporting of supplementary information under Article 7, paragraph 2 has been included in Finland 5th National Communication of the UNFCCC and is also provided in Table 14.1-1 in this report.

More detailed information is provided in SIAR Report 2010 FI.

Table 14.1-1 Functions of the national registry and its conformity with Data Exchange Standard.

Registry Administrator	Jouko Hepola Energy Market Authority Address: Lintulahdenkatu 10, FIN-00500 Helsinki Tel.: +358 10 60 5000
Parties with which Finland cooperates by maintaining the registry in a consolidated system	The Finnish national registry is not a part of any consolidated registry system. However, the VPN connection to the ITL is shared with several countries using the same tunnel.
Database structure and capacity of the national registry	The registry system, based on CR software, uses an Oracle 9I relational database dedicated data model for supporting the registry operations. Current total capacity is 8 GB, and current database size is 808 MB.
Conformity with DES	<p>The CR registry system was developed for the EU Emissions Trading Scheme by the European Commission. The scheme requires the Member States' registries to be compliant with the UN Data Exchange Standards (DES) specified for the Kyoto Protocol.</p> <p>The system contains the functionality to perform issuance, conversion, external transfer, (voluntary) cancellation, retirement and reconciliation processes using XML messages and web services as specified in the UN DES document.</p> <p>In addition, it also contains: 24-hour clean-up, transaction status enquiry, time synchronization, data logging requirements (including transaction log, reconciliation log, internal audit log and message archive) and the different identifier formats specified in the UN DES document.</p> <p>The registry development team has been in close contact with the ITL administrator and development team within the UNFCCC Secretariat during the development of the ITL functions.</p>
Procedure to minimise discrepancies in issuance, transfer, cancellation and retirement of registry units	<p>In order to minimise discrepancies between the registry and the transaction log, the following approach has been adopted for the registry system development under the EU ETS and UN DES:</p> <ul style="list-style-type: none"> - Communication between the national registry and the ITL is via web services using XML messages – as specified in the UN DES document. These web services, XML message format and the processing sequence are as specified in the UN DES document; - As far as possible, the registry validates data entries against the list of checks that are performed by the ITL – as documented in Annex E of the UN DES Annexes document – before forwarding the request to the ITL for processing. This will help to minimise the sending of incorrect information to the ITL for approval. This also holds for any incoming transaction or message relating to a transaction. The registry validates all communication using checks described in the DES and the EU ETS regulation before processing the request further. If any check fails, the process is terminated

	<p>and rolled back according to the requirements;</p> <ul style="list-style-type: none"> - All units that are involved in a transaction shall be earmarked internally within the registry, thereby preventing the units from being involved in another transaction until a response has been received from the ITL and the current transaction completed; - The web service that sends the message to the ITL for processing will ensure that an acknowledgement message is received from the ITL before completing the submission of the message. Where no acknowledgement message is received following a number of retries, the web service will terminate the submission and roll back any changes made to the unit blocks that were involved; - Where a 24-hour clean-up message is received from the ITL, the web service will roll back any pending transactions and the units that were involved, thereby preventing any discrepancies in the unit blocks between the registry and the ITL; - Finally, if an unforeseen failure were to occur, the data discrepancies between the registry and the ITL can be corrected via a manual intervention function within the registry. Following this, reconciliation will be performed to validate that the data is synchronised between the registry and the ITL.
<p>Overview of security measures (including maintenance of the measures) for unauthorised manipulations and to prevent operator error</p>	<p>For the CR registry the following security measures have been taken:</p> <ul style="list-style-type: none"> - Access to the registry is via digital certificate access. This robust authentication system uses the Finnish banking system's authentication arrangements. Username and password authentication can also be acquired by contacting the registry administrator; - The actions that a user can perform are controlled by a permissions system, hence preventing unauthorised access to restricted actions; - All actions performed are recorded by audit; - Access to the servers and the database, as well as other related material, is limited to personnel members of Innofactor Ltd who have passed the safety inspection (Finnish Security Police (SUPO)). - Database manipulations can only be carried out by registry administrators from the user interface. A dedicated CR development team is available to make any further security enhancements as and when required. <p>In order to prevent operator error, the registry software incorporates the following design:</p> <ul style="list-style-type: none"> - Validation of all user inputs to ensure that only valid details are submitted for processing; the procedures are regularly reviewed and maintained where necessary. One example of the maintenance measures taken is the recent introduction of the safety inspection (Finnish Security Police (SUPO)) for personnel working with the registry and who have

	access to the registry servers.
List of information publicly accessible through the user interface of the registry	<p>The following information is publicly accessible through the user interface at present:</p> <p><u>Public information required by Decision 13/CMP.1:</u> Account information* JI projects in Finland* Holding and transaction information of units Account holders authorised to hold Kyoto units in their account</p> <p><u>Public information required by Commission regulation (EC) No 2216/2004 (in addition to the above-mentioned public information):</u> Installation and permit details* Information about verified emissions, surrenders and compliance status of installations National allocation plan for Finland (NAP) Registry fees Kyoto units that can be held in the accounts</p> <p><u>Other public information:</u> Allocated allowances vs. verified emissions (in Finnish only) Approvals and authorisations concerning JI projects given by the Ministry of the Environment (in Finnish only) Approvals and authorisations concerning CDM projects given by the Ministry for Foreign Affairs of Finland (in Finnish only) * Accessible through the interface of the registry.</p>
Internet address of the interface	https://www.paastokaupparekisteri.fi
Measures to safeguard, maintain and recover data to ensure the integrity of data storage and the recovery of registry services in the event of a disaster	<p>In the event of a serious malfunction the following recovery procedures have been incorporated in the design of the registry system:</p> <ul style="list-style-type: none"> - Locally information in the database is held over a raid-array structure with automatic error detection and recovery. Therefore, any single database failure would be alerted and the registry would automatically switch over to use information from the remaining uncorrupted databases; <p>Data is also archived every 24 hours to an off-site recovery location, and this will also be used for taking over the live registry in the event that the main site becomes inoperable. This will then be followed by the reconciliation (with the ITL) and manual intervention processes in order to check for any inconsistencies that may exist in the registry and to restore data as needed. The recovery location for taking over the live registry is not yet operational but will be in the near future.</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 the Annex 7.

15 Information on minimization of adverse impacts in accordance with Article 3, paragraph 14

Finland strives to implement its commitments under the Kyoto Protocol in such a way that social, environmental and economic impacts on other Parties of the protocol, and developing countries in particular, are minimised. It takes into account the available knowledge on and understanding of possible impacts of its anticipated measures, based on information received from other Parties. At the same time, it keeps in mind the need to achieve the ultimate objective of the Climate Convention and the need for developed countries to lead in combating climate change and its adverse effects.

A summary of how Finland gives priority to the actions specified in Decision 15/CMP.1, paragraph 24 is given in Table 15.1-1 below. This and relevant complementary information is also provided in Finland's Fifth National Communication under the UNFCCC and Kyoto Protocol (especially Chapters 4 and 7).

Table 15.1-1 Summary of specific actions to minimise the adverse impact of response measures in developing countries.

Action	Implementation in Finnish policy
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.	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.
Removing subsidies associated with the use of environmentally unsound and unsafe technologies.	No subsidies for environmentally unsound and unsafe technologies have been identified.
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.
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 enhancing technologies that emit less greenhouse gases, with main focus on increased energy efficiency and promotion of renewable energy. Some examples are listed below.</p> <p>The two-phase energy auditing project in Vietnam aims to highlight the importance of energy auditing as a tool to increase energy efficiency and achieve savings. The objective of the first phase of the project was to identify the potential for improving energy efficiency in certain sectors in Vietnam. The second phase aims to build capacities of the authorities and professionals for carrying out energy audits, and to perform pilot audits in industry, building and transport sectors. The overall objectives of the project are to help Vietnam to strengthen the Vietnamese national policy framework and integrate energy efficiency and renewable energy use into national sustainable energy strategies, and to enhance national capacity for energy auditing and for implementing cost-effective measures.</p> <p>Finland supports district heating projects in China by providing interest subsidies to Concessional Credit Projects. The objective of these projects is to increase</p>

Action	Implementation in Finnish policy
	<p>energy efficiency and to reduce emissions from heat production by introducing centralised combined heat and power (CHP) generation and modern heat distribution systems.</p> <p>With Concessional Credit Projects in Vietnam the distribution of electricity is improved by optimising distribution voltages and by introducing distribution automation.</p>
Strengthening the capacity of developing country Parties identified in Article 4, paragraphs 8 and 9, of the Convention for improving efficiency in upstream and downstream activities relating to fossil fuels, taking into consideration the need to improve the environmental efficiency of these activities.	Finnish development policy supports low carbon development paths in developing countries. Finland has started to prepare guidelines for this purpose.
Assisting developing country Parties which 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> <p>The Energy and Environment Partnership with Central America (EEP), launched during the United Nations World Summit on Sustainable Development in 2002 by the Government of Finland and the Central American partner countries, is based on efficient, project-centred operating principles. Following the evaluation of the first phase of the project (2003-2005), the Finnish Ministry for Foreign Affairs has continued the funding of the project for the 2006-2009 period, and has allocated a total of EUR 7 million for the purpose. Austria joined the EEP in 2007, contributing a significant addition to the public financing of the partnership. The Dominican Republic joined in 2007, bringing the number of Central American partner countries up to eight. The recent second evaluation proposes that funding be continued for the next three-year period.</p> <p>Within the collaborative framework, partial funding has thus far been granted to 189 projects. These include research projects, such as feasibility studies, and pilot and demonstration schemes in all the main fields of renewable energy production, and in all the Central American partner countries. The projects have been developed by private and governmental organisations including, for example, companies and research institutes.</p> <p>Biannual thematic seminars, taking place in Central America, represent another aspect of the partnership. In the field of renewable energies, these have become perhaps the most important events in Central America. The seminars have brought together a significant number of private sector, governmental and non-governmental actors and organisations and served to increase awareness of the potential of renewable energy sources. So far, 13 such events have been organised, with more</p>

Action	Implementation in Finnish policy
	<p>than 2500 participants.</p> <ul style="list-style-type: none"> • The partnership is open to other European donors • The operating principles and the strategic foci of the partnership will be developed further, based on the practical experience gained and recommendations made by the evaluation • The thematic forums on renewable energies will be continued on a biannual basis • Cooperation with other EU renewable energy programmes and initiatives will be continued to the extent that provides benefits to the parties, and that promotes further cooperation • The Finnish Ministry for Foreign Affairs is currently in negotiations with the Central American Bank for Economic Integration (CABEI), with the aim of establishing a partial risk guarantee-facility for small and medium-sized enterprises • Finland is investigating the possibility of replicating the partnership model in other regions in Asia, Africa and Latin America.

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ANNEXES TO THE NATIONAL INVENTORY REPORT

ANNEX 1. Key categories

This annex contains the detailed information on key categories (for an overview refers Section 1.5 above). The following tables are provided:

- Tier 2 level assessment year 1990
- Tier 2 level assessment year 2008
- Tier 2 trend assessment including LULUCF
- Tier 2 trend assessment excluding LULUCF.

The tables follow the format and methodology (Tier 2) suggested in IPCC (2000, 2003). Uncertainty estimates used in the analysis can be found in Annex 6 of the present report. The level of disaggregation is discussed in Section 1.5 above and is shown in the following tables.

Tier 2 level assessment year 1990

A IPCC greenhouse gas source and sink categories	B Direct greenhouse gas ¹⁾	1990 estimate, non-LULUCF	1990 estimate, LULUCF	C Tier 2 level assessment	D' Normalised tier 2 level assessment, without LULUCF	E' Cumulative total of column D'	D Normalised tier 2 level assessment, with LULUCF	E Cumulative total of column D (additional LULUCF sources)
Sum		70356.74	..	0.377	1.000		1.000	
5.A.1. Forest Land remaining Forest Land - net carbon stock change in organic soils	CO2	..	12023.92	0.074	..	..	0.197	0.197
5.A.1. Forest Land remaining Forest Land - net carbon stock change in living biomass	CO2	..	-25438.37	0.067	..	..	0.176	0.373
5.A.1. Forest Land remaining Forest Land - net carbon stock change in mineral soils	CO2	..	-7742.46	0.056	..	..	0.150	0.523
5.B.1. Cropland Remaining Cropland - net carbon stock change in organic soils	CO2	..	5295.69	0.039	..	..	0.103	0.626
4.D.Agricultural soils: direct emissions, animal production and sludge spreading	N2O	3262.51	..	0.018	0.171	0.171	0.049	0.674
4.D.Agricultural soils: indirect emissions	N2O	711.72	..	0.014	0.131	0.301	0.037	0.711
2.B.2 Nitric Acid Production	N2O	1655.71	..	0.013	0.123	0.424	0.035	0.746
6.A. Solid Waste disposal on Land	CH4	3635.31	..	0.012	0.116	0.539	0.033	0.779
1.A. Fuel Combustion - solid fuels	CO2	14530.47	..	0.012	0.109	0.648	0.031	0.810
5.A.2. Cropland converted to Forest Land - net carbon stock change in organic soils	CO2	..	335.28	0.008	..	0.648	0.021	0.831
1.A. Fuel Combustion - liquid fuels	CO2	27779.60	..	0.006	0.058	0.706	0.017	0.848
4.A.Enteric fermentation	CH4	1918.96	..	0.005	0.046	0.752	0.013	0.861
5.B.1. Cropland Remaining Cropland - net carbon stock change in mineral soils	CO2	..	-419.37	0.003	..	0.752	0.009	0.869
4.B.Manure management	CH4	489.94	..	0.003	0.030	0.782	0.008	0.878
1.A. Fuel Combustion - other fuels	CO2	5693.53	..	0.003	0.028	0.809	0.008	0.886
1.A.3.b. Road Transportation - gasoline - cars with catalytic converters	N2O	88.14	..	0.003	0.025	0.834	0.007	0.893
5.A.2. Settlements converted to Forest Land - net carbon stock change in mineral soils	CO2	..	-109.78	0.003	..	0.834	0.007	0.900
5.C.3. Cropland converted to Grassland - net carbon stock change in mineral soils	CO2	..	-323.94	0.003	..	0.834	0.007	0.907
5.A.2. Wetlands converted to Forest Land / drained-WL - organic soils	CO2	..	104.52	0.002	..	0.834	0.007	0.913
5.A.2. Cropland converted to Forest Land - net carbon stock change in living biomass	CO2	..	-570.90	0.002	..	0.834	0.006	0.919
6.B.2 Domestic and Commercial Wastewater - densely populated areas	CH4	74.79	..	0.002	0.021	0.855	0.006	0.925
1.A.5 Other - other fuels (mostly indirect N2O from NOx)	N2O	439.27	..	0.002	0.020	0.875	0.006	0.931
5.A.2. Cropland converted to Forest Land - net carbon stock change in mineral soils	CO2	..	88.44	0.002	..	0.875	0.006	0.936
1.A.4. Other Sectors - biomass	CH4	161.28	..	0.002	0.018	0.893	0.005	0.941
5.A.2. Grassland converted to Forest Land - net carbon stock change in organic soils	CO2	..	-68.63	0.002	..	0.893	0.004	0.946
5.B.2 Forest Land converted to Cropland / organic soils - net carbon stock change in organic soils	CO2	..	200.51	0.002	..	0.893	0.004	0.950
5.D.2. Land Converted to Wetlands - peat extraction	CO2, CH4, N2O	..	1010.55	0.002	..	0.893	0.004	0.954
2.C.1 Iron and Steel production	CO2	1935.18	..	0.002	0.014	0.907	0.004	0.958
5 (IV) CO2 Emissions from Agricultural Lime Application (5.B)	CO2	..	617.87	0.001	..	0.907	0.004	0.962
6.B.2 Domestic and Commercial Wastewater - sparsely populated areas	CH4	30.55	..	0.001	0.009	0.916	0.002	0.964

A IPCC greenhouse gas source and sink categories	B			C	D ^a	E ^a	D	E
	Direct greenhouse gas ^{b)}	1990 estimate, non-LULUCF	1990 estimate, LULUCF	Tier 2 level assessment	Normalised tier 2 level assessment, without LULUCF	Cumulative total of column D ^a	Normalised tier 2 level assessment, with LULUCF	Cumulative total of column D (additional LULUCF sources)
6.B.3. N input from industrial wastewater	N2O	30.17	..	0.001	0.008	0.924	0.002	0.967
5.A.2. Grassland converted to Forest Land - net carbon stock change in living biomass	CO2	..	-219.95	0.001	..	0.924	0.002	0.969
1.A.3.b. Road Transportation - diesel	CH4	68.12	..	0.001	0.008	0.932	0.002	0.971
5.G Other (harvested wood products)	CO2	..	-945.64	0.001	..	0.932	0.002	0.974
5 (I) Direct N2O Emissions from N Fertilization (5.A)	N2O	..	26.82	0.001	..	0.932	0.002	0.976
2.F.8 Electrical Equipment	SF6	86.52	..	0.001	0.006	0.938	0.002	0.977
1.A. Fuel Combustion - gaseous fuels	CO2	4970.23	..	0.001	0.005	0.943	0.001	0.979
5.A.2. Grassland converted to Forest Land - net carbon stock change in mineral soils	CO2	..	23.14	0.001	..	0.943	0.001	0.980
1.B.2. Oil and Natural Gas - flaring	N2O	121.93	..	0.000	0.005	0.948	0.001	0.981
5.B.2 Forest Land converted to Cropland / mineral soils - net carbon stock change in mineral soils	CO2	..	47.74	0.000	..	0.948	0.001	0.982
1.A.4. Other Sectors - liquid fuels	CH4	56.43	..	0.000	0.003	0.951	0.001	0.983
1.A.4. Other Sectors - biomass	N2O	27.77	..	0.000	0.003	0.954	0.001	0.984
6.B.2 Domestic and Commercial Wastewater - sparsely populated areas	N2O	114.23	..	0.000	0.003	0.957	0.001	0.985
5.B.3 Wetlands converted to Cropland - net carbon stock change in organic soils	CO2	..	39.77	0.000	..	0.957	0.001	0.986
2.A.1 Cement Production	CO2	733.59	..	0.000	0.003	0.960	0.001	0.987
1.A.3.b. Road Transportation - gasoline	CH4	77.85	..	0.000	0.003	0.963	0.001	0.988
4.B.Manure management	N2O	230.40	..	0.000	0.003	0.965	0.001	0.988
1.A.2. Manufacturing Industries and Construction - biomass	CH4	56.43	..	0.000	0.003	0.968	0.001	0.989
6.B.3. N input from Fish Farming	N2O	8.28	..	0.000	0.002	0.970	0.001	0.990
1.A.2. Manufacturing Industries and Construction - solid fuels	CH4	46.74	..	0.000	0.002	0.972	0.001	0.990
1.A.1 Energy Industries - solid fuels	CH4	43.40	..	0.000	0.002	0.974	0.001	0.991
6.B.1 Industrial Wastewater	CH4	22.23	..	0.000	0.002	0.976	0.000	0.991
3. Solvent and Other Product Use	N2O	62.00	..	0.000	0.002	0.978	0.000	0.992
1.A.2. Manufacturing Industries and Construction - liquid fuels	CH4	36.75	..	0.000	0.002	0.979	0.000	0.992
5.C.1. Grassland Remaining Grassland - net carbon stock change in mineral soils	CO2	..	21.12	0.000	..	0.979	0.000	0.993
1.A.1 Energy Industries - other fuels	CH4	34.64	..	0.000	0.002	0.981	0.000	0.993
5.C.3. Cropland converted to Grassland - net carbon stock change in organic soils	CO2	..	19.48	0.000	..	0.981	0.000	0.994
6.B.2 Domestic and Commercial Wastewater - densely populated areas	N2O	17.07	..	0.000	0.001	0.982	0.000	0.994
5.C.1. Grassland Remaining Grassland - net carbon stock change in organic soils	CO2	..	18.72	0.000	..	0.982	0.000	0.994
1.A.1 Energy Industries - liquid fuels	CH4	25.03	..	0.000	0.001	0.983	0.000	0.995
2.A.2 Lime Production	CO2	382.60	..	0.000	0.001	0.984	0.000	0.995
1.A.4. Other Sectors - liquid fuels	N2O	18.18	..	0.000	0.001	0.985	0.000	0.995
3. Solvent and Other Product Use (indirect CO2 from NMVOC)	CO2	116.37	..	0.000	0.001	0.986	0.000	0.996
6.D Other: compost production	CH4	21.55	..	0.000	0.001	0.987	0.000	0.996
5.A.2. Wetlands converted to Forest Land / drained-WL - biomass	CO2	..	-24.52	0.000	..	0.987	0.000	0.996
6.D Other: compost production	N2O	20.43	..	0.000	0.001	0.988	0.000	0.996
1.B.2. Oil and Natural Gas - other (indirect CO2 from	CO2	95.45	..	0.000	0.001	0.989	0.000	0.997

A IPCC greenhouse gas source and sink categories	B Direct greenhouse gas ¹⁾	1990 estimate, non-LULUCF	1990 estimate, LULUCF	C Tier 2 level assessment	D ²⁾ Normalised tier 2 level assessment, without LULUCF	E ³⁾ Cumulative total of column D ²⁾	D Normalised tier 2 level assessment, with LULUCF	E Cumulative total of column D (additional LULUCF sources)
NMVOG)								
1.A.2. Manufacturing Industries and Construction - other fuels	CH4	17.01	..	0.000	0.001	0.990	0.000	0.997
2.A.3 Limestone and Dolomite Use	CO2	88.00	..	0.000	0.001	0.990	0.000	0.997
1.A.3.b. Road Transportation - gasoline - cars without catalytic converters	N2O	3.67	..	0.000	0.001	0.991	0.000	0.997
1.A.1 Energy Industries - gaseous fuels	CH4	15.63	..	0.000	0.001	0.992	0.000	0.997
1.A.2. Manufacturing Industries and Construction - gaseous fuels	CH4	15.26	..	0.000	0.001	0.992	0.000	0.998
2.B.1 Ammonia Production	CO2	44.00	..	0.000	0.001	0.993	0.000	0.998
2.B.5 Other: Hydrogen Production	CO2	56.94	..	0.000	0.001	0.994	0.000	0.998
1.A.3.a Civil Aviation	CH4	4.86	..	0.000	0.001	0.994	0.000	0.998
1.B.2. Oil and Natural Gas - oil refining	CH4	7.56	..	0.000	0.001	0.995	0.000	0.998
1.A.3.e. Other Transportation - diesel	N2O	3.84	..	0.000	0.000	0.995	0.000	0.998
1.A.3.b. Road Transportation - diesel	N2O	11.47	..	0.000	0.000	0.996	0.000	0.998
1.A.5. Other - liquid fuels	CH4	8.89	..	0.000	0.000	0.996	0.000	0.999
1.A.3.d Navigation - gasoline	CH4	4.13	..	0.000	0.000	0.996	0.000	0.999
1.A.2. Manufacturing Industries and Construction - biomass	N2O	6.80	..	0.000	0.000	0.997	0.000	0.999
1.A.3.d Navigation - residual oil & gas/diesel oil	CH4	2.56	..	0.000	0.000	0.997	0.000	0.999
5.B N2O emissions from disturbance associated with land-use conversion to cropland	N2O	..	3.70	0.000	..	0.997	0.000	0.999
5.A.2. Settlements converted to Forest Land - net carbon stock change in living biomass	CO2	..	-6.39	0.000	..	0.997	0.000	0.999
2.F.9 Other (grouped data)	HFCs, PFCs, SF6	7.94	..	0.000	0.000	0.997	0.000	0.999
5 (V) Biomass Burning (5.A)	CH4	..	4.06	0.000	..	0.997	0.000	0.999
5 (V) Biomass Burning (5.A)	CO2	..	3.86	0.000	..	0.997	0.000	0.999
2.B.5 Other: Chemicals Production (indirect CO2 from NMVOG)	CO2	24.41	..	0.000	0.000	0.997	0.000	0.999
1.A.3.e. Other Transportation - gasoline & diesel	CH4	4.61	..	0.000	0.000	0.997	0.000	0.999
1.B.2. Oil and Natural Gas - flaring	CH4	3.13	..	0.000	0.000	0.998	0.000	0.999
2.A.7 Other - Glass Production	CO2	20.80	..	0.000	0.000	0.998	0.000	0.999
2.A.6 Road Paving with Asphalt	CO2	21.00	..	0.000	0.000	0.998	0.000	0.999
1.A.3.c. Railways	CH4	1.51	..	0.000	0.000	0.998	0.000	0.999
1.A.4. Other Sectors - other fuels	CH4	1.47	..	0.000	0.000	0.998	0.000	0.999
1.A.1 Energy Industries - biomass	CH4	3.07	..	0.000	0.000	0.998	0.000	0.999
1.A.4. Other Sectors - solid fuels	CH4	2.34	..	0.000	0.000	0.999	0.000	1.000
5.A.2. Settlements converted to Forest Land - net carbon stock change in organic soils	CO2	..	0.55	0.000	..	0.999	0.000	1.000
1.A.2. Manufacturing Industries and Construction - liquid fuels	N2O	2.54	..	0.000	0.000	0.999	0.000	1.000
1.A.1 Energy Industries - other fuels	N2O	2.47	..	0.000	0.000	0.999	0.000	1.000
1.A.5. Other - liquid fuels	N2O	2.35	..	0.000	0.000	0.999	0.000	1.000
1.A.1 Energy Industries - solid fuels	N2O	2.29	..	0.000	0.000	0.999	0.000	1.000
2.C.1 Iron and Steel production	CO2	5.1135	..	0.000	0.000	0.999	0.000	1.000
1.A.3.e. Other Transportation - gasoline	N2O	0.63	..	0.000	0.000	0.999	0.000	1.000
1.A.1 Energy Industries - biomass	N2O	1.51	..	0.000	0.000	0.999	0.000	1.000

A IPCC greenhouse gas source and sink categories	B Direct greenhouse gas ¹⁾	1990 estimate, non-LULUCF	1990 estimate, LULUCF	C Tier 2 level assessment	D ²⁾ Normalised tier 2 level assessment, without LULUCF	E ³⁾ Cumulative total of column D ²⁾	D Normalised tier 2 level assessment, with LULUCF	E Cumulative total of column D (additional LULUCF sources)
1.B.2. Oil and Natural Gas - oil refining (indirect CO2 from CH4)	CO2	1.00	..	0.000	0.000	0.999	0.000	1.000
1.A.2. Manufacturing Industries and Construction - solid fuels	N2O	1.37	..	0.000	0.000	0.999	0.000	1.000
5.B.1. Cropland Remaining Cropland - net carbon stock change in living biomass	CO2	..	-1.44	0.000	..	0.999	0.000	1.000
1.A.4. Other Sectors - other fuels	N2O	1.24	..	0.000	0.000	0.999	0.000	1.000
1.A.2. Manufacturing Industries and Construction - other fuels	N2O	1.08	..	0.000	0.000	0.999	0.000	1.000
1.A.1 Energy Industries - gaseous fuels	N2O	1.03	..	0.000	0.000	1.000	0.000	1.000
2.A.4 Soda Ash Use	CO2	8.32	..	0.000	0.000	1.000	0.000	1.000
1.A.2. Manufacturing Industries and Construction - gaseous fuels	N2O	1.01	..	0.000	0.000	1.000	0.000	1.000
1.A.1 Energy Industries - liquid fuels	N2O	0.97	..	0.000	0.000	1.000	0.000	1.000
5.C.2. Forest Land converted to Grassland - net carbon stock change in mineral soils	CO2	..	0.53	0.000	..	1.000	0.000	1.000
1.A.3.d Navigation - gasoline	N2O	0.33	..	0.000	0.000	1.000	0.000	1.000
4.F Field Burning of Agricultural Residues	CH4	1.88	..	0.000	0.000	1.000	0.000	1.000
1.A.3.e. Other Transportation - LPG	CH4	0.29	..	0.000	0.000	1.000	0.000	1.000
1.A.3.d Navigation - residual oil & gas/diesel oil	N2O	0.43	..	0.000	0.000	1.000	0.000	1.000
1.A.4. Other Sectors - solid fuels	N2O	0.59	..	0.000	0.000	1.000	0.000	1.000
1.A.4. Other Sectors - gaseous fuels	CH4	0.59	..	0.000	0.000	1.000	0.000	1.000
5 (V) Biomass Burning (5.A)	N2O	..	0.41	0.000	..	1.000	0.000	1.000
1.A.3.a Civil Aviation	N2O	0.27	..	0.000	0.000	1.000	0.000	1.000
1.A.3.c. Railways	N2O	0.23	..	0.000	0.000	1.000	0.000	1.000
1.A.3.e. Other Transportation - LPG	N2O	0.39	..	0.000	0.000	1.000	0.000	1.000
1.A.5. Other - gaseous fuels	CH4	0.31	..	0.000	0.000	1.000	0.000	1.000
1.A.4. Other Sectors - gaseous fuels	N2O	0.22	..	0.000	0.000	1.000	0.000	1.000
5.B.2 Forest Land converted to Cropland / mineral soils - net carbon stock change in living biomass	CO2	..	-0.46	0.000	..	1.000	0.000	1.000
1.A.5. Other - other fuels	CH4	0.24	..	0.000	0.000	1.000	0.000	1.000
1.A.5. Other - biomass	CH4	0.22	..	0.000	0.000	1.000	0.000	1.000
1.A.5. Other - biomass	N2O	0.20	..	0.000	0.000	1.000	0.000	1.000
1.B.2. Oil and Natural Gas - gas transmission (indirect CO2 from CH4)	CO2	0.47	..	0.000	0.000	1.000	0.000	1.000
4.F Field Burning of Agricultural Residues	N2O	0.55	..	0.000	0.000	1.000	0.000	1.000
1.B.2. Oil and Natural Gas - gas transmission	CH4	3.57	..	0.000	0.000	1.000	0.000	1.000
1.A.5. Other - other fuels	N2O	0.15	..	0.000	0.000	1.000	0.000	1.000
1.B.2. Oil and Natural Gas - flaring	CO2	0.11	..	0.000	0.000	1.000	0.000	1.000
5.B.2 Forest Land converted to Cropland / organic soils - net carbon stock change in living biomass	CO2	..	-0.20	0.000	..	1.000	0.000	1.000
2.C.5 Other: Non-ferrous metals (indirect CO2 from NMVOC)	CO2	0.44	..	0.000	0.000	1.000	0.000	1.000
1.A.5. Other - gaseous fuels	N2O	0.06	..	0.000	0.000	1.000	0.000	1.000
5.C.2. Forest Land converted to Grassland - net carbon stock change in living biomass	CO2	..	-0.06	0.000	..	1.000	0.000	1.000
1.A.5. Other - solid fuels	CH4	0.01	..	0.000	0.000	1.000	0.000	1.000
2.F.1. Refrigeration and Air Conditioning Equipment	HFCs, PFCs	0.01	..	0.000	0.000	1.000	0.000	1.000
1.A.5. Other - solid fuels	N2O	0.00	..	0.000	0.000	1.000	0.000	1.000
1.A.3.b. Road Transportation - biomass	CH4	0.00	..	0.000	0.000	1.000	0.000	1.000

A IPCC greenhouse gas source and sink categories	B			C	D ¹	E ¹	D	E
	Direct greenhouse gas ¹⁾	1990 estimate, non-LULUCF	1990 estimate, LULUCF	Tier 2 level assessment	Normalised tier 2 level assessment, without LULUCF	Cumulative total of column D ¹	Normalised tier 2 level assessment, with LULUCF	Cumulative total of column D (additional LULUCF sources)
1.A.3.b. Road Transportation - biomass	N2O	0.00	..	0.000	0.000	1.000	0.000	1.000
1.A.3.b. Road Transportation - natural gas	CH4	0.00	..	0.000	0.000	1.000	0.000	1.000
1.A.3.b. Road Transportation - natural gas	N2O	0.00	..	0.000	0.000	1.000	0.000	1.000
1.B.2. Oil and Natural Gas - gas distribution	CH4	0.00	..	0.000	0.000	1.000	0.000	1.000
1.B.2. Oil and Natural Gas - gas distribution (indirect CO2 from CH4)	CO2	0.00	..	0.000	0.000	1.000	0.000	1.000
2.F.2 Foam Blowing	HFCs	0.00	..	0.000	0.000	1.000	0.000	1.000
2.F.4 Aerosols	HFCs	0.00	..	0.000	0.000	1.000	0.000	1.000
5.A.2. Wetlands converted to Forest Land / peat extraction - biomass	CO2	..	0.00	0.000	..	1.000	0.000	1.000
5.A.2. Wetlands converted to Forest Land / peat extraction - organic soils	CO2	..	0.00	0.000	..	1.000	0.000	1.000
5.B.2 Grassland converted to Cropland - net carbon stock change in mineral soils	CO2	..	0.00	0.000	..	1.000	0.000	1.000
5.C.2. Forest Land converted to Grassland - net carbon stock change in organic soils	CO2	..	0.00	0.000	..	1.000	0.000	1.000

¹⁾ Gases have been combined to protect confidential information (category 2.G), and to remove correlations (category 5.D.2).

Tier 2 level assessment year 2008

A IPCC greenhouse gas source and sink categories	B			C	D'	E'	D	E
	Direct greenhouse gas ¹⁾	2008 estimate, non-LULUCF	2008 estimate, LULUCF	Tier 2 level assessment	Normalised tier 2 level assessment, without LULUCF	Cumulative total of column D'	Normalised tier 2 level assessment, with LULUCF	Cumulative total of column D (additional LULUCF sources)
Sum		70138.716	-35393.837	0.365	1.000		1.000	
5.A.1. Forest Land remaining Forest Land - net carbon stock change in living biomass	CO2	..	-37321.830	0.092	..	..	0.252	0.252
5.A.1. Forest Land remaining Forest Land - net carbon stock change in mineral soils	CO2	..	-9429.713	0.065	..	..	0.178	0.430
5.B.1. Cropland Remaining Cropland - net carbon stock change in organic soils	CO2	..	5347.739	0.037	..	..	0.101	0.531
5.A.1. Forest Land remaining Forest Land - net carbon stock change in organic soils	CO2	..	5948.433	0.035	..	..	0.095	0.626
4.D.Agricultural soils: direct emissions, animal production and sludge spreading	N2O	2989.437	..	0.016	0.176	0.176	0.043	0.669
5.A.2. Settlements converted to Forest Land - net carbon stock change in mineral soils	CO2	..	-545.380	0.012	..	0.176	0.033	0.702
2.B.2 Nitric Acid Production	N2O	1560.532	..	0.012	0.130	0.307	0.032	0.734
4.D.Agricultural soils: indirect emissions	N2O	578.628	..	0.011	0.120	0.426	0.029	0.764
1.A. Fuel Combustion - solid fuels	CO2	12189.766	..	0.009	0.103	0.529	0.025	0.789
5.B.1. Cropland Remaining Cropland - net carbon stock change in mineral soils	CO2	..	-984.827	0.007	..	0.529	0.020	0.809
6.A. Solid Waste disposal on Land	CH4	1853.157	..	0.006	0.066	0.596	0.016	0.825
1.A. Fuel Combustion - liquid fuels	CO2	24209.689	..	0.005	0.057	0.653	0.014	0.839
5.A.2. Wetlands converted to Forest Land / drained-WL - organic soils	CO2	..	218.500	0.005	..	0.653	0.013	0.853
1.A. Fuel Combustion - other fuels	CO2	8865.797	..	0.004	0.049	0.701	0.012	0.865
4.A.Enteric fermentation	CH4	1556.593	..	0.004	0.042	0.743	0.010	0.875
5.A.2. Grassland converted to Forest Land - net carbon stock change in organic soils	CO2	..	-154.411	0.003	..	0.743	0.009	0.885
5.B.2 Forest Land converted to Cropland / organic soils - net carbon stock change in organic soils	CO2	..	387.900	0.003	..	0.743	0.008	0.892
4.B.Manure management	CH4	287.505	..	0.003	0.029	0.772	0.007	0.900
5.A.2. Cropland converted to Forest Land - net carbon stock change in organic soils	CO2	..	110.807	0.002	..	0.772	0.007	0.906
1.A.4. Other Sectors - biomass	CH4	206.182	..	0.002	0.026	0.798	0.006	0.913
5.A.2. Grassland converted to Forest Land - net carbon stock change in living biomass	CO2	..	-555.185	0.002	..	0.798	0.006	0.918
5.D.2. Land Converted to Wetlands - peat extraction	CO2, CH4, N2O	..	1308.350	0.002	..	0.798	0.005	0.924
2.C.1 Iron and Steel production	CO2	2523.30	..	0.002	0.021	0.819	0.005	0.929
2.F.1. Refrigeration and Air Conditioning Equipment	HFCs, PFCs	912.505	..	0.002	0.020	0.839	0.005	0.934
6.B.2 Domestic and Commercial Wastewater - densely populated areas	CH4	11.304	..	0.002	0.017	0.856	0.004	0.938
1.A.3.b. Road Transportation - gasoline - cars with catalytic converters	N2O	54.909	..	0.002	0.017	0.873	0.004	0.942
5.A.2. Grassland converted to Forest Land - net carbon stock change in mineral soils	CO2	..	67.503	0.002	..	0.873	0.004	0.946
5.B.3 Wetlands converted to Cropland - net carbon stock change in organic soils	CO2	..	192.189	0.001	..	0.873	0.004	0.950
1.A.3.b. Road Transportation - diesel	N2O	100.83	..	0.001	0.013	0.887	0.003	0.954
1.A.5 Other - other fuels (mostly indirect N2O from NOx)	N2O	250.790	..	0.001	0.013	0.899	0.003	0.957
5.A.2. Cropland converted to Forest Land - net	CO2	..	-294.081	0.001	..	0.899	0.003	0.960

A IPCC greenhouse gas source and sink categories	B Direct greenhouse gas ¹⁾	2008 estimate, non-LULUCF	2008 estimate, LULUCF	C Tier 2 level assessment	D ¹ Normalised tier 2 level assessment, without LULUCF	E ¹ Cumulative total of column D ¹	D Normalised tier 2 level assessment, with LULUCF	E Cumulative total of column D (additional LULUCF sources)
<i>carbon stock change in living biomass</i>								
5.A.2. Cropland converted to Forest Land - net carbon stock change in mineral soils	CO2	..	48.400	0.001	..	0.899	0.003	0.963
5 (I) Direct N2O Emissions from N Fertilization (5.A)	N2O	..	35.428	0.001	..	0.899	0.003	0.965
1.A. Fuel Combustion - gaseous fuels	CO2	8279.347	..	0.001	0.010	0.909	0.002	0.968
6.B.2 Domestic and Commercial Wastewater - sparsely populated areas	CH4	91.460	..	0.001	0.008	0.917	0.002	0.970
5.C.3. Cropland converted to Grassland - net carbon stock change in mineral soils	CO2	..	-84.113	0.001	..	0.917	0.002	0.972
2.B.5 Other: Hydrogen Production	CO2	648.178	..	0.001	0.007	0.924	0.002	0.973
5 (IV) CO2 Emissions from Agricultural Lime Application (5.B)	CO2	..	289.520	0.001	..	0.924	0.002	0.975
5.A.2. Wetlands converted to Forest Land / peat extraction - organic soils	CO2	..	24.603	0.001	..	0.924	0.002	0.976
6.B.3. N input from industrial wastewater	N2O	19.306	..	0.001	0.006	0.930	0.002	0.978
5.B.2 Forest Land converted to Cropland / mineral soils - net carbon stock change in mineral soils	CO2	..	61.537	0.000	..	0.930	0.001	0.979
1.A.1 Energy Industries - other fuels	CH4	5.810	..	0.000	0.005	0.935	0.001	0.980
1.A.1 Energy Industries - biomass	CH4	8.016	..	0.000	0.004	0.940	0.001	0.982
1.A.4. Other Sectors - biomass	N2O	33.981	..	0.000	0.004	0.944	0.001	0.983
5.C.1. Grassland Remaining Grassland - net carbon stock change in organic soils	CO2	..	52.840	0.000	..	0.944	0.001	0.984
1.B.2. Oil and Natural Gas - flaring	N2O	0.689	..	0.000	0.004	0.948	0.001	0.985
1.A.2. Manufacturing Industries and Construction - biomass	CH4	7.978	..	0.000	0.004	0.952	0.001	0.986
4.B. Manure management	N2O	420.895	..	0.000	0.004	0.956	0.001	0.987
1.A.1 Energy Industries - solid fuels	CH4	2.184	..	0.000	0.003	0.959	0.001	0.987
6.D Other: compost production	CH4	59.736	..	0.000	0.003	0.962	0.001	0.988
2.A.1 Cement Production	CO2	638.298	..	0.000	0.003	0.965	0.001	0.989
6.D Other: compost production	N2O	58.863	..	0.000	0.003	0.968	0.001	0.989
6.B.2 Domestic and Commercial Wastewater - sparsely populated areas	N2O	25.757	..	0.000	0.003	0.970	0.001	0.990
5.A.2. Wetlands converted to Forest Land / drained-WL - biomass	CO2	..	-59.561	0.000	..	0.970	0.001	0.991
1.A.4. Other Sectors - liquid fuels	CH4	10.875	..	0.000	0.002	0.973	0.001	0.991
6.B.1 Industrial Wastewater	CH4	24.028	..	0.000	0.002	0.975	0.001	0.992
5.B.2 Grassland converted to Cropland - net carbon stock change in mineral soils	CO2	..	23.031	0.000	..	0.975	0.000	0.992
5.C.1. Grassland Remaining Grassland - net carbon stock change in mineral soils	CO2	..	22.363	0.000	..	0.975	0.000	0.993
1.A.1 Energy Industries - gaseous fuels	CH4	4.619	..	0.000	0.002	0.976	0.000	0.993
1.A.2. Manufacturing Industries and Construction - liquid fuels	CH4	2.307	..	0.000	0.001	0.978	0.000	0.993
2.A.2 Lime Production	CO2	439.452	..	0.000	0.001	0.979	0.000	0.994
5.A.2. Settlements converted to Forest Land - net carbon stock change in living biomass	CO2	..	-29.403	0.000	..	0.979	0.000	0.994
1.A.1 Energy Industries - liquid fuels	CH4	0.883	..	0.000	0.001	0.980	0.000	0.994
2.A.3 Limestone and Dolomite Use	CO2	125.320	..	0.000	0.001	0.982	0.000	0.995
6.B.3. N input from Fish Farming	N2O	3.376	..	0.000	0.001	0.983	0.000	0.995
2.F.9 Other (grouped data)	HFCs, PFCs, SF6	33.287	..	0.000	0.001	0.984	0.000	0.995

A IPCC greenhouse gas source and sink categories	B Direct greenhouse gas ¹⁾	2008 estimate, non-LULUCF	2008 estimate, LULUCF	C Tier 2 level assessment	D ¹ Normalised tier 2 level assessment, without LULUCF	E ¹ Cumulative total of column D ¹	D Normalised tier 2 level assessment, with LULUCF	E Cumulative total of column D (additional LULUCF sources)
3. Solvent and Other Product Use	N2O	34.111	..	0.000	0.001	0.985	0.000	0.995
2.F.8 Electrical Equipment	SF6	13.862	..	0.000	0.001	0.986	0.000	0.996
6.B.2 Domestic and Commercial Wastewater - densely populated areas	N2O	54.733	..	0.000	0.001	0.987	0.000	0.996
1.A.2. Manufacturing Industries and Construction - other fuels	CH4	1.209	..	0.000	0.001	0.988	0.000	0.996
1.A.3.b. Road Transportation - gasoline	CH4	21.277	..	0.000	0.001	0.989	0.000	0.996
5.G Other (harvested wood products)	CO2	..	-94.772	0.000	..	0.989	0.000	0.997
1.B.2. Oil and Natural Gas - oil refining	CH4	11.130	..	0.000	0.001	0.989	0.000	0.997
1.A.2. Manufacturing Industries and Construction - gaseous fuels	CH4	0.989	..	0.000	0.001	0.990	0.000	0.997
1.A.4. Other Sectors - liquid fuels	N2O	34.660	..	0.000	0.001	0.991	0.000	0.997
2.F.4 Aerosols	HFCs	77.370	..	0.000	0.001	0.991	0.000	0.997
5.B N2O emissions from disturbance associated with land-use conversion to cropland	N2O	..	7.325	0.000	..	0.991	0.000	0.997
5.A.2. Settlements converted to Forest Land - net carbon stock change in organic soils	CO2	..	2.053	0.000	..	0.991	0.000	0.998
1.A.2. Manufacturing Industries and Construction - solid fuels	CH4	0.519	..	0.000	0.001	0.992	0.000	0.998
1.A.3.e. Other Transportation - diesel	N2O	3.974	..	0.000	0.001	0.992	0.000	0.998
5 (V) Biomass Burning (5.A)	CH4	..	1.284	0.000	..	0.992	0.000	0.998
1.A.3.b. Road Transportation - gasoline - cars without catalytic converters	N2O	2.288	..	0.000	0.000	0.993	0.000	0.998
3. Solvent and Other Product Use (indirect CO2 from NMVOC)	CO2	51.773	..	0.000	0.000	0.993	0.000	0.998
5.C.3. Cropland converted to Grassland - net carbon stock change in organic soils	CO2	..	5.734	0.000	..	0.993	0.000	0.998
1.A.3.a Civil Aviation	CH4	0.226	..	0.000	0.000	0.994	0.000	0.998
1.A.1 Energy Industries - biomass	N2O	83.745	..	0.000	0.000	0.994	0.000	0.999
1.A.2. Manufacturing Industries and Construction - biomass	N2O	77.253	..	0.000	0.000	0.995	0.000	0.999
1.A.3.b. Road Transportation - biomass	CH4	1.001	..	0.000	0.000	0.995	0.000	0.999
1.A.3.d Navigation - residual oil & gas/diesel oil	CH4	0.487	..	0.000	0.000	0.996	0.000	0.999
1.A.5. Other - liquid fuels	CH4	1.499	..	0.000	0.000	0.996	0.000	0.999
1.B.2. Oil and Natural Gas - other (indirect CO2 from NMVOC)	CO2	33.914	..	0.000	0.000	0.996	0.000	0.999
1.A.3.e. Other Transportation - gasoline & diesel	CH4	6.111	..	0.000	0.000	0.996	0.000	0.999
1.A.1 Energy Industries - other fuels	N2O	97.568	..	0.000	0.000	0.997	0.000	0.999
1.A.3.d Navigation - gasoline	CH4	2.877	..	0.000	0.000	0.997	0.000	0.999
1.A.1 Energy Industries - gaseous fuels	N2O	35.222	..	0.000	0.000	0.997	0.000	0.999
1.A.3.b. Road Transportation - diesel	N2O	100.826	..	0.000	0.000	0.997	0.000	0.999
2.A.7 Other - Glass Production	CO2	18.611	..	0.000	0.000	0.998	0.000	0.999
1.A.4. Other Sectors - other fuels	CH4	1.149	..	0.000	0.000	0.998	0.000	0.999
2.F.2 Foam Blowing	HFCs	8.528	..	0.000	0.000	0.998	0.000	0.999
2.C.1 Iron and Steel production	CO2	2523.302	..	0.000	0.000	0.998	0.000	0.999
1.B.2. Oil and Natural Gas - gas distribution	CH4	29.400	..	0.000	0.000	0.998	0.000	0.999
5.B.1. Cropland Remaining Cropland - net carbon stock change in living biomass	CO2	..	-2.596	0.000	..	0.998	0.000	0.999
1.A.3.c. Railways	CH4	0.129	..	0.000	0.000	0.998	0.000	1.000
1.A.2. Manufacturing Industries and Construction -	N2O	27.904	..	0.000	0.000	0.999	0.000	1.000

A IPCC greenhouse gas source and sink categories	B Direct greenhouse gas ¹⁾	2008 estimate, non-LULUCF	2008 estimate, LULUCF	C Tier 2 level assessment	D ¹ Normalised tier 2 level assessment, without LULUCF	E ¹ Cumulative total of column D ¹	D Normalised tier 2 level assessment, with LULUCF	E Cumulative total of column D (additional LULUCF sources)
liquid fuels								
1.B.2. Oil and Natural Gas - oil refining (indirect CO2 from CH4)	CO2	1.458	..	0.000	0.000	0.999	0.000	1.000
1.A.1 Energy Industries - solid fuels	N2O	62.895	..	0.000	0.000	0.999	0.000	1.000
1.A.3.d Navigation - gasoline	N2O	0.846	..	0.000	0.000	0.999	0.000	1.000
5.A.2. Wetlands converted to Forest Land / peat extraction - biomass	CO2	..	-2.460	0.000	..	0.999	0.000	1.000
5.C.2. Forest Land converted to Grassland - net carbon stock change in mineral soils	CO2	..	1.179	0.000	..	0.999	0.000	1.000
1.A.3.b. Road Transportation - natural gas	CH4	2.216	..	0.000	0.000	0.999	0.000	1.000
1.B.2. Oil and Natural Gas - gas distribution (indirect CO2 from CH4)	CO2	3.900	..	0.000	0.000	0.999	0.000	1.000
1.A.3.e. Other Transportation - gasoline	N2O	0.649	..	0.000	0.000	0.999	0.000	1.000
2.B.5 Other: Chemicals Production (indirect CO2 from NMVOC)	CO2	8.465	..	0.000	0.000	0.999	0.000	1.000
5 (V) Biomass Burning (5.A)	CO2	..	8.552	0.000	..	0.999	0.000	1.000
1.A.5. Other - liquid fuels	N2O	7.178	..	0.000	0.000	0.999	0.000	1.000
2.A.4 Soda Ash Use	CO2	11.402	..	0.000	0.000	0.999	0.000	1.000
1.A.2. Manufacturing Industries and Construction - other fuels	N2O	18.196	..	0.000	0.000	0.999	0.000	1.000
1.A.4. Other Sectors - other fuels	N2O	1.353	..	0.000	0.000	0.999	0.000	1.000
1.A.5. Other - gaseous fuels	CH4	0.209	..	0.000	0.000	0.999	0.000	1.000
1.A.2. Manufacturing Industries and Construction - gaseous fuels	N2O	15.601	..	0.000	0.000	1.000	0.000	1.000
1.A.4. Other Sectors - gaseous fuels	CH4	0.242	..	0.000	0.000	1.000	0.000	1.000
1.B.2. Oil and Natural Gas - flaring	CH4	0.023	..	0.000	0.000	1.000	0.000	1.000
1.A.1 Energy Industries - liquid fuels	N2O	24.248	..	0.000	0.000	1.000	0.000	1.000
1.A.3.b. Road Transportation - biomass	N2O	3.087	..	0.000	0.000	1.000	0.000	1.000
1.A.3.d Navigation - residual oil & gas/diesel oil	N2O	2.902	..	0.000	0.000	1.000	0.000	1.000
1.A.3.e. Other Transportation - LPG	CH4	0.514	..	0.000	0.000	1.000	0.000	1.000
1.A.2. Manufacturing Industries and Construction - solid fuels	N2O	10.249	..	0.000	0.000	1.000	0.000	1.000
5.C.2. Forest Land converted to Grassland - net carbon stock change in organic soils	CO2	..	0.305	0.000	..	1.000	0.000	1.000
1.A.3.e. Other Transportation - LPG	N2O	0.297	..	0.000	0.000	1.000	0.000	1.000
1.B.2. Oil and Natural Gas - gas transmission (indirect CO2 from CH4)	CO2	1.100	..	0.000	0.000	1.000	0.000	1.000
2.A.6 Road Paving with Asphalt	CO2	2.390	..	0.000	0.000	1.000	0.000	1.000
1.B.2. Oil and Natural Gas - gas transmission	CH4	8.400	..	0.000	0.000	1.000	0.000	1.000
1.A.3.a Civil Aviation	N2O	3.764	..	0.000	0.000	1.000	0.000	1.000
5.B.2 Forest Land converted to Cropland / mineral soils - net carbon stock change in living biomass	CO2	..	-0.684	0.000	..	1.000	0.000	1.000
1.A.4. Other Sectors - gaseous fuels	N2O	1.138	..	0.000	0.000	1.000	0.000	1.000
1.A.3.c. Railways	N2O	0.955	..	0.000	0.000	1.000	0.000	1.000
4.F Field Burning of Agricultural Residues	CH4	0.529	..	0.000	0.000	1.000	0.000	1.000
5.B.2 Forest Land converted to Cropland / organic soils - net carbon stock change in living biomass	CO2	..	-0.396	0.000	..	1.000	0.000	1.000
1.A.5. Other - gaseous fuels	N2O	1.043	..	0.000	0.000	1.000	0.000	1.000
5 (V) Biomass Burning (5.A)	N2O	..	0.131	0.000	..	1.000	0.000	1.000
1.A.4. Other Sectors - solid fuels	CH4	0.059	..	0.000	0.000	1.000	0.000	1.000

A IPCC greenhouse gas source and sink categories	B Direct greenhouse gas ¹⁾	2008 estimate, non-LULUCF	2008 estimate, LULUCF	C Tier 2 level assessment	D ¹ Normalised tier 2 level assessment, without LULUCF	E ¹ Cumulative total of column D ¹	D Normalised tier 2 level assessment, with LULUCF	E Cumulative total of column D (additional LULUCF sources)
1.A.4. Other Sectors - solid fuels	N2O	0.108	..	0.000	0.000	1.000	0.000	1.000
5.C.2. Forest Land converted to Grassland - net carbon stock change in living biomass	CO2	..	-0.132	0.000	..	1.000	0.000	1.000
2.C.5 Other: Non-ferrous metals (indirect CO2 from NMVOC)	CO2	0.299	..	0.000	0.000	1.000	0.000	1.000
4.F Field Burning of Agricultural Residues	N2O	0.155	..	0.000	0.000	1.000	0.000	1.000
1.A.5. Other - biomass	CH4	0.048	..	0.000	0.000	1.000	0.000	1.000
1.B.2. Oil and Natural Gas - flaring	CO2	99.455	..	0.000	0.000	1.000	0.000	1.000
1.A.5. Other - biomass	N2O	0.014	..	0.000	0.000	1.000	0.000	1.000
1.A.3.b. Road Transportation - natural gas	N2O	0.005	..	0.000	0.000	1.000	0.000	1.000
1.A.5. Other - other fuels	CH4	0.000	..	0.000	0.000	1.000	0.000	1.000
1.A.5. Other - other fuels	N2O	0.000	..	0.000	0.000	1.000	0.000	1.000
1.A.5. Other - solid fuels	CH4	0.000	..	0.000	0.000	1.000	0.000	1.000
1.A.5. Other - solid fuels	N2O	0.000	..	0.000	0.000	1.000	0.000	1.000
2.B.1 Ammonia Production	CO2	0.000	..	0.000	0.000	1.000	0.000	1.000

1) Gases have been combined to protect confidential information (category 2.G), and to remove correlations (category 5.D.2).

Tier 2 trend assessment, including LULUCF

A IPCC greenhouse gas source and sink categories	B Direct greenhouse gas ¹⁾	C 1990 estimate	D 2008 estimate	E Tier 2 trend assessment	F Contribution to assessment	G Cumulative total of column F
Sum		54371.308	34744.879	1.034	1.000	
5.A.1. Forest Land remaining Forest Land - net carbon stock change in living biomass	CO2	-25438.373	-37321.830	0.313	0.303	0.303
5.A.1. Forest Land remaining Forest Land - net carbon stock change in mineral soils	CO2	-7742.460	-9429.713	0.186	0.180	0.482
5.B.1. Cropland Remaining Cropland - net carbon stock change in organic soils	CO2	5295.693	5347.739	0.082	0.079	0.561
5.A.2. Settlements converted to Forest Land - net carbon stock change in mineral soils	CO2	-109.780	-545.380	0.064	0.062	0.623
5.A.1. Forest Land remaining Forest Land - net carbon stock change in organic soils	CO2	12023.917	5948.433	0.061	0.059	0.682
5.B.1. Cropland Remaining Cropland - net carbon stock change in mineral soils	CO2	-419.374	-984.827	0.032	0.031	0.713
4.D.Agricultural soils: direct emissions, animal production and sludge spreading	N2O	3262.507	2989.437	0.029	0.028	0.741
2.B.2 Nitric Acid Production	N2O	1655.710	1560.532	0.023	0.022	0.763
5.A.2. Wetlands converted to Forest Land / drained-WL - organic soils	CO2	104.519	218.500	0.020	0.020	0.783
1.A. Fuel Combustion - other fuels	CO2	5693.529	8865.797	0.016	0.015	0.798
5.A.2. Grassland converted to Forest Land - net carbon stock change in organic soils	CO2	-68.627	-154.411	0.015	0.014	0.812
5.A.2. Cropland converted to Forest Land - net carbon stock change in organic soils	CO2	335.280	110.807	0.014	0.014	0.826
4.D.Agricultural soils: indirect emissions	N2O	711.724	578.628	0.014	0.013	0.839
1.A. Fuel Combustion - solid fuels	CO2	14530.469	12189.766	0.013	0.013	0.852
5.B.2 Forest Land converted to Cropland / organic soils - net carbon stock change in organic soils	CO2	200.511	387.900	0.012	0.011	0.864
2.F.1. Refrigeration and Air Conditioning Equipment	HFCs, PFCs	0.013	912.505	0.011	0.010	0.874
5.A.2. Grassland converted to Forest Land - net carbon stock change in living biomass	CO2	-219.945	-555.185	0.009	0.009	0.883
6.A. Solid Waste disposal on Land	CH4	3635.310	1853.157	0.009	0.009	0.892
1.A. Fuel Combustion - liquid fuels	CO2	27779.603	24209.689	0.008	0.008	0.900
5.B.3 Wetlands converted to Cropland - net carbon stock change in organic soils	CO2	39.766	192.189	0.008	0.007	0.907
5.A.2. Grassland converted to Forest Land - net carbon stock change in mineral soils	CO2	23.137	67.503	0.007	0.007	0.914
1.A.4. Other Sectors - biomass	CH4	161.279	206.182	0.007	0.007	0.921
5.D.2. Land Converted to Wetlands - peat extraction	CO2, CH4, N2O	1010.555	1308.350	0.006	0.006	0.926
2.C.1 Iron and Steel production	CH4	5.114	9.034	0.006	0.006	0.932
5.C.3. Cropland converted to Grassland - net carbon stock change in mineral soils	CO2	-323.937	-84.113	0.006	0.005	0.937
4.A.Enteric fermentation	CH4	1918.963	1556.593	0.005	0.005	0.942
1.A.3.b. Road Transportation - diesel	CH4	11.472	5.201	0.004	0.004	0.946
4.B.Manure management	CH4	230.399	287.505	0.004	0.004	0.950
2.B.5 Other: Hydrogen Production	CO2	56.940	648.178	0.004	0.003	0.953
5.A.2. Wetlands converted to Forest Land / peat extraction - organic soils	CO2	0.000	24.603	0.003	0.003	0.956
1.A. Fuel Combustion - gaseous fuels	CO2	4970.235	8279.347	0.003	0.003	0.959
5 (I) Direct N2O Emissions from N Fertilization (5.A)	N2O	26.817	35.428	0.003	0.003	0.962
5.G Other (harvested wood products)	CO2	-945.637	-94.772	0.003	0.002	0.965

A IPCC greenhouse gas source and sink categories	B Direct greenhouse gas ¹⁾	C 1990 estimate	D 2008 estimate	E Tier 2 trend assessment	F Contribution to assessment	G Cumulative total of column F
1.A.1 Energy Industries - biomass	CH4	1.514	8.016	0.002	0.002	0.967
1.A.1 Energy Industries - other fuels	CH4	2.469	5.810	0.002	0.002	0.969
5.C.1. Grassland Remaining Grassland - net carbon stock change in organic soils	CO2	18.716	52.840	0.002	0.002	0.971
2.F.8 Electrical Equipment	SF6	86.518	13.862	0.002	0.002	0.972
5.A.2. Cropland converted to Forest Land - net carbon stock change in living biomass	CO2	-570.896	-294.081	0.002	0.002	0.974
5.B.2 Forest Land converted to Cropland / mineral soils - net carbon stock change in mineral soils	CO2	47.742	61.537	0.001	0.001	0.975
5 (IV) CO2 Emissions from Agricultural Lime Application (5.B)	CO2	617.871	289.520	0.001	0.001	0.977
6.D Other: compost production	CH4	21.554	59.736	0.001	0.001	0.978
6.D Other: compost production	N2O	20.430	58.863	0.001	0.001	0.979
6.B.2 Domestic and Commercial Wastewater - densely populated areas	CH4	17.069	11.304	0.001	0.001	0.980
1.A.2. Manufacturing Industries and Construction - biomass	CH4	6.805	7.978	0.001	0.001	0.981
1.A.4. Other Sectors - biomass	N2O	27.769	33.981	0.001	0.001	0.982
5.A.2. Cropland converted to Forest Land - net carbon stock change in mineral soils	CO2	88.440	48.400	0.001	0.001	0.983
6.B.2 Domestic and Commercial Wastewater - sparsely populated areas	CH4	114.232	91.460	0.001	0.001	0.984
5.B.2 Grassland converted to Cropland - net carbon stock change in mineral soils	CO2	0.000	23.031	0.001	0.001	0.985
4.B.Manure management	N2O	489.942	420.895	0.001	0.001	0.986
5.A.2. Wetlands converted to Forest Land / drained-WL - biomass	CO2	-24.523	-59.561	0.001	0.001	0.987
1.A.1 Energy Industries - solid fuels	CH4	2.294	2.184	0.001	0.001	0.988
1.A.5 Other - other fuels (mostly indirect N2O from NOx)	N2O	439.270	250.790	0.001	0.001	0.989
1.A.1 Energy Industries - gaseous fuels	CH4	1.033	4.619	0.001	0.001	0.990
1.A.3.b. Road Transportation - gasoline	CH4	77.854	21.277	0.001	0.001	0.990
5.A.2. Settlements converted to Forest Land - net carbon stock change in living biomass	CO2	-6.391	-29.403	0.001	0.001	0.991
1.A.2. Manufacturing Industries and Construction - solid fuels	CH4	1.367	0.519	0.001	0.001	0.991
1.B.2. Oil and Natural Gas - flaring	N2O	3.128	0.689	0.000	0.000	0.992
2.F.9 Other (grouped data)	HFCs, PFCs, SF6	7.940	33.287	0.000	0.000	0.992
6.B.1 Industrial Wastewater	CH4	22.225	24.028	0.000	0.000	0.993
2.A.1 Cement Production	CO2	733.590	638.298	0.000	0.000	0.993
5.C.1. Grassland Remaining Grassland - net carbon stock change in mineral soils	CO2	21.118	22.363	0.000	0.000	0.993
2.F.4 Aerosols	HFCs	0.000	77.370	0.000	0.000	0.994
2.A.3 Limestone and Dolomite Use	CO2	87.999	125.320	0.000	0.000	0.994
6.B.3. N input from Fish Farming	N2O	8.281	3.376	0.000	0.000	0.994
2.A.2 Lime Production	CO2	382.595	439.452	0.000	0.000	0.995
5.C.3. Cropland converted to Grassland - net carbon stock change in organic soils	CO2	19.476	5.734	0.000	0.000	0.995
6.B.2 Domestic and Commercial Wastewater - sparsely populated areas	N2O	30.546	25.757	0.000	0.000	0.995
1.B.2. Oil and Natural Gas - oil refining	CH4	7.560	11.130	0.000	0.000	0.996
2.B.1 Ammonia Production	CO2	44.000	0.000	0.000	0.000	0.996
1.A.3.b. Road Transportation - gasoline - cars with catalytic converters	N2O	88.140	54.909	0.000	0.000	0.996
5.A.2. Settlements converted to Forest Land - net carbon stock	CO2	0.550	2.053	0.000	0.000	0.996

A IPCC greenhouse gas source and sink categories	B Direct greenhouse gas ⁽¹⁾	C 1990 estimate	D 2008 estimate	E Tier 2 trend assessment	F Contribution to assessment	G Cumulative total of column F
<i>change in organic soils</i>						
5.B N2O emissions from disturbance associated with land-use conversion to cropland	N2O	3.705	7.325	0.000	0.000	0.997
1.A.1 Energy Industries - liquid fuels	CH4	0.969	0.883	0.000	0.000	0.997
1.A.3.b. Road Transportation - biomass	CH4	0.000	1.001	0.000	0.000	0.997
1.A.1 Energy Industries - biomass	N2O	3.071	83.745	0.000	0.000	0.997
1.A.2. Manufacturing Industries and Construction - other fuels	CH4	1.081	1.209	0.000	0.000	0.997
5 (V) Biomass Burning (5.A)	CH4	4.059	1.284	0.000	0.000	0.998
1.A.2. Manufacturing Industries and Construction - gaseous fuels	CH4	1.008	0.989	0.000	0.000	0.998
1.B.2. Oil and Natural Gas - other (indirect CO2 from NMVOC)	CO2	95.451	33.914	0.000	0.000	0.998
1.A.2. Manufacturing Industries and Construction - liquid fuels	CH4	2.539	2.307	0.000	0.000	0.998
1.A.1 Energy Industries - other fuels	N2O	34.637	97.568	0.000	0.000	0.998
3. Solvent and Other Product Use (indirect CO2 from NMVOC)	CO2	116.370	51.773	0.000	0.000	0.998
1.A.1 Energy Industries - gaseous fuels	N2O	15.631	35.222	0.000	0.000	0.998
1.A.3.e. Other Transportation - diesel	N2O	3.836	3.974	0.000	0.000	0.998
1.A.2. Manufacturing Industries and Construction - biomass	N2O	56.434	77.253	0.000	0.000	0.998
2.F.2 Foam Blowing	HFCs	0.000	8.528	0.000	0.000	0.999
3. Solvent and Other Product Use	N2O	62.000	34.111	0.000	0.000	0.999
1.A.3.d Navigation - residual oil & gas/diesel oil	CH4	0.426	0.487	0.000	0.000	0.999
1.A.3.e. Other Transportation - gasoline & diesel	CH4	4.611	6.111	0.000	0.000	0.999
1.B.2. Oil and Natural Gas - gas distribution	CH4	0.000	29.400	0.000	0.000	0.999
2.A.6 Road Paving with Asphalt	CO2	21.003	2.390	0.000	0.000	0.999
5.A.2. Wetlands converted to Forest Land / peat extraction - biomass	CO2	0.000	-2.460	0.000	0.000	0.999
2.C.1 Iron and Steel production	CO2	1935.180	2523.302	0.000	0.000	0.999
1.A.3.b. Road Transportation - natural gas	CH4	0.000	2.216	0.000	0.000	0.999
1.A.4. Other Sectors - solid fuels	CH4	2.343	0.059	0.000	0.000	0.999
1.A.3.b. Road Transportation - diesel	N2O	68.120	100.826	0.000	0.000	0.999
1.A.4. Other Sectors - liquid fuels	CH4	18.180	10.875	0.000	0.000	0.999
1.B.2. Oil and Natural Gas - flaring	CH4	0.106	0.023	0.000	0.000	0.999
1.B.2. Oil and Natural Gas - gas distribution (indirect CO2 from CH4)	CO2	0.000	3.900	0.000	0.000	0.999
1.A.3.a Civil Aviation	CH4	0.273	0.226	0.000	0.000	0.999
1.A.3.d Navigation - gasoline	CH4	4.133	2.877	0.000	0.000	0.999
5.B.1. Cropland Remaining Cropland - net carbon stock change in living biomass	CO2	-1.442	-2.596	0.000	0.000	0.999
5 (V) Biomass Burning (5.A)	CO2	3.863	8.552	0.000	0.000	0.999
1.A.5. Other - liquid fuels	CH4	2.348	1.499	0.000	0.000	0.999
5.C.2. Forest Land converted to Grassland - net carbon stock change in mineral soils	CO2	0.527	1.179	0.000	0.000	1.000
2.B.5 Other: Chemicals Production (indirect CO2 from NMVOC)	CO2	24.405	8.465	0.000	0.000	1.000
1.B.2. Oil and Natural Gas - oil refining (indirect CO2 from CH4)	CO2	1.000	1.458	0.000	0.000	1.000
1.A.4. Other Sectors - other fuels	CH4	1.244	1.149	0.000	0.000	1.000
2.A.7 Other - Glass Production	CO2	20.800	18.611	0.000	0.000	1.000
1.A.4. Other Sectors - liquid fuels	N2O	56.429	34.660	0.000	0.000	1.000
1.A.5. Other - gaseous fuels	CH4	0.061	0.209	0.000	0.000	1.000

A IPCC greenhouse gas source and sink categories	B Direct greenhouse gas ⁽¹⁾	C 1990 estimate	D 2008 estimate	E Tier 2 trend assessment	F Contribution to assessment	G Cumulative total of column F
1.A.3.b. Road Transportation - biomass	N2O	0.000	3.087	0.000	0.000	1.000
2.A.4 Soda Ash Use	CO2	8.320	11.402	0.000	0.000	1.000
1.A.1 Energy Industries - solid fuels	N2O	43.395	62.895	0.000	0.000	1.000
6.B.2 Domestic and Commercial Wastewater - densely populated areas	N2O	74.786	54.733	0.000	0.000	1.000
1.A.2. Manufacturing Industries and Construction - liquid fuels	N2O	36.749	27.904	0.000	0.000	1.000
1.A.4. Other Sectors - gaseous fuels	CH4	0.220	0.242	0.000	0.000	1.000
1.A.3.e. Other Transportation - gasoline	N2O	0.627	0.649	0.000	0.000	1.000
1.A.2. Manufacturing Industries and Construction - other fuels	N2O	17.011	18.196	0.000	0.000	1.000
5.C.2. Forest Land converted to Grassland - net carbon stock change in organic soils	CO2	0.000	0.305	0.000	0.000	1.000
1.A.3.d Navigation - gasoline	N2O	0.335	0.846	0.000	0.000	1.000
1.A.3.d Navigation - residual oil & gas/diesel oil	N2O	2.558	2.902	0.000	0.000	1.000
1.A.2. Manufacturing Industries and Construction - solid fuels	N2O	46.744	10.249	0.000	0.000	1.000
1.A.2. Manufacturing Industries and Construction - gaseous fuels	N2O	15.264	15.601	0.000	0.000	1.000
1.B.2. Oil and Natural Gas - gas transmission (indirect CO2 from CH4)	CO2	0.468	1.100	0.000	0.000	1.000
1.A.4. Other Sectors - other fuels	N2O	1.473	1.353	0.000	0.000	1.000
1.B.2. Oil and Natural Gas - gas transmission	CH4	3.570	8.400	0.000	0.000	1.000
1.A.3.e. Other Transportation - LPG	CH4	0.388	0.514	0.000	0.000	1.000
4.F Field Burning of Agricultural Residues	CH4	1.883	0.529	0.000	0.000	1.000
1.A.1 Energy Industries - liquid fuels	N2O	25.030	24.248	0.000	0.000	1.000
1.A.3.e. Other Transportation - LPG	N2O	0.286	0.297	0.000	0.000	1.000
1.A.3.b. Road Transportation - gasoline - cars without catalytic converters	N2O	3.672	2.288	0.000	0.000	1.000
1.A.4. Other Sectors - solid fuels	N2O	0.590	0.108	0.000	0.000	1.000
5.B.2 Forest Land converted to Cropland / mineral soils - net carbon stock change in living biomass	CO2	-0.459	-0.684	0.000	0.000	1.000
6.B.3. N input from industrial wastewater	N2O	30.166	19.306	0.000	0.000	1.000
1.A.5. Other - gaseous fuels	N2O	0.314	1.043	0.000	0.000	1.000
5 (V) Biomass Burning (5.A)	N2O	0.412	0.131	0.000	0.000	1.000
1.A.5. Other - other fuels	CH4	0.236	0.000	0.000	0.000	1.000
5.B.2 Forest Land converted to Cropland / organic soils - net carbon stock change in living biomass	CO2	-0.205	-0.396	0.000	0.000	1.000
1.A.5. Other - biomass	CH4	0.198	0.048	0.000	0.000	1.000
1.A.4. Other Sectors - gaseous fuels	N2O	0.593	1.138	0.000	0.000	1.000
1.A.5. Other - other fuels	N2O	0.147	0.000	0.000	0.000	1.000
1.A.3.a Civil Aviation	N2O	4.861	3.764	0.000	0.000	1.000
1.A.5. Other - biomass	N2O	0.215	0.014	0.000	0.000	1.000
4.F Field Burning of Agricultural Residues	N2O	0.551	0.155	0.000	0.000	1.000
1.B.2. Oil and Natural Gas - flaring	CO2	121.933	99.455	0.000	0.000	1.000
5.C.2. Forest Land converted to Grassland - net carbon stock change in living biomass	CO2	-0.061	-0.132	0.000	0.000	1.000
1.A.3.c. Railways	CH4	0.231	0.129	0.000	0.000	1.000
1.A.3.c. Railways	N2O	1.510	0.955	0.000	0.000	1.000
1.A.3.b. Road Transportation - natural gas	N2O	0.000	0.005	0.000	0.000	1.000
1.A.5. Other - solid fuels	CH4	0.001	0.000	0.000	0.000	1.000
2.C.5 Other: Non-ferrous metals (indirect CO2 from NMVOC)	CO2	0.440	0.299	0.000	0.000	1.000
1.A.5. Other - liquid fuels	N2O	8.892	7.178	0.000	0.000	1.000
1.A.5. Other - solid fuels	N2O	0.012	0.000	0.000	0.000	1.000

Tier 2 trend assessment, excluding LULUCF

A	B	C	D	E	F	G
IPCC greenhouse gas source and sink categories	Direct greenhouse gas ¹⁾	1990 estimate	2008 estimate	Tier 2 trend assessment	Contribution to assessment	Cumulative total of column F
Sum		54371.308	34744.879	0.179639	1.00000	
5 (I) Direct N2O Emissions from N Fertilization (5.A)	N2O	26.817	35.428	..	..	..
5 (IV) CO2 Emissions from Agricultural Lime Application (5.B)	CO2	617.871	289.520	..	..	..
5 (V) Biomass Burning (5.A)	CH4	4.059	1.284	..	..	..
5 (V) Biomass Burning (5.A)	CO2	3.863	8.552	..	..	..
5 (V) Biomass Burning (5.A)	N2O	0.412	0.131	..	..	..
5.A.1. Forest Land remaining Forest Land - net carbon stock change in living biomass	CO2	-25438.373	-37321.830	..	..	..
5.A.1. Forest Land remaining Forest Land - net carbon stock change in mineral soils	CO2	-7742.460	-9429.713	..	..	..
5.A.1. Forest Land remaining Forest Land - net carbon stock change in organic soils	CO2	12023.917	5948.433	..	..	..
5.A.2. Cropland converted to Forest Land - net carbon stock change in living biomass	CO2	-570.896	-294.081	..	..	..
5.A.2. Cropland converted to Forest Land - net carbon stock change in mineral soils	CO2	88.440	48.400	..	..	..
5.A.2. Cropland converted to Forest Land - net carbon stock change in organic soils	CO2	335.280	110.807	..	..	..
5.A.2. Grassland converted to Forest Land - net carbon stock change in living biomass	CO2	-219.945	-555.185	..	..	..
5.A.2. Grassland converted to Forest Land - net carbon stock change in mineral soils	CO2	23.137	67.503	..	..	..
5.A.2. Grassland converted to Forest Land - net carbon stock change in organic soils	CO2	-68.627	-154.411	..	..	..
5.A.2. Settlements converted to Forest Land - net carbon stock change in living biomass	CO2	-6.391	-29.403	..	..	..
5.A.2. Settlements converted to Forest Land - net carbon stock change in mineral soils	CO2	-109.780	-545.380	..	..	..
5.A.2. Settlements converted to Forest Land - net carbon stock change in organic soils	CO2	0.550	2.053	..	..	..
5.A.2. Wetlands converted to Forest Land / drained-WL - biomass	CO2	-24.523	-59.561	..	..	..
5.A.2. Wetlands converted to Forest Land / drained-WL - organic soils	CO2	104.519	218.500	..	..	..
5.A.2. Wetlands converted to Forest Land / peat extraction - biomass	CO2	0.000	-2.460	..	..	..

A	B	C	D	E	F	G
IPCC greenhouse gas source and sink categories	Direct greenhouse gas ¹⁾	1990 estimate	2008 estimate	Tier 2 trend assessment	Contribution to assessment	Cumulative total of column F
5.A.2. Wetlands converted to Forest Land / peat extraction - organic soils	CO2	0.000	24.603	..	..	..
5.B N2O emissions from disturbance associated with land-use conversion to cropland	N2O	3.705	7.325	..	..	..
5.B.1. Cropland Remaining Cropland - net carbon stock change in living biomass	CO2	-1.442	-2.596	..	..	..
5.B.1. Cropland Remaining Cropland - net carbon stock change in mineral soils	CO2	-419.374	-984.827	..	..	..
5.B.1. Cropland Remaining Cropland - net carbon stock change in organic soils	CO2	5295.693	5347.739	..	..	..
5.B.2 Forest Land converted to Cropland / mineral soils - net carbon stock change in living biomass	CO2	-0.459	-0.684	..	..	..
5.B.2 Forest Land converted to Cropland / mineral soils - net carbon stock change in mineral soils	CO2	47.742	61.537	..	..	..
5.B.2 Forest Land converted to Cropland / organic soils - net carbon stock change in living biomass	CO2	-0.205	-0.396	..	..	..
5.B.2 Forest Land converted to Cropland / organic soils - net carbon stock change in organic soils	CO2	200.511	387.900	..	..	..
5.B.2 Grassland converted to Cropland - net carbon stock change in mineral soils	CO2	0.000	23.031	..	..	..
5.B.3 Wetlands converted to Cropland - net carbon stock change in organic soils	CO2	39.766	192.189	..	..	..
5.C.1. Grassland Remaining Grassland - net carbon stock change in mineral soils	CO2	21.118	22.363	..	..	..
5.C.1. Grassland Remaining Grassland - net carbon stock change in organic soils	CO2	18.716	52.840	..	..	..
5.C.2. Forest Land converted to Grassland - net carbon stock change in living biomass	CO2	-0.061	-0.132	..	..	..
5.C.2. Forest Land converted to Grassland - net carbon stock change in mineral soils	CO2	0.527	1.179	..	..	..
5.C.2. Forest Land converted to Grassland - net carbon stock change in organic soils	CO2	0.000	0.305	..	..	..
5.C.3. Cropland converted to Grassland - net carbon stock change in mineral soils	CO2	-323.937	-84.113	..	..	..
5.C.3. Cropland converted to Grassland - net carbon stock change in organic soils	CO2	19.476	5.734	..	..	..
5.D.2. Land Converted to Wetlands - peat extraction	CO2, CH4, N2O	1010.555	1308.350	..	..	..
5.G Other (harvested wood products)	CO2	-945.637	-94.772	..	..	..
4.D.Agricultural soils: direct emissions, animal production	N2O	3262.507	2989.437	0.028843	0.16056	0.16056

A	B	C	D	E	F	G
IPCC greenhouse gas source and sink categories	Direct greenhouse gas ¹⁾	1990 estimate	2008 estimate	Tier 2 trend assessment	Contribution to assessment	Cumulative total of column F
and sludge spreading						
2.B.2 Nitric Acid Production	N2O	1655.710	1560.532	0.022660	0.12614	0.28670
1.A. Fuel Combustion - other fuels	CO2	5693.529	8865.797	0.015527	0.08643	0.37313
4.D.Agricultural soils: indirect emissions	N2O	711.724	578.628	0.013846	0.07708	0.45021
1.A. Fuel Combustion - solid fuels	CO2	14530.469	12189.766	0.013247	0.07374	0.52395
2.F.1. Refrigeration and Air Conditioning Equipment	HFCs, PFCs	0.013	912.505	0.010756	0.05988	0.58383
6.A. Solid Waste disposal on Land	CH4	3635.310	1853.157	0.009101	0.05066	0.63449
1.A. Fuel Combustion - liquid fuels	CO2	27779.603	24209.689	0.008226	0.04579	0.68029
1.A.4. Other Sectors - biomass	CH4	161.279	206.182	0.007001	0.03897	0.71926
2.C.1 Iron and Steel production	CO2	1935.180	2523.302	0.005795	0.03226	0.75152
4.A.Enteric fermentation	CH4	1918.963	1556.593	0.004781	0.02661	0.77813
1.A.3.b. Road Transportation - diesel	N2O	68.120	100.826	0.004077	0.02270	0.80083
4.B.Manure management	CH4	230.399	287.505	0.003981	0.02216	0.82299
2.B.5 Other: Hydrogen Production	CO2	56.940	648.178	0.003562	0.01983	0.84282
1.A. Fuel Combustion - gaseous fuels	CO2	4970.235	8279.347	0.003250	0.01809	0.86092
1.A.1 Energy Industries - biomass	CH4	1.514	8.016	0.002330	0.01297	0.87388
1.A.1 Energy Industries - other fuels	CH4	2.469	5.810	0.002046	0.01139	0.88527
2.F.8 Electrical Equipment	SF6	86.518	13.862	0.001642	0.00914	0.89441
6.D Other: compost production	CH4	21.554	59.736	0.001207	0.00672	0.90113
6.D Other: compost production	N2O	20.430	58.863	0.001203	0.00670	0.90783
6.B.2 Domestic and Commercial Wastewater - densely populated areas	CH4	17.069	11.304	0.001188	0.00661	0.91444
1.A.2. Manufacturing Industries and Construction - biomass	CH4	6.805	7.978	0.001147	0.00639	0.92083
1.A.4. Other Sectors - biomass	N2O	27.769	33.981	0.001102	0.00614	0.92696
6.B.2 Domestic and Commercial Wastewater - sparsely populated areas	CH4	114.232	91.460	0.001067	0.00594	0.93290
4.B.Manure management	N2O	489.942	420.895	0.001002	0.00558	0.93848
1.A.1 Energy Industries - solid fuels	CH4	2.294	2.184	0.000951	0.00529	0.94377
1.A.5 Other - other fuels (mostly indirect N2O from NOx)	N2O	439.270	250.790	0.000833	0.00464	0.94841
1.A.1 Energy Industries - gaseous fuels	CH4	1.033	4.619	0.000682	0.00380	0.95221
1.A.3.b. Road Transportation - gasoline	CH4	77.854	21.277	0.000641	0.00357	0.95578

A	B	C	D	E	F	G
IPCC greenhouse gas source and sink categories	Direct greenhouse gas ¹⁾	1990 estimate	2008 estimate	Tier 2 trend assessment	Contribution to assessment	Cumulative total of column F
1.A.2. Manufacturing Industries and Construction - solid fuels	CH4	1.367	0.519	0.000531	0.00295	0.95873
1.B.2. Oil and Natural Gas - flaring	N2O	3.128	0.689	0.000485	0.00270	0.96143
2.F.9 Other (grouped data)	HFCs, PFCs, SF6	7.940	33.287	0.000483	0.00269	0.96412
6.B.1 Industrial Wastewater	CH4	22.225	24.028	0.000464	0.00258	0.96670
2.A.1 Cement Production	CO2	733.590	638.298	0.000411	0.00229	0.96899
2.F.4 Aerosols	HFCs	0.000	77.370	0.000348	0.00194	0.97093
2.A.3 Limestone and Dolomite Use	CO2	87.999	125.320	0.000345	0.00192	0.97285
6.B.3. N input from Fish Farming	N2O	8.281	3.376	0.000328	0.00183	0.97468
2.A.2 Lime Production	CO2	382.595	439.452	0.000317	0.00176	0.97644
6.B.2 Domestic and Commercial Wastewater - sparsely populated areas	N2O	30.546	25.757	0.000295	0.00164	0.97808
1.B.2. Oil and Natural Gas - oil refining	CH4	7.560	11.130	0.000255	0.00142	0.97950
2.B.1 Ammonia Production	CO2	44.000	0.000	0.000252	0.00141	0.98091
1.A.3.b. Road Transportation - gasoline - cars with catalytic converters	N2O	88.140	54.909	0.000241	0.00134	0.98225
1.A.1 Energy Industries - liquid fuels	CH4	0.969	0.883	0.000223	0.00124	0.98349
1.A.3.b. Road Transportation - biomass	CH4	0.000	1.001	0.000209	0.00116	0.98465
1.A.1 Energy Industries - biomass	N2O	3.071	83.745	0.000201	0.00112	0.98577
1.A.2. Manufacturing Industries and Construction - other fuels	CH4	1.081	1.209	0.000199	0.00111	0.98688
1.A.2. Manufacturing Industries and Construction - gaseous fuels	CH4	1.008	0.989	0.000158	0.00088	0.98776
1.B.2. Oil and Natural Gas - other (indirect CO2 from NMVOC)	CO2	95.451	33.914	0.000136	0.00076	0.98851
1.A.2. Manufacturing Industries and Construction - liquid fuels	CH4	2.539	2.307	0.000120	0.00067	0.98918
1.A.1 Energy Industries - other fuels	N2O	34.637	97.568	0.000115	0.00064	0.98982
3. Solvent and Other Product Use (indirect CO2 from NMVOC)	CO2	116.370	51.773	0.000114	0.00063	0.99045
1.A.1 Energy Industries - gaseous fuels	N2O	15.631	35.222	0.000107	0.00060	0.99105
1.A.3.e. Other Transportation - diesel	N2O	3.836	3.974	0.000105	0.00058	0.99163
1.A.2. Manufacturing Industries and Construction - biomass	N2O	56.434	77.253	0.000101	0.00056	0.99219

A	B	C	D	E	F	G
IPCC greenhouse gas source and sink categories	Direct greenhouse gas ¹⁾	1990 estimate	2008 estimate	Tier 2 trend assessment	Contribution to assessment	Cumulative total of column F
2.F.2 Foam Blowing	HFCs	0.000	8.528	0.000092	0.00051	0.99271
3. Solvent and Other Product Use	N ₂ O	62.000	34.111	0.000089	0.00050	0.99321
1.A.3.d Navigation - residual oil & gas/diesel oil	CH ₄	0.426	0.487	0.000086	0.00048	0.99368
1.A.3.e. Other Transportation - gasoline & diesel	CH ₄	4.611	6.111	0.000083	0.00046	0.99415
1.B.2. Oil and Natural Gas - gas distribution	CH ₄	0.000	29.400	0.000066	0.00037	0.99451
2.A.6 Road Paving with Asphalt	CO ₂	21.003	2.390	0.000056	0.00031	0.99482
2.C.1 Iron and Steel production	CH ₄	5.114	9.034	0.000053	0.00029	0.99512
1.A.3.b. Road Transportation - natural gas	CH ₄	0.000	2.216	0.000050	0.00028	0.99539
1.A.4. Other Sectors - solid fuels	CH ₄	2.343	0.059	0.000049	0.00027	0.99567
1.A.3.b. Road Transportation - diesel	CH ₄	11.472	5.201	0.000048	0.00027	0.99593
1.A.4. Other Sectors - liquid fuels	CH ₄	18.180	10.875	0.000047	0.00026	..
1.B.2. Oil and Natural Gas - flaring	CH ₄	0.106	0.023	0.000046	0.00026	..
1.B.2. Oil and Natural Gas - gas distribution (indirect CO ₂ from CH ₄)	CO ₂	0.000	3.900	0.000045	0.00025	..
1.A.3.a Civil Aviation	CH ₄	0.273	0.226	0.000044	0.00025	..
1.A.3.d Navigation - gasoline	CH ₄	4.133	2.877	0.000043	0.00024	..
1.A.5. Other - liquid fuels	CH ₄	2.348	1.499	0.000041	0.00023	..
2.B.5 Other: Chemicals Production (indirect CO ₂ from NMVOC)	CO ₂	24.405	8.465	0.000036	0.00020	..
1.B.2. Oil and Natural Gas - oil refining (indirect CO ₂ from CH ₄)	CO ₂	1.000	1.458	0.000034	0.00019	..
1.A.4. Other Sectors - other fuels	CH ₄	1.244	1.149	0.000028	0.00016	..
2.A.7 Other - Glass Production	CO ₂	20.800	18.611	0.000027	0.00015	..
1.A.4. Other Sectors - liquid fuels	N ₂ O	56.429	34.660	0.000025	0.00014	..
1.A.5. Other - gaseous fuels	CH ₄	0.061	0.209	0.000023	0.00013	..
1.A.3.b. Road Transportation - biomass	N ₂ O	0.000	3.087	0.000023	0.00013	..
2.A.4 Soda Ash Use	CO ₂	8.320	11.402	0.000020	0.00011	..
1.A.1 Energy Industries - solid fuels	N ₂ O	43.395	62.895	0.000019	0.00011	..
6.B.2 Domestic and Commercial Wastewater - densely populated areas	N ₂ O	74.786	54.733	0.000019	0.00010	..
1.A.2. Manufacturing Industries and Construction - liquid fuels	N ₂ O	36.749	27.904	0.000018	0.00010	..
1.A.4. Other Sectors - gaseous fuels	CH ₄	0.220	0.242	0.000017	0.00010	..

A	B	C	D	E	F	G
IPCC greenhouse gas source and sink categories	Direct greenhouse gas ¹⁾	1990 estimate	2008 estimate	Tier 2 trend assessment	Contribution to assessment	Cumulative total of column F
1.A.3.e. Other Transportation - gasoline	N2O	0.627	0.649	0.000017	0.00010	..
1.A.2. Manufacturing Industries and Construction - other fuels	N2O	17.011	18.196	0.000014	0.00008	..
1.A.3.d Navigation - gasoline	N2O	0.335	0.846	0.000011	0.00006	..
1.A.3.d Navigation - residual oil & gas/diesel oil	N2O	2.558	2.902	0.000010	0.00005	..
1.A.2. Manufacturing Industries and Construction - solid fuels	N2O	46.744	10.249	0.000010	0.00005	..
1.A.2. Manufacturing Industries and Construction - gaseous fuels	N2O	15.264	15.601	0.000009	0.00005	..
1.B.2. Oil and Natural Gas - gas transmission (indirect CO2 from CH4)	CO2	0.468	1.100	0.000009	0.00005	..
1.A.4. Other Sectors - other fuels	N2O	1.473	1.353	0.000009	0.00005	..
1.B.2. Oil and Natural Gas - gas transmission	CH4	3.570	8.400	0.000008	0.00005	..
1.A.3.e. Other Transportation - LPG	CH4	0.388	0.514	0.000008	0.00004	..
4.F Field Burning of Agricultural Residues	CH4	1.883	0.529	0.000008	0.00004	..
1.A.1 Energy Industries - liquid fuels	N2O	25.030	24.248	0.000007	0.00004	..
1.A.3.e. Other Transportation - LPG	N2O	0.286	0.297	0.000007	0.00004	..
1.A.3.b. Road Transportation - gasoline - cars without catalytic converters	N2O	3.672	2.288	0.000007	0.00004	..
1.A.4. Other Sectors - solid fuels	N2O	0.590	0.108	0.000006	0.00003	..
6.B.3. N input from industrial wastewater	N2O	30.166	19.306	0.000005	0.00003	..
1.A.5. Other - gaseous fuels	N2O	0.314	1.043	0.000005	0.00003	..
1.A.5. Other - other fuels	CH4	0.236	0.000	0.000004	0.00002	..
1.A.5. Other - biomass	CH4	0.198	0.048	0.000004	0.00002	..
1.A.4. Other Sectors - gaseous fuels	N2O	0.593	1.138	0.000003	0.00002	..
1.A.5. Other - other fuels	N2O	0.147	0.000	0.000003	0.00001	..
1.A.3.a Civil Aviation	N2O	4.861	3.764	0.000002	0.00001	..
1.A.5. Other - biomass	N2O	0.215	0.014	0.000002	0.00001	1.2475E-05
4.F Field Burning of Agricultural Residues	N2O	0.551	0.155	0.000002	0.00001	2.2613E-05
1.B.2. Oil and Natural Gas - flaring	CO2	121.933	99.455	0.000002	0.00001	3.1301E-05
1.A.3.c. Railways	CH4	0.231	0.129	0.000001	0.00001	3.6383E-05

A	B	C	D	E	F	G
IPCC greenhouse gas source and sink categories	Direct greenhouse gas ¹⁾	1990 estimate	2008 estimate	Tier 2 trend assessment	Contribution to assessment	Cumulative total of column F
1.A.3.c. Railways	N ₂ O	1.510	0.955	0.000001	0.00000	4.0124E-05
1.A.3.b. Road Transportation - natural gas	N ₂ O	0.000	0.005	0.000000	0.00000	4.2106E-05
1.A.5. Other - solid fuels	CH ₄	0.001	0.000	0.000000	0.00000	4.3241E-05
2.C.5 Other: Non-ferrous metals (indirect CO ₂ from NMVOC)	CO ₂	0.440	0.299	0.000000	0.00000	4.3732E-05
1.A.5. Other - liquid fuels	N ₂ O	8.892	7.178	0.000000	0.00000	4.3936E-05
1.A.5. Other - solid fuels	N ₂ O	0.012	0.000	0.000000	0.00000	4.4038E-05

ANNEX 2. Description of the Compliance Monitoring Data System VAHTI

The VAHTI compliance data system is an operational 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 environmental permits of clients and on their wastes generated, discharges into water and emissions to air. In the future, the system will also include information on noise emissions. 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. In 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 800 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

In the year 2006 VAHTI contained information on 31,000 clients. 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 2006.

Activity	Water	Air	Waste	Total
Energy production and industrial installations	950	806	847	1 685
Municipalities	574	1	395	586
Fish farms	230	-	20	231
Others	64	85	879	899
Total	1 818	892	2 181	3 401

Small facilities as well as part of the medium sized facilities, such as small animal shelters and gasoline stations, are not yet requested to report to the authorities.

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 SO₂) and nitrogen oxides (as NO₂), 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)¹² 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

¹² 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.

Internet using a centralised data collection system¹³ the data will be automatically checked for completeness and only the completed data will be sent to the authorities for checking of the substance.

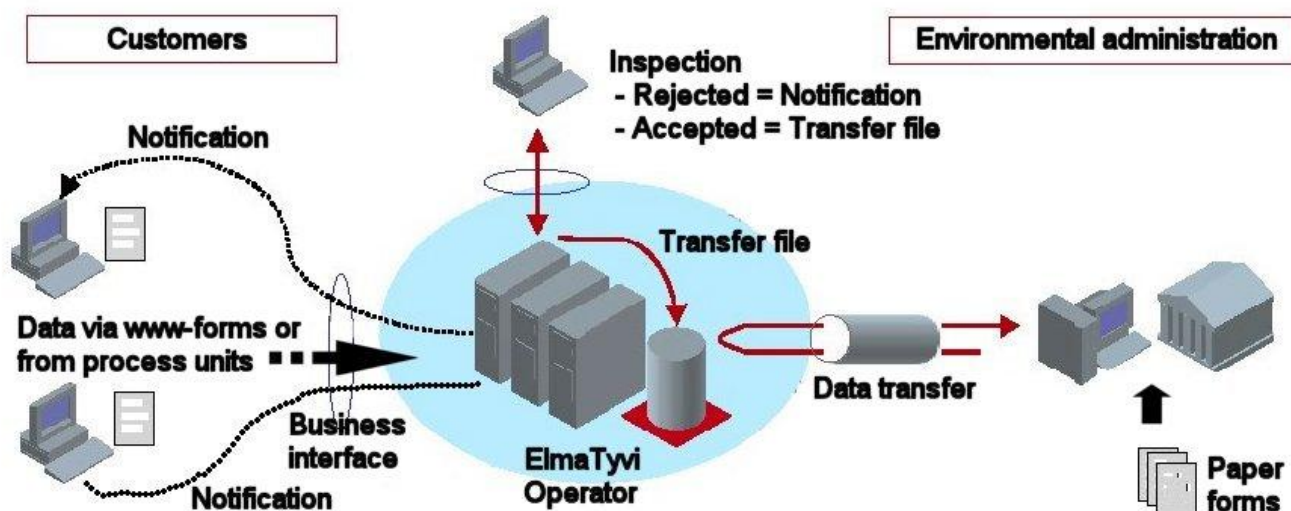


Figure 2. Reporting options for the operators

Further information on the VAHTI Data System is available from Mr Markku Hietamäki, Ministry of the Environment (email: firstname.surname@ymparisto.fi).

¹³ 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.

ANNEX 3. Discussion of the default CO₂ 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 CO₂/MJ coal combusted (given originally as 25.8 g C/MJ coal). This default value can be found in Table 1-2, p. 1.6 of the workbook of both the IPCC Guidelines (IPCC 1995) and the IPCC Revised Guidelines (IPCC 1997). The factor can also be found in Table 3.3 of OECD/IEA (1991) and its original source appears to be Grubb (1989).

Table 3.3 gives a range of variation equal to $\pm 3\%$. The text states that the variation is between world regions and due to “differences among ranks of coal.” (OECD/IEA 1991, p. 64). The default emission factor also appears in Table B–1 of OECD/IEA (1991, p. 154). Given the information reported in that table, the factor seems to be a weighted average reflecting the market shares of hard and brown coals in North America in 1987. In that same table, the factor given for Europe is 3.1% higher, equal to 26.6 g C/MJ (97.5 g CO₂/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

$$\bar{x}_t = s_{1,t}x_1 + s_{2,t}x_2 + \cdots + s_{n,t}x_n,$$

where it is understood that constant properties of a given type of coal over time are assumed.

The data

We obtained data on coal imports by country of origin from Table 10.3 of energy statistics prepared by Statistics Finland. These data are available for 1990–2003, except for 1996 when the table was not prepared.

Data on properties of fuel combusted in Finland were obtained from Taipale (1996). This study reports results from measurements carried out mainly during the 1990's. It gives water contents, carbon contents and net calorific values for coal of different origins. The statistics reported are the number of measurements, minimum, maximum and the mean. In case of the most important countries of coal origin, such as Poland and Russia, hundreds of measurements were available. This was the case for the net calorific value and water content. Measurements of carbon content were scarcer ranging from a few to tens of measurements, depending on the country of origin. For 13 countries or regions, the net calorific value and water content were not available. The carbon content was not available for 16 countries or regions. In all, the data consist of 23 countries or regions.

There is clearly a problem with the missing data. A first attempt was made by selecting values from literature to replace the missing data. Although the proportion of imports with the missing fuel property data was not greater than 1%-17%, depending on the year under consideration, this solution resulted in a correlation between the calculated emission factor and the proportion of missing data. The higher the proportion of missing data, the higher the calculated average emission factors.

The second attempt produced better results. An algorithm was constructed to select values at random from the available data to replace the missing values. The selection process was designed to give an equal probability of selection for any one value of fuel property. The sampling was done separately for each of the properties. Fuel properties for which data were available were modelled using triangular distributions, with min and max corresponding to the measured min and max, and the most likely value corresponding to the mean of all measurements. Import statistics were assumed relatively accurate. Imports were assumed to be normally distributed, means corresponding to the imported quantity and standard deviations equal to half of the unit used to report the data ($1000 \text{ t}/2 = 500 \text{ t}$).

Results and discussion

The simulation was designed to separate year-to-year variability from other uncertainties. Figure 1 shows a wide range of uncertainty in an individual year's emission factors and also that the years are clearly different from each other.

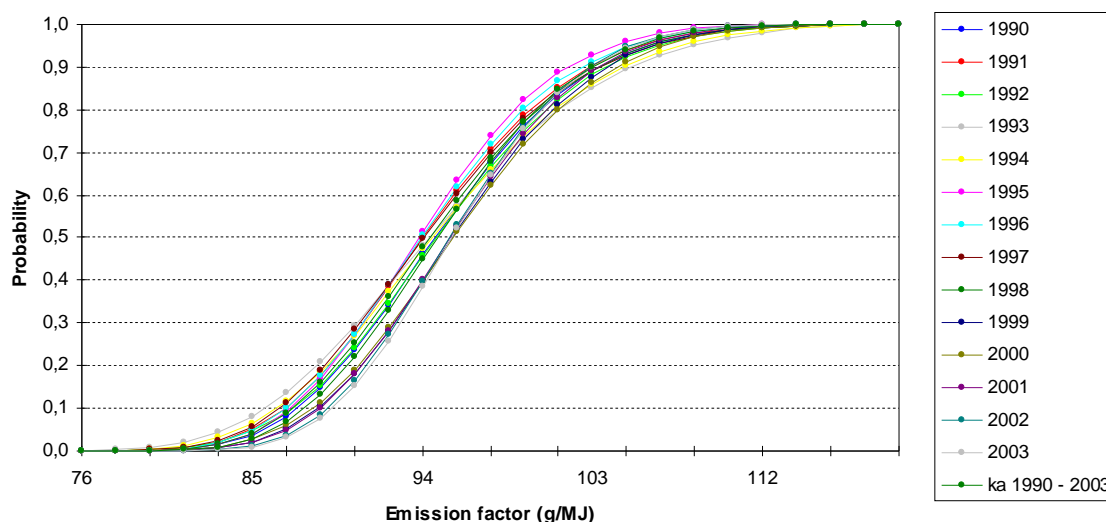


Figure 1. Uncertainty and year-to-year variability in the average coal emission factor.

Figure 2 shows a combined view of uncertainty as a trend over time. The central value of the simulated average emission factor (the light blue area in Fig. 2) does not display a clear trend over time. The 1996 emission factor, the year for which import data were not available, was calculated simply as the average of the 1995 and 1997 emission factors.

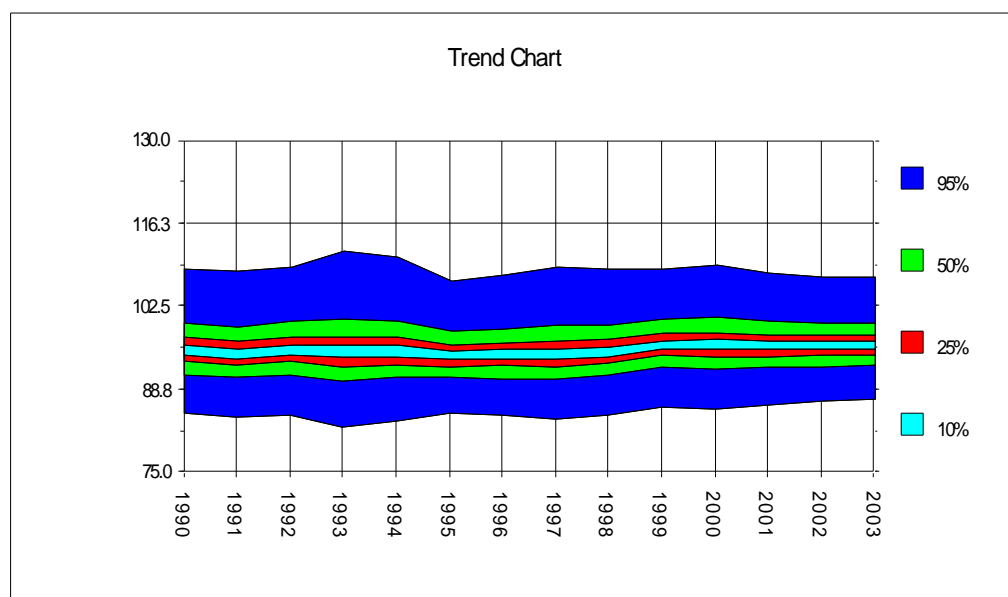


Figure 2. Uncertainty in the coal emission factor over time.

Figure 3 displays a time average of the simulation results. Two observations are immediate: (i) the distribution is centred around a value which is not far from the default emission factor 94.6 g/MJ; (ii) the width of the distribution suggests a much larger uncertainty than the $\pm 3\%$ given in the OECD/IEA (1991) for regional emission factors. Note, however, that this is in agreement with an example shown in that text for Greece, for which the national level of variation was found to be much wider (OECD/IEA, p. 155). The distribution in Figure 3 suggests an uncertainty around 12%-13%. It is much larger than the current uncertainty used for solid fuels in the inventory, which is 3%-5%.

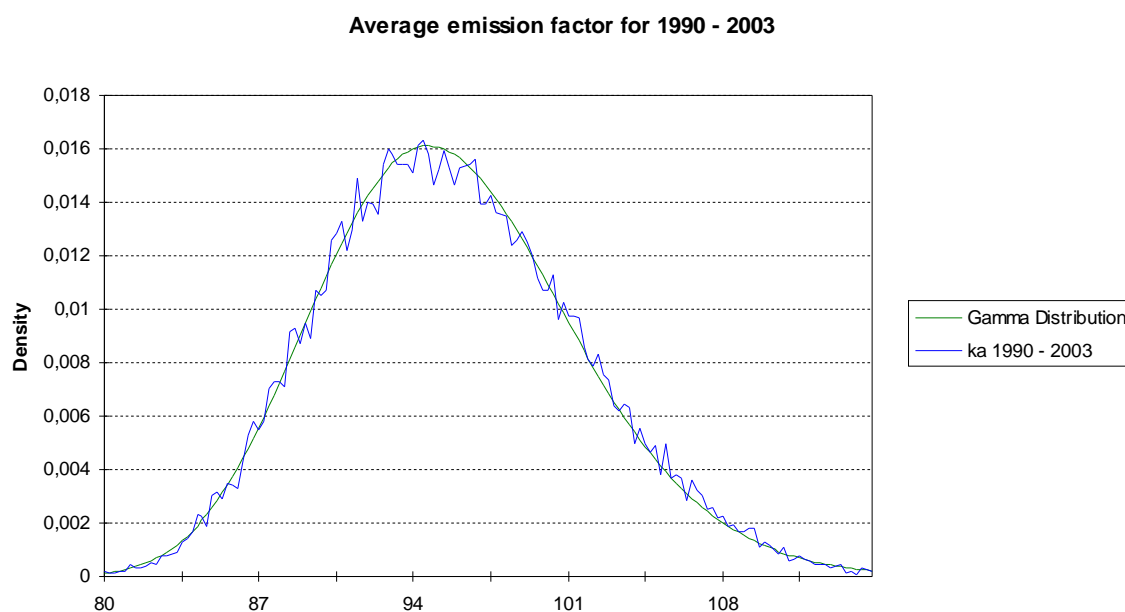


Figure 3. An average coal emission factor for 1990-2003.

Variance decomposition suggests that most of the uncertainty in the emission factor for 1990-2003 is due to a variable net calorific value of the Polish coal combusted in Finland (Fig. 4). The carbon content of Polish coal and the net calorific value of Russian coal are also important factors affecting uncertainty of the average emission factor. Other factors play a minor role in the overall uncertainty.

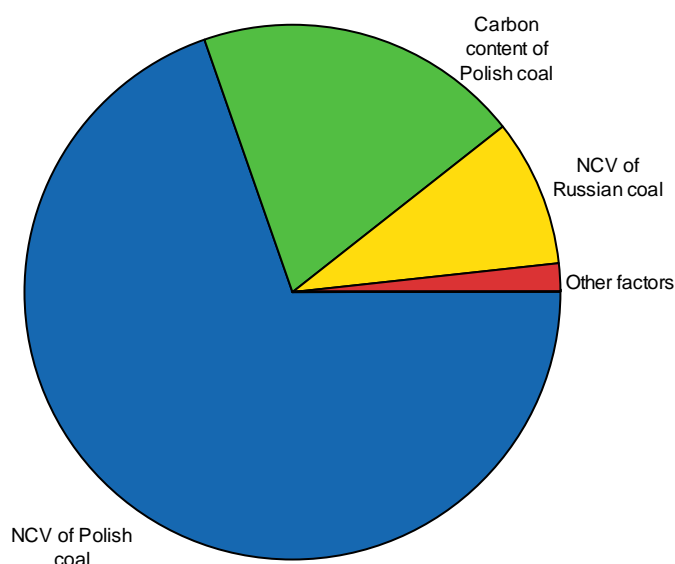


Figure 4. Variance decomposition of the average emission factor for 1990-2003.

Summary statistics for the simulation are given in Table 10. Estimates of the means are 0.3%-2.2% larger than the current default emission factor used.

Table 1. Summary statistics for simulation (n = 30 000) of coal emission factors. All numbers have the unit of measurement g/MJ.

	Year	Mean	Sd	MCSE*	Quantiles		
					2.5%	50.0%	97.5%
	1990	95.87	6.18	0.036	85.0	95.5	109.0
	1991	95.27	6.27	0.036	84.3	94.8	108.7
	1992	95.93	6.44	0.037	84.5	95.5	109.5
	1993	95.75	7.55	0.044	82.6	95.2	112.0
	1994	95.87	7.09	0.041	83.5	95.3	111.1
	1995	94.92	5.68	0.033	84.9	94.6	106.9
	1996	95.12	6.04	0.035	84.5	94.7	108.0
	1997	95.32	6.51	0.038	84.0	94.8	109.3
	1998	95.66	6.26	0.036	84.7	95.2	109.0
	1999	96.69	5.92	0.034	86.1	96.4	109.0
	2000	96.77	6.20	0.036	85.6	96.4	109.8
	2001	96.54	5.71	0.033	86.3	96.2	108.5
	2002	96.50	5.37	0.031	86.9	96.2	107.7
	2003	96.66	5.29	0.031	87.3	96.3	107.8

*Monte Carlo standard error of the mean, Sd/\sqrt{n} .

ANNEX 4. Tier 1 Reference calculation based on National Energy Balances of 2008

This annex will be included in the 2011 submission, as the finalised energy balance was not available for the preparation of this submission.

ANNEX 5. Assessment of completeness and (potential) sources and sinks of greenhouse gas emissions and removals excluded

Completeness of the Finnish inventory submission 2009 is evaluated by sectors in the tables below. The completeness is estimated by the gases (CO₂, CH₄, N₂O, F-gases, NMVOC) and emission categories according to the detailed CRF-classification.

Abbreviations used in tables:

X - included in the inventory

C - confidential business information

IE - included elsewhere

NA - not applicable

NE - not estimated

NO - not occurring in Finland

Energy, Fuel combustion (CRF 1.A)

Greenhouse gas source and sink categories	CO ₂	CH ₄	N ₂ O	Explanation, -if not estimated -if included elsewhere	Notes
1.A. Fuel combustion activities					
1. Energy industries					
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		
2. Manufacturing Industries and Construction					
a. Iron and Steel	X	X	X		
b. Non-Ferrous Metals	X	X	X		
c. Chemicals	X	X	X		
d. Pulp, Paper and Print	X	X	X		
e. Food Processing, Beverages and Tobacco	X	X	X		
f. Other Construction Other non-specified	X	X	X		
3. Transport					

Greenhouse gas source and sink categories	CO ₂	CH ₄	N ₂ O	Explanation, -if not estimated -if included elsewhere	Notes
a. Civil Aviation	X	X	X		
b. Road Transportation	X	X	X		
c. Railways	X	X	X		
d. Navigation	X	X	X		
e. Other Transportation Other off-road machinery	X	X	X		
4. Other Sectors					
a. Commercial/Institutional	X	X	X		
b. Residential	X	X	X		
c. Agriculture/Forestry/ Fisheries	X	X	X		
5. Other					
a. Stationary	X	X	X		
b. Mobile	X	X	X		

Energy, Fugitive emissions (CRF 1.B)

Greenhouse gas source and sink categories	CO ₂	CH ₄	N ₂ O	Explanation, -if not estimated -if included elsewhere	Notes
1.B Fugitive emissions from fuels					
1. Solid fuels					
a. Coal Mining	NO	NO	NO		
b. Solid Fuel Transformation	NO	NO	NO		
c. Other	NO	NO	NO		
2. Oil and Natural Gas					
a. Oil	X	X	NO		
b. Natural Gas	X	X			
c. Venting and Flaring	X	X	X		
d. Other Other non-specified	X	NO	NO		

Industrial Processes (CRF 2)

Greenhouse gas source and sink categories	CO ₂	CH ₄	N ₂ O	Explanation, -if not estimated -if included elsewhere	Notes
2. Industrial processes					
A. Mineral products					
1. Cement Production	X				
2. Lime Production	X				
3. Limestone and Dolomite Use	X				
4. Soda Ash Production and Use	X				
5. Asphalt Roofing	IE			Indirect CO ₂ emissions are included in 2.A 6 Road paving.	
6. Road Paving with Asphalt	X				
7. Other Glass production	X	NO	NO		
B. Chemical Industry					
1. Ammonia Production	X	NO	NO		No ammonia production in Finland after 1992.
2. Nitric Acid Production			X		
3. Adipic Acid Production	NO		NO		
4. Carbide Production	NO	NO			
5. Other Ethylene Production	NO	NO	NO		No emission occurring from that process.
5. Other Hydrogen Production Chemicals production	X	NO	NO		
5. Other Carbon black Dichloroethylene Styrene Methanol Other non-specified	NO	NO	NO		
C. Metal Production					
1. Iron and Steel Production	X	X			Includes emissions from integrated ferrochromium and stainless steel plant.
2. Ferroalloys Production	IE	NO		Emissions from integrated ferrochromium and stainless steel plant have been allocated to 2.C 1 Iron and steel production.	

Greenhouse gas source and sink categories	CO ₂	CH ₄	N ₂ O	Explanation, -if not estimated -if included elsewhere	Notes
3. Aluminium Production	NO	NO			
4. SF ₆ Used in Aluminium and Magnesium Foundries	NO	NO			
5. Other Non-ferrous metals	X	NO	NO	Only indirect CO ₂ emissions from NMVOC emissions	
D. Other Production					
1. Pulp and Paper	NO				
2. Food and Drink	NO				
G. Other	NO				

F-gases (CRF 2.F)

Greenhouse gas source and sink categories	HFC _s	PFC _s	SF ₆	Explanation, -if not estimated -if included elsewhere	Notes
2. Industrial processes					
E. Production of Halocarbons and SF ₆					
1. By-product Emissions	NO	NO	NO		
Production of HCFC-22	NO	NO	NO		
Other	NO	NO	NO		
F. Consumption of Halocarbons and SF ₆					
1. Refrigeration and Air Conditioning Equipment	X	X	NO		
2. Foam Blowing	X	NO	NO		Excl. one component foam.
3. Fire Extinguishers	X, C	NO	NO		Reported grouped with other confidential data.
4. Aerosols/ Metered Dose Inhalers	X	NO	NO		Incl. one component foam.
5. Solvents	NO	NO	NO		
6. Other applications using ODS substitutes	NO	NO	NO		
7. Semiconductor Manufacture	C, NA, NO	C, NA, NO	C, NA		Reported grouped with other confidential data.
8. Electrical Equipment	NO	NO	X		The activity data is confidential.

Greenhouse gas source and sink categories	HFC _s	PFC _s	SF ₆	Explanation, -if not estimated -if included elsewhere	Notes
9. Other	X	X	X		Confidential information grouped together as one "source category": HFC-23 from refrigeration and air conditioning; HFC-23, PFCs, and SF ₆ from semiconductor manufacturing; HFCs from fixed fire protection equipment; SF ₆ from shoes; SF ₆ from magnesium die-casting.

Solvent and other product use (CRF 3)

The evaluation of CRF category CRF 3 (Solvent and other product use) covers also the NMVOC emissions.

Greenhouse gas source and sink categories	CO ₂	NMVOC	N ₂ O	Explanation, -if not estimated -if included elsewhere	Notes
3. Solvent and Other Product Use					
A. Paint Application	X	X			
B. Degreasing and Dry Cleaning	X	X	NO		
C. Chemical Products, Manufacture and Processing	X	X			
D. Other					
1. Use of N ₂ O for Anaesthesia			X		Includes all uses of N ₂ O in Finland.
2. N ₂ O from Fire Extinguishers			IE	Included in Use of N ₂ O for Anaesthesia	
3. N ₂ O from Aerosol Cans			IE	Included in Use of N ₂ O for Anaesthesia	
4. Other Use of N ₂ O			IE	Included in Use of N ₂ O for Anaesthesia	
5. Other (as specified in table 3.A-D)					
Wood preservation	X	X	NO		
Printing industry	X	X	NO		
Other non-specified	NO	NO	NO		
Use of pesticides	X	X	NO		
Glass wool induction	X	X	NO		
Mineral wool induction	X	X	NO		
Domestic solvent use	X	X	NO		Car care products included.
Fat, edible and non edible oil extraction	X	X	NO		

Agriculture (CRF 4)

Greenhouse gas source and sink categories	CO ₂	CH ₄	N ₂ O	Explanation, -if not estimated -if included elsewhere	Notes
4. Agriculture					
A. Enteric fermentation					
1.Cattle		X			
Dairy Cattle		X			
Non-Dairy Cattle		IE		See 'Other'	
2.Buffalo		NO			
3.Sheep		X			
4.Goats		X			
5.Camels and Lamas		NO			
6.Horses		X			
7.Mules and Asses		NO			
8.Swine		X			
9.Poultry		NE		No methodology available	
10.Other		X			Suckler cows, heifers, bulls, calves, reindeer, fur animals
B. Manure Management					
1.Cattle		X	X		
Dairy Cattle		X	X		
Non-Dairy Cattle		IE	IE	See 'Other'	
2.Buffalo		NO	NO		
3.Sheep		X	X		
4.Goats		X	X		
5.Camels and Lamas		NO	NO		
6. Horses		X	X		
7.Mules and Asses		NO	NO		

Greenhouse gas source and sink categories	CO ₂	CH ₄	N ₂ O	Explanation, -if not estimated -if included elsewhere	Notes
8.Swine		IE	IE	See 'Other'	
9.Poultry		X	X		
10. Other		X	X		Suckler cows, heifers, bulls calves, reindeer, fur animals, reindeer, ponies, sows with piglets, boars, fattening pigs, weaned pigs
11.Anaerobic Lagoons		NO	NO		
12.Liquid Systems		X	X		
13. Daily spread		NO	NO		
14.Solid Storage and Dry Lot		X	X		
15.Other AWMS		X	X		Deep litter
C. Rice Cultivation NO					
D. Agricultural Soils					
1. Direct Soil Emissions		NE	X	No methodology available for CH ₄	
2.Pasture, range and paddock manure			X		
3.Indirect Emissions		NE	X	No methodology available for CH ₄	
4.Other Other non-specified Municipal sewage sludge applied on fields		NE	X		
E. Prescribed Burning of Savannas NO					
F. Field Burning of Agricultural Residues					
1.Cereals		X	X		
2.Pulse		NE	NE	Negligible amounts, data not available	
3.Tubers and Roots		NE	NE	Negligible amounts, data not available	
4.Sugar Cane		NO	NO		
5.Other		NA	NA		
G. Other NO					

Land Use Land Use Change and Forestry (CRF 5)

Greenhouse gas source and sink categories	CO ₂	CH ₄	N ₂ O	Explanation, -if not estimated -if included elsewhere	Notes
5. Land use, Land use change and Forestry					
A. Forest land					
1. Forest land remaining forest land	X	IE	IE	CH ₄ and N ₂ O emissions from Forest land are reported under CRF 5(I) N ₂ O emissions from N fertilisation and CRF 5(V) Biomass burning	
2. Land converted to forest land	IE	IE	IE	Sources and sinks from CRF 5.A.2 are included in CRF 5A.1 Forest land remaining forest land	
B. Cropland					
1. Cropland remaining cropland	X	NA	NA		Non-CO ₂ emissions included under agriculture CRF 4.D
2. Land converted to cropland	X	NA	X		
C. Grassland					
1. Grassland remaining grassland	X	NA	NA		Non-CO ₂ emissions included under agriculture CRF 4.D
2. Land converted to grassland	X	NA	X		
D. Wetlands					
1. Wetlands remaining wetlands	NE			Parties do not have to report categories presented in appendixes of GPG LULUCF (2003) (Appendix: 3a.3 Wetlands remaining wetlands).	
2. Land converted to wetlands (include peat extraction areas)	X	X	X		
E. Settlements					
1. Settlements remaining settlements	NE			Parties do not have to report categories presented in appendixes of GPG LULUCF (2003) (Appendix: 3a.4 Settlements).	
2. Land converted to settlements	NE			Parties do not have to report categories presented in appendixes of GPG LULUCF (2003) (Appendix: 3a.4 Settlements).	
F. Other land					

Greenhouse gas source and sink categories	CO ₂	CH ₄	N ₂ O	Explanation, -if not estimated -if included elsewhere	Notes
1. Other land remaining other land	NE			Parties do not have to report categories presented in appendixes of GPG LULUCF (2003) (Appendix: 3a.5 Other land).No methodology currently available	
2. Land converted to other land	NE			Parties do not have to report categories presented in appendixes of GPG LULUCF (2003) (Appendix: 3a.5 Other land).	
G. Other					
Harvested wood products	X				
Information items:					
Forest land converted to other land use categories	X	NE	X	No reliable methodology to estimate CH ₄ emissions.	
Grassland converted to other land use categories	X	NA	X		
5 (I) Direct N ₂ O emissions from N fertilization			X		
5(II) N ₂ O emissions from drainage of soils			IE, NE	N ₂ O emissions from Wetlands (peat extraction areas) are reported in the category 5.D 2 Land converted to Wetlands. N ₂ O emissions from other Wetlands and from Forest land are not reported due to that no reliable methodology is currently available and, inadequate activity data. Parties do not have to report categories presented in appendixes of GPG LULUCF (2003) (Appendix: 3.a.2)	
5(III) N ₂ O emissions from disturbance associated with land-use conversion to cropland			X		
5(IV) Carbon emissions from agricultural lime application	X				
5(V) Biomass Burning	X	X	X		

Waste (CRF 6)

Greenhouse gas source and sink categories	CO ₂	CH ₄	N ₂ O	Explanation, -if not estimated -if included elsewhere	Notes
6. Waste					
A. Solid Waste Disposal on Land					
1. Managed Waste Disposal on Land	NO	X			
2. Unmanaged Waste Disposal Sites	NO	IE		Unmanaged waste disposal, which occurred in early 1990's, is included under managed waste disposal.	
3. Other Municipal sludge Industrial sludge Industrial solid waste Construction and demolition waste	NO	X			
B. Wastewater Handling					
1. Industrial Wastewater		X	NE	No IPCC methodologies for N ₂ O available.	
2. Domestic and Commercial Wastewater		X	X		N ₂ O from human sewage is estimated partly by the means of population and partly by the means of N input (measured values)
3. Other N input from Fish Farming N input from industrial wastewater		NA	X		National emission source
C. Waste Incineration	IE	IE	IE	Waste incineration without energy recovery is nearly zero. Waste incineration with and without energy recovery are included in the calculations of the energy sector (CRF 1.A.).	
D. Other					
Composting	NO	X	X		

Land Use, Land-Use Change and Forestry Activities under the Kyoto Protocol (CRF 5(KP))

Greenhouse gas source and sink categories	CO ₂	CH ₄	N ₂ O	Explanation, -if not estimated -if included elsewhere	Notes
5(KP) Land use, land-use change and forestry activities under the Kyoto Protocol					
5(KP-I) Carbon stock changes and net CO ₂ emissions and removals					
A.1.1 Afforestation and reforestation above ground biomass below ground biomass litter dead wood soil	X, IE IE IE IE, NO X			Biomass: The method used for tree biomass estimation produce a combined estimate for above-ground and below-ground biomass. Litter and dead wood (DOM): C-stock changes in these pools for mineral soils are estimated using the Yasso mode that produce a combined estimate DOM and soil organic matter (SOM)	In NIR the description of the method is in Sections 11.3 and 7.2.2.2 and 7.2.2.3.
A.2 Deforestation above ground biomass below ground biomass litter dead wood soil	X, NO IE, NO IE, NE, NO X, IE X, NE			Gains in biomass is not estimated for all deforested areas because there is no applicable method. Losses in below-ground biomass are included in losses in above-ground biomass.	
B.1 Forest management above ground biomass below ground biomass litter dead wood soil	X IE IE IE X			Biomass: The method used for tree biomass estimation produce a combined estimate for above-ground and below-ground biomass. Litter and dead wood (DOM): C-stock changes in these pools for mineral soils are estimated using the Yasso mode that produce a combined estimate DOM and soil organic matter (SOM)	
5(KP-II)1. Direct N ₂ O emissions from N fertilisation					
A.1.1 Afforestation and reforestation			IE	All N ₂ O emission on forests is reported under FM	
B.1 Forest management			X, IE	The emission is reported in country level because the statistics on N fertilisers is compiled for whole country.	
5(KP-II)2. N ₂ O emissions from drainage of soils					
B.1 Forest management			NE	A method to estimate N ₂ O emissions from drainage of soils is given in Appendix 3a.2 and therefore it is not mandatory to a Party report them.	NIR Section 11.3.1.2
5(KP-II)3. D. N ₂ O emissions from disturbance associated with land-use conversion to cropland					
A.2 Deforestation			X		

Greenhouse gas source and sink categories	CO ₂	CH ₄	N ₂ O	Explanation, -if not estimated -if included elsewhere	Notes
5(KP-II)4. Carbon emissions from lime application					
A.1.1 Afforestation and reforestation					
A.2 Deforestation					
B.1 Forest management					
5(KP-II)5. GHG emissions from biomass burning					
A.1.1 Afforestation and reforestation	IE	IE	IE	Emissions are reported under FM	
A.2 Deforestation	NA	NA	NA		
B.1 Forest management	X, IE	X, IE	X, IE	Emissions are reported for whole country because the statistics on burned areas are compiled for whole country.	

ANNEX 6. Uncertainty and sensitivity analyses

Annex 6 provides the mandatory reporting table for uncertainty analysis. As Finland reports the results of tier 1 analysis (UNFCCC 2006, paragraph 14), the reporting is to be carried out using table 6.1 of the Good Practice Guidance (ibid., paragraph 32).

The table 6.1 is reported first, followed by discussion of factors affecting the uncertainty of N₂O from manure management (CRF 4.B 13).

Tier 1 uncertainty analysis – table 6.1 of IPCC (2000)

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
IPCC Greenhouse Gas Source and Sink Categories	Direct Greenhouse Gas ¹⁾	Base Year emissions, 1990	Current Year emissions, 2008	Activity data uncertainty ²⁾	Emission factor uncertainty ²⁾	Combined uncertainty	Combined uc as part of total national emissions in 2008	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions	Emission factor quality indicator	Activity data quality indicator	Expert judgement reference numbers	Footnote Reference numbers
1.A. Fuel Combustion - gaseous fuels	CO2	4970.23	8279.35	1 %	1 %	1 %	0.34 %	0.0938	0.1523	0.09 %	0.22 %	0.23 %	R	R	E1	
1.A. Fuel Combustion - liquid fuels	CO2	27779.60	24209.69	2 %	2 %	3 %	1.97 %	0.1182	0.4453	0.24 %	1.26 %	1.28 %	R	R	E1	
1.A. Fuel Combustion - other fuels	CO2	5693.53	8865.80	4 %	5 %	7 %	1.68 %	0.0960	0.1631	0.48 %	0.99 %	1.10 %	R	R	E1	
1.A. Fuel Combustion - solid fuels	CO2	14530.47	12189.8	2 %	10 %	10 %	3.55 %	0.0533	0.2242	0.53 %	0.51 %	0.74 %	M	R	E1	M4
1.A.1 Energy Industries - biomass	CH4	1.51	8.02	20 %	60 %	63 %	0.01 %	0.0001	0.0001	0.01 %	0.00 %	0.01 %	R/M	R	E1	M2
1.A.1 Energy Industries - biomass	N2O	3.07	83.75	20 %	60 %	63 %	0.15 %	0.0015	0.0015	0.09 %	0.04 %	0.10 %	R/M	R	E1	M2
1.A.1 Energy Industries - gaseous fuels	CH4	1.03	4.62	1 %	60 %	60 %	0.01 %	0.0001	0.0001	0.00 %	0.00 %	0.00 %	R/M	R	E1	M2
1.A.1 Energy Industries - gaseous fuels	N2O	15.63	35.22	1 %	60 %	60 %	0.06 %	0.0005	0.0006	0.03 %	0.00 %	0.03 %	R	R	E1	
1.A.1 Energy Industries - liquid fuels	CH4	0.97	0.88	2 %	60 %	60 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R/M	R	E1	M2
1.A.1 Energy Industries - liquid fuels	N2O	25.03	24.25	2 %	60 %	60 %	0.04 %	0.0002	0.0004	0.01 %	0.00 %	0.01 %	R	R	E1	
1.A.1 Energy Industries - other fuels	CH4	2.47	5.81	5 %	60 %	60 %	0.01 %	0.0001	0.0001	0.00 %	0.00 %	0.00 %	R	R	E1	
1.A.1 Energy Industries - other fuels	N2O	34.64	97.57	5 %	60 %	60 %	0.17 %	0.0014	0.0018	0.08 %	0.01 %	0.08 %	R	R	E1	
1.A.1 Energy Industries - solid fuels	CH4	2.29	2.18	2 %	60 %	60 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R	E1	
1.A.1 Energy Industries - solid fuels	N2O	43.40	62.90	2 %	60 %	60 %	0.11 %	0.0006	0.0012	0.04 %	0.00 %	0.04 %	R	R	E1	
1.A.2. Manufacturing Industries and Construction - biomass	CH4	6.80	7.98	15 %	60 %	62 %	0.01 %	0.0001	0.0001	0.00 %	0.00 %	0.01 %	R/M	R	E1	M2
1.A.2. Manufacturing Industries and Construction - biomass	N2O	56.43	77.25	15 %	60 %	62 %	0.14 %	0.0008	0.0014	0.05 %	0.03 %	0.05 %	R/M	R	E1	M2
1.A.2. Manufacturing Industries and Construction - gaseous fuels	CH4	1.01	0.99	1 %	60 %	60 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R/M	R	E1	M2
1.A.2. Manufacturing Industries and Construction - gaseous fuels	N2O	15.26	15.60	1 %	60 %	60 %	0.03 %	0.0001	0.0003	0.01 %	0.00 %	0.01 %	R	R	E1	
1.A.2. Manufacturing Industries and Construction - liquid fuels	CH4	2.54	2.31	2 %	60 %	60 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R	E1	
1.A.2. Manufacturing Industries and Construction - liquid fuels	N2O	36.75	27.90	2 %	60 %	60 %	0.05 %	0.0001	0.0005	0.00 %	0.00 %	0.01 %	R	R	E1	
1.A.2. Manufacturing Industries and	CH4	1.08	1.21	5 %	60 %	60 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R	E1	

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
IPCC Greenhouse Gas Source and Sink Categories	Direct Greenhouse Gas ¹⁾	Base Year emissions, 1990	Current Year emissions, 2008	Activity data uncertainty ²⁾	Emission factor uncertainty ²⁾	Combined uncertainty	Combined uc as part of total national emissions in 2008	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions	Emission factor quality indicator	Activity data quality indicator	Expert judgement reference numbers	Footnote Reference numbers
Construction - other fuels																
1.A.2. Manufacturing Industries and Construction - other fuels	N2O	17.01	18.20	5 %	60 %	60 %	0.03 %	0.0001	0.0003	0.01 %	0.00 %	0.01 %	R	R	E1	
1.A.2. Manufacturing Industries and Construction - solid fuels	CH4	1.37	0.52	2 %	60 %	60 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R	E1	
1.A.2. Manufacturing Industries and Construction - solid fuels	N2O	46.74	10.25	2 %	60 %	60 %	0.02 %	-0.0004	0.0002	-0.02 %	0.00 %	0.02 %	R	R	E1	
1.A.3.a Civil Aviation	CH4	0.27	0.23	5 %	100 %	100 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	D	R		L4
1.A.3.a Civil Aviation	N2O	4.86	3.76	5 %	150 %	150 %	0.02 %	0.0000	0.0001	0.00 %	0.00 %	0.00 %	R	R		
1.A.3.b. Road Transportation - biomass	CH4	0.00	1.00	1 %	50 %	50 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	E	E		E18
1.A.3.b. Road Transportation - biomass	N2O	0.00	3.09	1 %	150 %	150 %	0.01 %	0.0001	0.0001	0.01 %	0.00 %	0.01 %	E	E		E18
1.A.3.b. Road Transportation - diesel	CH4	11.47	5.20	1 %	50 %	50 %	0.01 %	0.0000	0.0001	0.00 %	0.00 %	0.00 %	M	R		L5
1.A.3.b. Road Transportation - diesel	N2O	68.12	100.83	1 %	158 %	158 %	0.46 %	0.0011	0.0019	0.17 %	0.00 %	0.17 %	M	R		L6, L7, L8, L9, L10, L19, L20, L21, L22, L23
1.A.3.b. Road Transportation - gasoline	CH4	77.85	21.28	1 %	50 %	50 %	0.03 %	-0.0005	0.0004	-0.03 %	0.00 %	0.03 %	M	R		L6, L9, L10, L19, L21
1.A.3.b. Road Transportation - gasoline - cars with catalytic converters	N2O	88.14	54.91	1 %	378 %	378 %	0.60 %	0.0000	0.0010	-0.01 %	0.00 %	0.01 %	M	R		L5
1.A.3.b. Road Transportation - gasoline - cars without catalytic converters	N2O	3.67	2.29	1 %	259 %	259 %	0.02 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	M	R		L6, L8, L11, L21
1.A.3.b. Road Transportation - natural gas	CH4	0.00	2.22	1 %	50 %	50 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	M	R		L5
1.A.3.b. Road Transportation - natural gas	N2O	0.00	0.01	1 %	150 %	150 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R		
1.A.3.c. Railways	CH4	0.23	0.13	5 %	110 %	110 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	M	R		M3
1.A.3.c. Railways	N2O	1.51	0.95	5 %	150 %	150 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R		
1.A.3.d Navigation - gasoline	CH4	4.13	2.88	20 %	100 %	102 %	0.01 %	0.0000	0.0001	0.00 %	0.00 %	0.00 %	D	R		L4
1.A.3.d Navigation - gasoline	N2O	0.33	0.85	20 %	150 %	151 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R		
1.A.3.d Navigation - residual oil & gas/diesel oil	CH4	0.43	0.49	10 %	100 %	100 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R		
1.A.3.d Navigation - residual oil & gas/diesel oil	N2O	2.56	2.90	10 %	150 %	150 %	0.01 %	0.0000	0.0001	0.00 %	0.00 %	0.00 %	R	R		
1.A.3.e. Other Transportation - diesel	N2O	3.84	3.97	30 %	150 %	153 %	0.02 %	0.0000	0.0001	0.00 %	0.00 %	0.01 %	R	R		

A IPCC Greenhouse Gas Source and Sink Categories	B Direct Greenhouse Gas ¹⁾	C Base Year emissions, 1990	D Current Year emissions, 2008	E Activity data uncertainty ²⁾	F Emission factor uncertainty ²⁾	G Combined uncertainty	H Combined uc as part of total national emissions in 2008	I Type A sensitivity	J Type B sensitivity	K Uncertainty in trend in national emissions introduced by emission factor uncertainty	L Uncertainty in trend in national emissions introduced by activity data uncertainty	M Uncertainty introduced into the trend in total national emissions	N Emission factor quality indicator	O Activity data quality indicator	P Expert judgement reference numbers	Q Footnote Reference numbers
1.A.3.e. Other Transportation - gasoline	N2O	0.63	0.65	30 %	150 %	153 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R		
1.A.3.e. Other Transportation - gasoline & diesel	CH4	4.61	6.11	30 %	50 %	58 %	0.01 %	0.0001	0.0001	0.00 %	0.00 %	0.01 %	R	R		
1.A.3.e. Other Transportation - LPG	CH4	0.39	0.51	30 %	50 %	58 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R	E16	
1.A.3.e. Other Transportation - LPG	N2O	0.29	0.30	30 %	150 %	153 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R	E16	
1.A.4. Other Sectors - biomass	CH4	161.28	206.18	15 %	150 %	151 %	0.89 %	0.0019	0.0038	0.28 %	0.08 %	0.30 %	R/M	R	E1	M2
1.A.4. Other Sectors - biomass	N2O	27.77	33.98	15 %	150 %	151 %	0.15 %	0.0003	0.0006	0.04 %	0.01 %	0.05 %	R/M	R	E1	M2
1.A.4. Other Sectors - gaseous fuels	CH4	0.22	0.24	5 %	75 %	75 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R/M	R	E1	M2
1.A.4. Other Sectors - gaseous fuels	N2O	0.59	1.14	5 %	50 %	50 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R	E1	
1.A.4. Other Sectors - liquid fuels	CH4	18.18	10.88	3 %	75 %	75 %	0.02 %	0.0000	0.0002	0.00 %	0.00 %	0.00 %	R/M	R	E1	M2
1.A.4. Other Sectors - liquid fuels	N2O	56.43	34.66	3 %	75 %	75 %	0.07 %	0.0000	0.0006	0.00 %	0.00 %	0.00 %	R	R	E1	
1.A.4. Other Sectors - other fuels	CH4	1.24	1.15	25 %	50 %	56 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R	E1	
1.A.4. Other Sectors - other fuels	N2O	1.47	1.35	25 %	150 %	152 %	0.01 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R	E1	
1.A.4. Other Sectors - solid fuels	CH4	2.34	0.06	10 %	75 %	76 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R	E1	
1.A.4. Other Sectors - solid fuels	N2O	0.59	0.11	10 %	50 %	51 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R	E1	
1.A.5 Other - other fuels (mostly indirect N2O from NOx)	N2O	439.27	250.79	15 %	60 %	62 %	0.45 %	-0.0006	0.0046	-0.03 %	0.10 %	0.10 %	R/M	R	E1	M2
1.A.5. Other - biomass	CH4	0.20	0.05	20 %	60 %	63 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R/M	R	E1	M2
1.A.5. Other - biomass	N2O	0.22	0.01	20 %	60 %	63 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R/M	R	E1	M2
1.A.5. Other - gaseous fuels	CH4	0.06	0.21	13 %	60 %	61 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R	E1	
1.A.5. Other - gaseous fuels	N2O	0.31	1.04	13 %	60 %	61 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R/M	R	E16	M2
1.A.5. Other - liquid fuels	CH4	2.35	1.50	7 %	60 %	60 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R	E16	
1.A.5. Other - liquid fuels	N2O	8.89	7.18	7 %	60 %	60 %	0.01 %	0.0000	0.0001	0.00 %	0.00 %	0.00 %	R	R	E16	
1.A.5. Other - other fuels	CH4	0.24	0.00	15 %	60 %	62 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R	E16	
1.A.5. Other - other fuels	N2O	0.15	0.00	15 %	60 %	62 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R	E21	
1.A.5. Other - solid fuels	CH4	0.00	0.00	10 %	60 %	61 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R	E16	
1.A.5. Other - solid fuels	N2O	0.01	0.00	10 %	60 %	61 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R	E16	

A IPCC Greenhouse Gas Source and Sink Categories	B Direct Greenhouse Gas ¹⁾	C Base Year emissions, 1990	D Current Year emissions, 2008	E Activity data uncertainty ²⁾	F Emission factor uncertainty ²⁾	G Combined uncertainty	H Combined uc as part of total national emissions in 2008	I Type A sensitivity	J Type B sensitivity	K Uncertainty in trend in national emissions introduced by emission factor uncertainty	L Uncertainty in trend in national emissions introduced by activity data uncertainty	M Uncertainty introduced into the trend in total national emissions	N Emission factor quality indicator	O Activity data quality indicator	P Expert judgement reference numbers	Q Footnote Reference numbers
1.B.2. Oil and Natural Gas - flaring	CH4	0.11	0.02	50 %	60 %	78 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R	E9	
1.B.2. Oil and Natural Gas - flaring	CO2	121.93	99.45	50 %	0 %	50 %	0.14 %	0.0004	0.0018	0.00 %	0.13 %	0.13 %			E14	
1.B.2. Oil and Natural Gas - flaring	N2O	3.13	0.69	50 %	60 %	78 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %			E14	
1.B.2. Oil and Natural Gas - gas distribution	CH4	0.00	29.40	5 %	0 %	5 %	0.00 %	0.0005	0.0005	0.00 %	0.00 %	0.00 %	R	R	E9	
1.B.2. Oil and Natural Gas - gas distribution (indirect CO2 from CH4)	CO2	0.00	3.90	5 %	25 %	25 %	0.00 %	0.0001	0.0001	0.00 %	0.00 %	0.00 %			E12	
1.B.2. Oil and Natural Gas - gas transmission	CH4	3.57	8.40	3 %	0 %	3 %	0.00 %	0.0001	0.0002	0.00 %	0.00 %	0.00 %	R	R	E9	
1.B.2. Oil and Natural Gas - gas transmission (indirect CO2 from CH4)	CO2	0.47	1.10	3 %	25 %	25 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %			E12	
1.B.2. Oil and Natural Gas - oil refining	CH4	7.56	11.13	2 %	90 %	90 %	0.03 %	0.0001	0.0002	0.01 %	0.00 %	0.01 %	R	R	E9	
1.B.2. Oil and Natural Gas - oil refining (indirect CO2 from CH4)	CO2	1.00	1.46	90 %	25 %	93 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %			E12	
1.B.2. Oil and Natural Gas - other (indirect CO2 from NMVOC)	CO2	95.45	33.91	5 %	10 %	11 %	0.01 %	-0.0005	0.0006	0.00 %	0.00 %	0.01 %			E11	
2.A.1 Cement Production	CO2	733.59	638.30	2 %	5 %	5 %	0.10 %	0.0031	0.0117	0.02 %	0.03 %	0.04 %	R	R	E9	
2.A.2 Lime Production	CO2	382.60	439.45	2 %	3 %	4 %	0.05 %	0.0036	0.0081	0.01 %	0.02 %	0.03 %	R	R	E9	
2.A.3 Limestone and Dolomite Use	CO2	88.00	125.32	7 %	9 %	11 %	0.04 %	0.0013	0.0023	0.01 %	0.02 %	0.03 %	R	R	E9	
2.A.4 Soda Ash Use	CO2	8.32	11.40	7 %	2 %	7 %	0.00 %	0.0001	0.0002	0.00 %	0.00 %	0.00 %	R	R	E9	
2.A.6 Road Paving with Asphalt	CO2	21.00	2.39	5 %	10 %	11 %	0.00 %	-0.0002	0.0000	0.00 %	0.00 %	0.00 %			E11	
2.A.7 Other - Glass Production	CO2	20.80	18.61	7 %	9 %	11 %	0.01 %	0.0001	0.0003	0.00 %	0.00 %	0.00 %			E12	
2.B.1 Ammonia Production	CO2	44.00	0.00	5 %	19 %	20 %	0.00 %	-0.0005	0.0000	-0.01 %	0.00 %	0.01 %			E13	
2.B.2 Nitric Acid Production	N2O	1655.71	1560.53	5 %	100 %	100 %	4.50 %	0.0092	0.0287	0.92 %	0.20 %	0.95 %	R/M	R		M1
2.B.5 Other: Chemicals Production (indirect CO2 from NMVOC)	CO2	24.41	8.47	5 %	10 %	11 %	0.00 %	-0.0001	0.0002	0.00 %	0.00 %	0.00 %			E11	
2.B.5 Other: Hydrogen Production	CO2	56.94	648.18	12 %	5 %	13 %	0.24 %	0.0113	0.0119	0.06 %	0.20 %	0.21 %	R	R	E9	
2.C.1 Iron and Steel production	CH4	5.11	9.03	3 %	20 %	20 %	0.01 %	0.0001	0.0002	0.00 %	0.00 %	0.00 %	R	R	E1	
2.C.1 Iron and Steel production	CO2	1935.18	2523.30	0 %	10 %	10 %	0.73 %	0.0237	0.0464	0.24 %	0.00 %	0.24 %			E10	
2.C.5 Other: Non-ferrous metals (indirect CO2 from NMVOC)	CO2	0.44	0.30	5 %	10 %	11 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %			E11	

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
IPCC Greenhouse Gas Source and Sink Categories	Direct Greenhouse Gas ¹⁾	Base Year emissions, 1990	Current Year emissions, 2008	Activity data uncertainty ²⁾	Emission factor uncertainty ²⁾	Combined uncertainty	Combined uc as part of total national emissions in 2008	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions	Emission factor quality indicator	Activity data quality indicator	Expert judgement reference numbers	Footnote Reference numbers
2.F.1. Refrigeration and Air Conditioning Equipment	HFCs, PFCs	0.01	912.50	26 %	0 %	26 %	0.69 %	0.0168	0.0168	0.00 %	0.62 %	0.62 %	R	R	E8	
2.F.2 Foam Blowing	HFCs	0.00	8.53	24 %	0 %	24 %	0.01 %	0.0002	0.0002	0.00 %	0.01 %	0.01 %	R	R	E8	
2.F.4 Aerosols	HFCs	0.00	77.37	10 %	0 %	10 %	0.02 %	0.0014	0.0014	0.00 %	0.02 %	0.02 %	R	R	E8	
2.F.8 Electrical Equipment	SF6	86.52	13.86	88 %	0 %	88 %	0.04 %	-0.0008	0.0003	0.00 %	0.03 %	0.03 %	R	R	E8	
2.F.9 Other (grouped data)	HFCs, PFCs, SF6	7.94	33.29	38 %	0 %	38 %	0.04 %	0.0005	0.0006	0.00 %	0.03 %	0.03 %	R	R	E8	
3. Solvent and Other Product Use	N2O	62.00	34.11	30 %	20 %	36 %	0.04 %	-0.0001	0.0006	0.00 %	0.03 %	0.03 %	R	R	E1	
3. Solvent and Other Product Use (indirect CO2 from NMVOC)	CO2	116.37	51.77	5 %	10 %	11 %	0.02 %	-0.0004	0.0010	0.00 %	0.01 %	0.01 %			E11	
4.A.Enteric fermentation	CH4	1918.96	1556.59	0 %	32 %	32 %	1.44 %	0.0061	0.0286	0.20 %	0.00 %	0.20 %	D/R	R		L4, L13
4.B.Manure management	CH4	230.40	287.51	0 %	16 %	16 %	0.13 %	0.0026	0.0053	0.04 %	0.00 %	0.04 %	R	R		
4.B.Manure management	N2O	489.94	420.89	0 %	82 %	82 %	0.99 %	0.0020	0.0077	0.16 %	0.00 %	0.16 %	R	R		L12, L14, L15, L16, L17, L4
4.D.Agricultural soils: direct emissions, animal production and sludge spreading	N2O	3262.51	2989.44	0 %	71 %	71 %	6.09 %	0.0166	0.0550	1.18 %	0.00 %	1.18 %	R/M	R		L1
4.D.Agricultural soils: indirect emissions	N2O	711.72	578.63	0 %	248 %	248 %	4.13 %	0.0023	0.0106	0.57 %	0.00 %	0.57 %	R/M	R		L1
4.F Field Burning of Agricultural Residues	CH4	1.88	0.53	15 %	20 %	25 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %			E15	
4.F Field Burning of Agricultural Residues	N2O	0.55	0.15	15 %	14 %	21 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %			E15	
5 (I) Direct N2O Emissions from N Fertilization (5.A)	N2O	26.82	35.43	10 %	380 %	380 %	0.39 %	0.0003	0.0007	0.13 %	0.01 %	0.13 %				see table 7.2_12
5 (IV) CO2 Emissions from Agricultural Lime Application (5.B)	CO2	617.87	289.52	20 %	20 %	28 %	0.24 %	-0.0019	0.0053	-0.04 %	0.15 %	0.16 %				see section 7.2.3.2
5 (V) Biomass Burning (5.A)	CH4	4.06	1.28	10 %	70 %	71 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %				see section 7.2.3.2
5 (V) Biomass Burning (5.A)	CO2	3.86	8.55	10 %	70 %	71 %	0.02 %	0.0001	0.0002	0.01 %	0.00 %	0.01 %				L25
5 (V) Biomass Burning (5.A)	N2O	0.41	0.13	10 %	70 %	71 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R	E17	
5.A.1. Forest Land remaining Forest Land - net carbon stock change in living biomass	CO2	-25438.37	-37321.83	0 %	33 %	33 %	-35.45 %	-0.3893	-0.6864	-12.85 %	0.00 %	12.85 %	D	R	E4	L24
5.A.1. Forest Land remaining Forest Land - net carbon stock change in mineral soils	CO2	-7742.46	-9429.71	0 %	92 %	92 %	-24.97 %	-0.0826	-0.1734	-7.59 %	0.00 %	7.59 %	R		E7	

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
IPCC Greenhouse Gas Source and Sink Categories	Direct Greenhouse Gas ¹⁾	Base Year emissions, 1990	Current Year emissions, 2008	Activity data uncertainty ²⁾	Emission factor uncertainty ²⁾	Combined uncertainty	Combined uc as part of total national emissions in 2008	Type A sensitivity	Type B sensitivity	Uncertainty in trend in national emissions introduced by emission factor uncertainty	Uncertainty in trend in national emissions introduced by activity data uncertainty	Uncertainty introduced into the trend in total national emissions	Emission factor quality indicator	Activity data quality indicator	Expert judgement reference numbers	Footnote Reference numbers
5.A.1. Forest Land remaining Forest Land - net carbon stock change in organic soils	CO2	12023.92	5948.43	0 %	78 %	78 %	13.35 %	-0.0318	0.1094	-2.48 %	0.00 %	2.48 %	D	R	E4	L24
5.A.2. Cropland converted to Forest Land - net carbon stock change in living biomass	CO2	-570.90	-294.08	0 %	50 %	50 %	-0.42 %	0.0013	-0.0054	0.07 %	0.00 %	0.07 %		M	E22	
5.A.2. Cropland converted to Forest Land - net carbon stock change in mineral soils	CO2	88.44	48.40	0 %	300 %	300 %	0.42 %	-0.0001	0.0009	-0.04 %	0.00 %	0.04 %		R	E20	
5.A.2. Cropland converted to Forest Land - net carbon stock change in organic soils	CO2	335.28	110.81	0 %	300 %	300 %	0.96 %	-0.0019	0.0020	-0.57 %	0.00 %	0.57 %		R	E20	
5.A.2. Grassland converted to Forest Land - net carbon stock change in living biomass	CO2	-219.95	-555.18	0 %	50 %	50 %	-0.80 %	-0.0076	-0.0102	-0.38 %	0.00 %	0.38 %		M	E22	
5.A.2. Grassland converted to Forest Land - net carbon stock change in mineral soils	CO2	23.14	67.50	0 %	300 %	300 %	0.58 %	0.0010	0.0012	0.29 %	0.00 %	0.29 %		R	E20	
5.A.2. Grassland converted to Forest Land - net carbon stock change in organic soils	CO2	-68.63	-154.41	0 %	300 %	300 %	-1.33 %	-0.0020	-0.0028	-0.61 %	0.00 %	0.61 %		R	E20	
5.A.2. Settlements converted to Forest Land - net carbon stock change in living biomass	CO2	-6.39	-29.40	0 %	50 %	50 %	-0.04 %	-0.0005	-0.0005	-0.02 %	0.00 %	0.02 %		M	E22	
5.A.2. Settlements converted to Forest Land - net carbon stock change in mineral soils	CO2	-109.78	-545.38	0 %	300 %	300 %	-4.71 %	-0.0087	-0.0100	-2.62 %	0.00 %	2.62 %		R	E20	
5.A.2. Settlements converted to Forest Land - net carbon stock change in organic soils	CO2	0.55	2.05	0 %	300 %	300 %	0.02 %	0.0000	0.0000	0.01 %	0.00 %	0.01 %		R	E20	
5.A.2. Wetlands converted to Forest Land / drained-WL - biomass	CO2	-24.52	-59.56	0 %	50 %	50 %	-0.09 %	-0.0008	-0.0011	-0.04 %	0.00 %	0.04 %		M	E22	
5.A.2. Wetlands converted to Forest Land / drained-WL - organic soils	CO2	104.52	218.50	0 %	300 %	300 %	1.89 %	0.0028	0.0040	0.84 %	0.00 %	0.84 %		R	E20	
5.A.2. Wetlands converted to Forest Land / peat extraction - biomass	CO2	0.00	-2.46	0 %	50 %	50 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %		M	E22	
5.A.2. Wetlands converted to Forest Land / peat extraction - organic soils	CO2	0.00	24.60	0 %	300 %	300 %	0.21 %	0.0005	0.0005	0.14 %	0.00 %	0.14 %		R	E20	
5.B N2O emissions from disturbance associated with land-use conversion to cropland	N2O	3.70	7.33	0 %	100 %	100 %	0.02 %	0.0001	0.0001	0.01 %	0.00 %	0.01 %		M	E19	
5.B.1. Cropland Remaining Cropland - net carbon stock change in living biomass	CO2	-1.44	-2.60	0 %	56 %	56 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %	R	R	E6	L3; see also section 7.5.3
5.B.1. Cropland Remaining Cropland - net carbon stock change in mineral soils	CO2	-419.37	-984.83	0 %	100 %	100 %	-2.83 %	-0.0132	-0.0181	-1.32 %	0.00 %	1.32 %				see appendix 7c

A IPCC Greenhouse Gas Source and Sink Categories	B Direct Greenhouse Gas ¹⁾	C Base Year emissions, 1990	D Current Year emissions, 2008	E Activity data uncertainty ²⁾	F Emission factor uncertainty ²⁾	G Combined uncertainty	H Combined uc as part of total national emissions in 2008	I Type A sensitivity	J Type B sensitivity	K Uncertainty in trend in national emissions introduced by emission factor uncertainty	L Uncertainty in trend in national emissions introduced by activity data uncertainty	M Uncertainty introduced into the trend in total national emissions	N Emission factor quality indicator	O Activity data quality indicator	P Expert judgement reference numbers	Q Footnote Reference numbers
5.B.1. Cropland Remaining Cropland - net carbon stock change in organic soils	CO2	5295.69	5347.74	20 %	90 %	92 %	14.19 %	0.0361	0.0984	3.25 %	2.78 %	4.28 %	R/M	R		L1
5.B.2 Forest Land converted to Cropland / mineral soils - net carbon stock change in living biomass	CO2	-0.46	-0.68	0 %	33 %	33 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %		M	E19	
5.B.2 Forest Land converted to Cropland / mineral soils - net carbon stock change in mineral soils	CO2	47.74	61.54	0 %	100 %	100 %	0.18 %	0.0006	0.0011	0.06 %	0.00 %	0.06 %		R	E19	
5.B.2 Forest Land converted to Cropland / organic soils - net carbon stock change in living biomass	CO2	-0.20	-0.40	0 %	33 %	33 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %		M	E19	
5.B.2 Forest Land converted to Cropland / organic soils - net carbon stock change in organic soils	CO2	200.51	387.90	0 %	100 %	100 %	1.12 %	0.0048	0.0071	0.48 %	0.00 %	0.48 %		R	E19	
5.B.2 Grassland converted to Cropland - net carbon stock change in mineral soils	CO2	0.00	23.03	0 %	100 %	100 %	0.07 %	0.0004	0.0004	0.04 %	0.00 %	0.04 %		R	E19	
5.B.3 Wetlands converted to Cropland - net carbon stock change in organic soils	CO2	39.77	192.19	0 %	100 %	100 %	0.55 %	0.0031	0.0035	0.31 %	0.00 %	0.31 %		R	E19	
5.C.1. Grassland Remaining Grassland - net carbon stock change in mineral soils	CO2	21.12	22.36	0 %	100 %	100 %	0.06 %	0.0002	0.0004	0.02 %	0.00 %	0.02 %	R	R	E5	
5.C.1. Grassland Remaining Grassland - net carbon stock change in organic soils	CO2	18.72	52.84	30 %	90 %	95 %	0.14 %	0.0008	0.0010	0.07 %	0.04 %	0.08 %	D	R		L24
5.C.2. Forest Land converted to Grassland - net carbon stock change in living biomass	CO2	-0.06	-0.13	0 %	33 %	33 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %		M	E19	
5.C.2. Forest Land converted to Grassland - net carbon stock change in mineral soils	CO2	0.53	1.18	0 %	100 %	100 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %		R	E19	
5.C.2. Forest Land converted to Grassland - net carbon stock change in organic soils	CO2	0.00	0.31	0 %	100 %	100 %	0.00 %	0.0000	0.0000	0.00 %	0.00 %	0.00 %		R	E19	
5.C.3. Cropland converted to Grassland - net carbon stock change in mineral soils	CO2	-323.94	-84.11	0 %	100 %	100 %	-0.24 %	0.0023	-0.0015	0.23 %	0.00 %	0.23 %		R	E19	
5.C.3. Cropland converted to Grassland - net carbon stock change in organic soils	CO2	19.48	5.73	0 %	100 %	100 %	0.02 %	-0.0001	0.0001	-0.01 %	0.00 %	0.01 %		R	E19	
5.D.2. Land Converted to Wetlands - peat extraction	CO2, CH4, N2O	1010.55	1308.35	15 %	13 %	20 %	0.74 %	0.0122	0.0241	0.15 %	0.51 %	0.53 %	D	R		L24

A IPCC Greenhouse Gas Source and Sink Categories	B Direct Greenhouse Gas ¹⁾	C Base Year emissions, 1990	D Current Year emissions, 2008	E Activity data uncertainty ²⁾	F Emission factor uncertainty ²⁾	G Combined uncertainty	H Combined uc as part of total national emissions in 2008	I Type A sensitivity	J Type B sensitivity	K Uncertainty in trend in national emissions introduced by emission factor uncertainty	L Uncertainty in trend in national emissions introduced by activity data uncertainty	M Uncertainty introduced into the trend in total national emissions	N Emission factor quality indicator	O Activity data quality indicator	P Expert judgement reference numbers	Q Footnote Reference numbers
5.G Other (harvested wood products)	CO2	-945.64	-94.77	0 %	11 %	11 %	-0.03 %	0.0094	-0.0017	0.10 %	0.00 %	0.10 %	D	R		L24
6.A. Solid Waste disposal on Land	CH4	3635.31	1853.16	0 %	43 %	43 %	2.29 %	-0.0086	0.0341	-0.37 %	0.00 %	0.37 %	R/D		E2	L4
6.B.1 Industrial Wastewater	CH4	22.23	24.03	10 %	104 %	105 %	0.07 %	0.0002	0.0004	0.02 %	0.01 %	0.02 %	R/D	R	E2	L4
6.B.2 Domestic and Commercial Wastewater - densely populated areas	CH4	17.07	11.30	5 %	104 %	105 %	0.03 %	0.0000	0.0002	0.00 %	0.00 %	0.00 %	R	R	E3	
6.B.2 Domestic and Commercial Wastewater - densely populated areas	N2O	74.79	54.73	5 %	380 %	380 %	0.60 %	0.0001	0.0010	0.05 %	0.01 %	0.05 %	R	R	E2	L4
6.B.2 Domestic and Commercial Wastewater - sparsely populated areas	CH4	114.23	91.46	15 %	32 %	35 %	0.09 %	0.0003	0.0017	0.01 %	0.04 %	0.04 %	R	R	E2	L2
6.B.2 Domestic and Commercial Wastewater - sparsely populated areas	N2O	30.55	25.76	10 %	380 %	380 %	0.28 %	0.0001	0.0005	0.04 %	0.01 %	0.04 %	R	R	E2	L2
6.B.3. N input from Fish Farming	N2O	8.28	3.38	10 %	380 %	380 %	0.04 %	0.0000	0.0001	-0.01 %	0.00 %	0.01 %	R	R	E2	L2
6.B.3. N input from industrial wastewater	N2O	30.17	19.31	5 %	380 %	380 %	0.21 %	0.0000	0.0004	0.00 %	0.00 %	0.00 %	R	R	E2	L2
6.D Other: compost production	CH4	21.55	59.74	30 %	50 %	58 %	0.10 %	0.0008	0.0011	0.04 %	0.05 %	0.06 %				AD, section 8.5.3; EF, table 4.1 in IPCC (2006)
6.D Other: compost production	N2O	20.43	58.86	30 %	50 %	58 %	0.10 %	0.0008	0.0011	0.04 %	0.05 %	0.06 %				AD, section 8.5.3; EF, table 4.1 in IPCC (2006)
<u>Total</u>		54 371.31	34 744.88				49.0%					16.3%				

1) Gases have been combined to protect confidential information (category 2.G), and to remove correlations (category 5.D.2).

2) A zero indicates that the combined uncertainty is reported for either AD of EF.

Sensitivity analysis

N₂O from manure management – solid storage and dry lot (CRF 4.B.13) of manure from swine

N₂O from manure management was identified as key category (section 1.5 and Annex 1). In 2007, the emissions amounted to 1.60 Gg. Most of it was due to manure managed in solid storage and dry lot (1.54 Gg). These estimates are reported in CRF table 4 “Sectoral report for agriculture”.

Of the amount emitted from solid storage and dry lot, 0.32 Gg were due to swine. The model for N₂O emissions is a four-variable function

$$y = \frac{1}{10^6} \frac{44}{28} n m s x,$$

where n is the swine count, m is the amount of nitrogen (kg) excreted in one year, s is the share of manure in solid storage and dry lot, and x is the emission factor for N₂O-N (kg/kg). Using the values $n = 1\,448\,000$, $m = 18.7$ kg, $s = 0.38$, and $x = 0.02$ kg/kg, one obtains the estimate $y \approx 0.32$ Gg.

Assessment began by listing of the distributions used previously for uncertainty assessment:

Variable	Distribution	Point estimate	2.5 and 97.5 percentiles relative to the point estimate
n	normal	1 448 000	–5/+5
m	normal	18.7 kg	–25/+25
s	normal	0.38	–20/+20
x	beta	0.02 kg/kg	–85/+15

The point estimates are national, referenced data (see section 6.3.2 above), except for the emission factor x , which in an IPCC default from table 4.12 in IPCC (2000). The selection of a skewed distribution for x was to reflect that the default value may be too high in light of a literature review, which suggested a range from 0.003 to 0.015 (Monni & Syri 2003, p. 55). It is noteworthy that IPCC currently suggests values 0.005 and 0.02 for solid storage and dry lot, respectively (IPCC 2006, p. 10.62). The new default value by IPCC for solid storage is just 25% of the previous default.

So, the first result from the analysis is a question regarding the emission factor for Finnish circumstances: *is the current factor too high, and if so, what might be the appropriate value?*

Next, a simulation model was constructed for uncertainty analysis using Monte Carlo simulation and sensitivity analysis using an extended version of Fourier Amplitude Sensitivity Test (FAST, Saltelli et al. 2005). Distributions in the above table were used for simulation, except that the distribution for x was replaced by a uniform distribution over the range [0.003, 0.015].

A sample of pseudo-random numbers was drawn and the model was evaluated on this sample. The simulation suggests an average emission level of 0.15 Gg, with 95% of the simulated values falling between 0.05 and 0.25 Gg.

Sensitivity analysis using extended FAST provides the following sensitivity indexes:

Variable	First order index	Total order index
x	0.83	0.86
m	0.08	0.10
s	0.05	0.07
n	0.00	0.01
Sum	0.96	1.04

The indexes are interpreted as follows. The total order index gives the fraction of variance (uncertainty) that would be left in average if all other variables could be fixed (their values known with certainty). For instance, if one could know the values of all other variables but x , then the fraction of variance of y that would be left was 86%. The first order index, on the other hand, gives the reduction in variance that would be obtained by fixing the value of the variable in question. For instance, fixing the value of m would reduce the uncertainty on average by 8%.

Note that the first order indexes do not add up to one (and the total order indexes add up to more than one) because a small part of the variance is due to interactions between variables. This is also the reason, why calculating both indexes is useful: significant differences between the two indexes would suggest that the variable in question is part of an important interaction. Also, an index value close to zero indicates that the variable is non-influential.

The analysis therefore suggests, given the model structure, and the choice of distributions, that the single most influential variable that affect the uncertainty of the emissions is the emission factor x . This simplified example was chosen on purpose to illustrate the application of variance-based sensitivity analysis to model assessment. The analysis could be expanded to include all manure management systems and domestic animals. It might however be best to first put some resources to the study of the N_2O -N emission factor, as this factor is used for other animal species as well.

ANNEX 7. Additional information to be considered as part of the annual inventory submission and the supplementary information required under Article 7, paragraph 1, of the Kyoto Protocol or other useful reference information

Legal entities authorised to participate in the mechanisms under Articles 6, 12 and 17 of the Kyoto Protocol

Legal entity	Reason for authorization
Ahlstrom Glassfibre Oy	Operators (companies with legally binding emission ceilings under the EU ETS)
Altia Oyj	Operator (company with a legally binding emission ceiling under the EU ETS)
Anjalankosken Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Biokraft 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)
Corenso United Oy Ltd	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)
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)
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)
Georgia-Pacific Nordic 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)
Helsingin Energia	Operator (company with a legally binding emission ceiling under the EU ETS)
Helsingin ja Uudenmaan sairaanhoitopiiri	Operator (company with a legally binding emission ceiling under the EU ETS)
Hexion Specialty Chemicals Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Huiskulan Puutarha Oy	Operator (company with a legally binding emission ceiling

Legal entity	Reason for authorization
	under the EU ETS)
Hyvinkään Lämpövoima	Operator (company with a legally binding emission ceiling under the EU ETS)
Höyrytys Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Ilmailulaitos Finavia, Hki - Vantaan lentoasema, Energia ja Vesi	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)
JK Juusto Kaira Oy	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)
Jujo 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)
Järvi-Suomen Voima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Kaarinan lämpölaite	Operator (company with a legally binding emission ceiling under the EU ETS)
Kainuun Energia Oy	Authorisation from the Ministry of the Environment
Kainuun Voima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Kajaanin Lämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Kannuksen Kaukolämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Kanteleen Voima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Karstulan Lämpöverkko Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Kauhavan Kaukolämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Kaukaan Voima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Keitele Energy Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Kemiart Liners Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Kemijärven Kaukolämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Kemin Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Keramia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Keravan Energia Oy	Operator (company with a legally binding emission ceiling

Legal entity	Reason for authorization
	under the EU ETS)
Keravan 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)
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)
Kuhmon Lämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Kuitu Finland Oy:n konkurssipesä	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)
Kymin Voima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Laanilan Voima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Lahti Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Laitilan Lämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Lappeenrannan Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Lapuan Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Liedon Lämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Loimaan Kaukolämpö 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 Energi ab	Operator (company with a legally binding emission ceiling under the EU ETS)
Maxit Oy Ab	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)
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)
M-real Oyj	Operator (company with a legally binding emission ceiling under the EU ETS)
Mussalon Kaukolämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Mylykoski Paper Oy	Operator (company with a legally binding emission ceiling under the EU ETS)

Legal entity	Reason for authorization
Myllyvoima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Mäntän Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Naantalin Kaupunki	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)
Nokian Lämpövoima 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
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)
O-I Manufacturing Finland 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)
Oulun Seudun Lämpö Oy	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 ja 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 Bar Oy Ab	Operator (company with a legally binding emission ceiling under the EU ETS)
Ovako Wire 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 Metsä-Botnia 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 Ky	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)
Pilkington Lahden Lasitehdas Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Pohjois-Pohjanmaan sairaanhoitopiirin kuntayhtymä	Operator (company with a legally binding emission ceiling under the EU ETS)
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)

Legal entity	Reason for authorization
Punkavoima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Puulaakson Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
PVO-Huippuvoima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
PVO-Lämpövoima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Pölkky Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Raisio kaupungin kaukolämpölaitos	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 Energia Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Rauman Voima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Raunion Saha Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Rautaruukki Oyj	Operator (company with a legally binding emission ceiling under the EU ETS), authorisation for CSM and JI projects
Rovaniemen Energia 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)
Salon kaupungin kaukolämpölaitos	Operator (company with a legally binding emission ceiling under the EU ETS)
Sampo Pankki Oyj	Authorisation from the Ministry of the Environment
Sappi Finland I 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 Myynti Oy	Authorisation from the Ministry of the Environment
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)
Stora Enso Oyj	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 Timber Oy Ltd	Operator (company with a legally binding emission ceiling under the EU ETS)
Stromsdal Oyj	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)
Sunila 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

Legal entity	Reason for authorization
	under the EU ETS)
Taivalkosken Voima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Tamfelt Oyj Abp	Operator (company with a legally binding emission ceiling under the EU ETS)
Tammisaaren Energia	Operator (company with a legally binding emission ceiling under the EU ETS)
Tampereen Energiantuotanto Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
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)
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)
Valmet Automotive 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)
Vari 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)
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)
Vattenfall Lämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Veljet Kuusisto Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Versowood Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Wienerberger Oy Ab	Operator (company with a legally binding emission ceiling under the EU ETS)
Vieskan Voima Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
Viitasaaren Lämpö Oy	Operator (company with a legally binding emission ceiling under the EU ETS)
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)
Ålands Energi ab	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)

